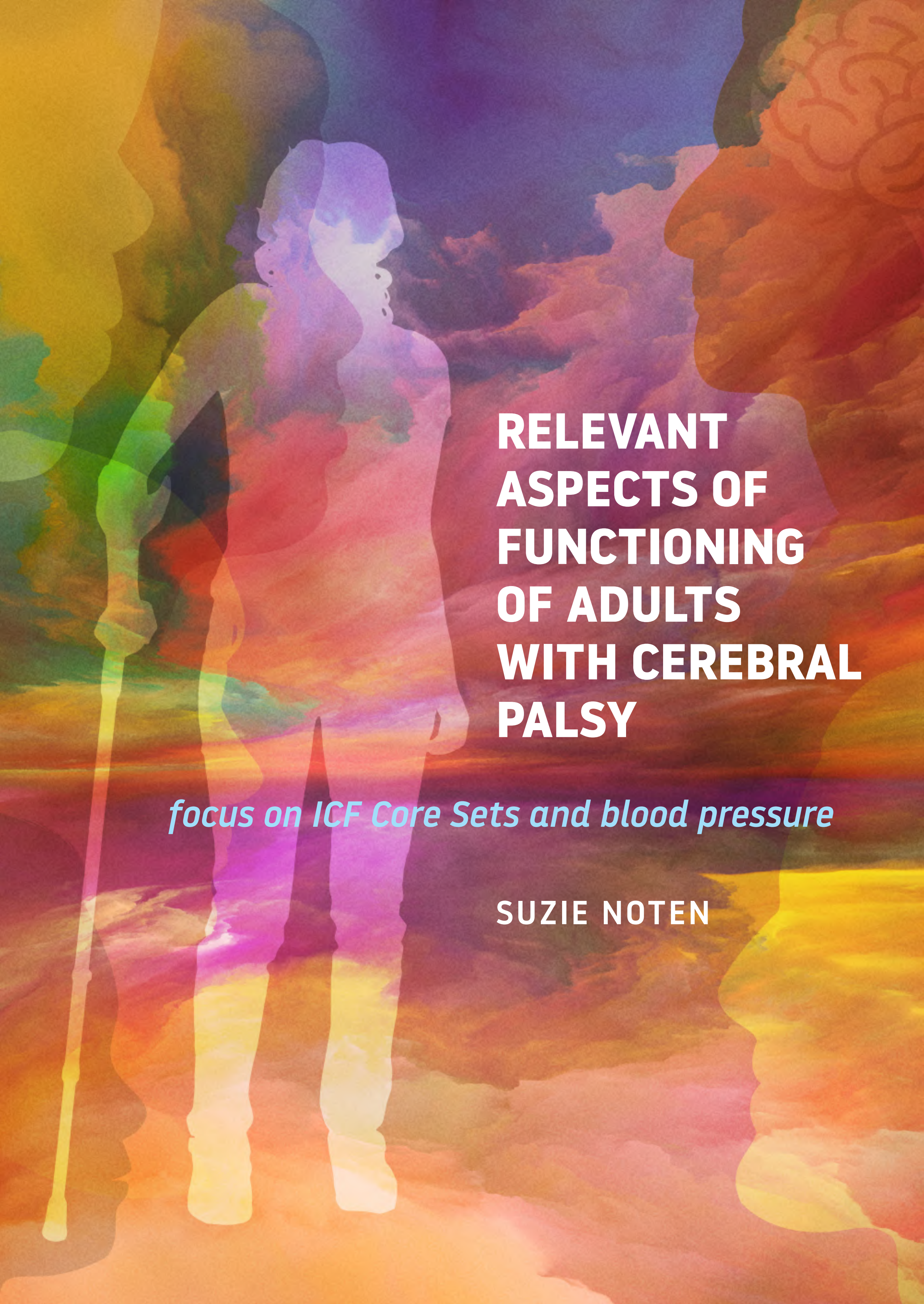

RELEVANT ASPECTS OF FUNCTIONING OF ADULTS WITH CEREBRAL PALSY

focus on ICF Core Sets and blood pressure

SUZIE NOTEN

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Relevante aspecten van functioneren van volwassenen met cerebrale parese:
focus op ICF Core Sets en bloeddruk

Relevant Aspects of Functioning of Adults with Cerebral Palsy:
focus on ICF Core Sets and blood pressure

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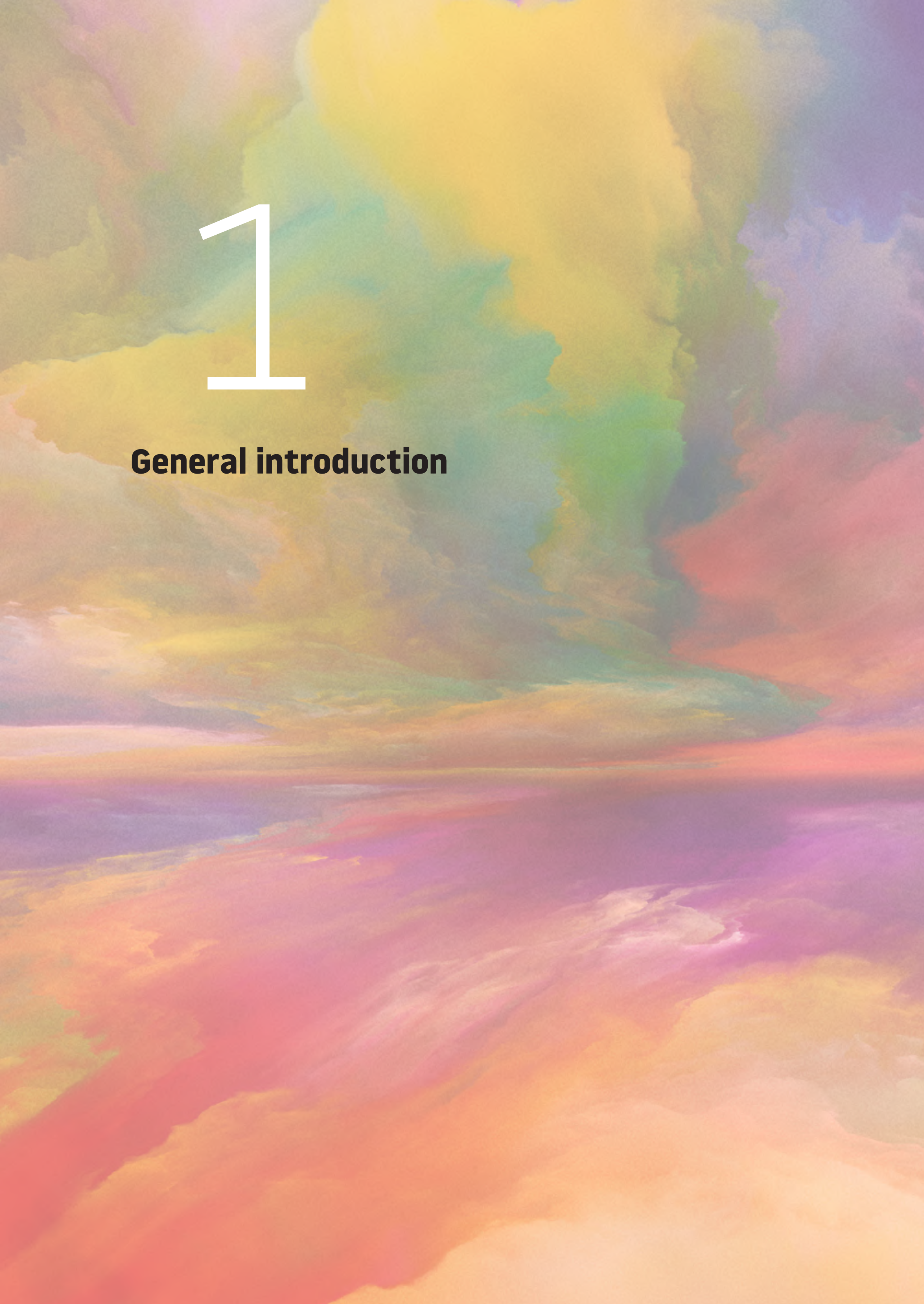
CONTENTS

PART I Development of Comprehensive and Brief ICF Core Sets for adults with cerebral palsy

PART II Blood pressure in adults with cerebral palsy



1

General introduction

This thesis consists of two parts on relevant aspects of functioning of adults with cerebral palsy (CP). The first part describes the development of the Comprehensive and Brief International Classification of Functioning, Disability and Health (ICF) Core Sets for adults with cerebral palsy (CP) and its results. The second part provides important insight into blood pressure in adults with CP. Both parts will be introduced here.

CEREBRAL PALSY

Cerebral palsy (CP) describes a 'group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of CP are often accompanied by disturbances of sensation, perception, cognition, communication, and behaviour, by epilepsy, and by secondary musculoskeletal problems'.[1] CP is the most common cause of physical disability in childhood, affecting approximately 2 to 2.5 per 1000 live births.[2-4]

The motor disorders can be classified into three subgroups: spastic, dyskinetic or ataxic type of CP.[5] CP subtypes are based on neurological findings, with the spastic type being the most common subtype in around 80% of individuals with CP.[6, 7] The severity of gross motor function limitations can be classified by using a five-level classification system, the Gross Motor Function Classification System (GMFCS). The scale ranges from I to V (Figure 1), and more than half of the population is classified as GMFCS I-II.[8] Individuals classified as GMFCS I walk without limitations, whereas those with GMFCS V are unable to walk independently and have limited head and trunk postures. Individuals with GMFCS IV and V often have an intellectual disability (ID).[8,9] All GMFCS levels considered, ID is present in about 50% of children and adolescents with CP.[10, 11] ID is often associated with verbal communication problems,[12] hinders the performance of daily activity,[13] and social participation is more affected by ID than by the level of gross motor functioning.[14] Research on adults with CP and ID is limited and more studies that differentiate relevant aspects of functioning of adults with CP with and without ID are warranted.

Figure 1 Gross Motor Function Classification System (GMFCS).[8]

A large majority of individuals with CP (75%) are nowadays at adult age.[15] This is a result of increased survival rates of individuals with CP over the past decades, which is due to several advances in health care. Previously, research mainly focused on children and youth with CP, but in the past decades there is an increasing focus on the impact of CP throughout the lifespan. Adults with CP present a broad spectrum of physical and cognitive impairments, limitations in activities, and restrictions in participation.[16]

As our knowledge of adults with CP has grown over the years, many outcomes of functioning and a large variation of outcome measurement instruments became available. Although many outcome measures are available for adults with CP, systematic assessment and comparison of data is hampered by a lack of standardization. Therefore, consensus is needed on the most important areas to asses as well as a universal language to describe those outcomes. This will improve our knowledge of functioning of adults with CP and provide us with a solid base for identifying and registering the impact of CP at adult age. The International Classification of Functioning, Disability and Health (ICF) can facilitate reaching consensus to describe functioning and disability in adults with CP.

ICF

To describe the impact of CP on outcomes of functioning, the International Classification of Functioning, Disability and Health, known as ICF, is often used in clinical and research settings. The ICF provides a universal language and framework to describe and assess functioning and disability.[17] It can be used to enhance communication across health care workers, researchers, policy-makers and society, and it enables the comparison of data. The ICF reflects a comprehensive biopsychosocial model that comprises body functions, body structures, activities and participation, and contextual factors, including environmental and personal factors. Functioning describes body functions and structures, activities and participation, while disability stands for impairments in body functions and body structures, activity limitations and participation restrictions. This can all be facilitated or hindered by environmental and personal factors. The level of functioning and disability is denoted by a dynamic interaction between the health condition and contextual factors. The ICF model is presented in Figure 2.

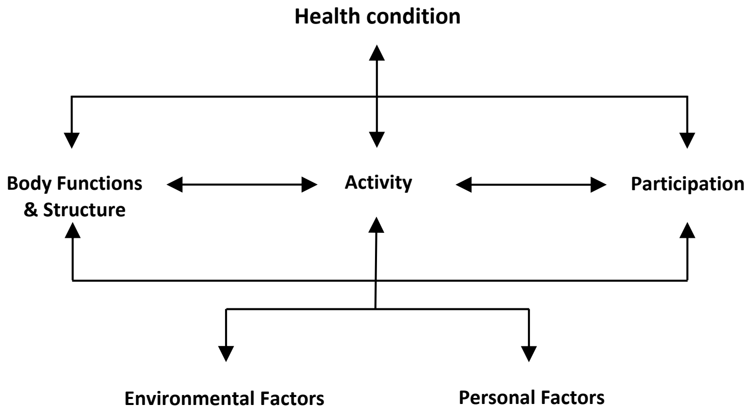


Figure 2 The International Classification of Functioning, Disability and Health (ICF).[17]

Functioning and disability

Body functions and structures

Body functions and structures describe functioning at the level of the body. Body functions include the physiology and psychology of the body and body structures encompass the anatomy of the body, such as organs, limbs and their components.

In adults with CP impairments in body functions are present in the neuromotor system. Common impairments, directly caused by the brain disturbances, are abnormal muscle tone, muscle weakness, and absence of selective motor control.[18] The abnormal muscle tone may result in several impairments in body structures, e.g. bone deformities and hip displacement were previously described in CP.[1, 10, 19] Impairments can also occur in other domains, such as in sensory functions, leading to problems with balance, hearing or seeing,[10, 20] or in voice and speech functions.[10] Difficulties with speech can be linked to the motor impairment, but also to the cognitive or sensory processing deficits.[21] Focus on cardiovascular functions is limited in adults with CP, but low levels of physical fitness were reported,[22] which may contribute to developing chronic conditions (e.g. hypertension or diabetes mellitus type).[23, 24]

Impairments can result in several health issues. Pain and fatigue are often studied health issues in adults with CP,[25-29] and are more frequently reported by adults with CP compared to the general population.[29] Pain and fatigue have a multidimensional nature. Possible causes of pain can be related to abnormal muscle tone, deformities or overuse of affected body parts,[29] and pain often co-occurs with fatigue.[16, 29] Adults with CP reported factors that contribute to fatigue, which were activity-related (e.g. walking long-distances), sleep duration and quality, general demands of life (e.g. work or socializing), and fatigue was also reported as a result of their abnormal muscle tone, or use of assistive devices.[30]

Activities and participation

Activities consist of the execution of a task or action. Activity limitations are difficulties an individual may have in executing activities, such as self-care and mobility. Self-care activities include bathing, toileting, dressing, eating, and drinking.[17] In previous studies, adults with CP experienced decreased levels of mobility and self-care over time, and often needed more assistance.[16, 31]

Participation is involvement in a life situation. Participation restrictions are problems that an individual may experience as a member of society, for example in social relationships, education and employment, recreation and leisure. Many adults with CP experience difficulties in several participation domains.[32-34] For example, young adults with CP experience difficulties in developing intimate relationships, and they also have less sexual experience than their able-bodied peers.[34] In adults with CP, employment rates are lower compared to the general population,[35] and also difficulties in recreation are reported.[33]

Contextual factors

Environmental factors

Environmental factors are external factors, including the physical, social and attitudinal environment in which people live and conduct their lives. Environmental factors can play a positive or negative role in people's functioning. It is important to include the interaction with environmental factors in the understanding of functioning and disability, and potential adjustments of the environment might improve outcome. For example, products and technology for mobility, such as wheelchairs or walkers, facilitate functioning of adults with CP. An example of a physical factor that can ease or hinder work or leisure is the accessibility of buildings. Support and positive attitudes, e.g. from family and friends, will motivate and enhance social life, while negative societal attitudes can affect self-confidence in people with CP.[36]

Personal factors

Personal factors are the particular background of an individual's life and living and comprise features of the individual that are not part of the health condition. Examples of personal factors are sex, age, sociodemographic status, educational level, and coping styles. It has been demonstrated in adults with CP that personal factors affect participation: e.g.

an avoidant coping style predicts more difficulty in interpersonal relationships.[37] Also, age interacts with several ICF domains; mobility and self-care deteriorated with advancing age, and some health issues, such as pain and fatigue, became more prevalent.[16]

CLASSIFICATION OF THE ICF

The classification of the ICF is divided into a hierarchical structure, which can be used to link problems to ICF codes of different levels. Each ICF component is denoted by letters: body functions (b), body structures (s), activities and participation (d) and environmental factors (e), which consists of categories at different levels. The ICF code starts with a letter (b,s,d,e), followed by chapter or first-level categories (first digit of the numeric code), which consists of more detailed second-level (second and third digit), third-level (fourth digit) or fourth-level codes (fifth digit). The component personal factors is identified as pf, but this is not yet classified in the ICF framework because of the wide variability among cultures. Items can be linked to ICF categories by following the refined linking rules.[38] An example of the linking process is, e.g. *pain in lower limb* that would be linked to the fourth-level ICF category *b28015*.

Chapter or first- level	b**2**	Sensory functions and pain
Second-level	b2**80**	Sensation of pain
Third-level	b280**1**	Pain in body part
Fourth-level	b2801**5**	Pain in lower limb

ICF CORE SETS

In total, the ICF model contains over 1400 categories, which makes the implementation in clinical practice and research challenging and time-consuming. To address this challenge, ICF Core Sets, or shortlists, have been introduced by the World Health Organization (WHO) and the ICF Research Branch.[39] ICF Core Sets are standardized, internationally accepted tools that aim to facilitate the practical application of the ICF. These Core Sets include selected ICF categories that are most relevant for describing functioning and disability of persons with a specific health condition. So far, more than 30 ICF Core Sets have been developed, e.g. for children and youth with CP,[40] persons with ADHD,[41] and for adults after stroke[42] and traumatic brain injury.[43]

The ICF Core Sets for children and youth with CP have been implemented in different paediatric contexts worldwide, demonstrating the benefits of standardized assessment and evaluation.[44] An early decline of function in adults with CP[16] and a natural change of life experiences from childhood to adulthood,[32] such as from living with their parents to independent housing and starting employment, makes that the ICF Core Sets for children and youth with CP are insufficiently applicable to adults. ICF Core Sets specific for adults with CP are therefore needed to cover all issues experienced at adult age.

The ICF Core Sets can support the standardization of the assessment and reporting of functioning of adults with CP in clinical practice and research. This can facilitate comparison of data across studies, disciplines, and settings worldwide. In clinical practice, ICF Core Sets can be employed for systematic clinical assessment and follow-up, and to establish comprehensive functioning profiles that guide intervention planning and rehabilitation. ICF Core Sets can serve as a reference pool for what to measure in research. It can assist appropriate selection and confirm content validity of existing instruments (e.g. questionnaires and clinical tools). In addition, ICF Core Sets can guide the design of studies that focus on functioning to ensure that all important aspects of functioning are considered.

A structured and scientific approach to develop ICF Core Sets consists of different steps (Figure 3).[39] The preparatory phase involves four studies to investigate relevant aspects of functioning and health from different perspectives: a systematic literature review (researcher's perspective), a qualitative study (patient's perspective), an expert survey (health professional's perspective), and a clinical study (clinical perspective). The results of these studies generated an aggregated list of candidate ICF categories. In the next phase, phase I, experts and health professionals from all WHO world regions define the first version of the ICF Core Sets, based on this list of candidate categories, according to an established consensus and decision-making process. Finally, the ICF Core Sets will be implemented (Phase II). This thesis focuses on the preparatory phase and Phase I.

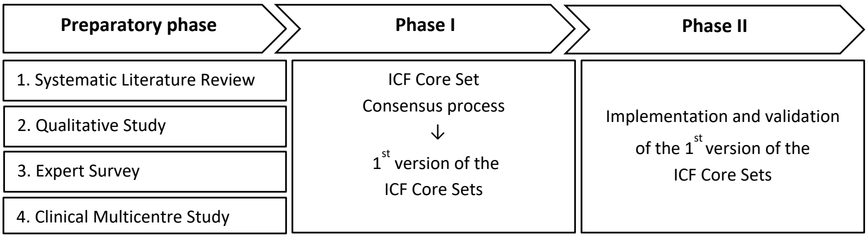


Figure 3 Process for developing ICF Core Sets.[39]

ICF Core Sets consist of Comprehensive and Brief Sets. A Comprehensive ICF Core Set represents all relevant aspects of functioning of persons with a specific health condition and should include enough categories that make an in-depth description of functioning possible, yet still be concise enough for practical application. A Comprehensive ICF Core Set can be used by team members from different professions for extensive interdisciplinary assessment. A Brief ICF Core Set, derived from the Comprehensive Set, includes the fewest, but most essential, ICF categories possible to provide a minimal international standard for describing, assessing and reporting functioning and health in clinical settings and research.[39, 45] The systematic registration and follow-up of relevant aspects of functioning by ICF Core Sets should make it easier to understand the impact of CP at adult age.

BLOOD PRESSURE

As described earlier in this introduction, many body functions and body structures in adults with CP can be impaired. Topics such as neuromotor functions, mental functions, and speech functions are often investigated in adults with CP. Focus on functions of the cardiovascular system, including blood pressure functions, is limited.

High blood pressure is one of the main risk factors of cardiovascular disease (CVD) in the general population.[46] Previous research has established that the risk of CVD was higher in adults with CP than in the general population.[47-49] Despite the importance of blood pressure, research and clinical practice have done little to understand or monitor blood pressure in people with CP, and as a consequence, there is limited knowledge of hypertension risk in this population. To date, only a few studies reported the prevalence of hypertension in adults with CP, which varied between 14 and 30%.[50-53] Those studies were limited by small sample size and relatively young age. For an adequate approach to blood pressure in current clinical practice, a reliable prevalence estimate is required. More information is also needed on subgroups at increased risk or which factors influence blood pressure levels in adults with CP.

AIMS OF THIS THESIS

Although the focus on the impact of CP throughout the lifespan is increasing, consensus on the most important areas of functioning of adults with CP and standardized assessment in clinical practice and research are lacking. Standardized assessment could facilitate comparison of data across studies, disciplines, and settings worldwide. The first aim of this thesis is to identify the most frequently addressed areas of functioning and contextual factors in adults with CP from different perspectives, and to reach international consensus on the Comprehensive and Brief ICF Core Sets for adults with CP by using the ICF framework.

The risk of cardiovascular diseases is higher in adults with CP than in the general population, but current knowledge on one of the main risk factors, blood pressure, is lacking. The second aim of this thesis is to extend the knowledge on this topic and provide a reliable estimate of overall blood pressure levels and prevalence of hypertension in adults with CP.

OUTLINE OF THIS THESIS

The first part of this thesis describes the development of the ICF Core Sets for adults with CP (chapters 2-6). In **chapters 2-5**, the four preparatory studies in the development of the ICF Core Sets are presented, capturing different perspectives: a systematic review (researcher's perspective), qualitative study (patient's perspective), expert survey (health professional's perspective), and clinical, multicentre study (clinical perspective), resulting in the most relevant ICF categories in adults with CP from different perspectives. **Chapter 2** describes the systematic literature review and presents those aspects of functioning evaluated in the scientific literature related to adults with CP. In **chapter 3**, aspects of functioning that are considered the most important from the lived experience of adults with CP with and without ID are identified. **Chapter 4** presents the results of an international survey that identifies areas of functioning of adults with CP that are considered relevant by health professionals and researchers. **Chapter 5** describes common problems in adults with CP with and without ID in a clinical setting, from an international perspective. The results from chapters 2-5 are combined in **chapter 6**. This chapter describes the consensus process of experts and health professionals on the ICF Core Sets and presents the first version of the Comprehensive and Brief ICF Core Sets for adults with CP. The second part (**chapter 7**) focuses on blood pressure in adults with CP and presents the overall blood pressure levels and prevalence of hypertension in adults with CP. This chapter also provides results for subgroups at increased risk and potential risk factors. In **chapter 8**, the main findings of this thesis are discussed with its strengths and limitations and provides clinical implications and directions for future research.

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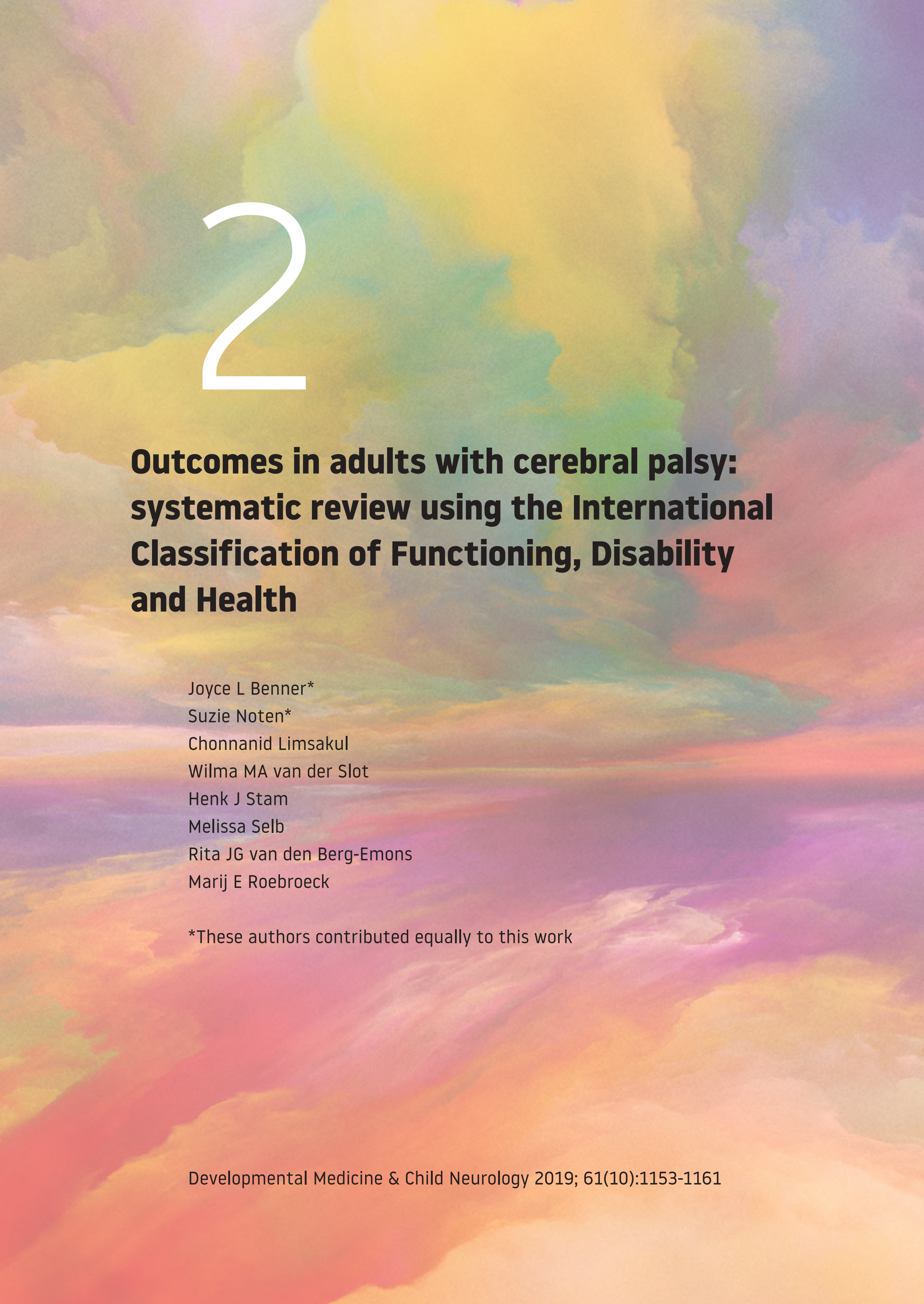
Part I

Development of Comprehensive and Brief ICF Core Sets for adults with cerebral palsy



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Outcomes in adults with cerebral palsy: systematic review using the International Classification of Functioning, Disability and Health

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ABSTRACT

Aim: In the context of the development of an International Classification of Functioning, Disability and Health (ICF) Core Set for adults with cerebral palsy (CP), this systematic review sought to identify the outcome measures used in studies on adults with CP, to examine their content using the ICF as a reference, and to demonstrate the most studied areas in this population.

Method: Embase, MEDLINE, Web of Science, PsycINFO, CINAHL, Cochrane, and Google Scholar were searched for studies on adults with CP published between 2000 and 2017. Meaningful concepts of commonly used outcome measures were linked to the ICF, and frequencies of resultant ICF categories were explored.

Results: In 274 included articles, 332 outcome measures were identified of which 155 were commonly used. In total, 4409 meaningful concepts were linked to the ICF. The component 'Activities and participation' included the most frequent categories, followed by 'Body functions'. The most frequent categories were b280 'Sensation of pain' (37.6%), d450 'Walking' (33.3%), and d850 'Remunerative employment' (27.5%).

Interpretation: The broad range of ICF categories identified in this systematic review emphasizes the heterogeneity of functioning and disability in adults with CP. The current results specifically reflect the researchers' perspective and will serve as candidate categories to consider in the development of an ICF Core Set for adults with CP.

INTRODUCTION

Cerebral palsy (CP) describes a group of permanent disorders of movement and posture causing activity limitations,[1] and is the most common cause of physical disability in childhood.[2] CP is caused by non-progressive disturbances in the developing fetal or infant brain, resulting in a motor disorder that is often accompanied by secondary impairments, for example cognitive or sensory impairments or communication impairments.[1] In developed countries, CP affects 2 to 2.5 per 1000 live births.[3-5] Much research in CP has focused on children. However, given the increasing survival rates and longevity of individuals with CP, with the majority experiencing adulthood,[6, 7] research in the last two decades has increasingly focused on the impact of CP throughout the lifespan.

Research on health-related status of adults with CP describes a broad range of outcomes.[8] Physical and cognitive impairments, activity limitations, and participation restrictions are well-recognized as disabling consequences in adult CP. The extent of these consequences often depends on the type and severity of the health condition, but also on various contextual factors. Given the wide variety of descriptors of outcomes and related factors found in the literature, a uniform language to describe the impact of CP in adulthood is desirable. In 2001, the World Health Organization (WHO) launched the International Classification of Functioning, Disability and Health (ICF)[9], now an internationally accepted standard for describing functioning and disability. In the ICF, functioning and disability are seen as the universal human experience of the complex interaction between a person's health condition and contextual factors. Whereas functioning is described by what the body does (i.e. body functions), body structures, tasks or actions an individual performs, and involvement in major life activities (i.e. activities and participation), disability is an umbrella term referring to body impairments, activity limitations, and participation restrictions. Contextual factors encompass environmental factors, describing the physical, social and attitudinal environment in which people live, and personal factors, comprising features of an individual that are not part of the health condition such as age, sex, or coping style.[9]

Systematic assessment of physical and cognitive impairments, and activity limitations and participation restrictions in relevant life areas, is essential in health care settings to identify problems in health and functioning, and to plan effective interventions.[10] Several outcome measures have been used to evaluate different areas of functioning and disability in adults with CP. However, there is no consensus on the most important areas to assess in these adults, nor is it clear how to select the most appropriate outcome measures. For clinicians and researchers to develop and provide optimal care for adults with CP, it is vital to have consensus on the outcomes to assess and on a universal language that describes those outcomes. The ICF is suitable for this purpose; however, with more than 1400 categories describing all areas of functioning, its applicability for everyday use in clinical settings is challenging. To address this challenge, WHO and the ICF Research Branch created a methodology for developing Core Sets of ICF categories.[11] An ICF Core Set can facilitate the description of the functioning of individuals with a specific health condition in everyday practice by providing a limited list of essential categories selected from the entire ICF. It can provide guidance for clinical assessments, planning of interventions, and selecting measures for evaluation. Moreover, ICF Core Sets offer the possibility to compare clinical data between patients, institutions, and countries, and may serve as a basis to improve communication between professionals and settings on an international level.[12]

So far, ICF Core Sets have been developed for various health conditions.[13] Among the 35 ICF Core Sets is one for children and young people with CP.[14-18] Since life experiences of individuals with CP naturally changes from childhood to adulthood,[19] and since health issues seem to deteriorate throughout the lifespan,[20] the ICF Core Set for children and young people with CP is considered insufficiently applicable to adults with CP. To address this issue, our research group initiated a project to develop an ICF Core Set for adults with CP across different types and severity levels.

ICF Core Sets are developed by means of a three-phase, multi-method scientific process.[11] The first phase is designed to collect current evidence, which involves four preparatory studies: a systematic literature review, a qualitative study, a multicenter cross-sectional study in a clinical setting, and a global expert survey. These are meant to consider the perspectives of researchers, patients, and clinicians, and to capture their views on relevant aspects of health and functioning. The second phase comprises an international consensus conference with experts and health care professionals. The final phase involves validating and implementing the first version of the ICF Core Set.[11] In the present article, we report on the systematic literature review, capturing the perspective of researchers on CP in adulthood by identifying a list of ICF categories that are most commonly addressed in the literature on adults with CP.[21] These categories will serve as candidate categories for the international consensus conference, during which the first version of the ICF Core Sets for adults with CP will be finalized.

The objective of this systematic literature review was to identify this list of candidate categories. Specific aims were to: (1) identify all outcome measures used in published studies on adults with CP over the past decades; (2) uncover the functioning content of those measures using the ICF; and (3) pinpoint the most frequently addressed areas of functioning and contextual factors in adults with CP using the ICF.

METHODS

Search strategy and eligibility criteria

Seven electronic databases (Embase, MEDLINE, Web of Science, PsycINFO, CINAHL, Cochrane, Google Scholar) were searched for literature published between January 2000 and January 2017. The search strategy was developed in consultation with an information specialist and included three major themes: 'cerebral palsy', 'adult', and 'outcome assessment'. Key terms were mapped to controlled headings and expanded to include free text terms, as appropriate for the specific database.

Results from the searches were gathered in EndNote and duplicates were removed. In a first round, titles and abstracts were screened for eligibility. Subsequently, full-text articles of the included abstracts were retrieved and screened for eligibility. Studies were included according to the following five criteria: (1) Observational and experimental study designs, and excluding meta-analyses, reviews, case studies, qualitative studies, comments, and study protocols; (2) Describing individuals with CP only, or in case-control design; (3) Describing more than 10 adults who are at least 18 years of age at time of the first measurement or at follow-up. Studies describing both children and adults with CP were included when at least 50% (and >10 participants) of the sample were adults, or in case this was unclear, the mean sample age was at least 18 years; (4) Reporting on outcomes of functioning, and excluding studies reporting on evaluations of services; for example, evaluation of transition services, or complications and adverse events of surgery; and (5) Inclusions were limited to full-paper peer-reviewed journal articles written in English. Multiple publications on the same study sample, including follow-up studies, were combined and counted as one study ('unique study') to avoid duplication of outcome measures. Publications of a study on a specific subset of a larger sample, using clearly distinct outcome measures, were not combined.

The first two authors (JB, SN) independently performed title/abstract and full-text screening. Disagreement about inclusion was discussed and resolved between the two reviewers. Any discrepancies were discussed with a third reviewer (RBE) until consensus was reached.

Data extraction

From each included study we extracted information on country, study design, and participant characteristics, using a standardized electronic data record sheet. The country where the study was conducted was allocated to one of the six WHO regions, whereby we further distinguished between North and South America.[9] Design of the study was recorded according to the Cochrane Consumers and Communication Review Group

Study Design Guide,[22] and grouped into observational or experimental designs. Participant characteristics included sample size, age, sex, CP subtype, and level of gross motor functioning. The subtype of CP was classified according to the diagnostic classification system of the Surveillance of Cerebral Palsy in Europe,[23] and for movement and posture abnormality: spastic, dyskinetic, ataxic, or mixed. Spastic CP was further distinguished for limb distribution if applicable, namely unilateral or bilateral spastic CP. Gross motor functioning was classified according to the Gross Motor Function Classification System (GMFCS).[24, 25] For studies with multiple publications, participant characteristics were extracted from the largest (often baseline) sample.

All outcome measures used in the included studies were recorded, and the number of studies in which the individual measures were used was documented. For studies with multiple publications, the outcome measures used were counted only once. We identified single-item and multiple-item measures. A single-item measure, for example, is the Modified Ashworth Scale, a clinical assessment. A multiple-item measure, for example, is the Short-Form Health Survey, a patient-oriented measure containing 36 individual items. Outcome measures comprised patient-oriented measures (i.e. self- or proxy-report questionnaires), clinical assessments (including those requiring specialized equipment), and non-tool measures (often single-patient-oriented questions) mentioned in the text of publications. From the outcome measures that were used in at least two studies (‘common measures’), we extracted all individual items before linking each item to the ICF.

Linking to the ICF

Before starting the linking process, three reviewers (JB, SN, and CL) acquired thorough knowledge of the refined ICF linking rules by consulting the eLearning tool,[26] and during practice sessions including a tutorial with an expert (MS) from the ICF Research Branch. On the basis of experience gathered over several years for various projects by many clinicians and researchers around the world, refinements were made to the original linking rules,[27, 28] addressing linking of all concepts within an item instead of only the most relevant one, linking to the most precise ICF category, and the use of the ‘other specified’ and ‘unspecified’ categories.[21]

For each item extracted from the common measures, we identified the meaningful concepts. A concept was defined as one separate meaningful entity; one or more concepts could be identified from a single item. For example, the item ‘during the past 4 weeks, how much did pain interfere with your normal work’ from the Short Form Health Survey contains two meaningful concepts: ‘pain’ and ‘work’. The meaningful concepts were then linked to the most precise ICF category in the components of ‘Body functions’ (denoted by the letter 'b'), 'Body structures' (s), 'Activities and participation' (d), and 'Environmental factors' (e).[21] Concepts were also linked to 'Personal factors' (pf) although these are not yet classified in the ICF. An ICF code starts with the letters b, s, d, or e, followed by a numeric code. The ICF is organized hierarchically: the first level is made up of chapters (first digit of the numeric code), and each chapter consists of second-level categories (second and third digit), followed by more detailed third-level and, for some cases, fourth-level categories (subsequent digits), as can be seen in the following example from the component 'Body functions': (1) first-level chapter: b2, 'Sensory functions and pain'; (2) second-level category: b280, 'Sensation of pain'; (3) third-level category: b2801 'Pain in body part'; and (4) fourth-level category: b28013, 'Pain in back'. Some concepts were assigned the code nd (not definable), for example for 'general health' (code nd-gh) as this is too general to link to an ICF category. Finally, a few concepts could not be linked since the information was beyond the scope of the ICF. In that case, the code nc (not covered) was used, for example for 'quality of life' (code nc-qol).

Since some of the identified measures were previously linked in other projects,[21] existing linking results were obtained from the ICF Research Branch and independently checked by two reviewers (JB, SN). Concepts identified in clinical assessments were pre-linked by a third reviewer(CL), a physician in physical medicine and rehabilitation. The first two reviewers independently checked the pre-linked ICF categories.

The linking process was performed independently by the same two reviewers (JB, SN). Results were compared, and disagreement was resolved by discussion. A minority of the discrepancies were discussed with a third reviewer (CL) until final agreement was reached. Initial interrater agreement of the independent linking conducted before consensus or consultation with the third linker in case of disagreement, was determined for second-level categories (see data analysis below) by calculating Cohen's Kappa.[29]

Data analysis

Frequency analysis was used to examine the total number of outcome measures and linked ICF categories that the common measures contained, along with corresponding percentages relative to the number of studies in which they were used. If an ICF category was repeatedly assigned within one multiple-item measure, or within one study, it was counted only once. ICF categories found in at least 5% of the studies were included in the list of candidate categories.[11] To be consistent with previous ICF Core Set studies, we only report the second-level categories; concepts linked to a more specific third- or fourth-level category were reported at their corresponding second-level category.

RESULTS

Study selection and characteristics

The initial search yielded 5472 records (Figure 1). After title and abstract screening, full-text articles of 685 records could be retrieved and were reviewed. A total of 274 articles (5.0%) finally met the eligibility criteria. Of these, 113 eligible articles included multiple publications of 38 unique studies and 161 were single publications. Therefore, 199 unique studies were finally included for further review.

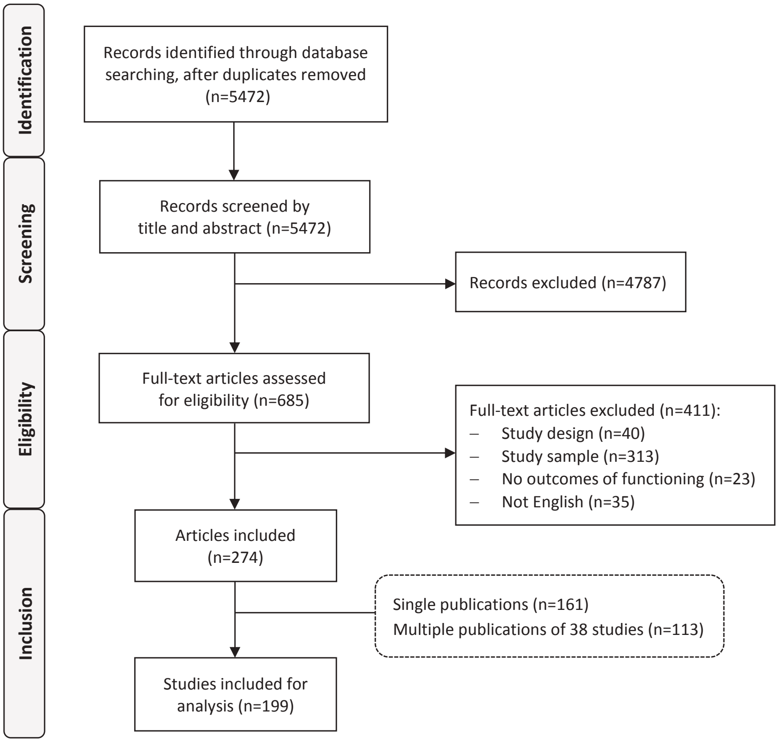

Figure 1 Flow diagram of article selection process.

Over half of the studies were published in the previous 6 years (Table 1). The 199 studies included 176 studies with an observational design and 23 experimental studies. Most studies were conducted in Europe (39.7%), Northern America (27.1%), and the Western Pacific (25.6%). Sample sizes ranged from 11 to 14 806 (median 33, interquartile range 20–69). Overall, 55.2% of the participants were male, and the mean age was 31 years, indicating that mainly younger adults were studied. A total of 139 studies (69.8%) reported participants' CP subtype and 91 studies (45.7%) used the GMFCS to classify their participants (see Table 1 and 2 for all study and participant characteristics).

Table 1 Characteristics of included studies (n=199).

Study characteristics	**n**	**%**
Publication year		
2000-2010	94	47.2
2011-2016	105	52.8
World Health Organization regions		
Europe	79	39.7
North America	54	27.1
Western Pacific	51	25.6
South America	11	5.5
Africa	2	1.0
Eastern Mediterranean	2	1.0
Study design		
Observational	176	88.5
Case series	30	15.1
Cross-sectional	103	51.8
Cohort	16	8.0
Case-control	27	13.6
Experimental	23	11.6
Randomized controlled trial	10	5.0
Others	13	6.6
Sample sizes		
10-20	58	29.1
21-50	74	37.2
51-100	34	17.1
101-500	27	13.6
501-1000	2	1.0
>1000	4	2.0

Table 2 Participant characteristics (n=32 933).

Participant characteristics	n	%
Age (n=10 841, 32.9%)	Mean (y:mo)	Range, y
Mean age of samples	31:0	18–58
Minimum age of samples	18:6	5–57
Maximum age of samples	51:1	20–84
Sex (n=32 443, 98.5%)		
Male	17 916	55.2
Female	14 527	44.8
CP subtype (n=8236, 25.0%)		
Spastic	6413	77.9
Unilateral spastic	1367	16.6
Bilateral spastic	3748	45.5
Unspecified	1298	15.8
Dyskinetic	1028	12.5
Ataxic	100	1.2
Mixed types	330	4.0
Unknown	365	4.4
GMFCS level (n=4337, n=34.5%)[a]		
Level I	758	17.5
Level II	905	20.9
Level III	697	16.1
Combined levels I-III	260	6.0
Level IV	712	16.4
Level V	748	17.2
Combined levels IV-V	221	5.1
Unknown	36	0.8

Data are n (%) unless otherwise stated. [a]One study was deliberately not included here, because its large sample of only persons classified in Gross Motor Function Classification System (GMFCS) level V (n=747) affected the distribution of the GMFCS.

Outcome measures

The studies used a total of 332 outcome measures, including 204 single-item and 128 multiple-item measures. Table 3 presents the single- and multiple-item outcome measures most often used in the 199 studies. Single-item measures included single (172) and multiple (32) types of measurement. For example, walking included multiple types of measurement as it was clinically assessed by the Six Minute Walk Test and self-reported on the Wilson Mobility Scale. A total of 242 types of single-item measures were identified; 20 (8.3%) were patient-oriented, 94 (38.8%) were clinical assessments, and 128 (52.9%) were non-tool measures. Multiple-item measures included 92 (71.9%) patient-oriented measures and 36 (28.1%) clinical assessments.

Table 3 Most frequent single- and multiple-item outcome measures used in studies (n=199) on adults with cerebral palsy.

Outcome measure	Type	Items in measure	Used in number of studies, n (%)
Single-item measures			
Pain	Patient-oriented, non-tool	1	40 (20.1)
Mobility of joints	Clinical, non-tool	1	29 (14.6)
Spasticity	Clinical, non-tool	1	29 (14.6)
Walking	Patient-oriented, clinical, non-tool	1	27 (13.6)
Muscle power	Clinical, non-tool	1	25 (12.6)
Gross motor function	Patient-oriented	1	22 (11.1)
Hip displacement	Patient-oriented, clinical, non-tool	1	22 (11.1)
Multiple-item measures			
Short-Form Health Survey (SF-36)	Patient-oriented	36	11 (5.5)
Barthel Index (BI)	Patient-oriented	10	8 (4.0)
Functional Independence Measure (FIM)	Clinical	18	8 (4.0)
Gross Motor Function Measure (GMFM)	Clinical	88	7 (3.5)
Functional Mobility Scale (FMS)	Clinical	3	6 (3.0)
Japanese Orthopedic Association (JOA) Score	Clinical	4	6 (3.0)
Assessment of Life Habits (LIFE-H)	Patient-oriented	80	5 (2.5)
Fatigue Severity Scale (FSS)	Patient-oriented	9	5 (2.5)

Representation of the most frequent single- and multiple-item outcome measures obtained from 199 studies.

In the single-item measures, assessment of pain was most frequent, measured by patient-oriented (52.5%) and non-tool measures (47.5%). Mobility of joints and spasticity were also frequently addressed, often measured by clinical assessments (86.2% and 82.8% respectively). Also, walking, muscle power, gross motor function, and hip displacement were used in more than 10% of the studies. In the multiple-item measures, the Short Form Health Survey (5.5%) was the most frequently used patient-oriented measure, followed by the Barthel Index (4.0%), Assessment of Life Habits (2.5%) and the Fatigue Severity Scale (2.5%). The most common clinical measures among multi-item measures were the Functional Independence Measure (4.0%), Gross Motor Function Measure (3.5%), the Functional Mobility Scale (3.0%) and Japanese Orthopedic Association score (3.0%).

A total of 156 out of 332 outcome measures were identified in at least two studies; these common measures were reported in 189 (95.0%) of the included studies. One multiple-item measure could not be retrieved in English. In the end, 114 single-item measures and 1044 items from 41 multiple-item measures (total of 1158 items) were linked to the ICF.

ICF categories

The 1158 items of the common measures revealed a total of 4409 meaningful concepts that were linked to the ICF. Overall, 24 concepts (0.5%) were linked to an ICF component, 106 concepts (2.4%) to first-level ICF categories (chapters), and 3956 concepts (89.7%) to second-, third- or fourth-level ICF categories. The other 323 concepts were regarded as personal factors (74, 1.7%), not covered (131, 3.0%), or not defined (118, 2.7%). The Cohen's Kappa of 0.61 (95% confidence interval 0.59–0.63) indicated moderate inter-rater agreement between the independent linkers.

Tables 4 and 5 show the chapters and second-level categories, respectively, identified in at least 5% of the studies using common measures. Second-level ICF categories present in at least 15% of the studies are depicted in the ICF model in Figure 2. 'Body functions' included seven chapters, of which b2 'Sensory functions and pain' (45.0%), and b7 'Neuromusculoskeletal and movement-related functions' (43.9%) were the most frequent (Table 4). More specifically, b280 'Sensation of pain' (37.6%) and b710 'Mobility of joint functions' (19.0%) were the most frequent second-level categories (Table 5). In 'Body structures', only chapter s7 'Structures related to movement' was identified; herein s750 'Structure of lower extremity' (21.7%) was most frequently measured. 'Activities and participation' was the overall most covered component, including nine chapters and 43 second-level categories. Among these, chapters d4 'Mobility' (55.6%), and d5 'Self-care' (34.9%) were the most frequent, and d450 'Walking' (33.3%) and d850 'Remunerative employment' (27.5%) were the most frequent second-level categories. Four chapters were identified in 'Environmental factors', of which e1 'Products and technology' (26.5%) was the most frequent. More specifically, e120 'Products and technology for personal indoor and outdoor mobility and transportation' (16.9%) was most frequent. In 'Personal factors', sociodemographic concepts were common (15.9%). Frequently used concepts that were not covered, or not defined by the ICF included those related to body composition (10.1%) and general health (9.5%).

Table 4 Relative frequency of first-level categories (chapters) identified in studies using common measures (n=189).

ICF code	Chapter	Used in number of studies, n (%)
b	***Body functions***	
b1	Mental functions	52 (27.5)
b2	Sensory functions and pain	85 (45.0)
b3	Voice and speech functions	17 (9.0)
b4	Functions of the cardiovascular, hematological, immunological and respiratory systems	35 (18.5)
b5	Functions of the digestive, metabolic and endocrine systems	37 (19.6)
b6	Genitourinary and reproductive functions	31 (16.4)
b7	Neuromusculoskeletal and movement-related functions	83 (43.9)
s	***Body structures***	
s7	Structures related to movement	60 (31.7)
d	***Activities and participation***	
d1	Learning and applying knowledge	28 (14.8)
d2	General tasks and demands	22 (11.6)
d3	Communication	26 (13.8)
d4	Mobility	105 (55.6)
d5	Self-care	66 (34.9)
d6	Domestic life	34 (18.0)
d7	Interpersonal interactions and relationships	39 (20.6)
d8	Major life areas	52 (27.5)
d9	Community, social and civic life	38 (20.1)
e	***Environmental factors***	
e1	Products and technology	50 (26.5)
e3	Support and relationships	25 (13.2)
e5	Services, systems and policies	23 (12.2)
pf	***Personal factors***	37 (19.6)
nc	***Not covered***	51 (27.0)
nd	***Not defined***	33 (17.5)

Only ICF categories measured in ≥5% of all studies applying common measures are presented. Categories are ordered numerically within each component.

Table 5 Relative frequency of second-level categories identified in studies using common measures (n=189).

ICF code	Category	Used in number of studies, n (%)
b	***Body functions***	
b280	Sensation of pain	71 (37.6)
b710	Mobility of joint functions	36 (19.0)
b620	Urination functions	30 (15.9)
b730	Muscle power functions	30 (15.9)
b735	Muscle tone functions	27 (14.3)
b152	Emotional functions	26 (13.8)
b455	Exercise tolerance functions	23 (12.2)
b525	Defecation functions	23 (12.2)
b770	Gait pattern functions	22 (11.6)
b760	Control of voluntary movement functions	21 (11.1)
b130	Energy and drive functions	20 (10.6)
b134	Sleep functions	20 (10.6)
b144	Memory functions	20 (10.6)
b126	Temperament and personality functions	19 (10.1)
b140	Attention functions	14 (7.4)
b164	Higher-level cognitive functions	13 (6.9)
b114	Orientation functions	12 (6.3)
b320	Articulation functions	12 (6.3)
b235	Vestibular functions	11 (5.8)
b210	Seeing functions	10 (5.3)
s	***Body structures***	
s750	Structure of lower extremity	41 (21.7)
s760	Structure of trunk	27 (14.3)
s730	Structure of upper extremity	13 (6.9)
s770	Additional musculoskeletal structures related to movement	10 (5.3)
d	***Activities and participation***	
d450	Walking	63 (33.3)
d850	Remunerative employment	52 (27.5)
d855	Non-remunerative employment	47 (24.9)
d510	Washing oneself	42 (22.2)
d540	Dressing	42 (22.2)
d455	Moving around	40 (21.2)
d920	Recreation and leisure	38 (20.1)
d410	Changing basic body position	35 (18.5)
d440	Fine hand use	35 (18.5)
d520	Caring for body parts	34 (18.0)
d640	Doing housework	32 (16.9)

Table 5 Relative frequency of second-level categories identified in studies using common measures (n=189). (continued)

ICF code	Category	Used in number of studies, n (%)
d445	Hand and arm use	31 (16.4)
d550	Eating	31 (16.4)
d420	Transferring oneself	29 (15.3)
d415	Maintaining a body position	28 (14.8)
d460	Moving around in different locations	28 (14.8)
d760	Family relationships	28 (14.8)
d465	Moving around using equipment	27 (14.3)
d530	Toileting	26 (13.8)
d430	Lifting and carrying objects	24 (12.7)
d750	Informal social relationships	24 (12.7)
d630	Preparing meals	19 (10.1)
d330	Speaking	17 (9.0)
d570	Looking after one's health	17 (9.0)
d650	Caring for household objects	17 (9.0)
d770	Intimate relationships	15 (7.9)
d240	Handling stress and other psychological demands	14 (7.4)
d166	Reading	13 (6.9)
d210	Undertaking a single task	13 (6.9)
d350	Conversation	13 (6.9)
d360	Using communication devices and techniques	13 (6.9)
d560	Drinking	13 (6.9)
d870	Economic self-sufficiency	13 (6.9)
d910	Community life	13 (6.9)
d175	Solving problems	12 (6.3)
d345	Writing messages	12 (6.3)
d470	Using transportation	12 (6.3)
d177	Making decisions	11 (5.8)
d310	Communicating with - receiving - spoken messages	11 (5.8)
d335	Producing nonverbal messages	11 (5.8)
d475	Driving	11 (5.8)
d620	Acquisition of goods and services	11 (5.8)
d930	Religion and spirituality	10 (5.3)
e	***Environmental factors***	
e120	Products and technology for personal indoor and outdoor mobility	32 (16.9)
e110	Products or substances for personal consumption	23 (12.2)
e115	Products and technology for personal use in daily living	21 (11.1)
e580	Health services, systems and policies	19 (10.1)

Table 5 Relative frequency of second-level categories identified in studies using common measures (n=189). (continued)

ICF code	Category	Used in number of studies, n (%)
e399	Support and relationships, unspecified	13 (6.9)
pf	***Personal factors***	
pf-sd	Personal factors, sociodemographics	30 (15.9)
pf	Personal factors, unspecified	25 (13.2)
nc	***Not covered***	
nc-bc	Not covered, body composition	19 (10.1)
nc	Not covered, unspecified	18 (9.5)
nc-hc	Not covered, health condition	16 (8.5)
nd	***Not defined***	
nd-gh	Not defined, general health	18 (9.5)
nd	Not defined, unspecified	14 (7.4)
nd-pb	Not defined, physical behavior	14 (7.4)
nd-ph	Not defined, physical health	11 (5.8)
nd-funct	Not defined, functioning	11 (5.8)

Only ICF categories measured in ≥5% of all studies applying common measures are presented. Categories are ordered according to their relative frequency within each component.

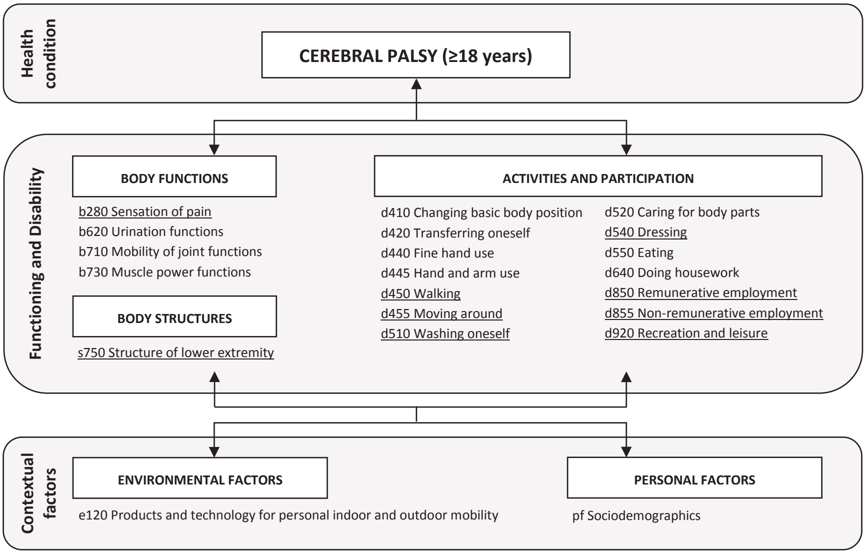

Figure 2 International Classification of Functioning, Disability and Health (ICF) framework,[9] including the most frequent categories studied in adults with CP. Note: only second-level ICF categories present in ≥15% of the studies are depicted here; those present in ≥20% of the studies are underlined.

DISCUSSION

This systematic review identified and quantified the most studied areas of functioning and disability reported in an extensive number of published studies on adults with CP using the ICF as a reference.[21] Most of the items of common outcome measures could be translated into the universal language of the ICF. The results summarize the functioning concepts addressed in studies pertaining to adults with CP so far. Accordingly, the results represent the researchers' perspective in the development of an ICF Core Set for adults with CP.

In line with the definition of CP,[1] ICF categories referring to mobility and movement-related functions were among the most frequently studied at adult age. 'Mobility' (d4) was the most frequently addressed ICF chapter – a chapter that includes 'Walking' (d450) and 'Moving around' (d455), and 'Changing and maintaining body positions' (d410 and d415); these activities are all reflected in the GMFCS.[24] 'Sensory functions and pain' (b2) was the second most frequent chapter, almost completely represented by the overall most frequent second-level category of 'Sensation of pain' (b280). Furthermore, we found high frequencies of categories in chapter b7 'Neuromusculoskeletal and movement-related functions', namely 'Functions of joint mobility' (b710), 'Muscle power and tone' (b730 and b735), 'Gait pattern' (b770) and 'Voluntary movement' (b760). Pain, limited joint mobility, decreased muscle power, and increased muscle tone are regularly observed in clinical practice. According to the ICF model, these (impairments in) 'Body functions' may affect the level of relevant activities and participation in major life areas, such as walking and self-care, and consequently employment and social and domestic life. The high frequency of concepts addressing 'Activities and participation' emphasize their importance. Regarding 'Contextual factors', 'Products and technology for mobility or for use in daily living' (e1) were frequently reported, which can both facilitate or hinder the aforementioned 'Body functions' and 'Activities and participation'.

The patient-oriented measures and clinical assessments found in the literature presumably reflect the instruments and assessments that are used in clinical practice. The Short Form Health Survey, Barthel Index, and Functional Independence Measure are the most widely used outcome measures in adults with CP, and have a common focus on 'Mobility' (d4) and 'Self-care' (d5). These instruments are also widely used in other populations with physical and mental disabilities such as stroke and traumatic brain injury.[30, 31] Recently, the ICF Research Branch developed a generic set of categories that can be applied for documenting functioning in clinical (rehabilitation) settings.[32] Comparable to the present results, 21 of the 30 categories in the ICF Generic-30 Set (often also called ICF Rehabilitation Set) are from the component 'Activities and participation', whereby 13 are 'Mobility' (d4) and 'Self-care' (d5) categories. Furthermore, 89% of the body function categories included in the ICF Generic-30 Set corresponds to the 'Body functions' frequently reported in the studies included in this review. This match of categories and consistency with clinically relevant instruments supports the notion that the ICF provides a universal language that can be used to describe outcomes of adults with CP. Nevertheless, since the population of adults with CP is very heterogeneous and presents itself with very specific and often increasing health-related issues that go beyond the aspects of functioning addressed by the ICF Generic-30 Set,[20] a CP-specific ICF Core Set would have added value in clinical practice. For example, this review identified certain sensory functions and functions related to fatigue, or activities such as fine hand use, that are not included in the ICF Generic-30 Set.

We identified only few 'Body structures' in the literature on adults with CP. In this component, only 'Structures related to movement' (s7), most frequently the trunk and lower extremities, were regularly measured, usually by clinical assessments with specialized equipment (i.e. radiography). These body structures were mainly measured in adults with CP with lower-functioning GMFCS levels; this is no surprise given the more severely affected deformities that are common in people whose gross motor function is more impaired.[33] Likewise, few concepts were linked to 'Personal factors', which suggests a lack of representation of important interactions between personal characteristics and functional status in published studies on adults with CP, or may reflect the type of studies included in this review. Most of these were conducted in rehabilitation settings and included outcome measures that describe functioning or determine treatment efficacy, potentially explaining the focus on body functions and activities and participation outcomes. Another concern may be that personal factors are still not classified in the ICF. Finally, some concepts were unable to link to the ICF. For example, 6% of the concepts were not covered by the ICF or insufficiently defined to allow linking to an ICF category. Notably, concepts such as physical behavior – often measured by accelerometry – or those related to body composition (e.g. waist circumference) were often measured but could not be linked to the ICF.

A population-specific ICF Core Set facilitates the development of standards. This review presents a state-of-the-art of research in adults with CP. The total of 332 different outcome measures identified reflects the large variation in outcomes that are considered relevant to study in adults with CP, but at the same time indicates a lack of standardization for frequent outcomes. Among the large quantity of outcome measures, we found a number of CP-specific measures, such as the GMFCS and Manual Ability Classification System. The GMFCS and the Manual Ability Classification System are, however, intended to classify the level of an individual's gross motor function and manual performance, respectively.[24, 34] Some of the included studies used the GMFCS as an outcome measure though. Consequently, this may have affected the present overview, since the GMFCS represents ICF categories in chapter d4 'Mobility'. Including them as outcome measures may therefore have slightly overestimated the frequency in this chapter. However, in almost half of the studies, the GMFCS was applied as a participant characteristic and thus not included in our frequency analysis.

Systematic reviews with ICF linking of outcome measures have been previously conducted for other conditions addressing physical and cognitive disabilities.[30, 31, 35] While some of these used random samples of the literature or included only clinical trials,[30] others linked a selection of the identified measures based on a relatively high occurrence rate or type of measure.[31, 35] In the current systematic review, all eligible literature from a comprehensive sample was selected and a variety of study designs were included. For the linkage of outcome measures, a bottom-line occurrence rate (i.e. used in two or more studies) was considered, regardless of its type. We were able to demonstrate by which type of measure the relevant areas of functioning and disability were most commonly addressed. Clinical assessments were often applied to study cognitive functions, neuromusculoskeletal and movement-related functions, and structures related to movement, whereas patient-oriented and non-tool measures were used to study activities and participation, mainly chapters d4 to d9.

The present methodology was in line with the systematic review conducted for the ICF Core Sets for children and young people with CP.[14] Minor differences were, however, present. For example, our literature search was more comprehensive (5472 vs 698 screened). On the other hand, Schiariti et al.[14] linked every outcome measure, although in some cases only the domains or purposes of measures were linked. Despite only linking the common outcome measures, we linked all items included in these measures. Finally, Schiariti et al.[14] used the ICF for Children and Youth, whereas we linked the extracted concepts to the 2001 reference version of the ICF. Apart from these differences in methodology, the distinction between the children/young people and adult populations with CP was mainly demonstrated by the results of both reviews. For example, control of voluntary movement was by far the most studied body function in children and young people, whereas for adults, sensation of pain was most common. In 'Activities and participation', walking was the most frequent category in both populations. However, for children and young people, other 'Mobility' categories (d4), such as 'Moving around' or 'Changing and maintaining body positions', continued to be most frequent, whereas for adults we identified 'Employment' (d8), 'Self-care activities' (d5) and 'Recreation' (d9) as the most frequent categories following walking. With regard to the differing ICF frameworks, the ICF Core Sets for children and young people with CP contain eight categories that only exist in the ICF for Children and Youth. However, we did not expect to find these categories (e.g. 'Acquiring language') in research on the adult population. In the end, the shared focus on movement-related functions, mobility, and self-care, strengthens that these domains are relevant for individuals with CP throughout the lifespan. Nevertheless, each stage of life has its own areas of attention. Our findings highlight that when young people with CP transition into adulthood, there is a shift of attention on specific aspects of functioning, namely towards participation in major life areas. A recent follow-up study of individuals with CP aged between 16 and 34 years demonstrated that, in young adulthood, housework, employment, and intimate relationships became much more relevant, while education and selected recreational activities became less relevant.[19] At the same time, difficulty in participation increased during the transition into the mid- and late-twenties.[19] Comparing the results of the literature reviews on children/young people and adults with CP emphasizes the shifting of relevant outcomes for individuals with CP when entering adult life.

This systematic literature review shows that functioning of adults with CP is an emerging field of research, as evident by the increasing number of articles published on this topic during the 16-year timeframe of this review. A small part of this research seems to be experimental: only 5% involved randomized controlled trials. Considering individuals with CP receive most of their treatment during childhood, it is not surprising that research examining the effects of interventions, such as randomized controlled trials, is not frequently found in the literature on adults with CP. On the other hand, from a clinical perspective, it is surprising to find that the rehabilitation-oriented studies included relatively young participants (median 31y), as young adults with CP generally do not receive rehabilitation care.[36] Nevertheless, it can be concluded that there is a paucity of intervention studies targeting the long-term consequences of living with CP.

Some limitations should be considered when interpreting the results of this review. First, our selection was limited to studies and outcome measures in English, and to studies published between 2000 and 2017. Also, qualitative studies were not included, since this is considered a separate preparatory study in ICF Core Set development process. These criteria were in line with the ICF methodology,[11] but some important concepts were potentially missed since qualitative research captures direct experiences of persons in their natural setting, often referring to environmental and personal factors. Similarly, certain concepts that only recently received attention in scientific literature might have been missed. Second, most studies were conducted in Europe, North America, and the Western Pacific. Any concepts that might be specifically relevant in low- and middle-income countries were therefore missed. Finally, initial agreement on ICF categories between the reviewers was modest. However, a strength of this review was that each step was conducted independently by two reviewers, and discussions with a third reviewer always led to consensus. As this is the first study in the development of an ICF Core Set for adults with CP, these limitations will presumably be levelled out in the other preparatory studies. For example, in the expert survey all six WHO-regions will be represented, so aspects of functioning in both low- and high-income countries will be captured.

CONCLUSION

This systematic review identified the most frequent outcomes used in studies of adults with CP, of which pain, mobility, self-care, employment, and recreation were most frequent. The broad range of ICF categories identified in this study underscores the heterogeneity of functioning and disability in adults with CP, but there is limited focus on environmental and personal factors in research, supporting the need to explore other perspectives as well. The present results will be combined with the results of the other preparatory studies. Together, all four preparatory studies capture the complementary perspectives of researchers, patients, and clinicians, and will serve as the scientific basis for the development of an ICF Core Set for adults with CP for use in both research and clinical practice.

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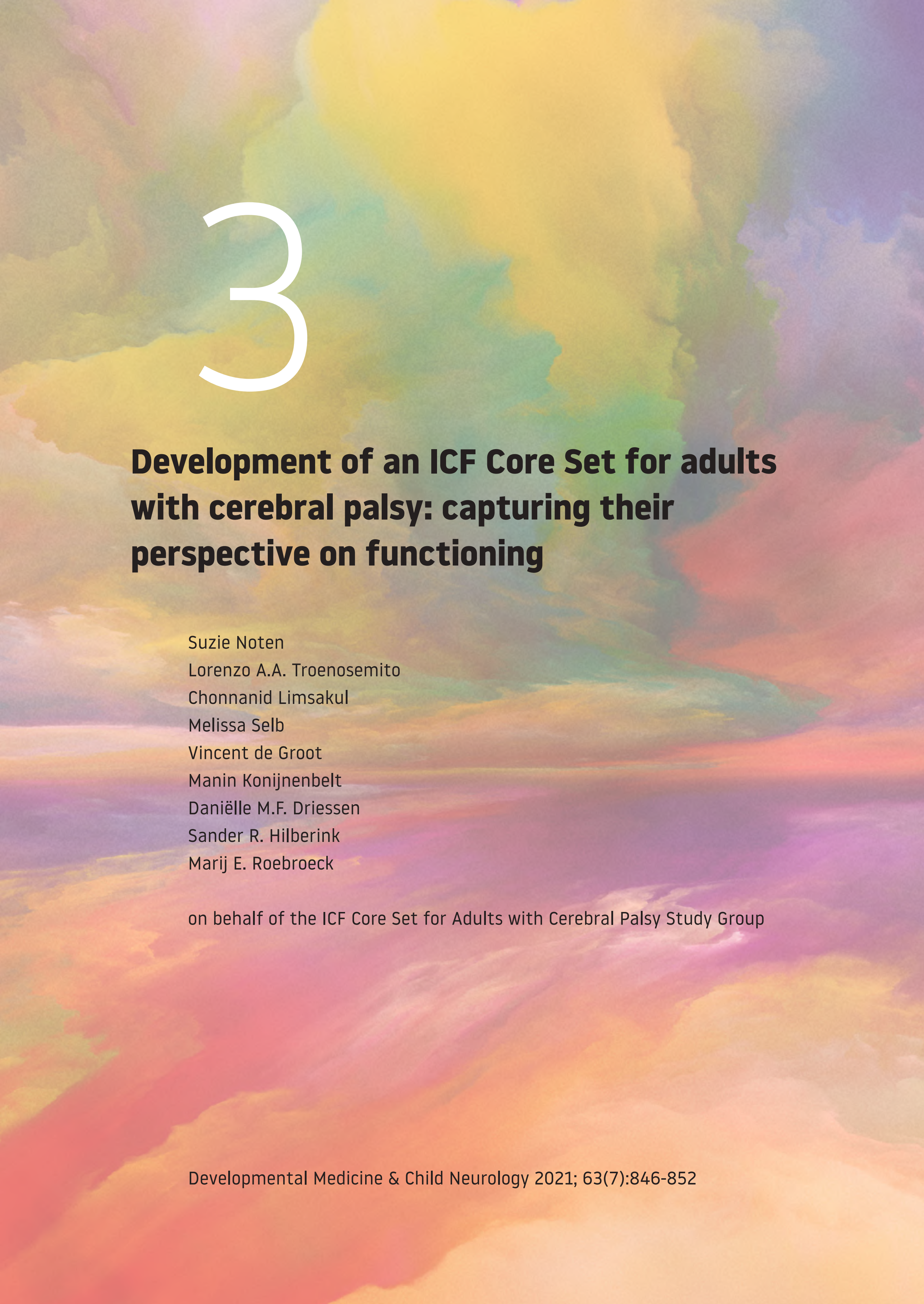

3

Development of an ICF Core Set for adults with cerebral palsy: capturing their perspective on functioning

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ABSTRACT

Aim: To examine the most relevant aspects of functioning of adults with cerebral palsy (CP) from their perspective, contributing to the development of an International Classification of Functioning, Disability and Health (ICF) Core Set for adults with CP.

Method: We conducted six focus group discussions with adults with CP without intellectual disability and seven interviews with adults with CP with intellectual disability and caregivers, addressing all ICF components. Meaningful concepts were identified from verbatim transcripts and linked to ICF categories by two independent researchers.

Results: In total, 31 adults with CP without intellectual disability (mean [SD] age 46y 1mo [14y 1mo]; 20 females; 11 males; Gross Motor Functioning Classification System (GMFCS) levels I-IV) and seven adults with CP with intellectual disability (mean [SD] age 25y 8mo [6y 8mo]; four females; three males; GMFCS levels III-V) participated. We identified 132 unique second-level categories, 47 addressing body functions, seven body structures, 43 activities and participation, and 35 environmental factors. The most frequently mentioned categories were emotional function, pain, muscle tone function, support of family, products and technology, and health services.

Interpretation: Adults with CP experienced problems in a broad range of body functions and activities and indicated the importance of environmental factors for functioning. The identified categories will be added to the list of candidate items to reach consensus on an ICF Core Set for adults with CP.

INTRODUCTION

Cerebral palsy (CP) is one of the most common developmental motor disorders amongst children, occurring in 2 to 2.5 per 1000 live births.[1-3] Nowadays, most people with CP are adults due to an increase in life expectancy for this population in the last decades.[4] Known determinants of functioning of persons with CP are the level of gross motor functioning, manual ability, speech impairments and intellectual functioning.[5, 6] Intellectual disability is present in about 49 to 51% of children and adolescents with CP.[7, 8] Intellectual disability limits daily activities,[9] and social participation is more strongly influenced by intellectual disability than by level of gross motor functioning.[10] Therefore, it is important to specifically examine the relevant aspects of functioning of adults with and without intellectual disability. Despite the increasing attention on adults with CP, research on adults with CP and intellectual disability is scarce.[11]

Thus far, studies have shown that CP at adult age results in several impairments and limitations in activities and participation. The large variation and lack of standardization of outcomes of functioning make comparison across studies or countries difficult.[12] Clinical care and research would benefit from a standardized outcome assessment. In this study, we used the International Classification of Functioning, Disability and Health (ICF) as a framework for describing different aspects of functioning, disability and health in adults with CP. The ICF encompasses the components: body functions, body structures, activities and participation, and environmental and personal factors.[13] In total, the ICF model contains over 1400 categories, which makes its implementation in clinical practice and research challenging. To address this challenge, ICF Core Sets have been developed. ICF Core Sets include the ICF categories that are most relevant for describing functioning of persons with specific health conditions and are available for children with CP;[14] but an ICF Core Set for adults with CP was not available. An early decline of function in adults with CP[15] and a shift to other areas of participation, such as independent living,[16] highlights the importance of developing an ICF Core Set for adults with CP.

A scientific approach for developing an ICF Core Set consists of different steps.[17] First, four preparatory studies are performed from different perspectives: a systematic literature study (researcher's perspective),[11] a qualitative study (patient's perspective), an expert survey (health professional's perspective)[18] and an empirical study (clinical perspective). The results of these studies are included in a list of ICF candidate categories, from which experts will decide on the final ICF Core Set.

In the present qualitative study, we aimed to identify those aspects of functioning, environmental and personal factors that are considered the most important from the lived experience of adults with CP with and without intellectual disability.

METHOD

Study design

A multicentre qualitative study with semi-structured focus group discussions and individual interviews was performed in adults with CP and/or their caregivers. Adults with CP without intellectual disability participated in focus groups in their geographical region. Caregivers as proxies of adults with CP with intellectual disability were individually interviewed and, where possible, the respective person with CP was present and answered for themself. A moderator (SN or LT) and a research assistant led the focus groups and interviews. The medical ethics committee of Erasmus MC University Medical Center (MEC-2018-1126) and the participating centres approved this study. Participants or their caregivers signed informed consent before participation.

Participants

Individuals were included if they were adults with CP (≥18y) and able to communicate in Dutch; individuals using augmentative communication systems were included in the sample. Participants were considered as having an intellectual disability if a health professional diagnosed the person as having an IQ level of less than 70 or a developmental age below 12 years old.[19] Participants were recruited at Amsterdam UMC, Amsterdam, Libra Rehabilitation & Audiology, Eindhoven, De Hoogstraat Rehabilitation, Utrecht, and by advertising the study on the website of the patient organization, CP Netherlands.

Data collection

CP-related and demographic information was collected on age, sex, ethnicity, type of CP, Gross Motor Function Classification System (GMFCS) level, educational level, working status, living status, marital status and if the person has children.

The focus groups and interviews were semi-structured, addressing six questions covering all ICF components, as follows.[17] (1) Body functions (b): If you think about your body and mind, what does not work the way it is supposed to? (2) Body structures (s): If you think about your body, in which parts are the problems? (3) Activities and participation (d): If you think about your daily life, what are your problems? (4) Environmental factors (e): If you think about your environment and your living conditions, what do you find helpful or supportive? (5) Environmental factors (e): If you think about your environment and your living conditions, what barriers do you experience? (6) Personal factors (pf): If you think about yourself, what is important about you and the way you handle your condition/situation? For the focus groups, an additional question was asked on the participants' strengths: (7) If you think about the positive side of living with CP, what would you like to mention?

Illustrations and probes (e.g. pain, health services) were used to clarify the questions. The duration of the focus groups ranged between 95 and 130 minutes; the interviews lasted between 40 and 80 minutes. Each focus group discussion and interview was digitally recorded.

Data analysis

A two-step procedure was conducted, comprising a qualitative analysis and a linking process to the ICF. Focus group discussions and interviews were analyzed using a meaning condensation procedure, as follows.[20] First, verbatim transcripts were divided into meaning units (using ATLAS.ti 8; ATLAS.ti Scientific Software Development GmbH, Berlin, Germany), that include an overall theme, not naturally following linguistic or grammatical rules, but where a shift of meaning is detected. These themes get broken down further into meaningful concepts.[20, 21] For example, the meaningful concepts of the statement 'I use medication for the pain in my legs' are 'use of medication' and 'pain in legs'. Next, these concepts were linked to the most precise ICF categories following established linking rules.[21] Each ICF component (b, s, d, e) consists of categories at different levels, starting with chapter or first-level categories (e.g. b2 sensory functions and pain), followed by a second-level (e.g. b280 sensation of pain), third-level (e.g. b2801 pain in body part) or fourth-level code (e.g. b28015 pain in lower limb). Personal factors were identified as "pf".

Two independent researchers (LT, SN), who received training on the ICF and linking methodology[22] performed the linking process. The first focus group and interview were linked by the two researchers independently to affirm their consistent application of the linking methodology. The other focus groups and interviews were randomly allocated; 50% of the meaningful units was linked by both researchers, the remaining 50% was linked by one researcher (LT or SN). Interrater agreement was determined for second-level categories by calculating Cohen's Kappa.[23] Linking results were compared and resolved in a consensus discussion. When consensus could not be reached, a third researcher was consulted (CL).

Concepts were linked to the most precise ICF category but were aggregated to the second-level for further analyses. A second-level category was only counted once for each focus group or interview. Frequency analysis of the second-level ICF categories was performed to identify the most frequently-reported categories. We aimed to include participants until a saturation level of 5% was reached, meaning that the focus groups and interviews resulted in no more than 5% new second-level categories. ICF categories that were reported as problem, facilitator, or barrier in more than one focus group or interview were included in the list of candidate categories provided for the subsequent consensus process.

RESULTS

Participants

We completed six focus groups with a total of 31 participants without intellectual disability (mean [SD] age 46y 1mo [14y 1mo], range 24–74y; 20 females, 11 males; 28 with spastic CP; GMFCS levels I–IV) and individual interviews representing seven participants with intellectual disability and/or their caregiver (mean [SD] age 25y 8mo [6y 8mo] range 19–38y; four females, three males; five with spastic and dyskinetic CP; GMFCS levels III–V). Participants' characteristics are presented in Table 1.

Table 1 Characteristics of adults with cerebral palsy with and without intellectual disability.

Participant characteristics	Adults without intellectual disability (N = 31)		Adults with intellectual disability (N = 7)	
Age, mean (SD) range, y:mo	46:1 (14:1), 24–74y		25:8 (6:8), 19–38y	
Sex, n (%)				
Male	11	(35.5)	3	(42.9)
Female	20	(64.5)	4	(57.1)
Type of CP, n (%)				
Spastic	28	(90.3)	1	(14.3)
Spastic and Dyskinetic	2	(6.5)	5	(71.4)
Spastic and Ataxic	1	(3.2)	1	(14.3)
Limb distribution, n (%)				
Unilateral	10	(32.3)	1	(14.3)
Bilateral	21	(67.7)	6	(85.7)
GMFCS level, n (%)				
I	9	(29.0)	0	(0.0)
II	8	(25.8)	0	(0.0)
III	9	(29.0)	1	(14.3)
IV	5	(16.2)	1	(14.3)
V	0	(0.0)	5	(71.4)

Table 1 Characteristics of adults with cerebral palsy with and without intellectual disability. (continued)

Participant characteristics	Adults without intellectual disability (N = 31)		Adults with intellectual disability (N = 7)	
Special education, n (%)	16	(51.6)	5	(71.4)
Level of education, n (%)				
No education	0	(0.0)	3	(42.8)
Primary education	2	(6.4)	3	(42.8)
Lower secondary education	4	(12.9)	1	(14.4)
Upper secondary education	10	(32.3)	0	(0.0)
Higher education	15	(48.4)	0	(0.0)
Work status, n (%)				
Student	2	(4.9)	0	(0.0)
Competitive employment	13	(31.7)	0	(0.0)
Sheltered employment	1	(2.4)	0	(0.0)
Non-remunerative employment	5	(12.2)	0	(0.0)
Homemaker	3	(7.3)	0	(0.0)
Receiving benefit grants	13	(31.7)	7	(100)
Other	4	(9.8)	0	(0.0)
Living status, n (%)				
Living alone	10	(32.3)	1	(14.3)
Living with parents	2	(6.4)	2	(28.6)
Living with partner	19	(61.3)	0	(0.0)
With others	0	(0.0)	4	(57.1)
Partner, n (%)	21	(67.7)	0	(0.0)
Children, n (%)	7	(22.6)	0	(0.0)

GMFCS, Gross Motor Function Classification System.

Relevant areas of functioning

In total, 2322 meaningful concepts (1390 in the focus groups; 932 in the interviews) were linked to 132 unique second-level categories, 47 addressing body functions, seven addressing body structures, 43 addressing activities and participation, and 35 addressing environmental factors. Additionally, 97 unique personal factors, 26 not covered codes and 79 non-definable codes were identified. A saturation level of 3.4% (focus groups) to 5.8% (interviews) was reached, indicating that identified categories were fairly thorough for adults with CP in general. Interrater agreement between the two linkers was moderate, Cohen's kappa 0.41 (95% Confidence Interval 0.39-0.44).

A list of second-level ICF categories mentioned in more than half of the focus groups (4 out of 6) and/or interviews (4 out of 7) is presented in Table 2 and quotes of typical examples of participants are presented below.

Table 2 Frequently mentioned second-level ICF categories in adults with cerebral palsy for the components body functions, body structures, activities and participation, environmental factors, in more than half of the focus groups (4 out of 6) and/or interviews (4 out of 7). ID= intellectual disability.

High frequent in adults with and without ID			**High frequent only in adults without ID**			**High frequent only in adults with ID**		
	Adults no ID	Adults ID		Adults no ID	Adults ID		Adults no ID	Adults ID
b Body functions								
b152 Emotional functions	6	6	b770 Gait pattern functions	6	0	b117 Intellectual functions	0	6
b280 Sensation of pain	6	6	b235 Vestibular functions	6	1	b167 Mental functions of language	2	6
b735 Muscle tone functions	6	6	b156 Perceptual functions	5	3	b210 Seeing functions	2	4
b130 Energy and drive functions	6	4	b320 Articulation functions	5	3	b525 Defecation functions	2	4
b455 Exercise tolerance functions	6	4	b730 Muscle power functions	5	2	b765 Involuntary movement functions	2	4
b760 Control of voluntary movement functions	6	4	b710 Mobility of joint functions	4	2			
b780 Sensations related to muscles and movement functions	4	4	b126 Temperament and personality functions	4	2			
s Body structures								
s750 Structure of lower extremity	5	6						
s760 Structure of trunk	5	5						
s730 Structure of upper extremity	4	4						
d Activities and participation								
d440 Fine hand use	5	6	d475 Driving	6	0	d550 Eating	3	6
d445 Hand and arm use	5	6	d850 Remunerative employment	6	0	d465 Moving around using equipment	0	5
d920 Recreation and leisure	6	4	d640 Doing housework	6	1			
d415 Maintaining a body position	4	4	d450 Walking	6	2			
			d540 Dressing	6	2			
			d430 Lifting and carrying objects	5	0			

Table 2 Frequently mentioned second-level ICF categories in adults with cerebral palsy for the components body functions, body structures, activities and participation, environmental factors, in more than half of the focus groups (4 out of 6) and/or interviews (4 out of 7). ID= intellectual disability. (continued)

High frequent in adults with and without ID			**High frequent only in adults without ID**			**High frequent only in adults with ID**		
	Adults no ID	Adults ID		Adults no ID	Adults ID		Adults no ID	Adults ID
			d230 Carrying out daily routine	5	1			
			d330 Speaking	5	1			
			d240 Handling stress and other psychological demands	5	2			
			d410 Changing basic body position	5	2			
			d510 Washing oneself	5	2			
			d350 Conversation	4	1			
			d360 Using communication devices and techniques	4	1			
			d455 Moving around	4	1			
			d770 Intimate relationships	4	1			
			d750 Informal social relationships	4	2			
e Environmental factors								
Facilitators			*Facilitators*			*Facilitators*		
e120 Products and technology for personal indoor and outdoor mobility and transportation	6	7	e320 Friends	4	1	e575 General social support services, systems and policies	3	5
e310 Immediate family	6	7						
e110 Products or substances for personal consumption	5	7	*Barriers*			*Barriers*		
e580 Health services, systems and policies	6	6	e460 Societal attitudes	6	2	e355 Health professionals	2	4

Table 2 Frequently mentioned second-level ICF categories in adults with cerebral palsy for the components body functions, body structures, activities and participation, environmental factors, in more than half of the focus groups (4 out of 6) and/or interviews (4 out of 7). ID= intellectual disability. (continued)

High frequent in adults with and without ID			**High frequent only in adults without ID**			**High frequent only in adults with ID**		
	Adults no ID	Adults ID		Adults no ID	Adults ID		Adults no ID	Adults ID
Facilitators			*Barriers*			*Barriers*		
e115 Products and technology for personal use in daily living	4	7	e575 General social support services, systems and policies	5	0	e310 Immediate family	3	4
e325 Acquaintances, peers, colleagues, neighbours and community members	6	4	e410 Individual attitudes of immediate family members	4	0			
e340 Personal care providers and personal assistants	5	5	e415 Individual attitudes of extended family members	4	0			
e355 Health professionals	4	5	e120 Products and technology for personal indoor and outdoor mobility and transportation	4	2			
e125 Products and technology for communication	4	4	e445 Individual attitudes of strangers	4	2			
			e450 Individual attitudes of health professionals	4	2			
Barriers								
e580 Health services, systems and policies	5	6						

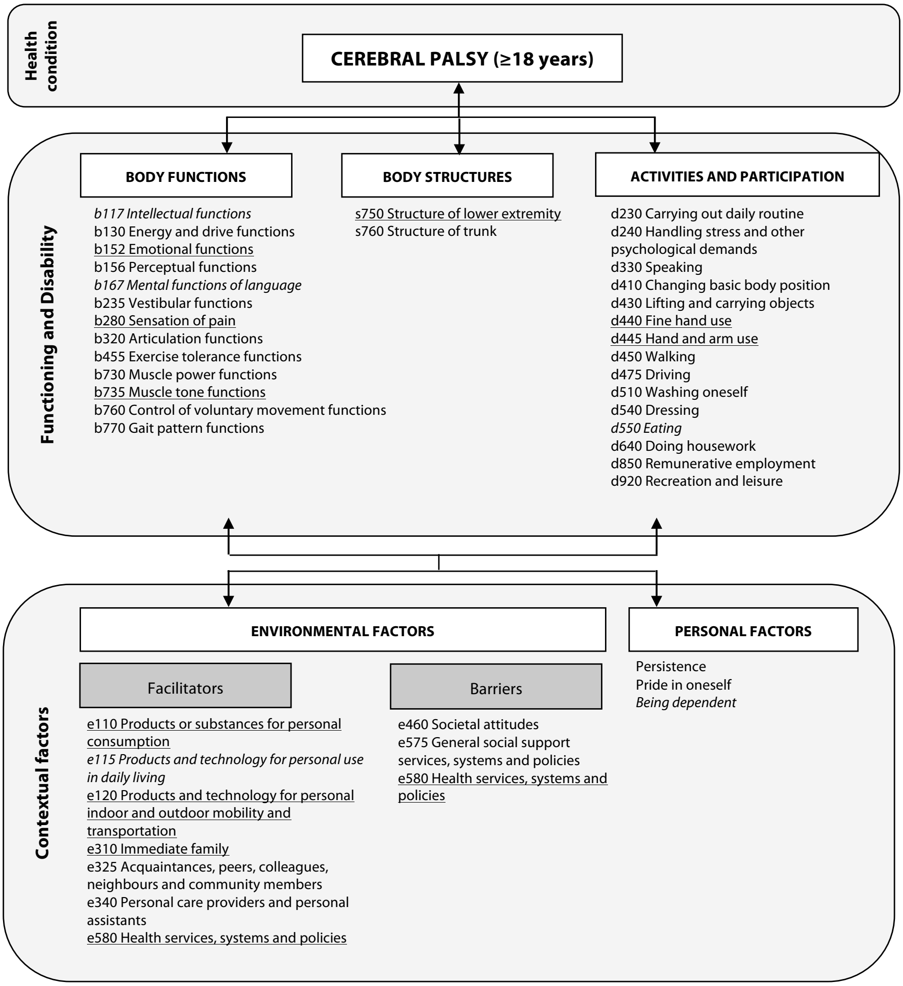

Figure 1 International Classification of Functioning, Disability and Health (ICF) framework including the second-level categories that were indicated in almost all focus groups (5 out of 6) or interviews (6 out of 7). Underlined categories: commonly mentioned in adults with and without intellectual disability (ID); categories in normal font: commonly mentioned in adults without ID; categories in Italics: commonly mentioned in adults with ID.

Figure 1 displays the ICF framework, including the second-level categories that were indicated in almost all focus groups (5 out of 6) or interviews (6 out of 7). Supplemental Table S1 shows all second-level ICF categories identified in more than one focus group or interview.

Body functions

'Walking costs a lot of energy and the muscles in my legs are weak, so sometimes I fall on the floor.' (57-year-old female, GMFCS level I)

For body functions, the indicated problems mostly addressed the chapters: Mental functions (b1; e.g. emotional functions, such as depression), Sensory functions and pain (b2; e.g. sensation of pain) and Neuromusculoskeletal and movement-related functions (b7; e.g. muscle tone). In addition, those without intellectual disability often mentioned energy levels, exercise tolerance function, balance, control of voluntary movement and gait pattern as relevant aspects of functioning. Adults with intellectual disability often described problems in mental function (language [e.g. reception and expression] and intellectual function).

Body structures

'I have contractures in my left arm and leg and I hardly have any muscles in my calf.' (24-year-old female, GMFCS level I)

The majority of the categories linked to body structures addressed the chapter: Structures related to movement (s7). Participants mainly described structures of the lower extremity, such as contractures in legs and hip dislocation, as most relevant.

Activities and participation

'I used to think that the only thing I couldn't do was walking. But you will discover that there is much more to it when you grow older.' (37-year-old female, GMFCS level III)

In the activities and participation component, the most frequently addressed chapters were: Mobility (d4; e.g. fine hand use and hand and arm use) and Self-care (d5). Adults without intellectual disability specifically mentioned problems in walking, driving, dressing, doing housework, remunerative employment and recreation and leisure. In adults with intellectual disability, self-care was commonly mentioned as a problem, predominately eating.

Environmental factors

Facilitators. 'The home of our friends is not wheelchair friendly, that's why they made a veranda for my daughter so that she can visit them.' (Caregiver of a 29-year-old female with intellectual disability, GMFCS level V)

Environmental factors that facilitate functioning were mainly found in chapters: Products and technology (e1; e.g. for mobility and transportation, such as wheelchairs, for personal consumption, such as medication, or for use in daily living, such as orthopaedic shoes), Support and relationships (e3; e.g. immediate family) and Services, systems and policies (e5; e.g. access to health services). Adults without intellectual disability often mentioned the support of acquaintances, peers, colleagues, neighbours and community members as valuable to them.

Barriers. 'It is a repetitive, occurring phenomenon that he encounters; people don't understand him because of his spasms and speech impairment. He gets no respect from, for example, the nursing staff; they just walk away.' (Caregiver of 27-year-old male with intellectual disability, GMFCS level IV)

Environmental factors that were frequently identified as a barrier were found in chapters: Support and relationships (e3), Attitudes (e4) and Health services, systems and policies (e5). Mainly the lack of collaboration across disciplines and transition from pediatric to adult health services were challenging for adults with and without intellectual disability. Adults without intellectual disability experienced societal attitudes as an important barrier.

Personal factors

'Motivating yourself is sometimes difficult, but I'm very proud when I achieve something. Last year I competed in the HandbikeBattle in Austria, and I managed to reach the finish line without any help.' (48-year-old female, GMFCS level III)

Personal factors commonly mentioned by adults without intellectual disability were persistence and pride in oneself. Adults with intellectual disability were described as dependent and calm. Living status (e.g. independent living or living in group homes) was identified in both groups.

Not covered and non-definable codes

'My difficulties in walking and the movement of the upper body during walking caused a neck hernia.' (45-year-old male, GMFCS level III)

The most frequently reported not covered codes referred to health conditions: burn-out and cervical disc herniation in adults without intellectual disability and asthma and epilepsy in adults with intellectual disability. Frequent non-definable codes were functioning and physical health for both groups and development for adults with intellectual disability.

Strengths associated with CP

'The fact that I realize that I am different also gives room for other people to be different.' (44-year-old male, GMFCS level IV)

Participants in the focus groups were asked about the positive side of living with CP. For this question, 77 meaningful concepts were linked to 81 unique second-level categories, 26 addressing body functions, four addressing body structures, 49 addressing activities and participation, and two addressing environmental factors. In addition, 25 unique personal factors, four not covered codes and seven non-definable codes were found.

Adults without intellectual disability mentioned that they were proud of themselves and what they achieved, even though it took a lot of effort. They have a lot of empathy and persistence and were considered optimistic. Having CP gave them insight into behaviors of other people and a different perspective on the world; this helped them to appreciate things more.

DISCUSSION

This qualitative study identified a broad range of problems that adults with CP experience. They indicated products and technology for mobility and personal use in daily living as important facilitators, as well as health services and support of family or others. Those without intellectual disability were proud of what they had achieved and described themselves as persistent and optimistic.

Adults with CP indicated a range of difficulties that refer to common impairments and activity limitations known to be related to CP and addressed both physical and mental issues. Impairments such as reduced balance and deterioration in walking are previously described as early functional decline.[24, 25] Adults with intellectual disability often mentioned problems in mental function, also affecting language, related to their intellectual impairment. Commonly mentioned structures were related to movement, specifically, structures of the lower extremity, such as contractures in the legs and hip dislocation, which are known problems in CP.[26]

Participants mainly explained difficulties in activities and participation by limited energy levels, affected mobility, and limited hand and arm use. In persons with intellectual disability, difficulties in self-care activities and moving around using equipment might be explained by their lower level of gross motor function, limited hand and arm use, or intellectual disability, which increased their dependency. Adults with CP experienced access to health care services as positive, but mentioned a lack of collaboration between disciplines and the transition to adult services as issues to be improved. Social support services were perceived as facilitating for adults with intellectual disability, while hindering for those without intellectual disability, due to problems in receiving social support and facing challenges by changes in regulations. Regarding societal attitude, adults without intellectual disability often have to deal with prejudices. Those with intellectual disability experienced a lack of support from health professionals or their extended family, who were not able to cope with their disability. Notwithstanding similarities in relevant aspects of functioning, the important differences between adults with and without intellectual disability underline the need to identify adults with intellectual disability as a group with specific problems.

Comparing the qualitative studies of adults versus children with CP, both studies mostly identified similar issues. Notwithstanding some differences, problems addressing mobility, self-care and health services seem to be important throughout the lifespan, whereas the focus on education changed towards employment. The study in children used a somewhat different methodology,[27] as they included only semi-structured interviews, and they linked items to the ICF for Children and Youth version.[13] However, only one category mentioned by children with CP (e5853 special education and training services) was not covered by the ICF. Adults with CP considered sensation of pain, emotional function (e.g. depression), and energy levels as relevant impairments which children did not. In addition, other problems became important in adulthood, such as driving, lifting and carrying objects (e.g. groceries) and doing housework. Where children often mentioned the poor accessibility of buildings, adults did not.

The present results are in line with the systematic review of adults with CP by Benner et al., which was another preparatory study in the project to develop the ICF Core Set for adults with CP.[11] Some notable differences should be mentioned. Intellectual function was only put forward in the present study, which might be explained by the intentional inclusion of adults with intellectual disability. We also identified a larger number of environmental factors, which suggests that adults with CP recognize these as important factors that have been little studied so far.[28] This emphasizes the importance of including the perspective of adults with CP to get a complete picture of relevant aspects of their functioning.

Some limitations of the study should be mentioned. Participants were recruited in The Netherlands, which might not capture the global perspective of adults with CP because of cultural differences. We assume that a worldwide perspective will be obtained from the other preparatory studies for the ICF Core Set, which are performed internationally. In the present sample, participants with intellectual disability were younger than those without intellectual disability, which might have influenced the outcomes. Despite additional efforts, we were not able to include older participants with intellectual disability. From other studies following up adults with CP during adulthood, we know that different problems might come up in older adults.[29] Finally, a different interview technique was used for adults with intellectual disability and without intellectual disability. Several caregivers of adults with intellectual disability expressed their preferences to take part in individual interviews rather than sharing their experiences in a group. In general, both methods are known to reveal rich and sensitive information, but sensitive topics are more likely to occur in focus groups.[30] In our study, rich information was obtained as saturation levels were adequate for both techniques, and intimate issues, such as romantic relationships or defecation, were also discussed during the interviews.

The present study supplied a comprehensive list of aspects of functioning and disability and environmental factors that are relevant to adults with CP, underlining the variability in problems they experience. Overall, relevant aspects of functioning are mostly similar between those with and without intellectual disability, except for some notable differences in intellectual function, language functions, mobility and self-care activities, which suggests specific ICF Core Sets for adults with CP with and without intellectual disability should be considered.

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Supplemental Table S1 Second-level ICF categories identified in more than one focus group or interview, for the components body functions, body structures, activities and participation, and environmental factors. ID=intellectual disability

ICF categories	Adults without ID (n=6 focus groups)	Adults with ID (n=7 individual interviews)
b Body functions		
b1 Mental functions	**38**	**38**
b114 Orientation functions	3	1
b117 Intellectual functions	0	6
b122 Global psychosocial functions	0	2
b126 Temperament and personality functions	4	2
b130 Energy and drive functions	6	4
b134 Sleep functions	1	3
b140 Attention functions	2	0
b144 Memory functions	2	1
b147 Psychomotor functions	2	0
b152 Emotional functions	6	6
b156 Perceptual functions	5	3
b160 Thought functions	3	1
b164 Higher-level cognitive functions	2	3
b167 Mental functions of language	2	6
b2 Sensory functions and pain	**20**	**15**
b210 Seeing functions	2	4
b215 Functions of structures adjoining the eye	1	1
b230 Hearing functions	1	1
b235 Vestibular functions	6	1
b240 Sensations associated with hearing and vestibular function	2	0
b265 Touch function	2	2
b280 Sensation of pain	6	6
b3 Voice and speech functions	**6**	**4**
b320 Articulation functions	5	3
b330 Fluency and rhythm of speech functions	1	1
b4 Function of the cardiovascular, haematological, immunological and respiratory systems	**11**	**11**
b415 Blood vessel functions	1	1
b420 Blood pressure functions	1	2
b435 Immunological system functions	2	3
b440 Respiration functions	1	1
b455 Exercise tolerance functions	6	4

Supplemental Table S1 Second-level ICF categories identified in more than one focus group or interview, for the components body functions, body structures, activities and participation, and environmental factors. ID=intellectual disability (continued)

ICF categories	**Adults without ID (n=6 focus groups)**	**Adults with ID (n=7 individual interviews)**
b5 Functions of the digestive, metabolic and endocrine systems	**5**	**14**
b510 Ingestion functions	1	2
b515 Digestive functions	1	2
b525 Defecation functions	2	4
b530 Weight maintenance functions	0	3
b540 General metabolic functions	1	1
b555 Endocrine gland functions	0	2
b6 Genitourinary and reproductive functions	**5**	**5**
b620 Urination functions	2	3
b640 Sexual functions	1	1
b650 Menstruation functions	2	1
b7 Neuromusculoskeletal and movement-related functions	**35**	**24**
b710 Mobility of joint functions	4	2
b715 Stability of joint functions	2	2
b730 Muscle power functions	5	2
b735 Muscle tone functions	6	6
b760 Control of voluntary movement functions	6	4
b765 Involuntary movement functions	2	4
b770 Gait pattern functions	6	0
b780 Sensations related to muscles and movement functions	4	4
b8 Functions of the skin and related structures	**3**	**3**
b810 Protective functions of the skin	0	3
b840 Sensation related to the skin	3	0
s Body structures		
s1 Structures of the nervous system	**1**	**1**
s110 Structure of brain	1	1
s7 Structures related to movement	**21**	**18**
s710 Structure of head and neck region	2	0
s720 Structure of shoulder region	3	1
s730 Structure of upper extremity	4	4
s750 Structure of lower extremity	5	6
s760 Structure of trunk	5	5
s770 Additional musculoskeletal structures related to movement	2	2

Supplemental Table S1 Second-level ICF categories identified in more than one focus group or interview, for the components body functions, body structures, activities and participation, and environmental factors. ID=intellectual disability (continued)

ICF categories	**Adults without ID (n=6 focus groups)**	**Adults with ID (n=7 individual interviews)**
d Activities and participation		
d1 Learning and applying knowledge	**8**	**4**
d155 Acquiring skills	2	0
d166 Reading	2	2
d170 Writing	2	2
d177 Making decisions	2	0
d2 General tasks and demands	**16**	**5**
d210 Undertaking a single task	3	2
d220 Undertaking multiple tasks	3	0
d230 Carrying out daily routine	5	1
d240 Handling stress and other psychological demands	5	2
d3 Communication	**15**	**5**
d310 Communicating with - receiving - spoken messages	2	2
d330 Speaking	5	1
d350 Conversation	4	1
d360 Using communication devices and techniques	4	1
d4 Mobility	**43**	**28**
d410 Changing basic body position	5	2
d415 Maintaining a body position	4	4
d430 Lifting and carrying objects	5	0
d440 Fine hand use	5	6
d445 Hand and arm use	5	6
d450 Walking	6	2
d455 Moving around	4	1
d465 Moving around using equipment	0	5
d470 Using transportation	3	2
d475 Driving	6	0
d5 Self-care	**18**	**17**
d510 Washing oneself	5	2
d520 Caring for body parts	2	2
d530 Toileting	1	2
d540 Dressing	6	2
d550 Eating	3	6
d560 Drinking	0	2
d570 Looking after one's health	1	1

Supplemental Table S1 Second-level ICF categories identified in more than one focus group or interview, for the components body functions, body structures, activities and participation, and environmental factors. ID=intellectual disability (continued)

ICF categories	Adults without ID (n=6 focus groups)	Adults with ID (n=7 individual interviews)
d6 Domestic life	**13**	**3**
d620 Acquisition of goods and services	2	1
d630 Preparing meals	3	1
d640 Doing housework	6	1
d650 Caring for household objects	2	0
d7 Interpersonal interactions and relationships	**11**	**10**
d710 Basic interpersonal interactions	0	2
d720 Complex interpersonal interactions	0	2
d740 Formal relationships	0	2
d750 Informal social relationships	4	2
d760 Family relationships	3	1
d770 Intimate relationships	4	1
d8 Major life events	**11**	**0**
d845 Acquiring, keeping and terminating a job	3	0
d850 Remunerative employment	6	0
d855 Non-remunerative employment	2	0
d9 Community, social and civic life	**6**	**4**
d920 Recreation and leisure	6	4
e Environmental factors		
FACILITATORS		
e1 Products and technology	**33**	**35**
e110 Products or substances for personal consumption	5	7
e115 Products and technology for personal use in daily living	4	7
e120 Products and technology for personal indoor and outdoor mobility and transportation	6	7
e125 Products and technology for communication	4	4
e130 Products and technology for education	2	1
e135 Products and technology for employment	2	0
e140 Products and technology for culture, recreation and sport	3	2
e150 Design, construction and building products and technology of buildings for public use	2	3
e155 Design, construction and building products and technology of buildings for private use	3	3
e160 Products and technology of land development	2	1

Supplemental Table S1 Second-level ICF categories identified in more than one focus group or interview, for the components body functions, body structures, activities and participation, and environmental factors. ID=intellectual disability (continued)

ICF categories	Adults without ID (n=6 focus groups)	Adults with ID (n=7 individual interviews)
e3 Support and relationships	**31**	**26**
e310 Immediate family	6	7
e315 Extended family	1	2
e320 Friends	4	1
e325 Acquaintances, peers, colleagues, neighbours and community members	6	4
e330 People in positions of authority	2	1
e340 Personal care providers and personal assistants	5	5
e350 Domesticated animals	1	1
e355 Health professionals	4	5
e360 Other professionals	2	0
e5 Services, systems and policies	**12**	**15**
e540 Transportation services, systems and policies	1	1
e555 Legal services, systems and policies	1	2
e575 General social support services, systems and policies	3	5
e580 Health services, systems and policies	6	6
e585 Education and training services, systems and policies	1	1
BARRIERS		
e1 Products and technology	**15**	**6**
e115 Products and technology for personal use in daily living	2	0
e120 Products and technology for personal indoor and outdoor mobility and transportation	4	2
e125 Products and technology for communication	1	1
e150 Design, construction and building products and technology of buildings for public use	3	2
e155 Design, construction and building products and technology of buildings for private use	2	1
e160 Products and technology of land development	3	0
e2 Natural environment and human-made changes to environment	**4**	**3**
e225 Climate	2	2
e250 Sound	2	1
e3 Support and relationships	**11**	**16**
e310 Immediate family	3	4
e315 Extended family	1	1

Supplemental Table S1 Second-level ICF categories identified in more than one focus group or interview, for the components body functions, body structures, activities and participation, and environmental factors. ID=intellectual disability (continued)

ICF categories	Adults without ID (n=6 focus groups)	Adults with ID (n=7 individual interviews)
e320 Friends	2	1
e325 Acquaintances, peers, colleagues, neighbours and community members	1	3
e340 Personal care providers and personal assistants	0	3
e345 Strangers	2	0
e355 Health professionals	2	4
e4 Attitudes	**24**	**10**
e410 Individual attitudes of immediate family members	4	0
e415 Individual attitudes of extended family members	4	0
e430 Individual attitudes of people in positions of authority	1	1
e440 Individual attitudes of personal care providers and personal assistants	0	2
e445 Individual attitudes of strangers	4	2
e450 Individual attitudes of health professionals	4	2
e455 Individual attitudes of other professionals	1	1
e460 Societal attitudes	6	2
e5 Services, systems and policies	**13**	**7**
e540 Transportation services, systems and policies	3	1
e575 General social support services, systems and policies	5	0
e580 Health services, systems and policies	5	6

4

Developing an ICF Core Set for adults with cerebral palsy: a global expert survey on relevant functions and contextual factors

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ABSTRACT

Objective: To identify areas of functioning in adults with cerebral palsy that are considered relevant by experts, in order to develop an International Classification of Functioning, Disability and Health (ICF) Core Set for adults with cerebral palsy.

Participants: Experts from various professional backgrounds worldwide who had experience working with adults with cerebral palsy for ≥2 years and were able to complete the survey in the English language.

Methods: A cross-sectional study using an international internet-based survey. The experts were asked to address relevant areas of functioning in adults with cerebral palsy. These areas of functioning were then linked to the ICF and the frequencies analysed.

Results: A total of 126 experts from 32 countries completed the survey. From the responses, 217 unique second-level ICF categories were identified. The three most frequently mentioned categories were "design, construction and building products and technology of buildings for public use (e150, 77%) and private use" (e155, 67%), followed by "sensation of pain" (b280, 62%).

Conclusion: The broad diversity of ICF categories reported by the experts emphasize the known heterogeneity of cerebral palsy and the variety of functioning in adulthood. They also reported on many environmental factors, illustrating the importance of person-environment interactions. These findings provide information about relevant issues for use in developing an ICF Core Set for adults with cerebral palsy.

INTRODUCTION

The framework of the International Classification of Functioning, Disability and Health (ICF) describes the functions and disabilities of individuals.[1] According to the ICF model, all aspects of life can be addressed by defining five ICF components: *Body functions, Body structures, Activities and participation, Environmental factors and Personal factors*. The ICF is considered useful in assessing outcomes in persons with any health condition, and thereby serves as a common language across healthcare disciplines and countries. However, a lack of knowledge of the ICF may hamper its use in clinical practice.[2] Moreover, since there are more than 1,400 ICF items, its application in patient care is challenging. To overcome these problems, ICF Core Sets are developed, which contain a comprehensive list of ICF categories for a specific health condition.[3, 4] ICF Core Sets for more than 30 health conditions[4] have been developed, including an ICF Core Set for children with cerebral palsy (CP).[5]

CP is a disorder of movement and posture caused by disturbances of the immature brain during infancy or childhood.[6] CP also affects other body functions and activities, such as intellectual functions and communication.[7, 8] With a prevalence of 2-3 per 1,000 live births,[9] CP is the most common cause of physical disability in children. In US, 85% of children with CP are expected to survive into adulthood, and as there is no cure for CP, their disabilities will endure or worsen.[8] New health issues and activity limitations may arise as their life situations change, such as increased fatigue or employment problems[10, 11] and thus an ICF Core set developed for children might not fully cover all issues experienced by adults with CP. Therefore, we are developing an ICF Core Set for adults with CP, which will cover all relevant areas of functioning in adulthood.

Due to increasing life expectancy, the number of adults with CP and their use of health care have increased. Nowadays, many organizations for childhood disabilities, such as the American Academy for Cerebral Palsy and Developmental Medicine (AACPDM), focus not only on children, but also on adults with CP. Moreover, the number of publications on the impact of CP in adulthood have increased in the past 20 years, addressing a variety of research topics.[12]

In order to develop an ICF Core Set scientific evidence is collected from four perspectives, by means of a systematic literature review (researcher's perspective), a qualitative study (perspective of persons with the health condition), an expert survey (health professional's perspective), and an empirical multicenter study (clinical perspective). In the second phase professional experts in adults with CP reach consensus on a final ICF Core Set for adults with CP, which will be validated and implemented in different settings.

This study reports the results of a worldwide expert survey of professionals with experience in working with adults with CP. The objectives of this study were: (*i*) to identify the most relevant ICF categories in adults with CP, addressed by health professionals and researchers, and (*ii*) to compare the response patterns between experts from different backgrounds and different countries.[13]

METHODS

A cross-sectional survey using an internet-based questionnaire was conducted among worldwide experts on adults with CP. The methodology followed the guidelines of the World Health Organization (WHO) ICF Research Branch for the development of an ICF Core Set.[4]

Study population

Clinical professionals and researchers were recruited from six WHO world regions: Africa, South-East Asia, Eastern Mediterranean, Europe, Western Pacific, and Region of the Americas (North, Middle and South). The inclusion criteria were: (*i*) professional background in one of the following areas: medicine (rehabilitation medicine, paediatrics, neurology or orthopaedic surgery), physical therapy, occupational therapy, psychology, speech or language therapy, nursing, social work, research or related field, such as exercise physiology; (*ii*) at least two years of experience in working with adults with CP aged ≥18 years; and (*iii*) sufficient knowledge of the English language to complete the survey.

Recruitment methodology

To ensure the survey represented perspectives from all 6 WHO world regions, experts were recruited using several strategies.[13-15] Emails were sent to contact persons from international/national organizations in the fields of CP, disability, rehabilitation medicine and physical therapy, requesting them to identify experts in their organizations who worked with adults with CP. Emails were also sent to dedicated research groups and clinical expert groups for adults with CP to identify eligible experts in this field, such as the Lifespan Care Committee of the AACPDM. In addition, the names of corresponding authors were extracted from research studies on adults with CP from 2000 to 2017, identified in a previous systematic review.[12] To create snowball sampling, all of the identified experts were asked to recommend other professionals from their network. The expert survey was announced to the attendees of two international conferences in 2018: the AACPDM Annual Meeting and the International Society of Physical and Rehabilitation Medicine (ISPRM) World Congress, and also on the website of the ICF Research Branch (https://www.icf-research-branch.org/).

Data collection protocol

All identified experts received an invitation to participate in the survey. They were provided with a link to the closed-access survey and detailed instructions on how to complete the survey. A link to an open-access survey was provided to those experts inviting additional colleagues to join the survey. Participants gave online informed consent to participate in the study. The respondents were asked to complete the survey within six weeks, and a reminder was sent two weeks before the deadline. To ensure the sample adequately represented the six WHO world regions, a second reminder was sent to the identified experts in the African and Western Pacific regions, since the responses from these regions were very low. Data were collected between October 2018 and January 2019.

Survey questionnaire

An internet-based questionnaire was developed using LimeSurvey. The first part covered the participant's demographic data such as sex, professional background, and years of experience in working with adults with CP. The second part included six open-ended questions about the most relevant problems of adults with CP from the expert's perspective. These questions addressed the ICF components *Body functions* (b), *Body structures* (s), *Activities and participation* (d), *Environmental factors* (e) and *Personal factors*. For *Environmental factors*, supportive and hindering factors were distinguished (Table 1).[4, 16]

Table 1 Open-ended questions in the expert survey.

1.	In your experience with adults with CP, what are the problems in body functions (including mental functions) they experience?
2.	In your experience with adults with CP, which parts of their body (brain included) are affected?
3.	In your experience with adults with CP, what are the difficulties/challenges they experience in their everyday activities and involvement in society?
4.	In your experience with adults with CP, what about their environment and living conditions might be <u>supportive</u> for them?
5.	In your experience with adults with CP, what about their environment and living conditions might be <u>hindering</u> for them?
6.	In your experience with adults with CP, which personal factors are important for them and the way they handle their CP?

CP: cerebral palsy

Linking to the ICF

Meaningful concepts, which were extracted from the expert's answers,[4] were linked to the most precise ICF categories according to the refined linking rules set out by Cieza et al.[17] The meaningful concepts were assigned to an ICF component denoted by letter, as follows: “b”: *Body functions*, “s”: *Body structures*, “d”: for *Activities and participation*, “e”: *Environmental factors*. The numeric codes following the letters were arranged hierarchically. In this system, the first digit indicates a chapter level, e.g. b1 for “mental functions”. Further numbers are added for a more specific category, two digits for the second level (e.g. b114 “Orientation functions”), and one additional digit each for the third level (b1142 “Orientation to person”) and fourth levels (b11420 “Orientation to self”). A meaningful concept can include one or more ICF categories. Even though Personal factors are not yet classified in the ICF, they refer to important factors related to an individual, such as self-efficacy, socioeconomic status and were labeled as “pf” items according to Cieza et al.[17]

Answers that were too general to be linked to an ICF category, such as general health, were coded as *not defined*. The answers which did not belong to the ICF universe, e.g. quality of life, were labeled as *not covered*.

All answers were linked by the first author (CL). To ensure the accuracy of the linking procedure, 50% of the answers were independently linked by a second researcher (SN). Both researchers had previously completed the E-learning ICF tool and received additional linking training from the ICF Research Branch coordinator (MS). To ensure the consistency of linking results, the first two surveys were linked and discussed before the remaining surveys were analyzed. The linking results of both researchers were compared, and disagreements between the two linkers were discussed until resolved. If consensus could not be reached, a third person (MR) was consulted to make a decision. The interrater agreement of the linking process was calculated on the second-level ICF categories prior to reaching consensus between the linkers in case of disagreement, using Cohen’s Kappa.[18]

Data analysis

ICF categories were analysed at the second level. All the third- and fourth-level categories were aggregated to their corresponding second level. If a second-level category was presented repeatedly by one participant, it was counted only once. Frequency analysis was used to analyse the categories reported by the experts. Categories indicated by at least 15% of the experts were included in the description of ICF categories for a consensus meeting.[13]

Differences of response patterns between experts from different clinical backgrounds (dichotomized as physicians vs therapists) and countries with different income levels according to gross national income per capita[19] (dichotomized as low- and middle-income vs high-income countries) were evaluated using logistic regression analysis, with professional background and country income as independent variables, corrected by years of working experience with adults with CP. One participant who chose both a physician and therapist background was excluded from this analysis (n=1) and the researcher group was excluded from the analysis due to the small number of respondents identified in this subsample (n=10). Only categories that were reported by at least 50 respondents were included in the analysis. The study analysis was performed by using SPSS version 24.0. To correct for multiple testing, we used a significance level with Bonferroni correction of $p < 0.0025$.

RESULTS

Descriptive information from the experts

Of the 421 experts approached to participate in the study, 126 experts from 32 countries completed the survey (Figure 1). Table 2 shows the characteristics of the experts; they mostly had many years of working experience with adults with CP, and are represent three types of professional background: physicians, therapists/nurses and researchers.

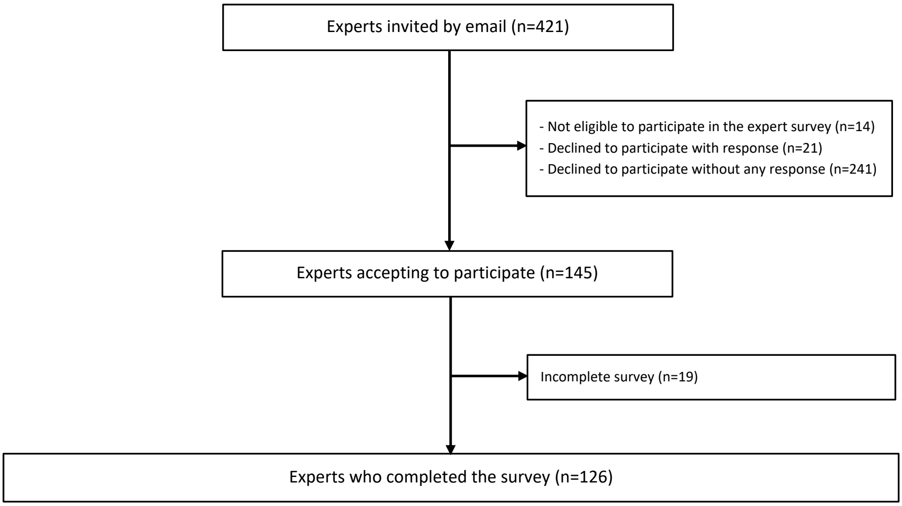

Figure 1 Flow diagram of the recruitment process.

Table 2 Characteristics of experts (n=126).

Characteristics	
Age (years), median (IQR)	45 (39-56)
Years of experience, median (IQR)	12 (8-22)
Sex (n=125)	n(%)
Male	32 (25.6)
Female	93 (74.4)
WHO Region (n=126)	n(%)
Africa	3 (2.4)
America	39 (31.0)
South-East Asia	14 (11.1)
Europe	57 (45.2)
Eastern Mediterranean	4 (3.2)
Western Pacific	9 (7.1)
Working field (n=126)	n(%)
Clinical setting	78 (61.9)
Disability care	7 (5.6)
Management	6 (4.8)
Research	18 (14.3)
Education	14 (11.1)
Others	3 (2.4)
Professional Background Subspecialty (n=167)	n(%)
Physician	72 (43.1)[a]
Rehabilitation physician	56
Neurologist/Neurosurgeon	1
Orthopedic surgeon	4
Pediatrician	3
Physician for people with intellectual disability	6
General practitioner	2
Therapist/nurse	49 (29.3)[a]
Physiotherapist	29
Occupational therapist	9
Speech and language therapist	6
Rehabilitation nurse	1
Social worker	2
Other	2
Researcher	39 (23.4)[a]
Other	7 (4.2)[a]

[a] Participants could choose more than one professional background. WHO=World Health Organization; IQR= interquartile range.

Overview of the experts' answers and linking results

From the 126 completed questionnaires, a total of 6,121 meaningful concepts were extracted, which were linked to 7,370 ICF categories. Overall, 3,545 (48.1%) concepts were linked to second-level ICF categories, 2,178 (29.6%) were assigned to third- and fourth-level ICF categories, and 840 (11.4%) were identified at the chapter level. A total of 251 (3.4%) *Personal factors*, 411 (5.6%) *non-definable codes,* and 145 (2.0%) *not covered codes* were identified. A Cohen's Kappa of 0.72 (95% confidence interval 0.70–0.73) indicated good inter-rater agreement between the independent linkers.

In total, 217 unique second-level ICF categories were identified, among which the largest number were allocated to *Environmental factors* (34.0%), followed by *Body functions* (22.0%), *Activities and participation* (21.0%) and *Body structures* (12.2%). The most frequently mentioned categories were 63 second-level categories, reported by at least 15% of the experts and five *Personal factor*s, indicated by ≥10% (Table 3). Figure 2 shows those categories indicated by ≥30% of the experts.

Table 3 Relative frequency of ICF categories mentioned by ≥15% of the experts (n=126).

ICF code	ICF category description	Experts, n(%)
b	***Body functions***	
b280	Sensation of pain	78 (61.9)
b735	Muscle tone functions	71 (56.4)
b117	Intellectual functions	61 (48.4)
b710	Mobility of joint functions	56 (44.4)
b130	Energy and drive functions	55 (43.7)
b152	Emotional functions	55 (43.7)
b730	Muscle power functions	49 (38.9)
b455	Exercise tolerance functions	44 (34.9)
b510	Ingestion functions	42 (33.3)
b126	Temperament and personality functions	38 (30.2)
b760	Control of voluntary movement functions	38 (30.2)
b7	Neuromusculoskeletal and movement-related functions	37 (29.4)
b210	Seeing functions	28 (22.2)
b3	Voice and speech functions	24 (19.1)
b164	Higher-level cognitive functions	23 (18.3)
b525	Defecation functions	22 (17.5)
b1	Mental functions	21 (16.7)
b620	Urination functions	21 (16.7)
b320	Articulation functions	20 (15.9)
b440	Respiration functions	20 (15.9)

Table 3 Relative frequency of ICF categories mentioned by ≥15% of the experts (n=126). (continued)

ICF code	ICF category description	Experts, n(%)
b770	Gait pattern functions	20 (15.9)
b156	Perceptual functions	19 (15.1)
b765	Involuntary movement functions	19 (15.1)
s	***Body structures***	
s110	Structure of brain	76 (60.3)
s750	Structure of lower extremity	72 (57.1)
s760	Structure of trunk	60 (47.6)
s730	Structure of upper extremity	58 (46.0)
s770	Additional musculoskeletal structures related to movement	48 (38.1)
s7	Structures related to movement	36 (28.6)
s430	Structure of respiratory system	22 (17.5)
s710	Structure of head and neck region	22 (17.5)
s320	Structure of mouth	21 (16.7)
s5	Structures related to the digestive, metabolic and endocrine systems	21 (16.7)
d	***Activities and participation***	
d4	Mobility	87 (69.1)
d850	Remunerative employment	61 (48.4)
d855	Non-remunerative employment	58 (46.0)
d5	Self-care	52 (41.3)
d920	Recreation and leisure	49 (38.9)
d3	Communication	47 (37.3)
d450	Walking	41 (32.5)
d9	Community, social and civic life	37 (29.4)
d7	Interpersonal interactions and relationships	36 (28.6)
d470	Using transportation	33 (26.2)
d770	Intimate relationships	33 (26.2)
d440	Fine hand use	30 (23.8)
d510	Washing oneself	26 (20.6)
d845	Acquiring, keeping and terminating a job	25 (19.8)
d550	Eating	24 (19.1)
d240	Handling stress and other psychological demands	22 (17.5)
d540	Dressing	21 (16.7)
d570	Looking after one's health	21 (16.7)
d530	Toileting	19 (15.1)
e	***Environmental factors***	
e150	Design, construction and building products and technology of buildings for public use	97 (77.0)
e155	Design, construction and building products and technology of buildings for private use	84 (66.7)

Table 3 Relative frequency of ICF categories mentioned by ≥15% of the experts (n=126). (continued)

ICF code	ICF category description	Experts, n(%)
e120	Products and technology for personal indoor and outdoor mobility and transportation	74 (58.7)
e310	Immediate family	70 (55.6)
e580	Health services, systems and policies	66 (52.4)
e315	Extended family	60 (47.6)
e540	Transportation services, systems and policies	58 (46.0)
e340	Personal care providers and personal assistants	52 (41.3)
e460	Societal attitudes	43 (34.1)
e1	Products and technology	42 (33.3)
e160	Products and technology of land development	42 (33.3)
e590	Labour and employment services, systems and policies	42 (33.3)
e115	Products and technology for personal use in daily living	41 (32.5)
e355	Health professionals	38 (30.2)
e3	Support and relationships	36 (28.6)
e135	Products and technology for employment	35 (27.8)
e555	Associations and organizational services, systems and policies	35 (27.8)
e525	Housing services, systems and policies	32 (25.4)
e575	General social support services, systems and policies	31 (24.6)
e140	Products and technology for culture, recreation and sport	27 (21.4)
e5	Services, systems and policies	26 (20.6)
e125	Products and technology for communication	23 (18.3)
e320	Friends	21 (16.7)
e585	Education and training services, systems and policies	21 (16.7)
pf	***Personal factors***[a]	
	Personal factors, socioeconomic status	18 (14.3)
	Personal factors, educational status	17 (13.5)
	Personal factors, living status	17 (13.5)
	Personal factors, independence	16 (12.7)
	Personal factors, resilience	13 (10.3)
nc	***Not covered***[b]	
	Not covered, health condition	53 (42.1)
nd	***Not defined***[c]	
	Not defined, accessibility	33 (26.2)
	Not defined, mental health	20 (15.9)

Categories are ordered according to their relative frequency within each component. [a]Personal factors mentioned by ≥10% of experts. [b]Items not covered by the ICF. [c]Items too general to be linked to an ICF category or a personal factor.

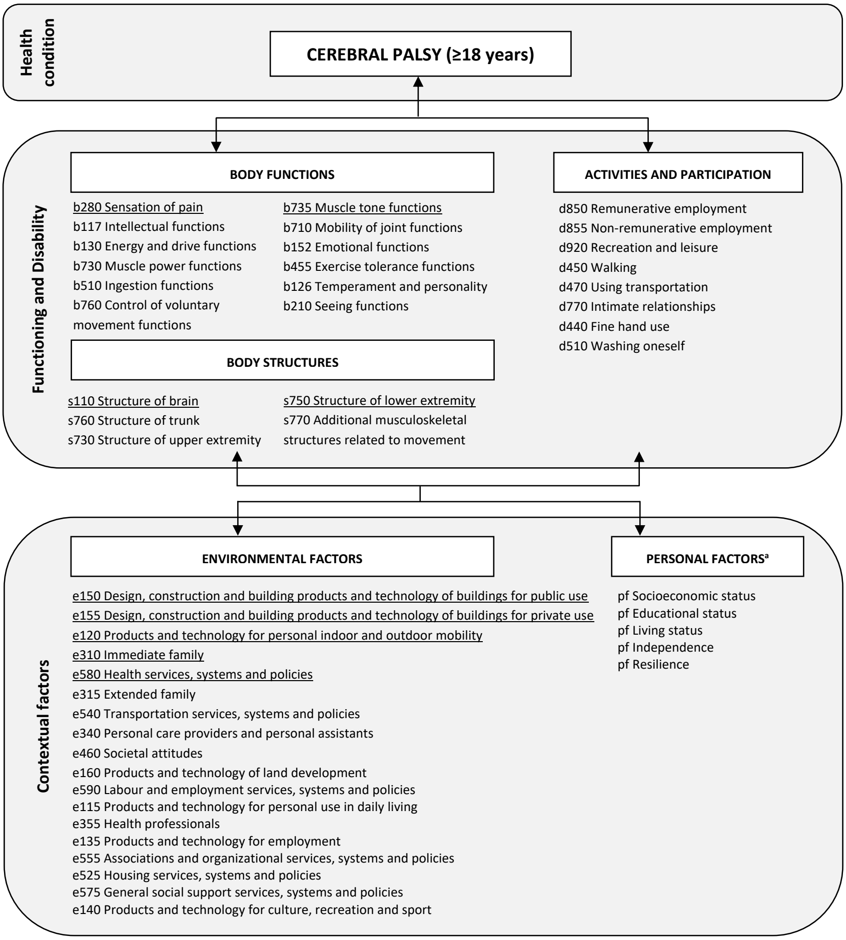

Figure 2 International Classification of Functioning, Disability and Health (ICF) framework, including the ICF categories reported by ≥30% of the experts. Those identified by ≥50% of the experts are underlined. [a]Personal factors reported by ≥10% are presented.

For *Body functions,* categories in all eight ICF chapters were identified, mostly addressing “Sensation of pain” and “Muscle tone functions”. The answers provided by the experts on *Body structures* also covered all eight ICF chapters, with most of the categories identified in ”Structures of the nervous system” and “Structures related to movement”. For *Activities and participation*, the highest-rated second-level categories by experts for adults with CP were related to “Mobility” and “Employment”.

A large number of categories involved *Environmental factors*, of which ”Design of buildings for public or private use” and “Products and technology for mobility and transportation" were most often indicated. In addition, experts frequently reported on the importance of the immediate family and healthcare services for functioning of adults with CP. Notably, these categories were reported as both facilitators and barriers for functioning (Table 4).

Table 4 The most frequently reported environmental factors reported as a facilitator or barrier by ≥15% of experts.

Facilitator		**Experts, n (%)**	**Barrier**		**Experts, n (%)**
e150	Design, construction and building products and technology of buildings for public use	72 (57.1)	e150	Design, construction and building products and technology of buildings for public use	71 (56.4)
e155	Design, construction and building products and technology of buildings for private use	63 (50.0)	e155	Design, construction and building products and technology of buildings for private use	53 (42.1)
e120	Products and technology for personal indoor and outdoor mobility and transportation	52 (41.3)	e120	Products and technology for personal indoor and outdoor mobility and transportation	42 (33.3)
e310	Immediate family	36 (28.6)	e540	Transportation services, systems and policies	37 (29.4)
e580	Health services, systems and policies	36 (28.6)	e580	Health services, systems and policies	34 (27.0)
e1	Products and technology	33 (26.2)	e160	Products and technology of land development	27 (21.4)
e540	Transportation services, systems and policies	31 (24.6)	e310	Immediate family	25 (19.8)
e115	Products and technology for personal use in daily living	30 (23.8)	e460	Societal attitudes	24 (19.1)
e315	Extended family	28 (22.2)	e1	Products and technology	22 (17.5)
e340	Personal care providers and personal assistants	27 (21.4)	e340	Personal care providers and personal assistants	22 (17.5)
e555	Associations and organizational services, systems and policies	26 (20.6)	e575	General social support services, systems and policies	20 (15.9)
e590	Labour and employment services, systems and policies	24 (19.1)	e115	Products and technology for personal use in daily living	19 (15.1)
e135	Products and technology for employment	22 (17.5)	e315	Extended family	19 (15.1)
e125	Products and technology for communication	21 (16.7)			
e140	Products and technology for culture, recreation and sport	20 (15.9)			
e160	Products and technology of land development	20 (15.9)			
e575	General social support services, systems and policies	20 (15.9)			

Table 5 Distribution of answers by professional background and by country income and odds ratios for the differences between background and country income, for the most frequently reported ICF categories that were reported by ≥50 experts.

ICF code	ICF category description	Professional background[a]			Country income		
		Physician n (%) (Total = 66)	**Therapist n (%) (Total = 49)**	**Physician (versus therapist) OR (95% CI); P-value**	**Experts from low- and middle-income countries, n (%) (Total = 29)**	**Experts from high-income countries n (%) (Total = 96)**	**Low- and middle-income countries (versus high-income countries) OR (95% CI); P-value**
b	*Body functions*						
b117	Intellectual functions	34 (51.5)	23 (46.9)	1.3 (0.6-2.9); 0.46	16 (55.2)	45 (46.9)	1.7 (0.7-4.1); 0.24
b130	Energy and drive functions	25 (37.9)	22 (44.9)	0.8 (0.4-1.6); 0.48	12 (41.4)	42 (43.8)	1.0 (0.4-2.4); 0.96
b152	Emotional functions	29 (43.9)	19 (38.8)	1.3 (0.6-2.7); 0.56	10 (34.5)	44 (45.8)	0.6 (0.3-1.6); 0.32
b280	Sensation of pain	43 (65.2)	27 (55.1)	1.8 (0.8-4.0); 0.17	10 (34.5)	68 (70.8)	0.2 (0.1-0.6); 0.0015[b]
b710	Mobility of joint functions	27 (40.9)	26 (53.1)	0.6 (0.3-1.3); 0.19	13 (44.8)	43 (44.8)	1.0 (0.4-2.3); 0.93
b735	Muscle tone functions	40 (60.6)	27 (55.1)	1.4 (0.7-3.1); 0.37	15 (51.7)	56 (58.3)	0.9 (0.4-2.1); 0.79
s	*Body structures*						
s110	Structure of brain	45 (68.2)	28 (57.1)	1.6 (0.8-3.6); 0.22	21 (72.4)	55 (57.3)	1.9 (0.7-4.8); 0.19
s730	Structure of upper extremity	31 (47.0)	24 (49.0)	0.9 (0.4-1.9); 0.76	17 (58.6)	41 (42.7)	1.8 (0.8-4.2); 0.18
s750	Structure of lower extremity	40 (60.6)	26 (53.1)	1.3 (0.6-2.8); 0.50	18 (62.1)	54 (56.3)	1.2 (0.5-2.8); 0.71
s760	Structure of trunk	35 (53.0)	20 (40.8)	1.6 (0.7-3.4); 0.24	13 (44.8)	47 (49.0)	0.8 (0.3-1.8); 0.54
d	*Activities and participation*						
d850	Remunerative employment	32 (48.5)	23 (46.9)	1.1 (0.5-2.4); 0.75	10 (34.5)	50 (52.1)	0.5 (0.2-1.2); 0.13
d855	Non-remunerative employment	32 (48.5)	20 (40.8)	1.4 (0.7-3.1); 0.36	9 (31.0)	48 (50.0)	0.5 (0.2-1.1); 0.08

Table 5 Distribution of answers by professional background and by country income and odds ratios for the differences between background and country income, for the most frequently reported ICF categories that were reported by ≥50 experts. (continued)

ICF code	ICF category description	Professional background[a]			Country income		
		Physician n (%) (Total = 66)	**Therapist n (%) (Total = 49)**	**Physician (versus therapist) OR (95% CI); P-value**	**Experts from low- and middle-income countries, n (%) (Total = 29)**	**Experts from high-income countries n (%) (Total = 96)**	**Low- and middle-income countries (versus high-income countries) OR (95% CI); P-value**
e	*Environmental factors*						
e120	Products and technology for personal indoor and outdoor mobility and transportation	33 (50.0)	36 (73.5)	0.4 (0.2-0.8); 0.02	17 (58.6)	56 (58.3)	1.1 (0.5-2.7); 0.84
e150	Design, construction and building products and technology of buildings for public use	48 (72.7)	41 (83.7)	0.6 (0.2-1.4); 0.22	21 (72.4)	75 (78.1)	0.8 (0.3-2.2); 0.70
e155	Design, construction and building products and technology of buildings for private use	42 (63.6)	35 (71.4)	0.8 (0.3-1.7); 0.51	20 (69.0)	63 (65.6)	1.4 (0.6-3.5); 0.48
e310	Immediate family	38 (57.6)	25 (51.0)	1.2 (0.6-2.6); 0.64	20 (69.0)	49 (51.0)	1.9 (0.8-4.8); 0.16
e315	Extended family	34 (51.5)	19 (38.8)	1.6 (0.8-3.5); 0.22	18 (62.1)	41 (42.7)	2.2 (0.9-5.2); 0.09
e340	Personal care providers and personal assistants	24 (36.4)	22 (44.9)	0.7 (0.3-1.5); 0.33	9 (31.0)	42 (43.8)	0.6 (0.2-1.4); 0.20
e540	Transportation services, systems and policies	28 (42.4)	25 (51.0)	0.8 (0.4-1.6); 0.45	12 (41.4)	45 (46.9)	0.9 (0.4-2.1); 0.77
e580	Health services, systems and policies	38 (57.6)	20 (40.8)	2.2 (1.0-4.7); 0.05	12 (41.4)	53 (55.2)	0.6 (0.3-1.5); 0.30

[a] The researcher group was excluded from the analysis due to their small number; [b] A significant difference, p-value < 0.0025 (with Bonferroni correction).

Comparison between professional backgrounds

Table 5 compares the response patterns of the frequently addressed second-level ICF categories between physicians and therapists, and between experts from low- and middle-income vs high-income countries. The patterns of answers did not differ between physicians and therapists. When considering country income, the experts from low- and middle-income countries were significantly less likely to describe "Sensation of pain" (b280) than the experts from high-income countries.

DISCUSSION

This study surveyed expert opinions on the important areas of functioning for adults with CP, in order to contribute to the development of an ICF Core Set for adults with CP. The professional experts surveyed, all of whom were working with adults with CP, identified a large number of categories in *Body functions* and *Body structures,* which reflect the nature of CP affecting several body systems.[6] "Sensation of pain" was the most frequently addressed category of *Body functions*, which is in line with the present knowledge showing that 71% of adults with CP experience pain in at least one part of the body.[20] Also, in research among adults with CP, pain is the most commonly studied issue.[12] This reflects the increased attention of professionals on pain during the last decade. Moreover, a large number of categories addressed the musculoskeletal and nervous systems; for example, "Muscle tone functions", and "Structure of brain", which is compatible with the definition of CP.[6] Notably, most experts (78.6%) reported mental or physical fatigue as important impairments for adults with CP; these were categorized as "Energy and drive functions" or "Exercise tolerance functions", respectively. The experts also often reported "depression", a common mood disorder in persons with disabilities,[21, 22] which we linked to "Emotional functions". As expected, "Remunerative and Non-remunerative employment" were the most frequent second-level categories addressed for *Activities and participation*, since these represent an important life area in adulthood.[11, 23] In addition, the experts often focused on basic activities of daily living by using general terms, which were linked to the ICF chapters "Mobility" and "Self-care".

The largest number of categories that the experts addressed for adults with CP were *Environmental factors*. Mostly, they reported these categories related to body impairments and activity limitations, for example, "*Practicing sports and attending social activities: if the person does not have accessible transportation and public places that allow the use of wheelchairs or other aids, they can't do these activities*". These comments underline the importance of person-environment interactions. The experts also often addressed "Products and technology", especially the design of buildings and mobility devices, which are essential for adults with CP in order to live independently and may support community participation. Furthermore, according to the professionals "Supportive people and relationships" seemed to be an important factor for functioning of adults with CP. In the present study, immediate families were identified as the most important persons for adults with CP, since many of them still lived with their parents or needed support from their family. The experts also regularly commented on "Services, systems and policies", of which health services were the most often indicated, showing the awareness of the experts of the need to continue health care services for persons with CP during their transition to adulthood and thereafter.[24-26] Notably, the experts considered most *Environmental factors* as both supportive and hindering factors for adults with CP, except for "Societal attitudes" which was only indicated as a hindering factor. According to the experts, stigmatization and discrimination can impede social engagements of adults with CP, and this may suggest that society should promote positive attitudes towards adults with CP. Finally, the experts identified several *Personal factors* of importance for adults with CP, but only with low frequencies in this survey, perhaps, because they lack a precise idea of which *Personal factors* were specifically relevant for adults with CP.

When comparing the categories addressed between professional backgrounds, no differences were found between physicians and therapists; both groups gave similar response patterns. However, potential differences may have been missed due to the small size of the subsamples. Also, there were no differences in response patterns between experts from high-income and low- and middle-income countries, except that the latter countries less frequently reported on "pain". This can be explained by noting that health professionals in limited-resource countries often have to prioritize other important issues, such as life-threatening conditions, over that of pain management.[27] Moreover, staff shortages, e.g. not having experts in specialized fields, such as a pain physician, is a huge problem in developing countries, which may have decreased these experts' attention on pain.[28]

We found a large number of categories addressing *Environmental factors* compared with a recent systematic literature review on outcomes in adults with CP.[12] The experts in our survey were notably concerned about person-environment interactions whereas only a few published studies have explored these areas; revealing a gap in the scientific literature. The present expert survey also included responses from many experts in low- and middle-income countries, while most studies in the systematic review were conducted in high-income countries. Thus, we believe this study adds a valuable worldwide perspective on relevant categories for developing an ICF Core Set for adults with CP.

These results are in line with the international expert survey on children with CP,[13] except for different highlights in *Activities and participation*. While “school education” was a common issue for children with CP, “employment” and “intimate relationship” were more common in adults with CP. This is in line with changing life situations throughout the lifespan. Thus, the importance of specific life areas may shift with age. Emerging adults with CP may need support from people in their environment and professionals to achieve new personal goals and optimal levels of functioning in adulthood.[29] For *Environmental factors*, “family” is the most important factor in the ICF Core Set for children with CP, and also appear to be important for adults with CP. However, in order to live independently in the modern world, “products and technology” are more relevant for adults with CP than for children. These differences show that relevant aspects of functioning and environments are different between adults and children with CP.

Although a sample of 126 experts is a firm base to estimate relevant aspects of functioning and environmental factors for adults with CP, the number of participants in some regions was quite low, for example, in the African region. In addition, it was difficult to reach some disability and professional organizations in these regions. There is no culture or infrastructure of professionals and patient organizations in low- and middle-income countries to carry out collaborative surveys into the health problems of their patient populations.[30] In addition, only a small number of healthcare workers and researchers in these regions probably had dedicated working experience with adults with CP. Moreover, the vast majority of physicians and therapists who responded to the survey were rehabilitation physicians and physical therapists, whereas only a small number of experts in other subspecialties participated. This might be a result of the method of sampling.[31] On the other hand, it is known that after leaving paediatric care, people with CP receive most of their care from rehabilitation physicians and physical therapists.[32] Focusing on mobility and movement-related function can be understood from the definition of CP as a disorder of movement and posture, although additional impairments are often presented. In addition, the English language might have been a limitation for experts from some regions, such as from the Eastern Mediterranean region. Furthermore, some parts of the answers were too general or broad to be linked to second-level categories. We adapted to this by allowing first-level categories to be included in the responses.

In conclusion, this study surveyed the ICF categories that are important for adults with CP from experts’ perspectives worldwide. The experts identified a wide diversity of ICF categories and, overall, highlighted the importance of person-environment interactions, noting in particular pain, employment, and accessible design of buildings. Together with all preparatory studies, the present results will help to reach a consensus on an ICF Core Set for adults with CP.

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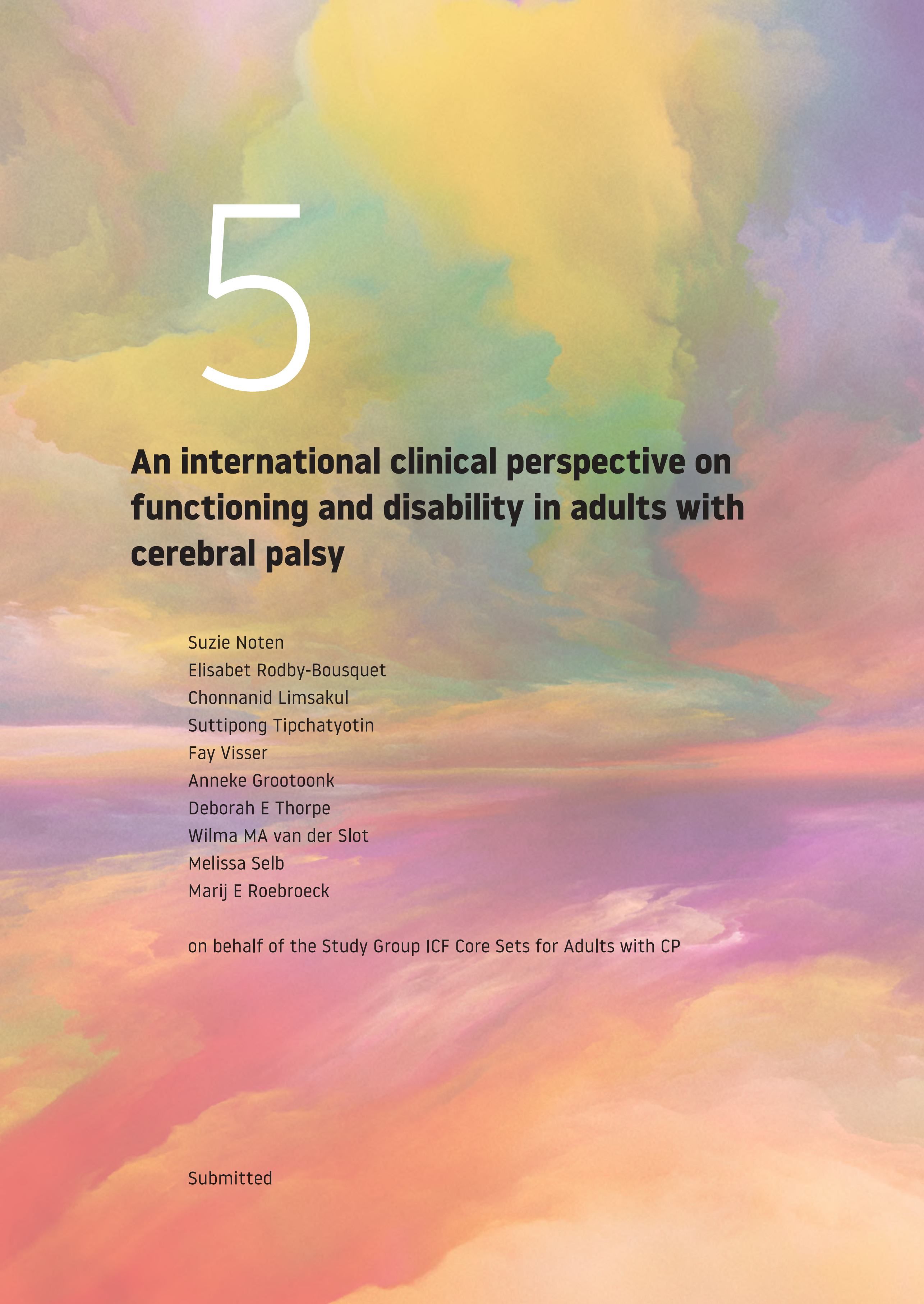

5

An international clinical perspective on functioning and disability in adults with cerebral palsy

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on behalf of the Study Group ICF Core Sets for Adults with CP

Submitted

6

International consensus on ICF Core Sets for adults with cerebral palsy: a basis for standardized assessment of functioning

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ABSTRACT

Aim: The aim of this article was to report on the results of the online international consensus process to develop the Comprehensive and Brief International Classification of Functioning, Disability and Health Core Sets (ICF-CSs) for adults with cerebral palsy (CP).

Method: An online iterative decision-making and consensus process involved 25 experts on adults with CP from all six regions of the World Health Organization (WHO). The most relevant categories were selected from a list of 154 unique second-level candidate categories to develop the ICF-CSs for adults with CP. This list resulted from evidence gathered during four preparatory studies - a systematic literature review, a qualitative study, an expert survey, and an empirical study.

Results: The consensus process resulted in the Comprehensive ICF-CS containing 120 second-level ICF categories: 33 body functions, 8 body structures, 50 activities and participation, 29 environmental factors, from which the most essential categories, 33 in total, were selected for the Brief ICF-CS.

Interpretation: The Comprehensive and Brief ICF-CSs for adults with CP were created during a novel online version of an established ICF-CS consensus process. These Core Sets can now be implemented in clinical care and research, and will promote standardized data collection worldwide.

INTRODUCTION

Cerebral palsy (CP) is the most common cause of physical disability in childhood, with a prevalence of 2 to 2.5 per 1000 live births in developed countries.[1-3] The non-progressive impairment of the developing fetal or infant brain causes abnormal development of movement and postural control, resulting in activity limitation.[4] The motor disorders are often accompanied by disturbances of cognition, communication, and behaviour. A high number of persons with CP experiences long-term consequences of the condition, requiring healthcare services to support their functioning.[5]

A large proportion of individuals with CP are at adult age, due to an increase in life expectancy.[6] Previously, research and healthcare primarily focused on children & youth with CP, but in the past decades, attention has broadened towards a lifespan perspective on the impact of CP and health issues.[7] Adults with CP present with a broad spectrum of functioning aspects and disability. Factors that impact the person's level of functioning are a combination of motor functioning problems and intellectual disability (ID),[8] interacting with contextual factors, e.g. environmental accessibility and use of technical devices.[9] Research on adults with CP has focussed increased attention on contextual factors over the past 20 years,[7] highlighting the importance of a comprehensive approach to functioning and disability in research and clinical practice. The International Classification of Functioning, Disability and Health (ICF)[10] fosters this approach, while also facilitating a comprehensive understanding of functioning and disability (collectively referred to as "functioning" from now on). The use of the ICF can improve healthcare service delivery, as we learned from clinical rehabilitation practice.[11]

The ICF is the internationally accepted reference for assessing and reporting functioning. It reflects a comprehensive bio-psychosocial model[10] of functioning, and can be used in clinical care,[11-14] e.g. for goal setting or intervention planning. Functioning is described by the components body functions (b), body structures (s), activities and participation (d), and contextual factors address the components environmental (e) and personal factors. ICF categories in each component contain a letter (b, s, d, e) and a numeric code and are hierarchically structured according to levels: chapter-level (e.g. b2 Sensory functions and pain), second-level (e.g. b280 Sensation of pain), third- (e.g. b2801 Pain in body part) or fourth-level (e.g. b28015 Pain in lower limb), with increasing specificity from the chapter to the fourth level. Personal factors (pf) are not yet classified in the ICF.[10]

The ICF is extensive, consisting of 1400+ categories, which makes its use in clinical care and research cumbersome. Given this, the World Health Organization (WHO) and ICF

Research Branch (www.icf-research-branch.org) introduced ICF Core Sets (ICF-CSs),[15] shortlists of the most relevant categories for specific health conditions selected from the full classification. These ICF-CSs can serve as an international standard for assessment and reporting of functioning. ICF-CSs have been created for several health conditions such as multiple sclerosis,[16] traumatic brain injury,[17] stroke,[18] and children & youth with CP,[19] but not yet for adults with CP. Considering that children & youth with CP grow into adult roles,[20] e.g. employment, and adults with CP may experience premature decline in functioning,[21] the ICF-CSs for children & youth with CP might not fully apply to adults. Therefore, we conducted a project to create a Comprehensive and a Brief ICF-CSs for adults with CP.

The Comprehensive ICF-CS should include sufficient categories to comprehensively describe the functioning profile of adults with CP, yet concise enough to be practical for routine assessments. The Brief ICF-CS should include the fewest categories possible while still capturing the most essential categories to serve as a minimal international standard for assessing and reporting functioning of adults with CP. This article reports on the results of the international consensus process to develop the first version of the ICF-CSs for adults with CP.

METHOD

The methodology of WHO and the ICF Research Branch was followed for developing the first version of the ICF-CSs for adults with CP.[15] This scientific process involved conducting preparatory studies: a systematic literature review,[22] a qualitative study,[23] an expert survey,[24] and an empirical study.[25] The results of these studies provided the evidence base for a consensus process to establish the first version of the ICF-CSs. Due to the COVID-19 pandemic, we pioneered an online version of the original face-to-face consensus conference.[15]

Preparatory studies

The four preparatory studies were conducted to generate an aggregated list of "candidate" second-level ICF categories to serve as the basis for deciding on the ICF-CSs for adults with CP, as well as to ensure that the ICF-CSs reflected different perspectives of relevant stakeholders – researchers, adults with CP and health professionals treating adults with CP as well as other experts. The systematic literature review identified 72 categories in the most commonly used outcome measures reported in studies on adults with CP published between 2000 and 2017.[22] The qualitative study involving six focus groups with adults with CP without ID and seven individual interviews with adults with

CP with ID and their caregivers, identified 132 categories.[23] While 63 categories were identified in the survey of 126 health professionals and researchers from 32 countries across all six WHO regions,[24] the empirical study pinpointed 104 categories reflecting common functioning problems experienced by adults with CP with and without ID visiting healthcare services in the Netherlands, Thailand, Sweden, and the United States.[25]

Altogether, the aggregated list of candidate categories comprised 154 categories (48 body functions, 9 body structures, 56 activities and participation categories and 41 environmental factors).

Participants

The inclusion criteria for participants in the consensus process were at least five years of experience in working with and/or conducting research with adults (age ≥18 years) with CP and fluency in English. We invited potential participants from all six WHO regions and a broad range of professional backgrounds, e.g. physical medicine and rehabilitation, neurology, orthopaedics, physical therapy, occupational therapy, speech/language therapy, nursing, psychology and other experts with experience with adults with CP and ID. We also strove for a good distribution of clinicians versus researchers. Moreover, an adult with CP and parents of adults with CP were invited to participate.

The pool of participants from the expert survey[24] was used as a source for identifying and inviting potential participants for the consensus process. This consensus participant pool was supplemented with persons from international study consortia on adults with CP and members and former members of the Lifespan Care Committee of the American Academy of Cerebral Palsy and Developmental Medicine. From responding experts the project team preselected available key experts in the field of adults with CP, and some experts were selected to ensure various countries of origin. A sample was drawn from the remaining respondents who accepted the invitation and met the inclusion criteria, whereby ensuring the aforementioned representation of WHO region, professional background and CP representatives.

Decision-making process

The Comprehensive and Brief ICF-CSs for adults with CP were developed in a two-part process – the comprehensive version in part one and the brief version in part two. The online decision-making and consensus process was conducted via Zoom, a cloud-based videoconferencing platform (https://zoom.us/), over a 4-week period with 1-3 hour sessions/week. See Figure 1.

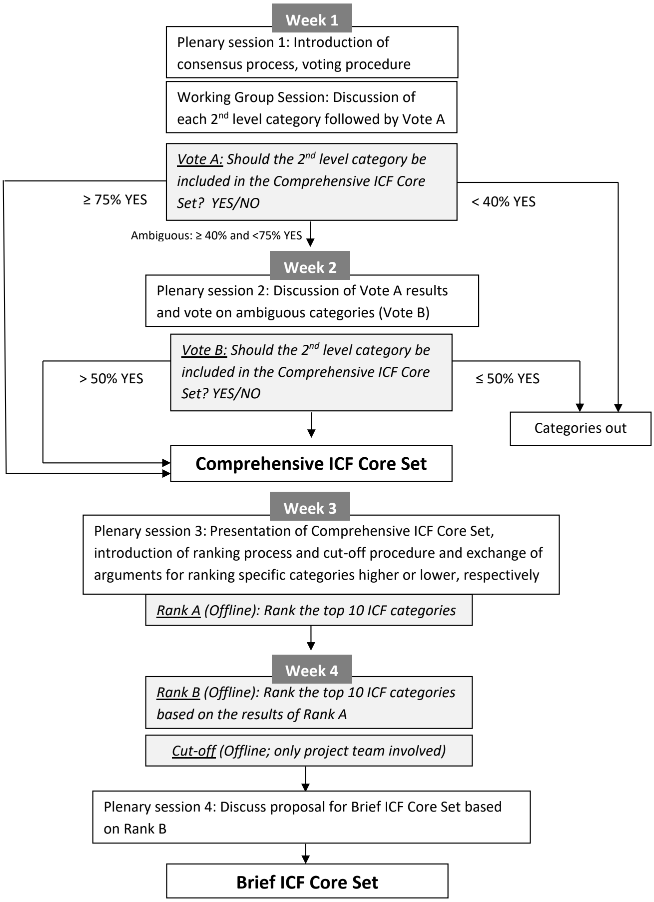

Figure 1 Decision-making process.

Before starting the consensus process, participants were asked to become familiar with the ICF by completing WHO's ICF e-learning tool (https://www.icf-elearning.com/) and view voiced-over presentations on the preparatory studies and the consensus and voting process. They also received a short recap of presentation content during the first plenary session. The list of 154 candidate categories was also sent to participants along with the request to select for themselves the categories they thought were essential to include in the Comprehensive ICF-CS for adults with CP. The project team decided beforehand that only second-level categories would be included in the ICF-CSs, as second-level categories cover several third- and/or fourth-level categories. ICF-CSs with second-level categories enable flexibility of use, since users can take the more detailed categories corresponding to the second-level ICF-CS category if needed.

The process for developing the Comprehensive ICF-CS consisted of a working group (WG) and a plenary session, including Votes A and B, respectively. Participants were allocated to three working groups of eight or nine voting participants each with a balanced representation of WHO regions, professional disciplines and sex, wherever possible. Each WG was led by a moderator (WS, ER-B, DT) and a WG assistant (LT, MR, SN).

In the WG session, participants discussed pros and cons of including each candidate ICF category in the Comprehensive ICF-CS, and voted (Vote A) directly after the discussion of each specific category. For the discussion and vote, participants were asked to consider the results of the preparatory studies, commonality between some categories, relevance of a category for adults with CP with and without ID based on participants' experience, clinical utility and cultural applicability. If a candidate category was included by at least 75% of the participants, it was automatically included in the Comprehensive ICF-CS for adults with CP. Categories garnering less than 40% positive votes were automatically excluded. Categories were considered "ambiguous" if 40% or more but less than 75% of the participants affirmed the inclusion of the category.

The results of Vote A were presented in plenary session 2, and as in the WG session, participants discussed and voted whether to include each ambiguous category (Vote B). In this round, categories receiving more than 50% positive votes were added to the Comprehensive ICF-CS for adults with CP.

The comprehensive version was the basis for developing the Brief ICF-CS. To prepare for this process, a voiced-over presentation briefed participants on the ranking process for developing the Brief ICF-CS, followed by a recap in plenary session 3. Two ranking rounds took place offline.

Participants were provided an Excel file containing the Comprehensive ICF-CS categories listed in individual spreadsheets according to ICF components. They were asked to rank the top 10 most essential ICF categories within each ICF component from 10 to 1, with "10" being most essential, and provide brief arguments for the top 5 categories to include and also for 5 categories to definitely exclude. The ranking results were analysed using descriptive statistics to generate a common ranking (rank A). For the second ranking round, an Excel file with the newly ordered list of categories according to rank A was sent to the participants with a summary of the aforementioned arguments for each category. Considering these arguments, participants again ranked the top 10 most essential ICF categories for each component to produce rank B. Striving for a feasible number of categories in the Brief ICF-CS, the project team decided a priori for a cut-off at 27% of the number of categories included in the Comprehensive ICF-CS. This cut-off is in line with the Brief ICF-CS for children & youth with CP 14-18 years of age.[19] Nevertheless, participants were shown brief versions of ICF categories with cut-offs at 20%, 25% and 33%.

RESULTS

Participants

Of 421 experts invited to participate in the consensus process, 143 accepted the invitation, and 89 met the inclusion criteria. From the 89 persons in the pool of experts, 25 persons (18 female, 7 male) participated in the consensus process, representing 11 different professional backgrounds, 15 countries (Argentina, Australia, Brazil, Canada, France, Germany, Hong-Kong, India, Morocco, the Netherlands, South Africa, Spain, Sweden, Turkey, United States), and all six WHO regions (Table 1).

Table 1 Participants of the consensus process by WHO region, country and professional discipline.

WG1	WG2	WG3	Sex	Profession or experience	Country	WHO region
	1		Male	Adult with CP and Researcher	The Netherlands	European Region
1			Female	Parent of adult daughter with CP	Canada	Region of the Americas
		1	Female	Parent of adult son with CP and Medical doctor in Public Health	India	South-East Asia Region
1			Male	Parent of adult son with CP, Orthopaedic surgeon, Director of CP Center	USA	Region of the Americas
	1		Female	Orthopaedic surgeon and Researcher	Brazil	Region of the Americas
1			Female	Specialist in PMR	Turkey	European Region
		1	Female	Specialist in PMR	Argentina	Region of the Americas
		1	Male	Specialist in PMR and Researcher	France	European Region
1			Female	Specialist in PMR and Researcher	The Netherlands	European Region
	1		Female	Specialist in PMR and Researcher	USA	Region of the Americas
	1		Male	Specialist in PMR, pain medicine and Researcher	Morocco	Eastern Mediterranean Region
		1	Male	Specialist in PMR with expertise in persons with intellectual disability	Canada	Region of the Americas
1			Female	Physical therapist	India	South-East Asia Region

Table 1 Participants of the consensus process by WHO region, country and professional discipline. (continued)

WG1	WG2	WG3	Sex	Profession or experience	Country	WHO region
		1	Female	Physical therapist and Researcher	USA	Region of the Americas
	1		Male	Physical therapist and Researcher	Hong-Kong	Western Pacific Region
	1		Female	Physical therapist and Researcher	Sweden	European Region
1			Female	Physical therapist and Researcher	Australia	Western Pacific Region
		1	Female	Physical therapist and Researcher	South Africa	African Region
1			Female	Occupational therapist and Researcher	USA	Region of the Americas
		1	Female	Occupational therapist and Director of re-integration center	The Netherlands	European Region
1			Female	Speech and language therapist and Researcher	Germany	European Region
1			Male	Nurse practitioner and Researcher	USA	Region of the Americas
		1	Female	Endocrinologist and Researcher	Australia	Western Pacific Region
	1		Female	Neurologic Gerontologist Rehabilitation Researcher	USA	Region of the Americas
	1		Female	Clinical neuropsychologist and Researcher	Spain	European Region

PMR: Physical Medicine and Rehabilitation, WG= working group.

Comprehensive ICF-CS for adults with CP

In the Comprehensive ICF-CS for adults with CP, 120 of the 154 second-level ICF categories were included: 33 (27%) body functions, 8 (7%) body structures, 50 (42%) activities and participation, 29 (24%) environmental factors (Table 2). For body functions, most of the categories were mental functions (b1) and neuromusculoskeletal and movement-related functions (b7). The body structures were mostly related to movement (s7). All the chapters of the activities and participation component were represented, with mobility (d4) and self-care (d5) as the most frequently covered chapters. For environmental factors most of the categories addressed products and technology (e1) and services, systems and policies (e5).

Table 2 The second-level ICF categories included in the Comprehensive (n=120) and Brief (n=33) ICF Core Sets for adults with cerebral palsy.

ICF Code	ICF category name	Categories included in the Brief Set (X)
b Body functions		
b1 Mental functions		
b114	Orientation functions	
b117	Intellectual functions	X
b130	Energy and drive functions	X
b134	Sleep functions	X
b144	Memory functions	
b147	Psychomotor functions	
b152	Emotional functions	
b156	Perceptual functions	
b164	Higher-level cognitive functions	X
b167	Mental functions of language	
b2 Sensory functions and pain		
b210	Seeing functions	
b230	Hearing functions	
b235	Vestibular functions	
b280	Sensation of pain	X
b3 Voice and speech functions		
b320	Articulation functions	
b330	Fluency and rhythm of speech functions	
b4 Function of the cardiovascular, haematological, immunological and respiratory systems		
b420	Blood pressure functions	
b440	Respiration functions	
b455	Exercise tolerance functions	
b5 Functions of the digestive, metabolic and endocrine systems		
b510	Ingestion functions	
b525	Defecation functions	
b530	Weight maintenance functions	
b6 Genitourinary and reproductive functions		
b620	Urination functions	
b640	Sexual functions	
b7 Neuromusculoskeletal and movement-related functions		
b710	Mobility of joint functions	X
b715	Stability of joint functions	
b730	Muscle power functions	X
b735	Muscle tone functions	X
b755	Involuntary movement reaction functions	
b760	Control of voluntary movement functions	X

Table 2 The second-level ICF categories included in the Comprehensive (n=120) and Brief (n=33) ICF Core Sets for adults with cerebral palsy. (continued)

ICF Code	ICF category name	Categories included in the Brief Set (X)
b765	Involuntary movement functions	
b770	Gait pattern functions	
b780	Sensations related to muscles and movement functions	
s Body structures		
s1 Structures of the nervous system		
s110	Structure of brain	
s3 Structures involved in voice and speech		
s320	Structure of mouth	
s7 Structures related to movement		
s710	Structure of head and neck region	
s720	Structure of shoulder region	
s730	Structure of upper extremity	X
s750	Structure of lower extremity	X
s760	Structure of trunk	
s770	Additional musculoskeletal structures related to movement	
d Activities and participation		
d1 Learning and applying knowledge		
d155	Acquiring skills	X
d160	Focusing attention	
d166	Reading	
d175	Solving problems	
d177	Making decisions	X
d2 General tasks and demands		
d220	Undertaking multiple tasks	
d230	Carrying out daily routine	X
d240	Handling stress and other psychological demands	
d3 Communication		
d310	Communicating with - receiving - spoken messages	X
d330	Speaking	
d335	Producing nonverbal messages	
d350	Conversation	
d360	Using communication devices and techniques	X
d4 Mobility		
d410	Changing basic body position	
d415	Maintaining a body position	
d420	Transferring oneself	X
d430	Lifting and carrying objects	
d440	Fine hand use	

Table 2 The second-level ICF categories included in the Comprehensive (n=120) and Brief (n=33) ICF Core Sets for adults with cerebral palsy. (continued)

ICF Code	ICF category name	Categories included in the Brief Set (X)
d445	Hand and arm use	
d450	Walking	X
d455	Moving around	
d460	Moving around in different locations	
d465	Moving around using equipment	
d470	Using transportation	
d475	Driving	
d5 Self-care		
d510	Washing oneself	
d520	Caring for body parts	
d530	Toileting	X
d540	Dressing	
d550	Eating	X
d560	Drinking	
d570	Looking after one's health	
d6 Domestic life		
d620	Acquisition of goods and services	
d630	Preparing meals	
d640	Doing housework	
d650	Caring for household objects	
d7 Interpersonal interactions and relationships		
d720	Complex interpersonal interactions	
d740	Formal relationships	
d750	Informal social relationships	
d760	Family relationships	X
d770	Intimate relationships	X
d8 Major life events		
d820	School education	
d830	Higher education	
d845	Acquiring, keeping and terminating a job	X
d850	Remunerative employment	
d855	Non-remunerative employment	
d870	Economic self-sufficiency	
d9 Community, social and civic life		
d910	Community life	X
d920	Recreation and leisure	X
d950	Political life and citizenship	

Table 2 The second-level ICF categories included in the Comprehensive (n=120) and Brief (n=33) ICF Core Sets for adults with cerebral palsy. (continued)

ICF Code	ICF category name	Categories included in the Brief Set (X)
e Environmental factors		
e1 Products and technology		
e115	Products and technology for personal use in daily living	X
e120	Products and technology for personal indoor and outdoor mobility and transportation	X
e125	Products and technology for communication	
e130	Products and technology for education	
e135	Products and technology for employment	
e140	Products and technology for culture, recreation and sport	
e150	Design, construction and building products and technology of buildings for public use	X
e155	Design, construction and building products and technology of buildings for private use	
e160	Products and technology of land development	
e3 Support and relationships		
e310	Immediate family	X
e320	Friends	
e325	Acquaintances, peers, colleagues, neighbours and community members	
e340	Personal care providers and personal assistants	X
e355	Health professionals	X
e360	Other professionals	
e4 Attitudes		
e410	Individual attitudes of immediate family members	
e425	Individual attitudes of acquaintances, peers, colleagues, neighbours and community members	
e430	Individual attitudes of people in positions of authority	
e440	Individual attitudes of personal care providers and personal assistants	
e450	Individual attitudes of health professionals	
e460	Societal attitudes	
e5 Services, systems and policies		
e525	Housing services, systems and policies	
e540	Transportation services, systems and policies	
e555	Associations and organizational services, systems and policies	
e570	Social security services, systems and policies	X
e575	General social support services, systems and policies	
e580	Health services, systems and policies	X
e585	Education and training services, systems and policies	
e590	Labour and employment services, systems and policies	

Brief ICF-CS for adults with CP

Agreeing with the 27% cut-off, the participants included 33 ICF Categories in the Brief ICF-CS for adults with CP: 9 (27%) body functions, 2 (6%) body structures, 14 (42%) activities and participation, 8 (24%) environmental factors (Figure 2). The most frequently covered chapters for body functions and body structures were the same as for the Comprehensive ICF-CS, while eight out of nine activities and participation chapters were covered. Besides chapters e1 and e5, support and relationships (e3) were also represented.

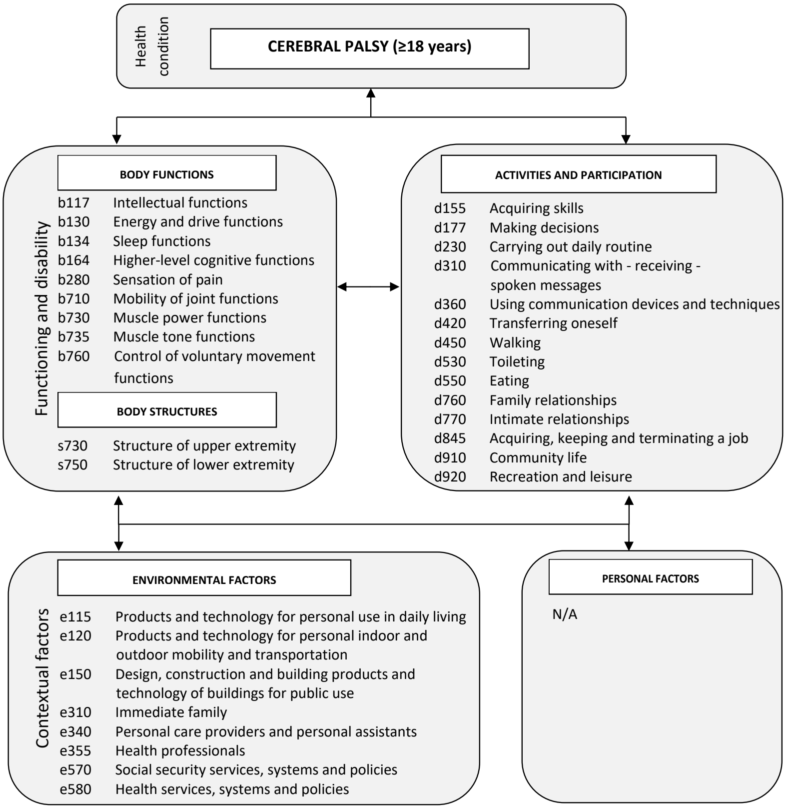

Figure 2 International Classification of Functioning, Disability and Health (ICF) framework including the ICF categories from the Brief ICF Core Set for adults with cerebral palsy (CP).

DISCUSSION

In this consensus process, a group of 25 international participants representing a variety of backgrounds and experience decided on the first version of the Comprehensive and

Brief ICF-CSs for adults with CP taking into consideration the evidence collected in the preparatory studies, systematic literature review,[22] qualitative study,[23] expert survey,[24] and empirical study.[25] This specific ICF-CS consensus process was the first one to be conducted online.

It is not surprising that the Comprehensive ICF-CS comprises a large number and broad range of ICF categories, since the adult population with CP is heterogeneous, and presents with different levels of motor and/or mental issues.[4] Most categories of the Comprehensive and Brief ICF-CSs represented the activities and participation component. Furthermore, environmental factors were well presented, with a similar number as body functions included. This distribution of factors follows a trend observed in healthcare that is shifting from a mainly biomedical approach toward a more comprehensive client-centred approach that also considers personal, social and environmental aspects.[26]

While the Comprehensive ICF-CS is wide-ranging, some aspects of functioning may be underrepresented in the Brief ICF-CS as a result of the 27% cut-off. For example, only the body structures of upper and lower extremities were included, although many of the participants argued that structures of the brain and trunk are highly relevant in adults with CP. In the activities and participation component, categories such as moving around using equipment (such as wheelchairs or crutches) or hand and arm use did not meet the cut-off but may be particularly relevant for specific adults with CP. Nevertheless, the experts agreed that the brief list of categories should be considered important when assessing functioning of adults with CP.

This ICF-CSs for adults with CP will complement the ICF-CSs that have been developed for children & youth with CP,[19] including a Comprehensive ICF-CS, a common Brief ICF-CS, and three age-specific Brief ICF-CSs (<6 years, 6-13 years, 14-18 years old). A comparison of the two comprehensive sets reveals that they share 98 second-level categories, 22 categories unique for adults and 36 categories unique for children & youth. These differences can be partially explained by age-specific aspects of functioning; some items were more specific for adults, such as higher education, employment and political life and citizenship, while others were specific to children, such as pre-school education. Furthermore, the ICF standard version was used to develop the ICF-CSs for adults with CP, while the children & youth version of the ICF was used for the ICF-CSs for children & youth with CP;[27] there are 8 categories in the Comprehensive ICF-CS for children & youth that are in the ICF children & youth version but not in the ICF. When comparing the Brief ICF-CS for adults with the Brief ICF-CS for children & youth with CP age 14-18 years old, many aspects are covered in both sets, e.g. intellectual functions, pain, muscle tone functions, walking, toileting, products for mobility, and healthcare services. Differences were also observed. For example, the children & youth categories addresses issues important to teenagers, i.e. *e320 friends and e420 individual attitudes of friends*, whereas the adult version highlights topics important to adults, e.g. *d177 making decisions, d230 carrying out daily routine* or *d770 intimate relationships*. The comparison of the adult and children & youth versions confirms the added value of the ICF-CSs for adults with CP as it underscores the importance of functioning categories that reflect the specific needs of adults 18+ years of age with CP.

The ICF-CSs for adults with CP can be used as the foundation for the systematic assessment of adults with CP, for standardizing data collection worldwide and supporting data comparison across studies, disciplines and settings. Standardized data will enable the creation of individual functioning profiles for goal-setting or treatment planning for adults with CP. The ICF-CSs focus on 'what' to measure; to promote standardized data collection it is also important 'how' to measure relevant aspects of functioning. Therefore, it is advisable to select standardized tools, such as questionnaires or clinical assessments that align with the content of the ICF-CSs for adults with CP.[28, 29] Before proceeding, it would be important to validate the ICF-CSs for adults in diverse social, cultural and economic contexts worldwide to identify any gaps in the current version.

Procedures that we followed for developing these ICF-CSs were unique. Due to the COVID-19 pandemic, we had the opportunity to pioneer an online version of the consensus process. Despite adhering as close as possible to the original methodology, concessions were necessary. For example, we decided for less voting rounds and sessions to reduce participant burden. This meant, however, less opportunity for discussion and more consideration of available information. We experienced that the results of all preparatory studies and also previous voting results were carefully considered. From experience in previous ICF-CS consensus conferences, physical presence and interactions during breaks and meals is shown to be helpful for interactive exchange. In the present online process, it took longer for participants to feel comfortable and provide input. Nevertheless, as in previous ICF-CS conferences, participants engaged quite actively as time passed. We also experienced that an online meeting takes longer than planned due to delays in audio or waiting for people to respond. This led to schedule changes and extension of meeting times. This, in turn, became an added challenge posed by the 9-hour spread of time zones across all six WHO regions. As some participants had to leave the meeting as it was past midnight and some had subsequent appointments, their votes in the last part of a meeting could not be considered. Where appropriate, participants who were unavailable for a session were asked to provide their arguments to be shared during the session. Other efforts were made to promote participant involvement, as well facilitate individual and shared decision-making, e.g. providing summaries of results and brief presentations on the next session activities. Despite these challenges, the overall experience was positive, and the methodology of this online process can serve as a model for future ICF-CS consensus processes and similar Delphi procedures. An additional advantage of the online format was a significant reduction of costs, as compared to an offline consensus meeting of several days.

Strengths and limitations

Some strengths and limitations should be considered when interpreting the results of this consensus process. A strength of this process is the international group of participants representing a mix of backgrounds and experience, inclusion of adults with CP and three parents of adults with CP, of which two were also clinicians. However, some professional backgrounds were underrepresented, e.g. experts in neurology, social work, or nursing, which may have influenced the results. Additionally, although all six WHO regions were represented in the preparatory studies and consensus process, the majority of the participants combined were from the United States (24%) and the European region (32%), while only a few participants were from the Eastern Mediterranean and African regions (each 4%). To address this limitation, the consensus process participants were regularly asked to consider the applicability of the ICF-CSs worldwide, including different cultural backgrounds and socioeconomic circumstances, in discussions and voting.

CONCLUSION

The Comprehensive and Brief ICF-CSs for adults with CP were created during a novel online version of an established ICF-CS consensus process. These ICF-CSs can now be implemented in clinical care and research, and will promote standardized data collection worldwide.

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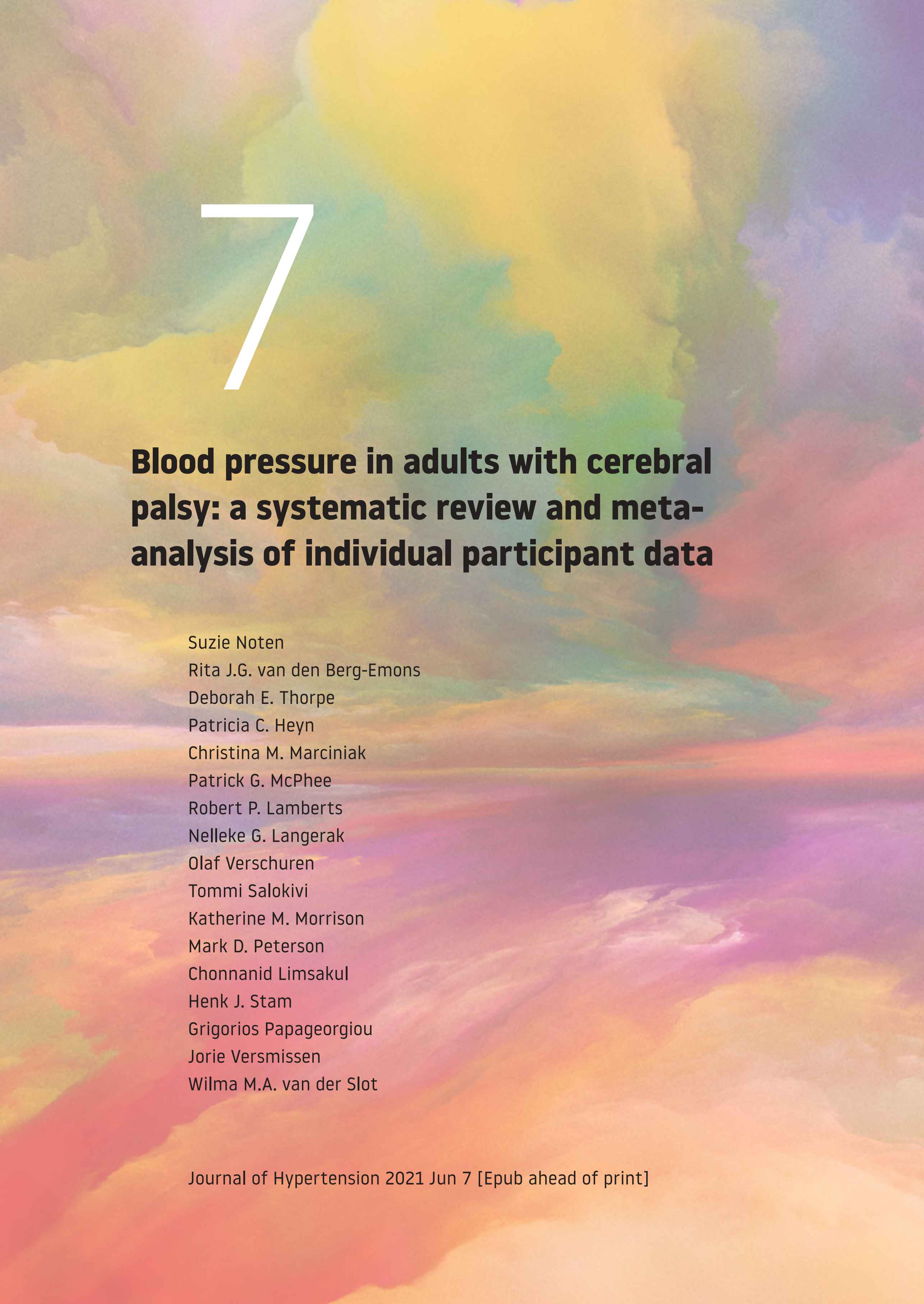
Part II

Blood pressure in adults with cerebral palsy



7

Blood pressure in adults with cerebral palsy: a systematic review and meta-analysis of individual participant data

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ABSTRACT

Objectives: This systematic review and meta-analysis was designed to determine the overall mean blood pressure and prevalence of hypertension among a representative sample of adults living with cerebral palsy (CP) by combining individual participant data. Additional objectives included estimating variations between subgroups and investigating potential risk factors for hypertension.

Methods: Potential datasets were identified by literature searches for studies published between January 2000 and November 2017 and by experts in the field. Samples of adults with CP (n≥10, age≥18y) were included if blood pressure data, CP-related factors (e.g. CP subtype), and sociodemographic variables (e.g. age, sex) were available. Hypertension was defined as ≥140/90mmHg and/or use of antihypertensive medication.

Results: We included data from 11 international cohorts representing 444 adults with CP (median (IQR) age of the sample was 29.0 (23.0-38.0); 51% males; 89% spastic type; Gross Motor Function Classification System levels I-V). Overall mean systolic blood pressure was 124.9mmHg (95% Confidence Interval (CI) 121.7-128.1) and overall mean diastolic blood pressure was 79.9mmHg (95% CI 77.2-82.5). Overall prevalence of hypertension was 28.7% (95% CI 18.8%-39.8%). Subgroup analysis indicated higher blood pressure levels or higher prevalence of hypertension in adults with CP above 40 years of age, males, those with spastic CP or those who lived in Africa. Body mass index, resting heart rate and alcohol consumption were risk factors that were associated with blood pressure or hypertension.

Conclusions: Our findings underscore the importance of clinical screening for blood pressure in individuals with CP beginning in young adulthood.

INTRODUCTION

Cerebral palsy (CP) is the most common childhood-onset physical disability, with an incidence of 2 to 3 per 1000 live births.[1] CP is caused by a non-progressive disturbance to the developing fetal or infant brain that affects movement and posture.[2] The life expectancy of individuals with CP has improved in recent decades, and increasing numbers of children with CP now survive into adulthood; therefore it is important to understand the long-term effects of CP across the lifespan.[3, 4]

In adults with CP, functional deterioration,[5] low levels of aerobic fitness[6, 7] and physical activity,[8, 9] pronounced sedentary behavior,[10] and obesity[7, 11] are prevalent. From the general population, it is known that these factors are associated with the risk of developing cardiovascular disease (CVD),[12] suggesting that adults with CP may be at increased risk. Indeed, in recent years, adults with CP have been shown to have a greater risk of CVD than the general population.[11, 13, 14] However, the literature is scarce and clinical attention towards CVD risk factors in adults with CP is limited. One of the main risk factors of CVD is high blood pressure (BP), which is an important problem worldwide and was the leading cause of death and disability in 2010.[15]

Research and clinical practice have done little to understand BP in people with CP, and as a consequence, there is limited knowledge of hypertension risk in this population. To date, only a few studies reported the prevalence of hypertension among adults with CP, which ranged between 14% and 30%.[7, 16-18] Furthermore, those studies were limited by small sample size, relatively young age,[7, 16, 18] or assessed self-reported hypertension.[17] Therefore, no uniform conclusion on BP levels in CP can be drawn from these publications, and reliable hypertension prevalence estimates are not available. In addition, little is known about specific subgroups of adults with CP who might be at increased risk (e.g. subtype of CP or level of gross motor functioning), as well as potential risk factors influencing BP levels, such as body mass index (BMI) or physical (in)activity. This knowledge would contribute to a better understanding of hypertension risk in adults living with CP, which is urgently needed in current clinical practice and future research in this area.

Therefore, we performed a systematic review and meta-analysis, combining individual participant data (IPD) from available published and unpublished studies on BP in adults with CP. This study was designed to determine the overall mean level of BP and the prevalence of both prehypertension and hypertension. We also aimed to estimate variations in BP levels and prevalence of prehypertension and hypertension by age, sex and CP characteristics and to explore associations between potential risk factors and BP levels (e.g. biological and lifestyle-related risk factors).

METHODS

This systematic review and meta-analysis followed the guidelines outlined in the Preferred Reporting Items for a Systematic Review and Meta-analysis of Individual Participant Data (PRISMA-IPD Statement).[19] The study was approved by the Medical Ethical Committee of the Erasmus MC University Medical Center, Rotterdam, The Netherlands (MEC-2017-1084).

Study selection process

A systematic literature search in Embase, Medline Ovid, PsycINFO Ovid, CINAHL, Cochrane, Web of Science and Google Scholar databases was performed for studies published between January 2000 and November 2017, with the following broad search terms: blood pressure or hypertension and cerebral palsy. The detailed search strategy was developed in consultation with an information specialist and considered only full-text articles without any language constraints (Supplemental Table S1).

Results from the different databases were combined and duplicates removed. First, two independent reviewers (SN and CL) screened titles and abstracts for eligibility; full-text articles were obtained from potentially eligible articles and screened. Subsequently, the results of both reviewers were compared, and differences were discussed in a consensus meeting. When consensus could not be reached, a third reviewer (RvdB-E) was consulted. References of included studies, as well as conference proceedings, were checked to further identify potentially relevant studies. To identify unpublished studies, experts working in the field were approached to inquire for potential datasets.

Studies were eligible if they fulfilled the following criteria: observational study or trial (baseline data); study was approved by a Medical Ethical Committee, and informed consent of the study participants was available; recruitment took place in the year 2000 or more recently; sample size was at least ten adults with CP (≥18 years); BP and essential sample characteristics: age, sex and CP characteristics (type, distribution, or gross motor functioning) were available. Studies were excluded if BP data were self-reported, self-measured at home or measured with a finger or wrist cuff device. In addition, samples with only hypertensive participants were excluded.

Data collection

The corresponding authors/investigators of eligible studies were contacted to confirm the inclusion criteria and to start the collaboration with an agreement to share anonymous data. Information on study design, method of measurement, BP data, usage of antihypertensive medication, sample characteristics, CP-related factors, biological risk factors and lifestyle-related risk factors were requested from the primary investigator. Eligible and anonymous IPD were safely shared using encrypted files and checked for both completeness and correctness. Samples were included up to November 2018. The primary meta-analysis and all sub-analyses were performed in December 2018 – March 2020.

Methodological quality assessment

Two investigators independently assessed the methodological quality (SN and CL), using 11 items of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement,[20] selected in a previous meta-analysis by our research group.[21] Items were scored as yes (1), partially (0.5) or no (0). A study was considered high quality when the total score was eight or more. Disagreements in rating were discussed until consensus was reached. If necessary, a third reviewer was consulted (RvB-E). The main publication of each included sample was used to score the methodological quality. In the case that documentation in a publication was insufficient, other publications of the same sample were checked if available, or the primary investigator was contacted to provide the missing information; scores were adjusted accordingly. Primary investigators were also contacted in the event that studies had not yet been published; in this case, the study protocol was used to score the methodological quality. All studies were included in the analysis, regardless of their methodological quality scores.

Data items and determinants

Primary outcomes were overall mean systolic BP and diastolic BP, and the prevalence of prehypertension and hypertension. Participants without systolic BP and/or diastolic BP data were excluded. Prevalence of prehypertension and hypertension was defined by the hypertension guidelines of the European Society of Cardiology and European Society of Hypertension.[12] In the guidelines, prehypertension is defined as systolic BP 130-139 mmHg and/or diastolic BP 85-89 mmHg, and hypertension as systolic BP ≥140 mmHg and/or diastolic BP ≥90 mmHg, or use of antihypertensive medication. These guidelines were used because they were comparable to the previous American Hypertension guidelines,[22] which were applicable in the period in which the included studies were performed.

Classification of BP was evaluated as determined by the European Hypertension guidelines. BP was classified as optimal (systolic BP <120 mmHg and diastolic BP <80 mmHg), normal (systolic BP 120-129 mmHg and/or diastolic BP 80-84 mmHg), high normal (systolic BP 130-139 mmHg and/or diastolic BP 85-89 mmHg), grade 1 hypertension (systolic BP 140-159 mmHg and/or diastolic BP 90-99 mmHg), grade 2 hypertension (systolic BP 160-179 mmHg and/or diastolic BP 100-109 mmHg) or grade 3 hypertension (systolic BP ≥180 mmHg and/or diastolic BP ≥110 mmHg).

Personal characteristics were obtained if available, and included: intellectual disability (defined as a moderate to severe level of intellectual functioning, indicated as an IQ level below 70),[23] level of education, employment, civil status and living situation.

Subgroups of adults with CP were categorized by age, sex, CP subtype, CP distribution, GMFCS level and continent of residence, to estimate the effect of each of these factors on BP levels and prevalence of prehypertension and hypertension. Age was classified into three categories (18-29, 30-39 and ≥40 years). CP subtype was classified according to neurological signs (spastic or other subtypes [dyskinetic, ataxic or mixed]) and distribution to unilateral or bilateral.[24] Gross motor functioning was classified using the Gross Motor Function Classification System (GMFCS).[25] Continents of the included samples were North America, Europe and Africa. Reference groups can be found in Table 3.

If available, the following data were collected from the original authors to explore the effect of potential risk factors on BP levels and hypertension: CP-related factors (muscle tone, pain, fatigue), biological risk factors (family history of CVD, BMI, waist-to-hip ratio, resting heart rate, aerobic fitness, total cholesterol (TC), high-density lipoprotein cholesterol (HDL), low-density lipoprotein cholesterol (LDL), TC/HDL ratio, triglycerides, glucose, insulin and diabetes) and lifestyle-related risk factors (alcohol consumption, smoking and physical activity). Data on the following factors were limited and could not be included in the multivariable analysis, thus only descriptive results are reported: CP-related factors of pain and fatigue, biological risk factors waist-to-hip ratio, aerobic fitness, TC, HDL, LDL, TC/HDL ratio, triglycerides, glucose, insulin and diabetes and lifestyle-related risk factor physical activity. In case the scaling or type of measurement differed across datasets, variables were translated to common scales if possible. Conversion to common scales or outcomes measures was needed for intellectual disability, muscle tone, pain, fatigue, aerobic fitness and physical activity. Supplemental Table S2 provides a description of all procedures of translating variables to ensure common scales across studies.[26-32]

The American Hypertension guidelines proposed by the American College of Cardiology and the American Heart Association were recently adapted and lower cut-off values for prehypertension and hypertension were recommended.[33] The impact of this change on the prevalence of prehypertension and hypertension was explored in this study. Prehypertension was determined by the new guidelines as systolic BP 120-129 mmHg and diastolic BP <80 mmHg; hypertension as systolic BP ≥130 mmHg or diastolic BP ≥80 mmHg or use of antihypertensive medication. We also evaluated classification of BP as determined by the new guidelines; BP was classified as normal (systolic BP <120 mmHg and diastolic BP <80 mmHg), elevated (systolic BP 120-129 mmHg and diastolic

BP <80 mmHg), hypertension stage 1 (systolic BP 130-139 mmHg or diastolic BP 80-89 mmHg), hypertension stage 2 (systolic BP 140-180 mmHg or diastolic BP 90-120 mmHg) or hypertensive crisis (systolic BP >180 mmHg and/or diastolic BP >120 mmHg).

Statistics

Descriptive statistics were performed for personal characteristics, CP-related factors, biological and lifestyle-related risk factors. In case of more than one BP measurement in a person, the median BP was used for analysis; in case of only one measurement, this measurement was used.

Primary analyses

Estimates and 95% confidence intervals (CI) for the primary outcomes were obtained by a two-stage meta-analysis model. First, the means and standard errors of systolic BP and diastolic BP and proportions and standard errors of prehypertension and hypertension were estimated from the IPD. Secondly, pooled estimates for the outcomes were obtained via a random-effects meta-analysis model using the DerSimonian and Laird estimator[34] and the arcsine-transformation (for proportions).[35] The random-effects model takes the heterogeneity of samples into account. Statistical heterogeneity was quantified using the I^2 measure, which describes the amount of variation attributed to heterogeneity rather than sampling error across samples.[36] Funnel plots for BP were created to inspect for evidence of publication bias. Descriptive statistics were used to explore the classification of BP.

Secondary analyses

Linear and logistic multivariable regression models, including study as a fixed-effect were used to estimate the association of age, sex, CP subtype, CP distribution, GMFCS level and continent with the primary outcomes. Estimates were adjusted for these factors. Estimated beta coefficients (β) and odds ratios (ORs) and 95% CIs were calculated. A P-value ≤0.05 was considered significant.

To explore the effect of potential risk factors on BP levels, separate extended multivariable regression models were used, adjusted for one risk factor each. This method was performed because a multivariable regression model including all the factors was not feasible due to the large number of parameters to be estimated. These risk factors were selected based on availability of the data and included muscle tone, family history of CVD, BMI, resting heart rate, alcohol consumption, and smoking. The models were adjusted for age, sex, CP subtype, CP distribution, GMFCS level and continent. P-values were adjusted for multiple comparisons using the Holm method.

Use of antihypertensive medication was used to define hypertension. If the information on the use of antihypertensive medication was missing, and BP levels were normal, hypertension could not be defined, and the participant was excluded from the analysis. Participants using antihypertensive medication or who had missing information on the use of antihypertensive medication were excluded from the analyses to determine the overall mean systolic and diastolic BP and prehypertension, and subgroup analyses.

RESULTS

Study selection and characteristics

The literature review produced a total of 1144 potentially eligible articles after removal of duplicates. After title and abstract screening, 41 full-text articles were reviewed, and seven published studies were found eligible. In addition, 31 experts in the field were approached to obtain unpublished studies, which resulted in an additional 11 eligible studies. Most excluded studies had clinically-based BP data obtained from medical records or registers. These data were collected during regular medical checks or hospitalization, and might have been affected by other illnesses or procedures (e.g. surgery); also, it was suggested by the contact person that sample characteristics were often limited or unavailable.

Six duplicates were found and removed, and one study was excluded because no informed consents were available. Eventually, 11 studies (six published, five unpublished at that time) met the inclusion criteria,[7, 13, 37-43, Lamberts et al, unpublished data, 2017, Verschuren et al, unpublished data, 2015-2016] and all primary investigators agreed to collaborate (Figure 1). Included studies were five cross-sectional studies,[7,37,40,42, Verschuren et al, unpublished data, 2015-2016] five cohort studies,[13,38,39,43, Lamberts et al, unpublished data, 2017] and one RCT (baseline measurement was used),[41] executed between 2004 and 2017 in North America, Europe, and Africa.

A total of 444 adults with CP, 51% males, mainly with spastic CP (89%) and GMFCS levels I-V were included. Median (IQR) age of the sample was 29.0 (23.0-38.0). Thirty-seven participants (8%) used antihypertensive medication, and 4 participants (1%) had missing information on the use of antihypertensive medication (Table 1). Personal characteristics, CP-related factors, biological and lifestyle-related risk factors are presented in Supplemental Table S3.

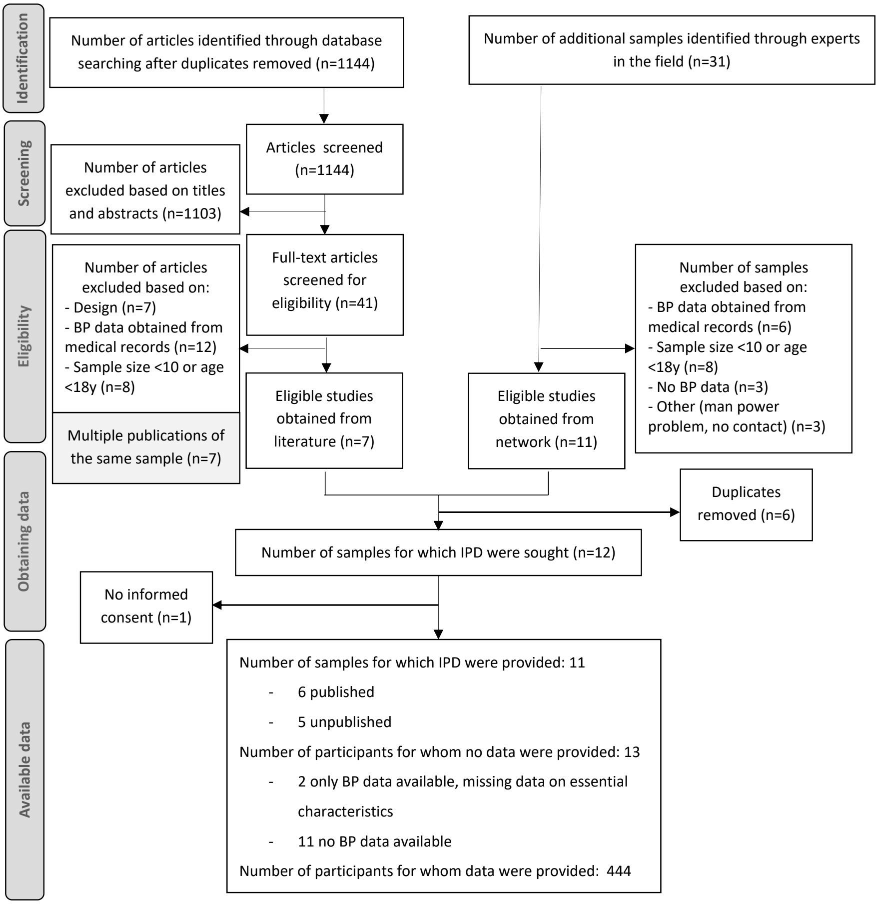


Figure 1 The PRISMA IPD flow diagram. BP=blood pressure, IPD= Individual Participant Data.

Table 1 Study characteristics of the 11 single studies.

Study	Country	Design	Year of assessment	Sample characteristics						
				n	*Age median (IQR)*	*Sex n (%)*	*CP subtype n (%)*	*CP distribution n (%)*	*GMFCS level n (%)*	*Number of participants using anti-hypertensive medication n (%)*
Total sample				444	29.0 (23.0-38.0)	M:228 (51) F:216 (49)	Spas: 313 (89) Other: 40 (11) Md: 91	Uni: 97 (23) Bi: 320 (77) Md: 27	I: 140 (33) II: 139 (32) III: 73 (17) IV: 53 (12) V: 27 (6) Md: 12	37 (8) Md: 4
Heyn et al[13]	USA, Colorado	Cohort (baseline)	2015-2017	70	23.9 (21.1-27.4)	M: 32 (46) F: 38 (54)	md	Uni: 26 (37) Bi: 44 (63)	I: 28 (40) II: 27 (38) III: 13 (19) IV: 2 (3) V: 0 (0)	2 (3)
Marciniak et al[42]	USA, Illinois	Cross-sectional	2014-2017	46	29.5 (25.0-43.0)	M: 19 (41) F: 27 (59)	Spas: 12 (32) Other: 25 (68) Md: 9	Uni: 5 (11) Bi: 41 (89)	I: 7 (15) II: 8 (17) III: 9 (20) IV: 15 (33) V: 7 (15)	6 (13)
Thorpe et al[38]	USA, North Carolina	Cohort (baseline)	2006-2012	89	27.0 (23.0-36.0)	M: 47 (53) F: 42 (47)	Spas: 89 (100) Other: 0 (0)	Uni: 28 (31) Bi: 61 (69)	I: 30 (34) II: 22 (25) III: 16 (18) IV: 18 (20) V: 3 (3)	15 (17)
McPhee et al[40]	Canada, Ontario	Cross- sectional	2012-2014	42	31.0 (24.2-37.8)	M: 21 (50) F: 21 (50)	Spas: 31 (74) Other: 11 (26)	Uni: 10 (26) Bi: 29 (74) Md: 3	I: 5 (12) II: 9 (21) III: 10 (24) IV: 11 (26) V: 7 (17)	0 (0)

Table 1 Study characteristics of the 11 single studies. (continued)

Study	Country	Design	Year of assessment	Sample characteristics						
Morrison et al[39]	Canada, Ontario	Cohort	2011-2013	12	33.0 (31.0-34.0)	M: 6 (50) F: 6 (50)	md	Uni: 6 (50) Bi: 6 (50)	md	2 (17)
van den Berg-Emons et al[41]	The Netherlands	RCT (baseline)	2010	44	21.0 (19.0-22.0)	M: 23 (52) F: 21 (48)	Spas: 44 (100) Other: 0 (0)	Uni: 21 (49) Bi: 22 (51) Md: 1	I: 25 (57) II: 16 (37) III: 2 (4) IV: 1 (2) V: 0 (0)	0 (0)
van der Slot et al[7]	The Netherlands	Cross- sectional	2004-2006	51	36.0 (32.5-41.5)	M: 33 (65) F: 18 (35)	Spas: 51 (100) Other: 0 (0)	Uni: 0 (0) Bi: 51 (100)	I: 12 (23) II: 26 (51) III: 9 (18) IV: 4 (8) V: 0 (0)	2 (4)
Verschuren et al, unpublished data, 2015-2016	The Netherlands	Cross- sectional	2015-2016	23	34.8 (22.9 – 50.9)	M: 12 (52) F: 11 (48)	Spas: 23 (100) Other: 0 (0)	md	I: 9 (39) II: 8 (35) III: 4 (18) IV: 1 (4) V: 1 (4)	1 (4) Md: 4
Salokivi et al[37]	Finland	Cross- sectional	2013-2014	14	40.0 (26.0-46.5)	M: 7 (50) F: 7 (50)	Spas: 10 (71) Other: 4 (29)	Uni: 1 (7) Bi: 13 (93)	I: 0 (0) II: 2 (14) III: 2 (14) IV: 1 (7) V: 9 (65)	0 (0)
Lamberts et al, unpublished data, 2017	South Africa	Cohort (baseline)	2017	28	38.9 (34.6-45.6)	M: 12 (43) F: 16 (57)	Spas: 28 (100) Other: 0 (0)	Uni: 0 (0) Bi: 28 (100)	I: 11 (39) II: 12 (43) III: 5 (18) IV: 0 (0) V: 0 (0)	5 (18)
Langerak et al[43]	South Africa	Cohort (baseline)	2017	25	35.9 (34.3-41.1)	M: 16 (64) F: 9 (36)	Spas: 25 (100) Other: 0 (0)	Uni: 0 (0) Bi: 25 (100)	I: 13 (52) II: 9 (36) III: 3 (12) IV: 0 (0) V: 0 (0)	4 (16)

Bi=bilateral; F=female; GMFCS=Gross Motor Function Classification System; M=male; Md=missing data; Other=Other subtypes of cerebral palsy (dyskinetic, ataxic or mixed); RCT=Randomized Controlled Trial; Spas=Spastic; Uni=unilateral.

Methodological quality assessment

The results of the methodological quality assessment are presented in Supplemental Table S4. There was an 83% agreement (73 of 88 items) between the two raters and disagreements regarding the scoring were minimal and were all solved in a consensus meeting. All studies had good methodological quality (score above 8), except for one study rated as 5.[37]

Blood pressure

BP was measured between one and five times per participant across studies, of which five studies measured BP once. Measurements were primarily performed with a digital device; in two of the samples, BP was measured manually.[7, 41] Devices were properly maintained, calibrated, and validated, and appropriately sized cuffs were used for assessments. Five studies measured BP at the unaffected or least affected side,[7, 38, 39, 42, Verschuren et al, unpublished data, 2015-2016] four at the left arm[37, 41,43 Lamberts et al, unpublished data, 2017] and two at the right arm[13, 40] (Supplemental Table S5).

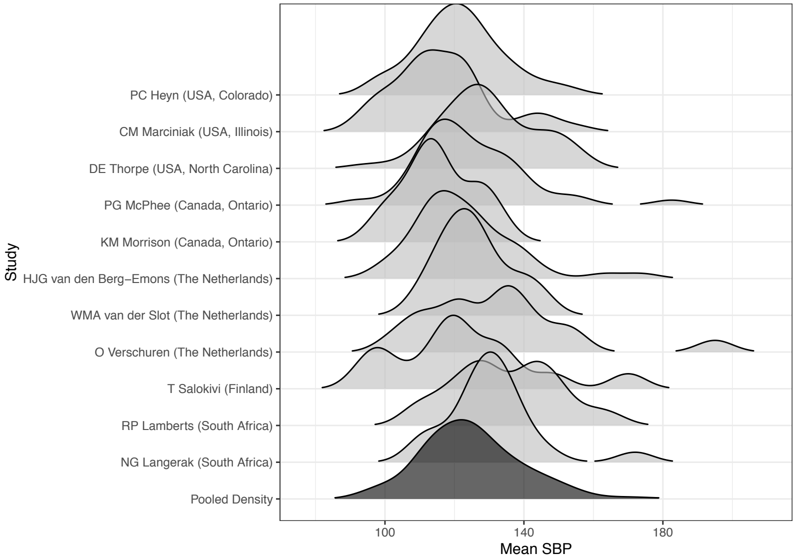
The overall mean systolic BP of the total sample was 124.9 mmHg (95% CI 121.7 - 128.1), and the overall mean diastolic BP was 79.9 mmHg (95% CI 77.2 - 82.5). According to the European Hypertension guidelines, the overall prevalence of prehypertension was 21.6% (95% CI 17.7 - 25.7) and the overall prevalence of hypertension was 28.7% (95% CI 18.8 - 39.8). Density plots for systolic and diastolic BP and forest plots for prehypertension and hypertension can be found in Figure 2. The level of heterogeneity (I^2) was substantial (>75%) for most of the analyses, which reflects considerable variation in results between studies.

The funnel plots for systolic and diastolic BP indicated that publication bias was highly unlikely as there were study effects reported on both sides of the pyramid (Supplemental Table S6).

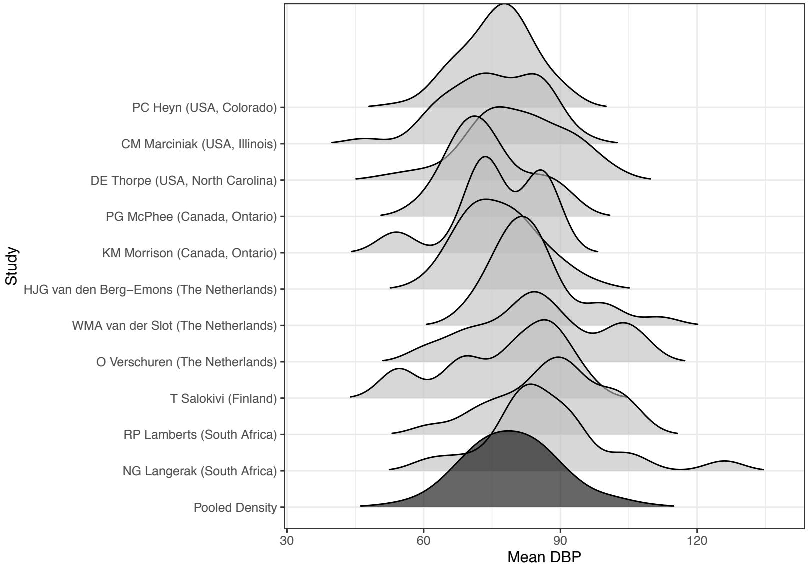
BP levels of more than half of the participants were classified as optimal (30.0%, systolic BP <120 mmHg and diastolic BP <80 mmHg) or normal (25.8%, systolic BP 120-129 mmHg and diastolic BP 80-84 mmHg). The number and percentage of participants per classification of BP can be found in Table 2.

Adults with CP above 40 years of age were more likely to have high systolic BP than adults aged 18-29 (β=5.14, 95% CI 1.04 - 9.24, P=0.014). Males were more likely to have high systolic BP than females (β=3.87, 95% CI 0.75 - 7.00, P=0.015). Lower systolic BP levels were found in other subtypes of CP than in spastic CP (β=-7.06, 95% CI -12.25 - -1.87, P=0.008). Also, higher systolic BP levels were found in individuals in Africa when

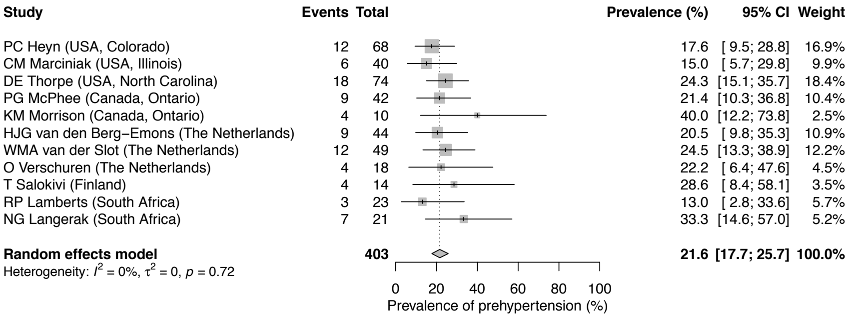
Figure 2 Density plots for systolic blood pressure (SBP) and diastolic blood pressure (DBP) and forest plots for overall prevalence of prehypertension and hypertension.



Density plot for systolic blood pressure
Included participants N=403; participants using antihypertensive medication or with missing information on antihypertensive medication were excluded (N=41)



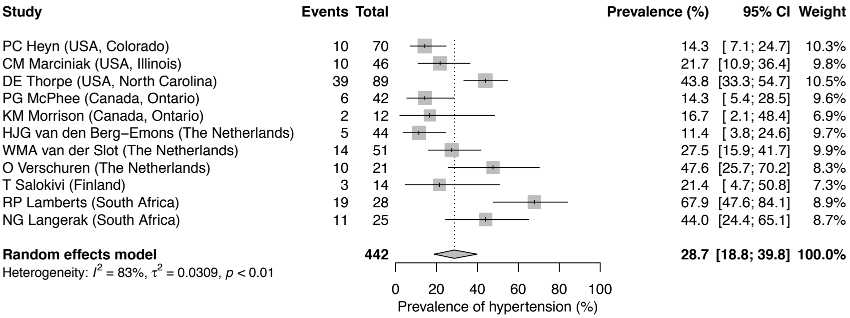
Density plot for diastolic blood pressure
Included participants N=403; participants using antihypertensive medication or with missing information on antihypertensive medication were excluded (N=41)



Study	Events	Total	Prevalence (%)	95% CI	Weight
PC Heyn (USA, Colorado)	12	68	17.6	[9.5; 28.8]	16.9%
CM Marciniak (USA, Illinois)	6	40	15.0	[5.7; 29.8]	9.9%
DE Thorpe (USA, North Carolina)	18	74	24.3	[15.1; 35.7]	18.4%
PG McPhee (Canada, Ontario)	9	42	21.4	[10.3; 36.8]	10.4%
KM Morrison (Canada, Ontario)	4	10	40.0	[12.2; 73.8]	2.5%
HJG van den Berg−Emons (The Netherlands)	9	44	20.5	[9.8; 35.3]	10.9%
WMA van der Slot (The Netherlands)	12	49	24.5	[13.3; 38.9]	12.2%
O Verschuren (The Netherlands)	4	18	22.2	[6.4; 47.6]	4.5%
T Salokivi (Finland)	4	14	28.6	[8.4; 58.1]	3.5%
RP Lamberts (South Africa)	3	23	13.0	[2.8; 33.6]	5.7%
NG Langerak (South Africa)	7	21	33.3	[14.6; 57.0]	5.2%
Random effects model Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.72$		**403**	**21.6**	**[17.7; 25.7]**	**100.0%**

Forest plot for prehypertension

Prehypertension is defined as systolic blood pressure 130-139 mmHg and/or diastolic blood pressure 85-89 mmHg, following the European Hypertension guidelines (Williams, 2018). Included participants N=403; participants using antihypertensive medication or with missing information on antihypertensive medication were excluded (N=41)



Study	Events	Total	Prevalence (%)	95% CI	Weight
PC Heyn (USA, Colorado)	10	70	14.3	[7.1; 24.7]	10.3%
CM Marciniak (USA, Illinois)	10	46	21.7	[10.9; 36.4]	9.8%
DE Thorpe (USA, North Carolina)	39	89	43.8	[33.3; 54.7]	10.5%
PG McPhee (Canada, Ontario)	6	42	14.3	[5.4; 28.5]	9.6%
KM Morrison (Canada, Ontario)	2	12	16.7	[2.1; 48.4]	6.9%
HJG van den Berg−Emons (The Netherlands)	5	44	11.4	[3.8; 24.6]	9.7%
WMA van der Slot (The Netherlands)	14	51	27.5	[15.9; 41.7]	9.9%
O Verschuren (The Netherlands)	10	21	47.6	[25.7; 70.2]	8.3%
T Salokivi (Finland)	3	14	21.4	[4.7; 50.8]	7.3%
RP Lamberts (South Africa)	19	28	67.9	[47.6; 84.1]	8.9%
NG Langerak (South Africa)	11	25	44.0	[24.4; 65.1]	8.7%
Random effects model Heterogeneity: $I^2 = 83\%$, $\tau^2 = 0.0309$, $p < 0.01$		**442**	**28.7**	**[18.8; 39.8]**	**100.0%**

Forest plot for hypertension

Hypertension is defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg or use of antihypertensive medication, following the European Hypertension guidelines (Williams, 2018). Included participants N=442; participants with systolic BP < 140 mmHg and diastolic BP < 90 mmHg and missing information on antihypertensive medication were excluded (N=2)

Table 2 Classification of blood pressure following the European Hypertension guidelines.

Category	Systolic blood pressure (mmHg)		Diastolic blood pressure (mmHg)	Number of participants	Percentage of participants
Optimal	<120	And	<80	121	30.0%
Normal	120-129	And/or	80-84	104	25.8%
High normal	130-139	And/or	85-89	88	21.8%
Grade 1 hypertension	140-159	And/or	90-99	67	16.6%
Grade 2 hypertension	160-179	And/or	100-109	18	4.5%
Grade 3 hypertension	≥180	And/or	≥110	5	1.3%

Williams, 2018. Included participants N=403; participants using antihypertensive medication or with missing information on antihypertensive medication were excluded (N=41) compared to Europe (β=8.35, 95% CI 3.25 - 13.44, P=0.001). Diastolic BP was higher in adults greater than 40 years of age compared to adults aged 18-29 (β=4.02, 95% CI 0.92 - 7.11, P=0.011). Higher diastolic BP levels were found in individuals in Africa when compared to Europe (β=7.79, 95% CI 3.94 - 11.64, P<0.001). Prevalence of hypertension was higher in adults above 40 years of age than in adults aged 18-29 (OR=2.91, 95% CI 1.52 - 5.62, P=0.001). It was also higher in Africa (OR=3.90; 95% CI 1.77 - 8.82, P<0.001) and North America (OR=2.31, 95% CI 1.23 - 4.49, P=0.011) compared to Europe. The results of subgroup analyses are presented in Table 3.

For systolic BP, BMI was a significant risk factor (β=0.57, 95% CI 0.32 - 0.83, P<0.001). For diastolic BP, BMI (β=0.38, 95% CI 0.18 - 0.58, P=0.002) and resting heart rate (β=0.22, 95% CI 0.10 - 0.33, P=0.002) were significant risk factors. For hypertension, BMI (β=1.10, 95% CI 1.05 - 1.15, P<0.001) and alcohol consumption (β=0.30, 95% CI 0.12 - 0.68, P=0.038) were significant risk factors (Table 4).

Consistently, the European Hypertension guidelines for BP cutoffs were used;[12] however, we also examined the recently adapted American guidelines.[33] When using the American Hypertension guidelines, the overall prevalence of prehypertension was 11.8% (95% CI 7.6 - 16.9; Supplemental Table S7) and the overall prevalence of hypertension was 61.4% (95% CI 51.0 - 71.3; Supplemental Table S7). BP levels of more than half of the participants were classified as hypertension stage 1 (34.0%, systolic BP 130-139 mmHg or diastolic BP 80-89 mmHg) or normal (30.0%, systolic BP <120 mmHg and diastolic BP <80 mmHg) according to the American Hypertension guidelines (Supplemental Table S7).

Table 3 Mean systolic and diastolic blood pressure, prehypertension and hypertension per age categories, sex, CP subtype, CP distribution, GMFCS and continent.

		Systolic blood pressure			Diastolic blood pressure		
	N	**Mean (95% CI)**	**Beta (95% CI)**	**P-value**	**Mean (95% CI)**	**Beta (95% CI)**	**P-value**
Age							
18-29	212	124.7 (122.2 - 127.1)	Reference Category	Reference Category	79.6 (77.7 - 81.4)	Reference Category	Reference Category
30-39	107	125.7 (122.6 - 128.7)	1.01 (-3.07 - 5.10)	0.626	79.9 (77.6 - 82.2)	0.33 (-2.76 - 3.41)	0.834
≥40	84	129.8 (126.7 - 132.9)	5.14 (1.04 - 9.24)	0.014	83.6 (81.2 - 85.9)	4.02 (0.92 - 7.11)	0.011
Sex							
Women	192	124.2 (122.0 - 126.5)	Reference Category	Reference Category	79.7 (78.0 - 81.4)	Reference Category	Reference Category
Men	211	128.1 (126.0 - 130.2)	3.87 (0.75 - 7.00)	0.015	81.6 (80.0 - 83.2)	1.92 (-0.44 - 4.27)	0.111
CP subtype							
Spastic	281	127.1 (125.5 - 128.8)	Reference Category	Reference Category	81.1 (79.8 - 82.3)	Reference Category	Reference Category
Other	37	120.1 (115.3 - 124.9)	-7.06 (-12.25 --1.87)	0.008	78.3 (74.7 - 81.9)	-2.75 (-6.67 - 1.17)	0.168
CP distribution							
Unilateral	91	126.8 (122.7 - 130.9)	Reference Category	Reference Category	79.2 (76.1 - 82.3)	Reference Category	Reference Category
Bilateral	290	126.2 (124.4 - 128.0)	-0.65 (-5.38 - 4.08)	0.786	81.1 (79.7 - 82.5)	1.92 (-1.65 - 5.49)	0.291
GMFCS							
I	128	125.6 (122.4 - 128.7)	Reference Category	Reference Category	80.4 (78.0 - 82.7)	Reference Category	Reference Category
II	129	128.9 (126.1 - 131.7)	3.32 (-0.87 - 7.51)	0.120	83.0 (80.9 - 85.1)	2.62 (-0.55 - 5.78)	0.105
III	66	123.9 (119.9 - 127.9)	-1.66 (-6.93 - 3.60)	0.535	79.0 (76.0 - 82.0)	-1.34 (-5.32 - 2.63)	0.507
IV	44	127.0 (122.6 - 131.5)	1.48 (-4.37 - 7.32)	0.620	80.1 (76.7 - 83.4)	-0.30 (-4.71 - 4.11)	0.892
V	26	121.6 (115.6 - 127.7)	-3.94 (-11.09 - 3.21)	0.279	77.5 (72.9 - 82.1)	-2.88 (-8.27 - 2.52)	0.296
Continent							
Europe	125	123.6 (120.8 -126.3)	Reference Category	Reference Category	79.9 (77.8 - 82.0)	Reference Category	Reference Category
Africa	44	131.9 (127.5 - 136.3)	8.35 (3.25 - 13.44)	0.001	87.7 (84.4 - 91.0)	7.79 (3.94 - 11.64)	<0.001
North America	234	126.3 (123.9 - 128.6)	2.69 (-1.07 - 6.44)	0.160	79.1 (77.3 - 80.8)	-0.83 (-3.66 - 2.01)	0.568

Included participants N=403; participants using antihypertensive medication or with missing information on use of antihypertensive medication were excluded (N=41). GMFCS=Gross Motor Function Classification System

Table 3 Mean systolic and diastolic blood pressure, prehypertension and hypertension per age categories, sex, CP subtype, CP distribution, GMFCS and continent. (continued)

	Prehypertension				**Hypertension**			
	N	**Prevalence (95% CI)**	**OR (95% CI)**	**P-value**	**N**	**Prevalence (95% CI)**	**OR (95% CI)**	**P-value**
Age								
18-29	212	21.4 (15.0 - 29.6)	Reference Category	Reference Category	225	21.5 (15.1 - 29.7)	Reference Category	Reference Category
30-39	107	19.2 (11.8 - 29.8)	0.88 (0.41 - 1.83)	0.729	117	30.8 (21.6 - 41.9)	1.63 (0.84 - 3.17)	0.151
≥40	84	27.2 (18.0 - 39.0)	1.38 (0.67 - 2.80)	0.380	100	44.3 (33.4 - 55.9)	2.91 (1.52 - 5.62)	0.001
Sex								
Women	192	18.3 (12.6 - 25.8)	Reference Category	Reference Category	215	27.6 (20.6 - 35.8)	Reference Category	Reference Category
Men	211	25.7 (19.5 - 33.2)	1.55 (0.88 - 2.76)	0.132	227	31.1 (24.2 - 38.9)	1.18 (0.71 - 1.97)	0.516
CP subtype								
Spastic	281	21.8 (17.1 - 27.5)	Reference Category	Reference Category	311	30.9 (25.4 - 37.0)	Reference Category	Reference Category
Other	37	24.1 (12.1 - 42.4)	1.14 (0.44 - 2.76)	0.780	40	19.8 (9.6 - 36.3)	0.55 (0.22 - 1.29)	0.186
CP distribution								
Unilateral	91	26.6 (15.2 - 42.2)	Reference Category	Reference Category	97	25.0 (14.0 - 40.6)	Reference Category	Reference Category
Bilateral	290	21.1 (16.0 - 27.2)	0.74 (0.32 - 1.70)	0.471	320	30.5 (24.6 - 37.1)	1.31 (0.59 - 3.03)	0.510
GMFCS								
I	128	20.1 (12.3 - 31.0)	Reference Category	Reference Category	138	27.2 (18.1 - 38.6)	Reference Category	Reference Category
II	129	18.3 (11.7 - 27.6)	0.89 (0.41 - 1.94)	0.775	139	39.4 (29.8 - 50.0)	1.75 (0.90 - 3.46)	0.105
III	66	36.4 (23.2 - 52.0)	2.27 (0.92 - 5.70)	0.076	73	19.3 (10.8 - 32.2)	0.64 (0.26 - 1.53)	0.323
IV	44	26.1 (13.8 - 43.8)	1.41 (0.48 - 4.07)	0.528	53	30.6 (17.9 - 47.1)	1.18 (0.46 - 3.02)	0.729
V	26	17.1 (6.2 - 39.3)	0.82 (0.19 - 2.96)	0.773	27	21.8 (8.9 - 44.5)	0.75 (0.20 - 2.43)	0.642
Continent								
Europe	125	24.0 (16.5 - 33.5)	Reference Category	Reference Category	130	17.9 (11.6 - 26.6)	Reference Category	Reference Category
Africa	44	24.2 (12.2 - 42.1)	1.01 (0.39 - 2.54)	0.981	53	46.0 (30.5 - 62.3)	3.90 (1.77 - 8.82)	<0.001
North America	234	20.3 (14.0 - 28.4)	0.81 (0.41 - 1.57)	0.524	259	33.5 (26.0 - 42.0)	2.31 (1.23 - 4.49)	0.011

Prehypertension is defined as systolic blood pressure 130-139 mmHg and/or diastolic blood pressure 85-89 mmHg. Included participants N=403; participants using antihypertensive medication or with missing information on antihypertensive medication were excluded (N=41). Hypertension is defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg or use of antihypertensive medication, following the European Hypertension guidelines (Williams, 2018). Included participants N=442; participants with systolic BP < 140 mmHg and diastolic BP < 90 mmHg and missing information on antihypertensive medication were excluded (N=2). GMFCS=Gross Motor Function Classification System.

Linear and logistic multivariable regression models, including study as a fixed-effect were used to estimate the association of age, sex, CP subtype, CP distribution, GMFCS level and continent with the primary outcomes. Estimates were adjusted for these factors. Beta's (β) and odds ratios (ORs) and 95% CIs were estimated. A P-value ≤0.05 was considered significant.

Table 4 The effect of potential risk factors on systolic and diastolic blood pressure, prehypertension and hypertension following current European Hypertension guidelines.

	Systolic blood pressure		Diastolic blood pressure	
	Beta (95% CI)	**P-value**	**Beta (95% CI)**	**P-value**
Muscle tone (ref cat: no)	2.78 (-3.84 - 9.40)	0.816	0.94 (-4.46 - 6.35)	1.000
Family history of CVD (ref cat: no)	7.84 (0.83 - 14.84)	0.145	4.47 (-0.25 - 9.19)	0.316
BMI	0.57 (0.32 - 0.83)	<0.001	0.38 (0.18 - 0.58)	0.002
Resting heart rate	0.11 (-0.04 - 0.26)	0.543	0.22 (0.10 - 0.33)	0.002
Alcohol consumption (ref cat: no)	-5.69 (-10.15 - -1.23)	0.089	-2.94 (-6.64 - 0.74)	0.467
Smoking (ref cat: no)	-0.96 (-7.15 - 5.24)	0.816	-0.04 (-4.86 - 4.78)	1.000

	Prehypertension		Hypertension	
	Beta (95% CI)	**P-value**	**Beta (95% CI)**	**P-value**
Muscle tone (ref cat: no)	0.51 (0.16 - 1.66)	1.000	2.29 (0.73 - 7.65)	0.650
Family history of CVD (ref cat: no)	4.55 (1.13 - 20.34)	0.295	0.78 (0.12 - 4.16)	1.000
BMI	1.03 (0.98 - 1.07)	1.000	1.10 (1.05 - 1.15)	<0.001
Resting heart rate	1.01 (0.99 - 1.04)	1.000	1.01 (0.99 - 1.04)	1.000
Alcohol consumption (ref cat: no)	1.55 (0.70 - 3.39)	1.000	0.30 (0.12 - 0.68)	0.038
Smoking (ref cat: no)	0.27 (0.06 - 0.89)	0.360	1.45 (0.52 - 3.98)	1.000

Williams, 2018. Separate extended multivariable regression models were used, adjusted for one risk factor each. The models were adjusted for age, sex, CP subtype, CP distribution, GMFCS level and continent. P-values were adjusted for multiple comparisons using the Holm method. BMI=body mass index; CI= confidence interval; CVD= cardiovascular disease; Ref cat= reference category.

DISCUSSION

This systematic review and meta-analysis combined BP data from six published and five unpublished studies and included 444 adults with CP with a median age of 29.0 years, living on three different continents. The study indicated that the overall mean level of BP in adults with CP was 124.9/79.9 mmHg and provides a reliable estimate of the overall prevalence of hypertension of 28.7%, according to current European Hypertension guidelines.

Our results suggest that in this young sample of adults with CP, BP levels and the prevalence of hypertension are relatively high. Three reference studies were identified: (1) a worldwide meta-analysis that established reference values for central BP and its amplification in a general healthy population (n=45 436, mean age 49.6y);[44] (2) a study that was performed by the Dutch National Institute for Public Health and the Environment (RIVM, 'Nederland de maat genomen', 2009-2010), measuring BP in the Dutch population according to age categories (n=3865, mean age 52.3y);[45] and (3) a prospective cohort study in young adults (n=4851, mean age 24.9y at baseline) in the United States of America.[46] According to our findings, systolic BP was substantially higher in adults with CP (124.9 mmHg, median age 29.0y) than in American adults of a slightly younger age (110.4 mmHg, 24.9y)[46] and comparable to two reference samples with a mean age of almost 20 years older (study 1: 126.2 mmHg, 49.6y and 2: 126.1 mmHg, 52.3y).[44, 45] Diastolic BP in adults with CP (79.9 mmHg) was also higher than in all three reference studies (study 1: 75.4 mmHg, study 2: 77.3 mmHg, study 3: 68.6 mmHg). Prevalence of hypertension (28.7%) was higher in our study than in study 2 (23.9%) and 3 (13.2%). Importantly, BP was found to be comparable or higher in our relatively young adults with CP. These comparisons should be interpreted with caution as only one reference study included international data, while the other two reference samples were national studies (Dutch and American). The prevalence of hypertension we found in our study was similar to a previous study in the USA in adults with CP that described self-report data on hypertension from medical files. They found an incidence of hypertension of 30.0% in adults with CP (n=1015, mean age 58y) compared to 22.1% in adults without CP (n=206 600, mean age 45y).[17] This study was limited by self-report data which might be susceptible to response bias, and their mean age was higher compared to our sample; however, these findings also suggest that adults with CP are at risk for hypertension.

Subgroup analyses indicated that higher BP levels and prevalence of hypertension were found in adults with CP above 40 years of age or those who lived in Africa. In addition, systolic BP levels were higher among males or those with spastic CP. Age-related changes in BP are consistent with findings in the general population, where hypertension becomes progressively more common with advancing age.[47] This could be related to the large increases in arterial stiffness, which seems to progress faster and at a younger age in adults with CP compared to the general population.[48] Systolic BP levels were higher in males than in females, which is consistent with findings in the general population.[49]

To date, little attention has been given to subgroups of adults with CP regarding the risk for hypertension. Higher BP levels were expected in spastic CP, based on clinical experience, and previous studies in stroke patients.[50, 51] In stroke patients, BP was found to be significantly higher in paretic arms of patients with a spastic tone and lower in arms with a flaccid tone. Accordingly, measuring BP in the unaffected arm was recommended. Our results suggest that systolic BP is higher in adults with spastic CP than in adults with other subtypes of CP. This suggests that spasticity might affect BP levels in adults with CP. Little is known regarding the precise effect of spasticity on blood vessels or on the BP measurement itself in either CP or other diagnoses with spasticity (i.e., whether the higher BP measured is representative of an increased CVD risk or rather a mechanical effect due to the increased muscle tone). In our meta-analysis, almost half of the included studies measured BP in the least affected or unaffected arm, while others used the left or right arm not taking into account whether this arm was affected by spasticity. It is important to acknowledge that 70% of participants had a bilateral distribution of CP, so elevated tone might have been present in the least affected arm as well. It should also be noted that the majority of adults with CP in this study had spastic CP; only 10% had other subtypes of CP, which consisted of dyskinetic or ataxic CP, often in combination with spastic CP. Since spasticity is the most common motor abnormality in persons with CP and affected arms are often underdeveloped in CP, future research should investigate the influence of tone and/or contractures and its underlying mechanisms on BP levels in adults with CP. In fact, we suggest that central BP measurement should be used as an accurate measure of BP.

Higher BP levels were also expected in more severely affected adults with CP (e.g. bilateral distribution and lower levels of gross motor functioning) as a consequence of a more sedentary and less active lifestyle.[52] Surprisingly, analyses of CP distribution and GMFCS levels revealed no differences in BP levels. An explanation for this result on CP distribution is that adults with CP with bilateral distribution can be diplegic or tetraplegic. Therefore, it is possible that some of those adults maintain mobility and manage to be active. Although unexpected, this finding might reflect bias towards a healthier segment of the CP population with GMFCS IV and V. Indeed many factors can contribute to hypertension, including excess visceral adiposity,[53] which was found to be present in adults with CP.[54] We were limited in our ability to explore all factors that are associated with elevated BP, and thus future research is needed to examine additional mechanisms that explain why some subtypes of CP are at higher risk for hypertension.

Another key finding in the subgroup analysis was that BP levels and prevalence of hypertension were highest in adults with CP who lived in Africa, only diastolic BP levels were higher in North America. The external validity of these findings should be interpreted cautiously as a variety of factors could have influenced BP levels. For some of the participants in Africa, it was the first time their BP was measured, so heightened sympathetic nervous system activity (e.g. anxiety) could be an unaccounted factor. Additionally, adults with CP do not have regular BP assessments, partly because of travel time to the clinic. Finally, although some participants in these cohorts from Africa used antihypertensive medication, for others, these medications might be unaffordable.

BMI, resting heart rate and alcohol consumption were factors that influenced systolic or diastolic BP levels or hypertension. No significant results were found for muscle tone, family history of CVD and smoking. These data must be interpreted with caution because of missing data, large confidence intervals, and our limited ability to include all covariates in a single model. More research is needed to investigate the exact effect of potential risk factors on BP in adults with CP. Some of these factors are modifiable, which emphasizes the importance of stimulating a healthy lifestyle with more physical activity and a healthy diet and might be impetus for a behavioral intervention to regulate BP in adults with CP.

Early detection of hypertension in the general population can prevent end-organ damage such as CVD. As a higher risk of CVD was seen in adults with CP than in the general population,[13] it is of importance to focus on modifiable risk factors, such as BP. BP is one of the eight outcomes included in the final Core Outcome Set of Measurement Instruments for assessing multimorbidity risk in adults with CP.[55] We, therefore, recommend that regular clinical checks and monitoring of BP should be included in their standard care. In some of the countries included in this study, i.e. the United States of America and Finland, BP measurements are included in standard health clinic procedures, whereas in other countries, it is not. More attention should be given to diagnosing hypertension in adults with CP, which should start at a young adult age. Further research should focus on whether prevention, treatment and management of hypertension in adults with CP could be similar to the general population.

As shown in our study, prevalence estimates of hypertension depend on the cut-off used to define hypertension. In 2017, the definition of hypertension in the American Hypertension guidelines was changed from ≥140/90 mmHg to ≥130/80 mmHg. This results in a higher prevalence of hypertension, mainly because many adults with CP in our meta-analysis had BP values between these cut-off values; 137 (34.0%) adults with CP had BP values in hypertension stage 1 (systolic BP 130-139 mmHg OR diastolic BP 80-89 mmHg). In general, lowering the cut point might result in more awareness and prevention, but it would also increase the number of people being prescribed antihypertensive medication, which increases the costs of health care.

The strength of this meta-analysis is that samples from published and unpublished studies measuring BP in adults with CP were included, resulting in a large sample of 444 adults with CP covering all GMFCS levels and a wide age range. There are also limitations to this study. A factor that may have affected the results is the method of BP measurements. Most of the studies included in our meta-analysis followed the guideline for measuring BP.[33] Nonetheless, different BP devices were used, and almost half of the studies measured it only once, while at least two measurements are recommended. Since all data were collected for research purposes, BP measurements were all taken on the same day. In case of hypertensive levels in clinical practice, BP is re-measured after two weeks, which will minimize white coat syndrome, random error and provide a more accurate basis for estimation of BP. Therefore, some caution is needed when interpreting our results. As different measurement methods likely influence BP levels, consensus is needed to standardize the method of measurement of BP in adults with CP. For the above mentioned Core Outcome Set of Measurement Instruments, it was recommended to measure BP with a calibrated device and appropriate sized cuff, in a seated position, after 10 minutes of rest, on the least affected side.[55] The most recent guideline recommends repeated unsupervised measurements as used in the hallmark study SPRINT.[56] Further research could fine-tune the optimal method to measure BP in adults with CP, taking into account the potential effect of spasticity, as mentioned earlier in the discussion. It would be interesting to correlate office measurements to the gold standard, 24h ambulatory BP measurement, to also allow conclusions about white coat effect and masked hypertension in adults with CP.

Another limitation is that our sample was relatively young. In order to draw conclusions across the lifespan of CP, it is recommended to include older adults with CP in future research. In addition, results on subgroup analyses should be interpreted with caution due to few observations in some subgroups (e.g. GMFCS level V); however, these distributions correspond with the general CP population. Additionally, studies were performed in three different parts of the world, including North America, Europe and Africa, but not all World Health regions were represented, which limits generalizability beyond these populations. Another limitation is that secondary outcomes were assessed by a variety of scales and required conversion to a common scale (e.g. muscle tone was measured by different scales and in different muscles), which was not always possible. To facilitate comparison across studies, health care institutions, and countries, we need to make sure that outcome assessment is standardized. The Core Outcome Set of Measurement Instruments for assessing multimorbidity risk in adults with CP[55] is a good example, but consensus is also needed for other outcomes, e.g. pain and fatigue. The implementation of the ICF Core Set for adults with CP, which is currently under development, could also contribute to this.[57] Finally, it should be noted that some samples may be biased. Participants from individual studies were recruited through flyers and advertisements, patient registry databases and rehabilitation clinics, assuming the use of convenience samples. However, patients looking after their health are more willing to respond to advertisements or calls for research, which might have resulted in an underestimation of the true BP levels in adults with CP.

The results of this meta-analysis in a relatively young cohort indicate that almost 30% of adults with CP are hypertensive. We, therefore, recommend clinical screening for BP in adults with CP beginning in young adulthood.

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Supplemental Table S1 Search strategy.

Embase.com

(‘blood pressure’/exp OR ‘blood pressure monitoring’/exp OR ‘abnormal blood pressure’/exp OR ‘blood pressure measurement’/de OR ‘hypertension encephalopathy’/de OR ‘blood pressure monitor’/exp OR (((blood OR vessel* OR vascul* OR intravascul* OR venous OR arter*) NEAR/3 (pressure OR tension*)) OR hypotens* OR hypertens* OR prehypertens* OR normotens* OR ankle-brachial-ind*):ab,ti) AND (‘cerebral palsy’/exp OR ‘spastic paresis’/de OR (((cerebral* OR brain OR spastic) NEXT/3 (pals* OR paralys* OR hemipleg* OR diplegi* OR paresis)) OR ‘encephalopathia infantilis’):ab,ti) NOT ([animals]/lim NOT [humans]/lim) NOT (child/exp NOT adult/exp)

Medline Ovid

(exp “blood pressure”/ OR exp “Hypertension”/ OR Prehypertension/ OR exp Hypotension/ OR exp “Blood Pressure Determination”/ OR “Blood Pressure Monitors”/ OR (((blood OR vessel* OR vascul* OR intravascul* OR venous OR arter*) ADJ3 (pressure OR tension*)) OR hypotens* OR hypertens* OR prehypertens* OR normotens* OR ankle-brachial-ind*).ab,ti,kf.) AND (“cerebral palsy”/ OR (((cerebral* OR brain OR spastic) ADJ3 (pals* OR paralys* OR hemipleg* OR diplegi* OR paresis)) OR “encephalopathia infantilis”).ab,ti,kf.) NOT (exp animals/ NOT humans/) NOT ((exp child/ OR exp infant/) NOT exp adult/)

PsycINFO Ovid

(exp “blood pressure”/ OR exp “Hypertension”/ OR exp Hypotension/ OR (((blood OR vessel* OR vascul* OR intravascul* OR venous OR arter*) ADJ3 (pressure OR tension*)) OR hypotens* OR hypertens* OR prehypertens* OR normotens* OR ankle-brachial-ind*).ab,ti.) AND (“cerebral palsy”/ OR (((cerebral* OR brain OR spastic) ADJ3 (pals* OR paralys* OR hemipleg* OR diplegi* OR paresis)) OR “encephalopathia infantilis”).ab,ti.) NOT (exp animals/ NOT humans/) NOT ((100.ag.) NOT 300.ag.)

CINAHL EBSCOhost

(MH “blood pressure+” OR MH “Blood Pressure Devices+” OR MH “Blood Pressure Determination+” OR MH “Hypertension+” OR MH Hypotension+ OR TI (((blood OR vessel* OR vascul* OR intravascul* OR venous OR arter*) N2 (pressure OR tension*)) OR hypotens* OR hypertens* OR prehypertens* OR normotens* OR ankle-brachial-ind*) OR AB (((blood OR vessel* OR vascul* OR intravascul* OR venous OR arter*) N2 (pressure OR tension*)) OR hypotens* OR hypertens* OR prehypertens* OR normotens* OR ankle-brachial-ind*)) AND (MH “cerebral palsy” OR TI (((cerebral* OR brain OR spastic) N2 (pals* OR paralys* OR hemipleg* OR diplegi* OR paresis)) OR “encephalopathia infantilis”) OR AB (((cerebral* OR brain OR spastic) N2 (pals* OR paralys* OR hemipleg* OR diplegi* OR paresis)) OR “encephalopathia infantilis”)) NOT (MH animals+ NOT MH humans+) NOT ((MH child+ OR MH infant+) NOT MH adult+)

Cochrane CENTRAL

((((blood OR vessel* OR vascul* OR intravascul* OR venous OR arter*) NEAR/3 (pressure OR tension*)) OR hypotens* OR hypertens* OR prehypertens* OR normotens* OR ankle-brachial-ind*):ab,ti) AND ((((cerebral* OR brain OR spastic) NEXT/3 (pals* OR paralys* OR hemipleg* OR diplegi* OR paresis)) OR ‘encephalopathia infantilis’):ab,ti) NOT (([mh ^child] OR [mh ^infant]) NOT [mh ^adult])

Web of Science

TS=(((((blood OR vessel* OR vascul* OR intravascul* OR venous OR arter*) NEAR/2 (pressure OR tension*)) OR hypotens* OR hypertens* OR prehypertens* OR normotens* OR ankle-brachial-ind*)) AND ((((cerebral* OR brain OR spastic) NEAR/2 (pals* OR paralys* OR hemipleg* OR diplegi* OR paresis)) OR “encephalopathia infantilis”)) NOT ((child* OR infant* OR neonat* OR newborn*) NOT adult*))

Google Scholar

“blood|intravascular|venous|arterial pressure| tension”| hypotension| hypertension| prehypertension| normotension|”ankle-brachial-index” “cerebral|brain| spastic palsy| paralysis| hemiplegia| diplegia| paresis”| “encephalopathia infantilis”

Supplemental Table S2 Methods of conversion to common scales or outcome measures.

Outcome and measurement instrument	Question or item and answer or scores	Method of conversion
Intellectual disability	Defined as a moderate to severe level of intellectual functioning, indicated as an IQ level below 70 (DSM-5)	***Yes, no***
Short Test of Mental Status (STMS)[1] Heyn et al[2]	Short Test of Mental Status total score A. Orientation Score, B. Attention, C. Learning, D. Calculation, E. Abstraction, F. Information, G. Construction, H. Recall	*Total score 1-28=yes* *Total score 29-38=no*
Mental retardation Thorpe et al[3]	*Yes, no*	*Idem*
IQ Morrison et al[4]		*IQ ≤ 70=yes* *IQ > 70=no*
Cognitive functioning Salokivi et al[5]	Moderate cognitive functioning: at the level of 6-8 years of age, Severe cognitive functioning: at the level of 3-5 years of age, Very severe cognitive functioning: at the level of 2 years of age or under	*All yes*
Exclusion criteria severe cognitive impairments van den Berg-Emons et al[6] van der Slot et al[7]		*All no*
No severe communication or understanding problems that impede proper measurement performance Verschuren et al, unpublished data, 2015-2016		*All no*
Not included in study Lamberts et al, unpublished data, 2017 Langerak et al[8]		*All no*

Supplemental Table S2 Methods of conversion to common scales or outcome measures. (continued)

Outcome and measurement instrument	Question or item and answer or scores	Method of conversion
Muscle tone	Tone in hip adductors, knee extensors, knee flexors, ankle plantar flexors, elbow flexors, wrist flexors Normal tone: No increase in muscle tone Hypertonia: Slight increase in muscle tone, manifested by a catch and release or by minimal resistance throughout the remained (less than half) of the range of motion or at the end when the affected part(s) is moved in flexion or extension, more marked increase in muscle tone through most of the range of motion, but affected part(s) easily flexed, considerable increase in tone, passive movement difficult, affected part(s) rigid in flexion or extension If one of the muscles is hypertone, than hypertonia; otherwise normal tone	***Normotonic, hypertonic***
Modified Ashworth Scale[9] Heyn et al[2] Marciniak et al[10] van den Berg-Emons et al[6]	Muscles: knee extensors, knee flexors, ankle plantar flexors, left and right *no increase in muscle tone (0), slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the range of motion when the affected part(s) is moved in flexion or extension (1), slight increase in muscle tone, manifested by a catch and release or by minimal resistance throughout the remainder (less than half) of the range of motion (1+), more marked increase in muscle tone through most of the range of motion, but affected part(s) easily flexed (2), considerable increase in tone, passive movement difficult affected part(s) (3), rigid in flexion or extension (4)* Heyn et al[2] Muscles: knee extensors, knee flexors, elbow flexors, wrist flexors, left and right *no increased tone (0), catch but no increased tone through the remainder of the range or catch with increased tone through < 50 percent of the range (1), catch followed by increased tone through greater than 50 percent of the range of the joint (2), moderate to marked increased tone throughout (3), rigid in flexion or extension (4)* Marciniak et al[10] Muscles: hip adductors, knee extensors, knee flexors, ankle plantar flexors elbow flexors, wrist flexors, left and right *no increase in muscle tone (0), slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the range of motion when the affected part(s) is moved in flexion or extension (1), slight increase in muscle tone, manifested by a catch and release or by minimal resistance throughout the remainder (less than half) of the range of motion (1+), more marked increase in muscle tone throughout most of the range of motion (2), considerable increase in tone, passive movement difficult (3), rigid in flexion or extension (4)* van den Berg-Emons et al[6]	*0= normal tone* *1-4= hypertonia*

Supplemental Table S2 Methods of conversion to common scales or outcome measures. (continued)

Outcome and measurement instrument	Question or item and answer or scores	Method of conversion
Ashworth Scale[11] Lamberts et al, unpublished data, 2017 Langerak et al[8]	Muscles: hip adductors, knee extensors, knee flexors, ankle plantar flexors, left and right *no increase in tone (0), slight increase in tone giving a catch when limb is moved in flexion/ extension (1), more marked increase in tone but limb easily flexed (2), considerable increase in tone, passive movement difficult (3), limb rigid in flexion or extension (4)* Lamberts et al, unpublished data, 2017 Langerak et al[8]	*0= normal tone* *1-4= hypertonia*
Clinical tone measurement van der Slot et al[7]	Arm, leg, left and right *Normal, hypertone, spastic*	*Normal= idem, hypertone=idem, spastic=hypertonia*
Pain		***None, very mild, mild, moderate, severe, very severe***
Patient-Reported Outcomes Measurement Information System (PROMIS) - 57 Profile (v2.1) [12] Heyn et al[2]	Item 57. In the past 7 days, how would you rate your pain on average? *No pain (0) - worst imaginable pain (10)*	*No pain (0)=none, 1,2=very mild, 3,4=mild, 5,6=moderate, 7,8=severe, 9, 10=very severe*
Wong-Baker FACES Pain Rating Scale[13] Thorpe et al[3]	Ask the person to choose the face that best describes how he/she is feeling *No pain, hurts a little, hurts a little more, hurts even more, hurts a whole lot, hurts as much as you can imagine*	*No pain=none, hurts a little=very mild, hurts a little more=mild, hurts even more=moderate, hurts a whole lot=severe, hurts as much as you can imagine=very severe*
Short Form Health Survey (SF-36)[14] van den Berg-Emons et al[6] van der Slot et al[7] Lamberts et al, unpublished data, 2017 Langerak et al[8]	Item 7. Bodily pain: How much bodily pain have you had during the past 4 weeks? *None, very mild, mild, moderate, severe, very severe*	*Idem*

Supplemental Table S2 Methods of conversion to common scales or outcome measures. (continued)

Outcome and measurement instrument	Question or item and answer or scores	Method of conversion
Fatigue		***No fatigue, fatigue, severe fatigue***
Patient-Reported Outcomes Measurement Information System (PROMIS) - 57 Profile v2.1[12] Heyn et al[2]	Item 25. I feel fatigued Item 26. I have trouble starting things because I am tired Item 27. How run-down did you feel on average? Item 28. How fatigued were you on average? Item 29. How much were you bothered by your fatigue on average? Item 30. To what degree did your fatigue interfere with your physical functioning? Item 31. How often did you have to push yourself to get things done because of your fatigue? Item 32. How often did you have trouble finishing things because of your fatigue? *Not at all (1), a little bit (2), somewhat (3), quite a bit (4), very much/always (5)*	T-score < 55 within normal limits = no fatigue, T-score 55-60 mild= fatigue, T-score 60-70 moderate=fatigue, T-score > 70 severe=severe fatigue
Fatigue Severity Scale (FSS)[15] van den Berg-Emons et al[6] van der Slot et al[7] Lamberts et al, unpublished data, 2017 Langerak et al[8]	During the past week, I have found that: Item 1. My motivation is lower when I am fatigued. Item 2. Exercise brings on my fatigue. Item 3. I am easily fatigued. Item 4. Fatigue interferes with my physical functioning. Item 5. Fatigue causes frequent problems for me. Item 6. My fatigue prevents sustained physical functioning. Item 7. Fatigue interferes with carrying out certain duties and responsibilities. Item 8. Fatigue is among my three most disabling symptoms. Item 9. Fatigue interferes with my work, family, or social life. *Strongly disagree with the statement (1) - strongly agree with the statement. (7)*	FSS < 4.0=no fatigue, FSS 4.0 - 5.0= fatigue, FSS ≥ 5.1=severe fatigue
Aerobic fitness	Patients included in case of maximum exertion, based on Respiratory Exchange Ratio (RER) for different sex and age groups (Edvardsen, 2014) Male and female 20-49y RER ≥ 1.10 50-64y RER ≥ 1.05 ≥65y RER ≥ 1.00	***VO2 max (ml/kg/min)***

Supplemental Table S2 Methods of conversion to common scales or outcome measures. (continued)

Outcome and measurement instrument	Question or item and answer or scores	Method of conversion
Progressive ramp protocol on electronically braked cycle ergometers (Jaeger ER800; Jaeger Tonnies, Breda, The Netherlands or Corival V2 Lode B.V., Groningen, The Netherlands) van den Berg-Emons et al[6]		*Idem*
Electronically braked cycle ergometer according to the McMaster All-Out Progressive Continuous Protocol (Jaeger ER 800; Jaeger Tonnies, Breda, The Netherlands) van der Slot et al[7]		*Idem*
10m Shuttle walk/run test Lamberts et al, unpublished data, 2017 Langerak et al[8]		*Idem*
Physical activity		***In %***
Ambulatory Monitoring system VitaMove (2M Engineering, Veldhoven, The Netherlands) van den Berg-Emons et al[6]	Physical activity including standing, general movement, walking, wheelchair driving, cycling, running	*Idem*
Accelerometry-based Activity Monitor (AM; TEMEC Instruments, Kerkrade, The Netherlands) van der Slot et al[7]	Physical activity including standing, standing public transport, general movement, walking, wheelchair driving, cycling, running, climbing up, climbing down	*Idem*

Supplemental Table S3 Personal characteristics and mean levels of CP-related factors, biological and lifestyle-related risk factors of the total sample (N=444).

Personal characteristics	
Intellectual disability n (%)	N=353; Md=91
No	300 (85)
Yes	53 (15)
Education n (%)	N=287; Md=157
Prevocational practical education or less	81 (28)
Prevocational theoretical education and secondary education	65 (23)
Higher vocational education and university	119 (41)
Other	22 (8)
Employment n (%)	N=218; Md=226
School / study	48 (22)
Paid job	102 (47)
Volunteer work	14 (7)
Day-center occupation	3 (1)
Unemployed / seeking for jobs	33 (15)
Occupationally disabled	18 (8)
Civil status n (%)	N=319; Md=125
Single	257 (81)
Partner / married	58 (18)
Separated / widow	4 (1)
Living situation n (%)	N=198; Md=246
Alone	94 (47)
With partner (and children)	14 (7)
With parents / family	61 (31)
With others, group home	29 (15)
Continent n (%)	N=444; Md=0
Europe	132 (30)
Africa	53 (12)
North America	259 (58)
Cerebral palsy-related factors	
Muscle tone n (%)	N=260; Md=184
Normal tone	27 (10)
Hypertonia	233 (90)
Pain n (%)	N=304; Md=140
None	135 (44)
Very mild	58 (19)
Mild	64 (21)
Moderate	33 (11)
Severe	12 (4)
Very severe	2 (1)

Supplemental Table S3 Personal characteristics and mean levels of CP-related factors, biological and lifestyle-related risk factors of the total sample (N=444). (continued)

Cerebral palsy-related factors	
Fatigue n (%)	N=218; Md=226
No fatigue	133 (61)
Fatigue	54 (25)
Severe fatigue	31 (14)
Biological risk factors	
Family history of CVD n (%)	N=155; Md=289
No	85 (55)
Yes	70 (45)
BMI (kg/m^2)	N=397; Md=47
	25.10 ± 6.14
Waist-to-hip ratio (in stance)	N=132; Md=312
	0.94 ± 0.14
Resting heart rate (beats / min)	N=251; Md=193
	80.32 ± 14.77
Aerobic fitness - VO2max (ml/kg/min)	N=101; Md=343
	33.03 ± 9.31
Total cholesterol (mmol/L)	N=194; Md=250
	4.59 ± 0.94
HDL (mmol/L)	N=194; Md=250
	1.37 ± 0.42
LDL (mmol/L)	N=193; Md=251
	2.78 ± 0.83
TC/HDL ratio	N=194; Md=250
	3.66 ± 1.55
Triglycerides (mmol/L)	N=192; Md=252
	1.15 ± 0.72
Glucose (mmol/L)	N=173; Md=271
	4.93 ± 0.80
Insulin (IU)	N=115; Md=329
	10.25 ± 8.57
Diabetes n (%)	N=294; Md=150
No	290 (99)
Yes	4 (1)
Lifestyle-related risk factors	
Alcohol consumption n (%)	N=329; Md=115
No	240 (73)
Yes	89 (27)
Smoking n (%)	N=307; Md=137
No	269 (88)
Yes	38 (12)
Physical activity (%)	N=89; Md=355
	18.90 ± 8.03

Md= missing data; BMI= body mass index; CVD= cardiovascular disease

Supplemental Table S4 Scores on the methodological quality assessment of included studies.

Study	Title/ abstract	Methods						Results		Discussion		Total score
	1. Title and abstract	2. Study design	3. Setting	4. Participants	5. Variables	6. Data sources/ measurement	7. Bias	8. Participants	9. Descriptive data	10. Limitations	11. Generalizability	
Heyn et al[2]	1	1	**1**	1	**1**	1	1	1	**1**	1	1	11
Van der Slot et al[7]	1	1	**1**	1	1	1	1	1	1	1	1	11
Van den Berg-Emons et al[6]	1	1	**1**	1	**1**	1	**1**	1	0.5	1	1	10.5
Morrison et al[4]	1	1	1	1	1	1	**1**	1	1	0.5	1	10.5
Marciniak et al[10]	1	1	**1**	**1**	1	**1**	0	**1**	**1**	**1**	**0.5**	9.5
Lamberts et al, unpublished data, 2017	**1**	**1**	**1**	**1**	**0.5**	**1**	**1**	**1**	**1**	**0.5**	**0**	9
Langerak et al[8]	**1**	**1**	**1**	**1**	**0.5**	**1**	**1**	**1**	**1**	**0.5**	**0**	9
McPhee et al[16]	1	1	0.5	0.5	1	1	0	1	1	1	1	9
Thorpe et al[3]	1	1	**1**	**1**	0.5	0.5	0	**1**	0.5	**1**	1	8.5
Verschuren et al, unpublished data, 2015-2016	**0**	**1**	**1**	**1**	**1**	**1**	**0.5**	**1**	**1**	**0.5**	**0.5**	8.5
Salokivi et al[5]	**1**	**1**	**1**	**1**	0.5	0	0	0.5	0	0	0	5

Rating: 1=yes, 0.5=partially, 0=no. Bold numbers indicate that these ratings are based upon additional information derived from other publications of the same study sample or clarification from the primary investigator. Selected items from Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement (von Elm, 2014). 1. Title and abstract: Is the study's design indicated with a commonly used term in the title or the abstract? Is an informative and balanced summary of what was done and what was found provided in the abstract? 2. Study design: Are key elements of study design presented early in the paper? 3. Setting: Are settings, locations, and relevant dates, including periods of recruitment, exposure, follow-up and data collection described? 4. Participants: Are the eligibility criteria, and the sources and methods of selection of participants given? 5. Variables: Are all outcomes, exposures, predictors, potential confounders, and effect modifiers clearly defined? Are diagnostic criteria given (if applicable)? 6. Data sources/ measurement: For each variable of interest, are sources of data and details of methods of assessment (measurement) given? 7. Bias: Are any efforts to address potential sources of bias described? 8. Participants: Are the numbers of individuals at each stage of the study reported– e.g., numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed. Are reasons for non-participation at each stage described? 9. Descriptive data: Are characteristics of study participants (e.g., demographic, clinical, social) and information on exposures and potential confounders given? Is number of participants with missing data for each variable of interest indicated? 10. Limitations: Are limitations of the study, taking into account sources of potential bias or imprecision, discussed? Are both direction and magnitude of any potential bias discussed? 11. Generalizability: Is the generalizability (external validity) of the study results discussed?

Supplemental Table S5 Information on blood pressure measurements.

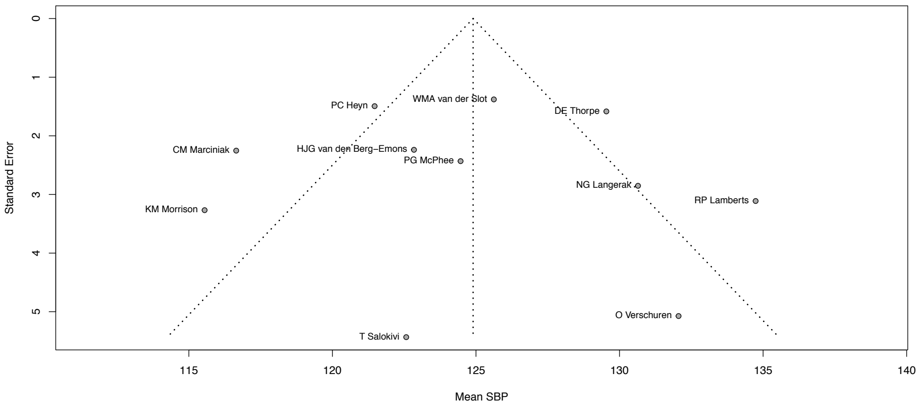
Samples	Device: type (brand)	Number of BP measurements per participant	Properly maintained, calibrated, and validated device and appropriately sized cuff	Patient selection (hypertensive patients selected)	Side of measurements	Cuff positioned at level of heart	Position	Five minutes rest before measurement	At least 30 minutes prior to the measurement:		
									No exercise	No smoking and no caffeine	No alcohol
Heyn et al[2]	Digital (WelchAllyn)	1	Yes	No	Right arm	Yes	Seated	Yes	Yes	Yes	Yes
Marciniak et al[10]	Digital (Dinamap)	Average of 3	Yes	No	Unaffected/ least affected side	Yes	Seated	Yes	Yes	Yes	Yes
Thorpe et al[3]	Digital (GE Procare 400)	1	Yes	No	Dominant or unaffected/ least affected side	Yes	Seated	Yes	Yes	Yes	Yes
McPhee et al[16]	Digital (Dinamap Pro 100, Critikon LCC, Tampa, Fla, USA)	4	Yes	No	Right arm	Yes	Supine	Yes	Yes	Yes	Yes
Morrison et al[4]	Oscillometic (BP Tru, BPM 300, VSM Medtech Ltd, Vancouver, BC)	5	Yes	No	Unaffected/ least affected side	Yes	Seated	Yes	Yes	Yes	Yes
van den Berg-Emons et al[6]	Manual (Speidel and Keller Maxi Stabil 3)	2	Yes	No	Left arm	Yes	Seated	Yes	Yes	Yes	Yes

Supplemental Table S5 Information on blood pressure measurements. (continued)

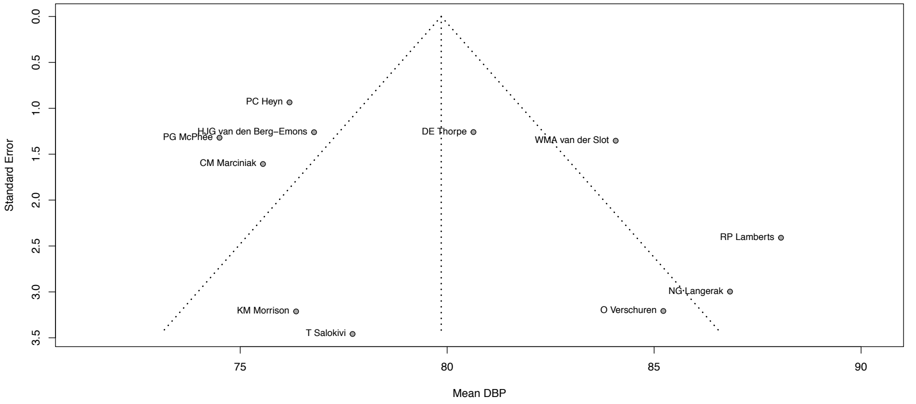
Samples	Device: type (brand)	Number of BP measurements per participant	Properly maintained, calibrated, and validated device and appropriately sized cuff	Patient selection (hypertensive patients selected)	Side of measurements	Cuff positioned at level of heart	Position	Five minutes rest before measurement	At least 30 minutes prior to the measurement:		
									No exercise	No smoking and no caffeine	No alcohol
van der Slot et al[7]	Manual (Maxi Stabil, Speidel & Keller, Germany)	2	Yes	No	Unaffected/ least affected side	Yes	Seated	Yes	Yes	Yes	Yes
Verschuren et al, unpublished data, 2015-2016	Digital (Omron Healthcare, Model M3, Kyoto)	1	Yes	No	Unaffected/ least affected side	Yes	Seated	Yes	Yes	Yes	Yes
Salokivi et al[5]	Digital (Omron)	1	Yes	No	Left arm	Yes	Both	Yes	Yes	Yes	Yes
Lamberts et al, unpublished data, 2017	Digital (Omron MIT Elite Plus)	2	Yes	No	Left arm	Yes	Seated	Yes	Yes	Yes	Yes
Langerak et al[8]	Digital (Omron MIT Elite Plus)	2	Yes	No	Left arm	Yes	Seated	Yes	Yes	Yes	Yes

Supplemental Table S6 Funnel plots for systolic and diastolic blood pressure. DBP=diastolic blood pressure, SBP=systolic blood pressure

Funnel plot for systolic blood pressure

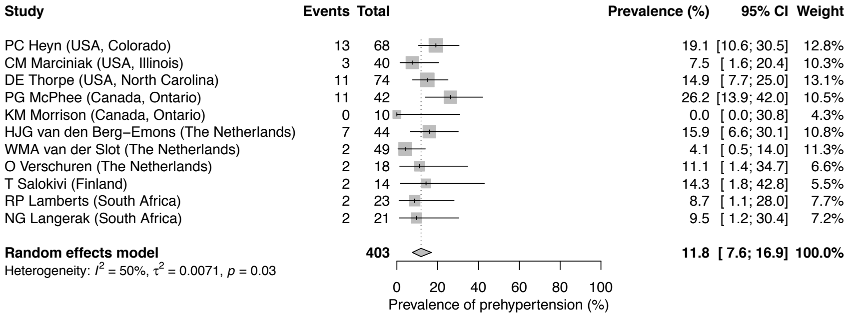


Funnel plot for diastolic blood pressure



Supplemental Table S7 Forest plots for overall prevalence of prehypertension and hypertension, and classification of blood pressure following current American Hypertension guidelines (Whelton, 2018).[17] BP=blood pressure

Forest plot for prevalence of prehypertension

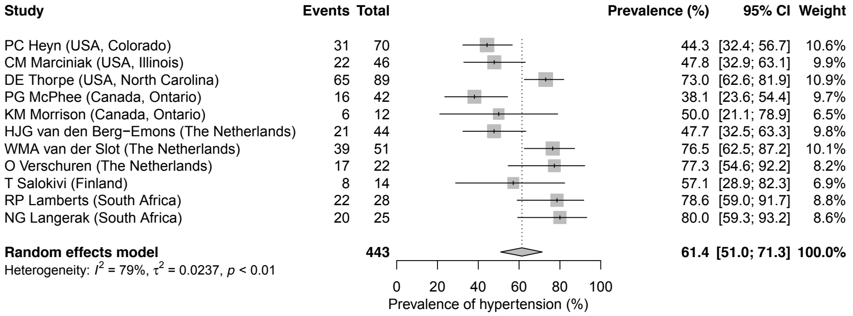


Study	Events	Total	Prevalence (%)	95% CI	Weight
PC Heyn (USA, Colorado)	13	68	19.1	[10.6; 30.5]	12.8%
CM Marciniak (USA, Illinois)	3	40	7.5	[1.6; 20.4]	10.3%
DE Thorpe (USA, North Carolina)	11	74	14.9	[7.7; 25.0]	13.1%
PG McPhee (Canada, Ontario)	11	42	26.2	[13.9; 42.0]	10.5%
KM Morrison (Canada, Ontario)	0	10	0.0	[0.0; 30.8]	4.3%
HJG van den Berg−Emons (The Netherlands)	7	44	15.9	[6.6; 30.1]	10.8%
WMA van der Slot (The Netherlands)	2	49	4.1	[0.5; 14.0]	11.3%
O Verschuren (The Netherlands)	2	18	11.1	[1.4; 34.7]	6.6%
T Salokivi (Finland)	2	14	14.3	[1.8; 42.8]	5.5%
RP Lamberts (South Africa)	2	23	8.7	[1.1; 28.0]	7.7%
NG Langerak (South Africa)	2	21	9.5	[1.2; 30.4]	7.2%
Random effects model		**403**	**11.8**	**[7.6; 16.9]**	**100.0%**

Heterogeneity: $I^2 = 50\%$, $\tau^2 = 0.0071$, $p = 0.03$

Prehypertension is defined as systolic BP 120-129 mmHg and diastolic BP <80 mmHg. Included participants N=403; participants using antihypertensive medication or with missing information on antihypertensive medication were excluded (N=41)

Forest plot for prevalence of hypertension



Study	Events	Total	Prevalence (%)	95% CI	Weight
PC Heyn (USA, Colorado)	31	70	44.3	[32.4; 56.7]	10.6%
CM Marciniak (USA, Illinois)	22	46	47.8	[32.9; 63.1]	9.9%
DE Thorpe (USA, North Carolina)	65	89	73.0	[62.6; 81.9]	10.9%
PG McPhee (Canada, Ontario)	16	42	38.1	[23.6; 54.4]	9.7%
KM Morrison (Canada, Ontario)	6	12	50.0	[21.1; 78.9]	6.5%
HJG van den Berg−Emons (The Netherlands)	21	44	47.7	[32.5; 63.3]	9.8%
WMA van der Slot (The Netherlands)	39	51	76.5	[62.5; 87.2]	10.1%
O Verschuren (The Netherlands)	17	22	77.3	[54.6; 92.2]	8.2%
T Salokivi (Finland)	8	14	57.1	[28.9; 82.3]	6.9%
RP Lamberts (South Africa)	22	28	78.6	[59.0; 91.7]	8.8%
NG Langerak (South Africa)	20	25	80.0	[59.3; 93.2]	8.6%
Random effects model		**443**	**61.4**	**[51.0; 71.3]**	**100.0%**

Heterogeneity: $I^2 = 79\%$, $\tau^2 = 0.0237$, $p < 0.01$

Hypertension is defined as systolic BP ≥130 mmHg or diastolic BP ≥80 mmHg or use of antihypertensive medication. Included participants N=443; participants with systolic BP < 130 mmHg and diastolic BP < 80 mmHg and missing information on antihypertensive medication were excluded (N=1)

Classification of blood pressure

Category	Systolic blood pressure (mmHg)		Diastolic blood pressure (mmHg)	Number of participants	Percentage of participants
Normal	<120	And	<80	121	30.0%
Elevated	120-129	And	<80	55	13.6%
Hypertension stage 1	130-139	or	80-89	137	34.0%
Hypertension stage 2	140-180	or	90-120	87	21.6%
Hypertensive crisis	>180	And/or	>120	3	0.7%

Included participants N=403; participants using antihypertensive medication or with missing information on antihypertensive medication were excluded (N=41)

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8

General discussion

This thesis consists of two parts on relevant aspects of functioning of adults with cerebral palsy (CP). The first part (chapters 2-6) describes the development of the Comprehensive and Brief International Classification of Functioning, Disability and Health (ICF) Core Sets for adults with CP and its results. The second part (chapter 7) provides important insight into blood pressure in adults with CP. Both parts will be discussed here.

Part I: Development of Comprehensive and Brief ICF Core Sets for adults with cerebral palsy

The aim of the first part of this thesis was to develop ICF Core Sets for adults with CP. The World Health Organization (WHO) has created the ICF framework to standardize the description of functioning and disability for specific health conditions worldwide.[1] To facilitate the application of this extensive framework, ICF Core Sets have been developed for groups of individuals with the same condition.[2] ICF Core Sets are shortlists of ICF categories from the whole ICF classification that describe relevant aspects of functioning. These shortlists can be used as a guideline for the standardization of assessment and reporting of functioning of adults with CP in clinical practice and research. This can facilitate the comparison of data across patients, disciplines, settings and countries. Therefore, ICF Core Sets for adults with CP will provide us with a solid basis for describing the impact of CP at adult age.

Main findings

A multi-method scientific process was followed to develop the ICF Core Sets for adults with CP. The results of four preparatory studies (chapters 2-5) were combined and discussed during an international consensus process, including 25 experts in the field (chapter 6). The strength of this methodology is that stakeholders with different perspectives are involved. Core outcomes were identified by researchers, various health care professionals, as well as adults with CP with and without intellectual disability (ID) or their representatives.

In all four preparatory studies, a broad range of ICF categories was identified, reflecting the heterogeneity of functioning and disability of adults with CP. The four preparatory studies were conducted to generate an aggregated list of candidate ICF categories to serve as the basis for deciding on the ICF Core Sets for adults with CP. This list comprised 154 unique ICF categories: 48 body functions, 9 body structures, 56 activities and participation and 41 environmental factors. Personal factors could not be included in the ICF Core Sets, because these are not yet classified in the ICF due to a large variability among cultures. Eventually, the first version of the Comprehensive (120 ICF categories) and Brief (33 ICF categories) ICF Core Sets for adults with CP were developed. Examples of categories that were included in the Core Sets were intellectual functions, sensation of pain, muscle tone (*body functions*), structure of upper and lower extremity (*body structures*), mobility, self-care (*activities and participation*), products for mobility, and health care services (*environmental factors*).

Comparing different perspectives

Four perspectives were captured in the preparatory studies, including the researcher's perspective (systematic literature review), patient's perspective (qualitative study), health professional's perspective (expert survey), and clinical perspective (clinical study). The representation of body functions, body structures, activities and participation, and environmental factors varied according to the perspective (Table 1). Body functions were well covered by all four studies, activities and participation were present in all studies, but notably higher in the literature review and clinical study, and the environmental factors were present in all studies but notably underrepresented in the literature review.

Table 1 Distribution of categories identified in the preparatory studies.

	Literature review N (%)	**Qualitative study N (%)**	**Experts survey N (%)**	**Clinical study N (%)**	**Four studies combined, unique N (%)**
Body functions	20 (28)	47 (36)	20 (32)	27 (26)	***48 (31)***
Body structures	4 (5)	7 (5)	8 (13)	4 (4)	***9 (6)***
Activities and participation	43 (60)	43 (33)	14 (22)	53 (51)	***56 (36)***
Environmental factors	5 (7)	35 (26)	21 (33)	20 (19)	***41 (27)***
Total	**72**	**132**	**63**	**104**	**154**

The importance of including different perspectives, specifically that of adults with CP themselves or their representatives, was underlined in our studies. Some categories (48 of 154) were unique for one of the studies: 37 categories in the qualitative study, 8 in the clinical study, 2 in the experts' survey and 1 in the literature review. In the Comprehensive ICF Core Set, 21 of those 48 categories were included, emphasizing the strength of including various stakeholders when developing an ICF Core Set.

Similarities were also found in the four studies, particularly for distinct characteristics of CP, e.g. muscle tone, structure of lower extremity and mobility. Studies agreed on 35 of the 154 categories. Subsequently, nearly all (34 of the 35 categories) of those aspects of functioning were included in the Comprehensive ICF Core Set for adults with CP. Below, all four preparatory studies will be discussed separately.

Systematic literature review

Chapter 2 described a systematic literature review that identified the most frequent outcomes of functioning used in studies of adults with CP published between 2000 and 2017.[3] The number of studies published on functioning of adults with CP has increased since 2000, establishing the increasing focus on the impact of CP at adult age.

In all included studies, a total of 332 outcome measures were identified, of which 156 common measures (defined as used in at least two studies). A large variation of outcome measures, each measuring varying aspects of functioning and health in adults with CP, is not conducive to standardization. The subsequent inconsistency in reporting makes comparison of results across studies, health care centres and countries challenging. These findings advocate for standardized outcome assessment.

Qualitative study

In **chapter 3**, we examined the most relevant aspects of functioning of adults with cerebral palsy (CP) from their perspective. The lived experience of adults with and without ID was studied separately: focus groups were performed in adults without ID, and interviews were performed in adults with ID or their proxies. The observed differences between the most relevant aspects of functioning of these subgroups will be discussed below.

Interestingly, of all four preparatory studies, the largest number of ICF categories was found in this qualitative study, representing 132 of the 154 ICF categories in the candidate list. Also, many unique categories were found, which were not reported in the other studies. This emphasizes the importance of including the lived experience of adults with CP in determining relevant topics for the ICF Core Sets.

A prior qualitative study aimed to determine relevant problems experienced by young adults with CP.[4] Problems frequently mentioned in that study were regarding functional mobility, self-care, recreation and leisure, and employment; those problems were incorporated as targets for rehabilitation care. These are in line with the problems found in our adults with CP.

Expert survey

Chapter 4 presented the results of an international survey that identified areas of functioning of adults with CP that are considered relevant by health professionals and researchers. A total of 126 international experts completed the survey. This study compared response patterns of the frequently addressed ICF categories between physicians and therapists. No differences were found between these two groups, indicating that both groups agree on relevant aspects of functioning of adults with CP.

Clinical study

Chapter 5 described common problems in adults with CP with and without ID in a clinical setting, from an international perspective. The functioning problems of adults with CP visiting health care centres are diverse and highly prevalent.

The demonstrated broad range of problems in functioning is in line with previously found impairments and disabilities common in CP. A recent systematic review and meta-analysis presented the epidemiology of most frequently studied outcomes in adults with CP.[5] This study was an in-depth analysis of the studies obtained in the systematic literature review on functioning of adults with CP (chapter 2).[3] The results of this meta-analysis revealed that 65% of adults with CP experienced pain, 58% were ambulant, 66% had little or no limitations in manual ability, 18% had tertiary education, and 39% were employed. The results of our clinical study are in line with the outcomes in this meta-analysis, with frequencies being higher for problems with manual ability and walking.

The present results strengthen the expertise of clinicians that many adults with CP have a broad spectrum of impairments and disabilities, reflecting the long-term consequences and disability burden of this condition in many areas.[6] Although body functions and structures are generally targets for therapies and interventions, participation outcomes such as employment and social relationships, are considered highly valued outcomes by the people living with CP and their health care providers.[7] This is in line with the trend observed in health care, representing the shift from a medical approach towards a more comprehensive client-centred approach.[8] This shift is also confirmed by our systematic literature review (chapter 2),[3] in which activities and participation were more prominent than body functions. Our results underline that the broad spectrum of impairments and disabilities should be taken into account in treatment.[7]

Strikingly, despite the high frequency of functioning problems reported in this study, routine follow-up and health care for adults with CP is still limited. Research pointed at a large decrease in health care use after the transition to adulthood.[9, 10] This is remarkable because adults with CP reported increasing difficulty in transition to adult roles and deterioration of health outcomes.[6] Young adults with CP reported challenges with the transition to adult care,[11] thus, we need to provide coordinated care that supports their needs. One of the unmet needs commonly reported by young adults with CP is information, e.g. on consequences of CP.[12] Therefore, it is necessary to inform young adults and prepare them in time for their transition to adult care with the involvement of all care providers, as well as their families. It is also essential to follow-up adults with CP later in life to address health care needs that change over time. Hereby, systematic follow-up is essential to detect problems in time. This confirms the importance of developing an ICF Core Set for adults with CP to use in daily clinical practice for standardized assessment and follow-up.

Candidate list of ICF categories

The four preparatory studies were conducted to generate a list of candidate ICF categories to serve as the basis for deciding on the ICF Core Sets. The categories of the candidate list were in line with the definition of CP:[13] categories related to mobility and movement-related body functions were identified in all studies. Mental functions were also prevalent body functions, including energy and drive functions, higher-level cognitive functions, and emotional functions. Common body structures were structures related to movement, such as contractures and bone deformities of the lower and upper extremity.[14]

According to the ICF model, impairments in body functions and structures interact with a person's level of activities and participation. In all the preparatory studies, this was seen in basic daily activities, e.g. mobility and self-care. Self-care activities such as washing oneself, toileting, dressing and eating were often mentioned in our studies on adults with CP. Mobility items such as walking, fine hand use, and moving around using transportation were also often indicated.

Environmental factors play an important role in people's functioning. Of all ICF domains, environmental factors were most often mentioned in the expert survey, recognizing the role of the environment in functioning of adults with CP. Interestingly, few environmental factors were found in the literature review[3] compared to the other three preparatory studies, revealing a gap in the scientific literature so far. This suggests that researchers so far have not often considered the role of environmental factors on functioning of adults with CP.

Environmental factors can facilitate or hinder functioning of adults with CP. For the qualitative study, expert survey, and clinical study, the distinction between facilitators and barriers could be made, for the systematic review, this information was not available. Overall, more facilitators were demonstrated than barriers, suggesting that the physical, social and attitudinal environment is experienced as supportive. Examples of important facilitators were products and technology for mobility (e.g. walkers or wheelchairs), or for use in daily living (e.g. orthopaedic shoes), support of immediate family, personal care providers, and health professionals, and health care services. Health care services were often experienced as positive, but adults with CP indicated a lack of collaboration between disciplines and suggested to improve the transition to adult services. Important barriers for functioning were accessibility of buildings for public or private use (e.g. many stairs or doorsteps), and transportation services (e.g. lack of fully accessible vehicles). These factors could also hamper participation, such as employment and leisure. In the expert survey, most environmental factors were indicated as facilitators and barriers, except for societal attitude, which was indicated only as a barrier. Stigmatization and discrimination still exist against people with disabilities, which can interfere with social engagement and could also affect physical and mental health.[15-17] Therefore, it is essential to increase acceptance and decrease social distance between adults with CP and other members of society. Our findings emphasize that environmental factors should be taken into account when assessing functioning of adults with CP. Changes in the environment could likewise improve the functioning of adults with CP, such as improvements in the accessibility of buildings and changes in the attitudes of persons without a disability.

All studies also yielded personal factors, such as socioeconomic status, living status, and perseverance. Personal factors are not yet classified in the ICF, and could not be included in the ICF Core Sets for adults with CP. However, it is recommended to systematically report essential personal factors because those could influence functioning in a positive or negative way. For instance, personal factors such as perseverance and positive attitudes could impact adherence to treatment, so they should be considered by health professionals.

Intellectual disability

Adults with and without ID were included in two preparatory studies, the qualitative and clinical study, and a distinction was made between their results.

Notwithstanding similarities in relevant aspects of functioning (e.g. pain, muscle tone, fine hand use, and products for mobility), notable differences between adults with and without ID should be mentioned. In the qualitative and clinical study, the largest difference between adults with and without ID was logically found for intellectual functions, related to the intellectual impairment of adults with ID. In the clinical study, the prevalence of problems for all reported mental functions was found higher in adults with ID than in adults without ID. However, it is important to realize that problems in some mental functions seem to be present in both groups, such as energy and drive functions and emotional functions.

In the clinical study, many difficulties in activities and participation were highly prevalent in adults with ID: at least 75% of these adults experienced difficulties in more than 50% of the categories, such as employment and communication. These results match those observed in earlier studies that have demonstrated that persons with ID show the least favourable development of daily activity performance and reach their limits earlier.[18] Also, for communication and social interaction, individuals with ID showed the least favourable development.[19] In line with this, restrictions in participation in young adulthood were more common in those with lower gross motor skills, low manual ability or intellectual disability.[20] This confirms that greater difficulties in activities and participation are present in adults with ID. A notable difference between the two groups was found for the environmental factor social support services. This factor was perceived as facilitating for adults with ID, while those without ID experienced it more often as a barrier, due to problems in receiving social support and facing challenges by changes in regulations.

Although differences between adults with and without ID were present, we have decided to create one ICF Core Set for adults with CP comprising functioning and disability of adults with and without ID because similarities were found in both groups. During the consensus process, separate results were shown for adults with and without ID in the qualitative and clinical study, and the experts were explicitly instructed to keep in mind both adults with and without ID in the discussion and voting process. Therefore, we believe that the ICF Core Sets for adults with CP cover both groups.

Assessment of functioning and disability can be challenging in adults with ID. Adults with ID are not always able to communicate - sending and receiving of information - and indicate what problems they perceive, making proxy interviews inevitable. Therefore, caregivers as proxies of adults with CP with ID were interviewed in our studies. The caregivers knew the respective person with ID well, making this the best suitable method for the goal of our study. If possible, the respective person with CP was present and answered for him or herself. This should be taken into account when implementing the ICF Core Sets, by choosing an appropriate assessment method in adults with ID, e.g. by using observation scales to measure pain.

Consensus process

The results from chapters 2-5 were combined and used for the consensus process, as described in **chapter 6**. This chapter described the pioneer consensus process of experts and health professionals and presented the final Comprehensive and Brief ICF Core Sets for adults with CP. The Comprehensive ICF Core Set includes a greater number of ICF categories, to describe the entire functioning profile of adults with CP, and should be concise enough to be practical for comprehensive, interdisciplinary assessments. The Brief ICF Core Set, derived from the Comprehensive Set, includes the fewest categories possible while still capturing the most essential categories to serve as a minimal international standard for assessing and reporting functioning of adults with CP in clinical settings and research.

In the Comprehensive ICF Core Set, 120 ICF categories were included, of which 33 ICF categories were selected for the Brief ICF Core Set (Chapter 6, Table 2). Most covered domains in the Comprehensive Set were mental functions, movement-related functions, mobility, self-care, products and technology, and services, systems and policies (Figure 1). These domains were highly prevalent in the preparatory studies and were discussed in the subheading ‘Candidate list of ICF categories’. A notable finding is that most categories of the Comprehensive and Brief ICF Core Sets concerned activities and participation, underlining its importance in adults with CP. The number of environmen-

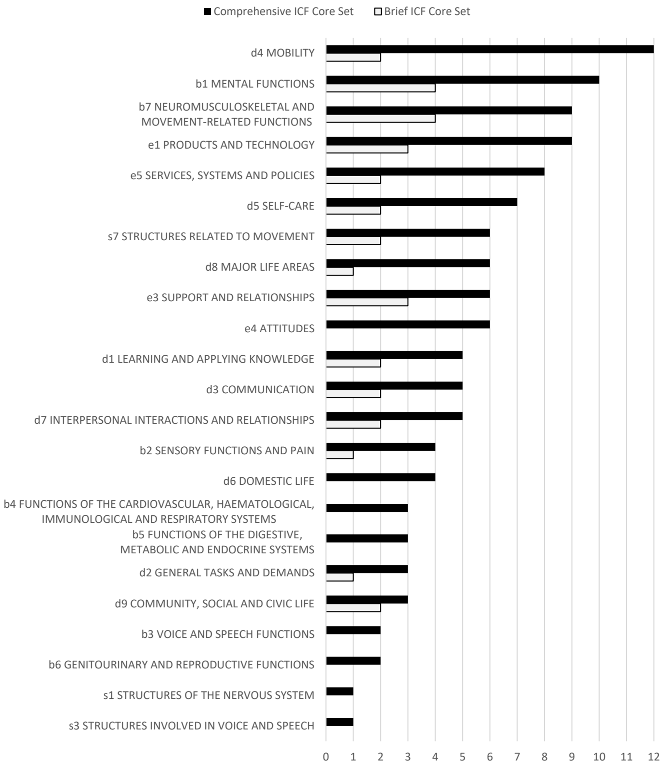

Figure 1 The number of International Classification of Functioning, Disability and Health (ICF) categories per chapter included in the Comprehensive and Brief ICF Core Sets for adults with cerebral palsy (CP).

tal categories was similar to the number of included body functions, which is in line with the trend observed in health care.[8]

ICF categories included in the Brief Core Set are displayed in Figure 2. While the Comprehensive ICF Core Set is wide-ranging, some aspects of functioning may be underrepresented in the Brief ICF Core Set as a result of the 27% cut-off. The cut-off is in line with the Brief ICF Core Set for children & youth with CP from 14 to 18 years of age, and aligns well with the intention of the Brief Set to include the fewest categories possible for basic documentation of functioning and disability. The experts agreed on the brief list of categories, nevertheless, some argued for more body structures, such as the structure of the brain and trunk. Also 'moving around using equipment' or 'hand and arm use' were not included but may be particularly relevant for specific adults with CP. During the validation and implementation process, it will become clear whether the categories in the Brief Set are sufficient.

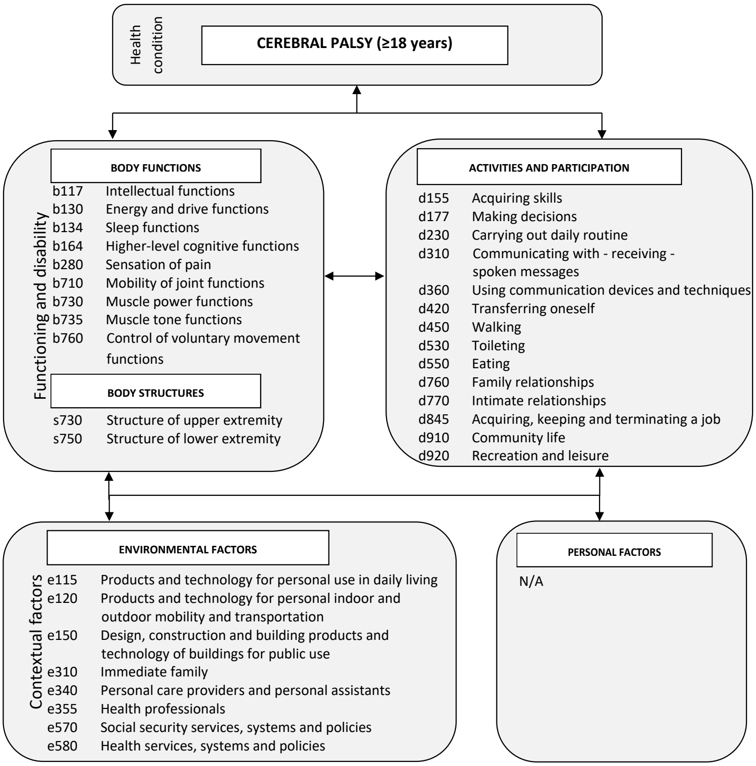

Figure 2 International Classification of Functioning, Disability and Health (ICF) framework including the ICF categories from the Brief ICF Core Set for adults with cerebral palsy (CP).[1]

Because of the COVID-19 pandemic, we pioneered an online version of the original face-to-face consensus conference. Lessons learned from this process should be taken into account when organizing future meetings online. We have tried to stay as close as possible to the original methodology, but we had to adapt some parts to reduce participant burden.[2] This resulted, however, in less opportunity for discussion. The number of working group sessions was reduced from two to one, and we have performed two ranking rounds for the Brief Set instead of three. Although the number of sessions was reduced, efforts were made to support the participants, as well facilitate individual and shared decision-making, e.g. providing voiced-over presentations before and during the process, and summaries of results. In the present online process, it seemed to take longer for participants to feel comfortable and share their experience. Nevertheless, as in previous ICF Core Set conferences, participants engaged quite actively as time passed. An online meeting is also less conductive to discussion, so more prompting was needed. From experience in previous ICF Core Set consensus conferences, physical presence and spending time together is shown to be helpful for interactive exchange. Therefore, we suggest arranging more time for a meet and greet or social event at the start of the process, which might encourage participants to feel comfortable from the start. Despite some challenges, the overall experience was positive, and this pioneer online consensus process can be used for future ICF Core Set consensus processes and similar Delphi procedures.

ICF Core Sets children & youth with CP

The ICF Core Sets for adults with CP will complement the ICF Core Sets that have been developed for children & youth with CP,[21] including one Comprehensive ICF Core Set, one common Brief ICF Core Set, and three age-specific Brief ICF Core Sets (<6 years, 6-13 years, 14-18 years old).

Although many similar categories were included in the Comprehensive ICF Core Sets for children & youth and adults with CP, such as intellectual functions, pain, muscle tone, walking, products for mobility, and health care services, there are important differences between the two. Differences could partly be explained by age-specific aspects of functioning: some categories were more specific for adults, e.g. higher education, employment, blood pressure functions, sexual functions, and political life and citizenship, while other categories were specific to children, e.g. pre-school education. Furthermore, the ICF standard version was used for the ICF Core Sets for adults with CP,[1] while the ICF Core Sets for children & youth were developed using the children and youth version of the ICF (ICF-CY).[22] Eight categories in the Comprehensive ICF Core Set for children & youth are found in the ICF-CY and not in the ICF, e.g. d331 pre-talking and d880 engagement in play.

When comparing the Brief ICF Core Set for adults with the Brief ICF Core Set for children & youth with CP age 14-18 years old, the adult version highlights topics important in adult life, e.g. d177 making decisions, d230 carrying out daily routine or d770 intimate relationships, whereas the children & youth version categories address issues important to teenagers with CP, i.e. e320 friends and e420 individual attitudes of friends. This may be due to more autonomous functioning of adults with CP in daily life, e.g. decision-making that affect major life areas like work, performing daily routines independently, intimate relationships of adults with CP. Furthermore, support provided by personal assistants and health professionals, and social security were included as essential environmental factors in the brief set for adults with CP but not in the Core Set for youth 14-18 years old; these factors may be understood as important for enabling autonomy in adult life. The comparison of the adult and children & youth version confirms the added value of the ICF Core Sets for adults with CP as it underscores the importance of functioning categories that reflect the specific needs of adults 18+ years of age with CP.

ICF Generic and Rehabilitation Sets

The ICF Generic Set is a minimal set which is developed by the ICF Research Branch for a brief description of functioning and health of individuals with varying health conditions and the general population.[23] This Generic Set supports comparison of functioning across health conditions and settings worldwide, and across the general population. It is recommended to include the ICF Generic Set categories in every ICF Core Set because it will contribute to data comparison of key outcomes. The ICF Generic Set is composed of seven ICF categories representing the components body functions and activities and participation: energy and drive functions, emotional functions, sensation of pain, carrying out daily routine, walking, moving around and remunerative employment. In our project, all these seven categories were obtained from the preparatory studies and included in the Comprehensive ICF Core Set for adults with CP. Four of the seven categories (energy and drive functions, sensation of pain, carrying out daily routine, and walking) are included in the Brief ICF Core Set for adults with CP.

The categories of this Generic Set are included in a larger set, the ICF Rehabilitation Set, also called the ICF Generic-30 Set, which comprises 30 categories that were found to be important for routine documentation of functioning of clinical populations.[24] In total, 28 of these 30 categories (93%) were included in the Comprehensive ICF Core Set for adults with CP: ICF category *assisting others (d660),* was not included in the candidate list for adults with CP, because assisting others with their communication, self-care, or movement does often not apply to adults with CP. Regarding *basic interpersonal interaction* (d710) evidence from the preparatory studies was limited, and experts decided to exclude this category. However, other categories comprising interpersonal interactions and relationships were included, e.g. complex interpersonal interactions, formal, informal and family relationships.

The large agreement between the sets supports the importance of using these sets in the documentation of relevant outcomes of functioning in clinical settings. On the other hand, adults with CP comprise a heterogeneous group, presenting themselves with specific health-related issues that go beyond the aspects of functioning addressed by the ICF Rehabilitation Set. Some examples of categories that are not included in the ICF Rehabilitation Set, but are considered relevant for adults with CP, are, e.g. intellectual functions, muscle tone functions and fine hand use. This underlines the importance of a specific ICF Core Set for adults with CP for documentation of their functioning.

PART II: Blood pressure in adults with cerebral palsy

The risk of cardiovascular diseases is higher in adults with CP than in the general population,[25-27] but extensive knowledge on one of the main risk factors, blood pressure, was lacking. Only a few studies have reported on the prevalence of hypertension in adults with CP,[28-31] but those studies were limited by small sample size and relatively young age. For an adequate approach to managing blood pressure in current clinical practice, a reliable prevalence estimate was required. More information was also needed on subgroups at increased risk and on factors that influence blood pressure levels in adults with CP.

Main findings

Chapter 7 presented the results of our systematic review and meta-analysis on blood pressure in adults with CP. The strength of this study is that it is the first that provided a reliable prevalence estimate of overall mean level of blood pressure and prevalence of hypertension in adults with CP, including individual participant data from international samples. The overall mean level of blood pressure was 124.9/79.9mmHg, and the prevalence of hypertension was 28.7% in a group of 444 adults with a median age of 29.0 years. Those results suggest that blood pressure levels and the prevalence of hypertension are relatively high in this rather young sample of adults with CP.

Variations in blood pressure levels and prevalence of hypertension were estimated by subgroups and the association between potential risk factors and blood pressure levels was explored. Higher blood pressure levels or higher prevalence of hypertension were found in adults with CP above 40 years of age, males, those with spastic CP or those who lived in Africa, indicating that attention should be paid to those subgroups. Risk factors that were found were body mass index, resting heart rate and alcohol consumption. Found risk factors are all modifiable, and stimulating a healthy lifestyle with more physical activity or a healthy diet could have a positive influence on those factors. These results should, however, be interpreted with caution, because not all study groups had data available on risk factors, resulting in missing data. Furthermore, conversion to a common scale was not possible in all cases due to the use of different measurements, e.g. pain was measured by different scales of which not all results could be compared. This advocates for standardization of assessment and reporting, emphasizing the importance of our ICF Core Set.

Specific Core Set to assess multimorbidity risk

In research and clinical practice, more attention is being paid to systematic assessment and reporting of data. Recently, a specific Core Outcome Set of Measurement Instruments for assessing multimorbidity risk in clinical practice and research in adolescents and adults with CP has been developed.[32, 33] A high prevalence of chronic diseases is reported in adults with CP, including cardiometabolic conditions.[30, 34] Screening and prevention of modifiable risk factors could be a first step in the management of those conditions. For this core set eight outcomes were determined by an international consortium: health-related fitness (cardiorespiratory endurance, body size, body composition), lifestyle behaviours (physical behaviour, sleep, nutrition) and traditional (bio) markers (blood pressure, blood lipids and glucose). Subsequently, outcome measurement instruments that are feasible to assess the core outcomes in clinical practice and research were selected by experts. The importance of blood pressure is supported by this Core Outcome Set of Measurement Instruments and is also one of the categories included in our Comprehensive ICF Core Set for adults with CP.

PART I AND II

Generalizability and study limitations

The samples of the systematic literature review, qualitative study, clinical study, and blood pressure study showed a representative distribution of CP subtype and Gross Motor Function Classification System (GMFCS) levels,[35, 36] and included adults with and without ID. Because this distribution is not equal, some subgroups are small, e.g. GMFCS levels IV and V, subgroup analyses of the blood pressure study should therefore be interpreted with caution.

Although the age range of adults with CP included in our studies was between 18 and 84 years, mostly young adults were included, with a mean age of separate studies between

25 and 46 years. Literature and clinical practice indicate deterioration of functioning and increased presence of health issues in adults with CP in the long-term.[6] Deterioration in walking function was previously reported, and associated with an increased presence of pain and fatigue.[37] Pain also interfered with daily activities, such as self-care,[37] and an increased need for assistance was reported.[6] Also, risk of health issues increased with advancing age, such as increased risk of arthritis and osteoporosis.[38] Although the *deterioration* or *increase* itself is not captured in a specific ICF category, this can be registered by systematic monitoring of functioning of adults with CP over time. We believe that a broad range of outcomes of functioning is included; however, it is important to realize that these ICF Core Sets might not fully cover specific problems of persons above middle-age. Also, for blood pressure, the majority of adults with CP included had a relatively young age, which limits drawing conclusions across the lifespan of CP.

On the other hand, it is not unexpected that persons above middle-age are to a lesser extent represented in our studies because the diagnosis of CP has only been used for a few decades. Furthermore, only in recent years the referral from paediatric to adult care has increased.[11] As a result, older adults are not always known in adult care, and therefore they are to a lesser extent included in research worldwide.[9, 10]

In the present studies, adults with CP were recruited through flyers and advertisements, patient registry databases, rehabilitation clinics, and patient organizations, assuming that a convenient sample has been included. However, patients looking after their health may be more willing to respond to advertisements or calls for research, which might have resulted in an underestimation of the true BP levels in adults with CP. This effect is assumed to be negligible for the final ICF Core Sets, because various stakeholders were involved.

Although not all professional backgrounds were included in the preparatory studies or consensus process, a large variety of disciplines were represented. Ultimately, a more diverse representation of disciplines would have been preferable in both the expert survey and consensus process. The vast majority of experts included in the survey and the pool of participants for the consensus process were rehabilitation physicians and physical therapists, with only a small number of experts with other professional backgrounds, e.g. social work. On the other hand, this is not surprising, as CP is defined as a disorder of movement and posture,[13] with a prominent role for rehabilitation physicians and physical therapists. Although some disciplines might have been missing or underrepresented, the strength is that a large diversity of backgrounds and experts with many years of experience in working with adults with CP were present.

Also, not all countries were included in the preparatory studies or consensus process, but low-, middle- and high-income countries were represented in all these studies. The clinical study, expert survey, literature review and consensus process were all performed internationally; the qualitative study was conducted in the Netherlands only due to financial and logistical reasons. The expert survey included experts from 32 countries. This study was announced at two international conferences, and we contacted disability and professional organizations worldwide. Despite these efforts, we had difficulties reaching experts from the African and Eastern Mediterranean Region, resulting in a low number of participants from those regions. In the consensus study, experts with 11 professional backgrounds from 15 countries participated. All six WHO regions were represented, but the majority of participants were from the United States of America and Europe. We assume that altogether the global perspective of functioning of adults with CP was captured. For the blood pressure study, included studies were performed in three different parts of the world, including North America, Europe and Africa, but not all WHO regions were represented, limiting generalizability beyond these populations.

For the comparison of data, blood pressure measurements should be standardized. Most of the studies included in our meta-analysis followed the general recommendations for blood pressure measurements[39] and those are also largely in line with the recommendations for adults with CP as initiated by the Core Set for assessing multimorbidity risk.[32, 33] Several observations from our meta-analysis are important to mention. All measurements were taken for research purposes and therefore taken on the same day. In clinic, re-measurement of blood pressure would normally be performed after two weeks to minimize white coat syndrome, random errors and to provide a more accurate basis for the estimation of blood pressure. Additionally, almost half of the included studies measured blood pressure in the least affected or unaffected arm, while others used the left or right arm irrespective of the CP distribution. In a previous study in patients with stroke, blood pressure was found to be significantly higher in paretic arms of patients with a spastic tone and lower in arms with a flaccid tone.[40, 41] They recommended measuring blood pressure in the unaffected arm. This advice does not apply to adults with bilateral CP; in that case, blood pressure should be measured on the least affected side.

To date, not much is known about the exact effect of spasticity on blood vessels, blood pressure or on the blood pressure measurement itself. However, it is important to investigate whether the higher blood pressure measured is representative of an increased CVD risk or rather a mechanical effect due to the increased muscle tone. We know that the risk of developing CVD in adults with CP is higher than in the general population, so blood pressure could likewise play a role in this.[25-27]

Implications and implementations

ICF Core Sets

This first version of the ICF Core Sets for adults with CP will be the basis for universal and standardized data collection in both clinical settings and research. This will facilitate the comparison of data across studies, disciplines and settings worldwide. These shortlists of ICF categories will serve as a guideline for the systematic assessment of functioning of adults with CP, i.e. they will indicate core areas and assist users by providing a checklist of 'what' to measure. The next phase of the Core Set development process includes the validation and implementation of the ICF Core Sets. We intend to collaborate with the Lifespan Care Committee and the Adults and Aging Special Interest Group of the American Academy for Cerebral Palsy and Developmental Medicine (AACPDM) on planning the implementation and validation. These two AACPDM groups consist of different stakeholders working with adults with CP from all parts of the world. Also, the experts from the consensus process will be involved in this phase.

In contrast to the preparatory phase, there is no established procedure for conducting this last phase, which makes it challenging. In this phase, guidelines should be provided on 'how' to measure functioning to promote the use of the ICF Core Sets and optimize standardization in adults with CP. Therefore, appropriate, user-friendly measures (e.g. questionnaires or clinical tools) that align with the content of the ICF Core Sets for adults with CP should be identified as a step toward implementing the Core Sets. The large variation of outcome measures, each measuring varying aspects of functioning and health, identified in our systematic literature review, is not conducive to standardization.[3] Together with the different outcome measures that could not be combined in the blood pressure study (e.g. for pain), it emphasizes the importance of this next step.

Although no standardized way of implementing ICF Core Sets is available, we can learn from the steps already taken for implementing the ICF Core Sets for children & youth with CP, including their challenges faced. An ICF educational e-tool was built to educate users on applying the children & youth Core Sets in clinical practice.[42] Furthermore, an ICF-based toolbox was created, including multiple-item measures that guide how to measure the relevant aspects of functioning included in the ICF Core Sets for children & youth.[43] This toolbox operationalized these Core Sets for clinical practice and research. This toolbox contains measures from the systematic literature review, one of the preparatory studies conducted to develop the Core Sets,[44] that best reflect the ICF categories included in the Core Sets for children & youth with CP and were shown to be reliable and valid. In addition, a group of experts was consulted to identify any additional measures. The outcomes of functioning evaluated by the measures were then linked to ICF codes.[44, 45]

We recommend that creating a comparable toolbox should be the next immediate step in implementing the ICF Core Sets for adults with CP. Some of the toolbox instruments for children & youth with CP could also apply to adults with CP, e.g. Life-Habits questionnaire (LIFE-H). Developing the toolbox would also involve evaluating which measurement instruments obtained from the systematic review (Chapter 2)[3] align well with the ICF Core Sets for adults with CP. Also, part of the items of the Core Outcome Set of Measurement Instruments to assess risk factors for cardiometabolic disease[32, 33] are included in the ICF Core Set for adults with CP, e.g. blood pressure and sleep, so these instruments could be integrated into the toolbox as well. Eventually, researchers and clinicians can select one or a combination of standardized instruments from this toolbox that best fits the purpose of the individualized assessment and follow-up of adults with CP. The assessments of various areas of functioning can be distributed among members of a multidisciplinary team, each taking on its own area of expertise. To minimize costs and burden of both adults with CP and professionals, information could be collected through web-based applications, also enabling the distribution of results across disciplines and settings. The implementation is a dynamic process, and after its application, the content will be revised over time to keep up with new insights and trends in research and clinical practice. The ICF Core Sets for adults with CP will also provide a starting point for future studies that will serve to validate the content of the ICF Core Sets to ensure optimal applicability across different social, cultural and economic contexts worldwide.

Furthermore, the ICF Core Sets for adults with CP can be of great importance to further support the ongoing standardization of data collection in individuals with CP, and improve the uniformity of CP registers across all ages. Several national and international registers have already been created, including the Netherlands CP register for children with cerebral palsy, aiming to improve and evaluate health care of children with CP.[46] In 2014, 38 CP registers and surveillance programs were available including individuals with CP from infancy until adulthood, which were found to be heterogeneous, and data were not collected in a standardized way, making comparison difficult.[47] Several initiatives are also available that facilitate the standardization of outcomes in children and youth with CP, e.g. the aforementioned ICF Core Sets[21] and ICF-based toolbox of measures for children and youth with CP,[43] and also the National Institute of Neurological Disorders and Stroke (NINDS)/ AACPDM Common Data Elements (CDE) for cerebral palsy, for clinical research studies including common definitions, the standardization of case report forms, and a more comprehensive set of measures.[48] To support routine outcome monitoring in adulthood, the available initiatives for children and youth should be continued for adults with CP, using the ICF Core Sets for adults with CP as a reference. This will offer the essential basis for registers and other initiatives to continue systematic assessment of children and youth with CP into adulthood, for a lifelong follow-up, which would extend our understanding of the condition across the lifespan.

Blood pressure

The new knowledge on blood pressure and hypertension levels in adults with CP suggests that relatively young adults with CP are fairly at risk, and therefore regular clinical checks and monitoring of blood pressure is recommended, beginning in young adulthood. This is important because early detection of hypertension in the general population has shown to prevent end-organ damage, such as cardiovascular disease.[39, 49, 50]

In some countries included in our meta-analysis, i.e. health care centres in the United States of America and Finland, blood pressure measurement is a standard health clinic procedure for everyone, including adults with CP, whereas in other countries, i.e. South Africa, it is not. Continued efforts are needed to add routinely blood pressure screenings in adults with CP as a standard health clinic procedure worldwide, for example by general practitioners or rehabilitation physicians.

In Rotterdam, the Netherlands, blood pressure is measured as part of the healthy lifestyle programme for people with a chronic brain injury, including CP.[51] Rijndam Rehabilitation and Erasmus MC developed the healthy lifestyle programme and evaluated this programme in a randomized controlled trial.[52] The programme includes training, advice and coaching aiming at improved fitness, an active lifestyle and healthy nutrition. Our findings on blood pressure in adults with CP are meaningful to this programme because it confirms the importance of blood pressure measurements. A healthy lifestyle contributes to lowering blood pressure, which is supported by the programme. This fits well with the physical activity recommendations for health promotion and prevention of lifestyle-related diseases for people with CP.[53] This is also supported by a Dutch physical activity and fitness programme for older adults with intellectual disability, which showed positive effects on physical activity, muscle strength, and blood pressure.[54]

Future research

The ICF Core Sets for adults with CP will be the basis for universal and standardized data collection in both clinical settings and research worldwide. Continued efforts are needed to implement and validate the ICF Core Sets for adults with CP, to ensure its worldwide applicability in various social, cultural and economic contexts, including middle- and low-income countries. We believe that the ICF Core Sets we have created apply to both adults with and without ID, but further research should demonstrate whether the current versions of the Core Sets sufficiently cover all relevant aspects of functioning of both groups.

Further studies must consider environmental factors to understand the complete picture of all factors contributing to functioning of adults with CP. The findings on environmental factors emphasize the importance of including environmental support in interventions and follow-up measures. It nevertheless suggests that barriers need remedying.

Mainly young adults with CP were included in the development of the ICF Core Sets and in the meta-analysis on blood pressure. Further work needs to be done to establish whether study results also apply to adults with CP above middle-age, to ensure that the impact of CP across the entire lifespan is covered. Blood pressure levels in adults with CP across the whole age range will give us insight into the development of hypertension throughout the lifespan.

According to our study results, monitoring of blood pressure is recommended in adults with CP, beginning in young adulthood. More research is required to fine-tune the optimal method to measure blood pressure in adults with CP, also taking into account the potential effect of spasticity. Further studies regarding the role of risk factors would be worthwhile, which would be of great help in managing blood pressure in adults with CP.

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Summary

Samenvatting

Dankwoord

About the author

Summary

*This thesis consists of two parts on relevant aspects of functioning of adults with cerebral palsy (CP). The first part (**chapters 2-6**) describes the different steps in the development of the Comprehensive and Brief International Classification of Functioning, Disability and Health (ICF) Core Sets for adults with CP and its results. These ICF Core Sets can be used to support the standardization of assessment and reporting of functioning of adults with CP in clinical practice and research. This will facilitate the comparison of data across studies, disciplines, and settings worldwide. The second part (**chapter 7**) provides important insight into blood pressure in adults with CP. A reliable prevalence estimate of hypertension can contribute to an adequate approach to managing blood pressure in current clinical practice. More information is also provided on subgroups at increased risk and on potential risk factors that influence blood pressure levels in adults with CP.*

Chapter 1 contains the general introduction on topics addressed in this thesis, such as CP, the ICF framework, ICF Core Sets, and blood pressure. This chapter also encloses the aims and outline of this thesis.

In the first part of this thesis, a multi-method scientific process was followed to develop the ICF Core Sets for adults with CP (**chapters 2-6**). Four preparatory studies were conducted, including different perspectives: a systematic literature study (researcher's perspective, **chapter 2**), a qualitative study (patient's perspective, **chapter 3**), an expert survey (health professional's perspective, **chapter 4**) and a clinical study (clinical perspective, **chapter 5**). The results of the four preparatory studies were combined and discussed during an international consensus process (**chapter 6**).

In **chapter 2,** we describe the systematic literature review that identified the most studied outcomes of functioning of adults with CP that were reported in published studies between 2000 and 2017. A total of 199 unique studies were included, representing 32,933 adults with CP with a mean age of 31.0 years (range 18-84 years). The number of studies published on functioning of adults with CP has increased since 2000. A total of 332 different outcome measures were found, reflecting the large variation of outcome measures available for adults with CP, which is not conducive to standardization. This emphasizes the need for developing an ICF Core Set for adults with CP. The functioning content of common outcome measures was first uncovered and then linked to ICF categories. A broad range of ICF categories was identified and the most frequently addressed areas of functioning were pain, mobility, self-care, employment, and recreation.

Activities and participation were more frequently studied than body functions and structures, and the focus on environmental factors was limited.

Chapter 3 describes the qualitative study, which identified aspects of functioning that are considered most important from the lived experience of adults with CP, including adults with and without intellectual disability (ID). We conducted six focus group discussions with adults without ID and seven interviews with adults with ID or their proxies. Verbatim transcripts were divided into themes, which were linked to ICF categories. Adults with CP indicated a range of difficulties that refers to common impairments and activity limitations known to be related to CP and addressed both physical and mental issues. They indicated products for mobility and personal use in daily living as important facilitators for functioning, as well as health services and support of family. Adults with ID often mentioned problems in mental functions, also affecting language, related to their intellectual impairment.

In **chapter 4**, we describe the results of an international survey amongst health professionals and researchers to identify relevant areas of functioning of adults with CP, from their perspective. Experts had at least two years of experience in working with adults with CP. A total of 126 experts from 32 countries, representing all six World Health Organization (WHO) regions, completed the survey. The experts identified a broad variation of ICF categories, e.g. pain, muscle tone functions, mobility and employment, reflecting the heterogeneity of CP. Also, many environmental factors were identified in this study, e.g. design of buildings for public and private use, and products for mobility, which recognizes the role of the environment in functioning of adults with CP.

In **chapter 5,** we investigated common problems in adults with CP with and without ID who had visited the health care centres in the last three years, from an international perspective. A total sample of 101 adults with CP from the Netherlands, Sweden, Thailand and the United States was included, including 69 adults without ID and 32 adults with ID. Semi-structured interviews were performed by using a tailored version of the ICF checklist 2.1a. The ICF checklist 2.1a contains 123 ICF categories that are considered important by the WHO; this checklist was adapted to ensure its specificity to functioning of adults with CP. Of the 106 items, 104 were frequently reported, comprising 27 body functions, 4 body structures, 53 activities and participation, and 20 environmental factors. A broad range and a high frequency of specific functioning problems, and facilitating and hindering factors were indicated. Difficulties in activities and participation were most frequently reported, e.g. mobility and employment, especially in adults with ID. Environmental factors were more often mentioned as facilitators than as barriers.

Chapter 6 describes the consensus process to select the most relevant categories of functioning of adults with CP. Evidence was gathered during the four preparatory studies – the systematic literature review, the qualitative study, the expert survey, and the clinical study – which resulted in a candidate list of 154 unique candidate categories. An online iterative decision-making and consensus process was conducted to select the most relevant categories in adults with CP. For this process, 25 international experts in adults with CP were included, representing six WHO regions and various professional backgrounds. Due to the COVID-19 pandemic, this process was unique in its form because of its online performance, including plenary sessions, working groups and voting rounds. Eventually, this process resulted in the Comprehensive ICF Core Set, comprising 120 ICF categories: 33 body functions, 8 body structures, 50 activities and participation, and 29 environmental factors. The most essential categories, 33 in total, were selected for the Brief ICF Core Set. Examples of categories that were included in the Core Sets were intellectual functions, sensation of pain, muscle tone (*body functions*), structure of upper and lower extremity (*body structures*), mobility, self-care (*activities and participation*), products for mobility, and health care services (*environmental factors*). The ICF Core Sets will provide the basis in the process to universal and standardized data collection in clinical practice and research. This now needs to be validated and implemented to ensure its worldwide applicability in various social, cultural and economic contexts, including middle- and low-income countries.

In the second part of this thesis (**chapter 7)**, we describe a systematic review and meta-analysis of blood pressure and hypertension in adults with CP. Potential datasets were identified by literature searches for studies published between 2000 and 2017, and experts in the field. We obtained individual participant data from six published and five unpublished studies, including 444 adults with CP with a median age of 29.0 years, living in North America, Europe or Africa. The average level of blood pressure was 124.9/79.9mmHg, and the prevalence of hypertension was 28.7%. Our findings suggest that blood pressure levels and prevalence of hypertension are relatively high in the rather young sample of adults with CP. Higher blood pressure levels or higher prevalence of hypertension were found in adults with CP above 40 years of age, as well as among males, those with spastic type of CP or those who live in Africa. Risk factors associated with blood pressure or hypertension were body mass index, resting heart rate and alcohol consumption. Our findings underscore the importance of clinical screening for blood pressure in individuals with CP beginning in young adulthood.

Chapter 8 contains the general discussion. The main results of this thesis are interpreted and discussed in the context of other literature. Methodological considerations, clinical implications and directions for future research are provided.

Samenvatting

*Dit proefschrift bestaat uit twee delen, gericht op relevante aspecten van het functioneren van volwassenen met cerebrale parese (CP). Het eerste deel (**hoofdstukken 2-6**) beschrijft de verschillende stappen in de ontwikkeling van Core Sets voor volwassenen met CP volgens de Internationale classificatie van het menselijk functioneren (ICF) en de resultaten daarvan. Deze ICF Core Sets kunnen worden gebruikt ter ondersteuning van standaardisatie van rapportage en het meten van functioneren van volwassenen met CP in de klinische praktijk en in onderzoek. Hierdoor kunnen gegevens tussen studies, disciplines en instellingen wereldwijd eenvoudiger worden vergeleken. Het tweede deel (**hoofdstuk 7**) biedt belangrijk inzicht in de bloeddruk bij volwassenen met CP. Een betrouwbare prevalentieschatting van hypertensie kan bijdragen aan een passende behandelaanpak van bloeddruk bij volwassenen met CP in de klinische praktijk. Er wordt ook informatie gegeven over subgroepen die een verhoogd risico hebben op een hoge bloeddruk en over mogelijke risicofactoren die de bloeddruk bij volwassenen met CP kunnen beïnvloeden.*

Hoofdstuk 1 bevat de algemene inleiding over onderwerpen die in dit proefschrift worden behandeld, waaronder CP, het ICF raamwerk, ICF Core Sets en bloeddruk. Dit hoofdstuk bevat ook de doelstellingen en de opzet van dit proefschrift.

In het eerste deel van dit proefschrift werd een wetenschappelijke methode gevolgd om de ICF Core Sets voor volwassenen met CP te ontwikkelen (**hoofdstukken 2-6**). Vier voorbereidende studies werden uitgevoerd vanuit verschillende perspectieven: een systematische literatuurstudie (perspectief van de onderzoeker, **hoofdstuk 2**), een kwalitatieve studie (perspectief van de patiënt, **hoofdstuk 3**), een expertenquête (perspectief van de zorgverlener, **hoofdstuk 4**) en een klinische studie (klinisch perspectief, **hoofdstuk 5**). De resultaten van de vier voorbereidende studies werden gecombineerd en besproken tijdens een internationaal consensus proces (**hoofdstuk 6**) om tot de ICF Core Sets te komen.

In **hoofdstuk 2** beschrijven we de systematische literatuurstudie waarin de meest onderzochte uitkomsten van functioneren van volwassenen met CP werden geïdentificeerd in studies gepubliceerd tussen 2000 en 2017. In totaal werden 199 unieke studies geïncludeerd, die 32.933 volwassenen met CP beschreven met een gemiddelde leeftijd van 31,0 jaar (18-84 jaar). Het aantal gepubliceerde studies over het functioneren van volwassenen met CP is sinds het jaar 2000 toegenomen. In totaal werden 332 verschillende uitkomstmaten gevonden, die de grote variatie in uitkomstmaten van volwassenen met CP weerspiegelt, wat niet gunstig is voor standaardisatie van rapportage. Dit benadrukt de noodzaak om ICF Core Sets te ontwikkelen voor volwassenen met CP. De meest gebruikte meetinstrumenten werden gelinkt aan ICF categorieën. Er werd een breed scala aan ICF categorieën gevonden en de meest frequent onderzochte domeinen waren pijn, mobiliteit, zelfverzorging, werk en recreatie. Activiteiten en participatie werden vaker bestudeerd dan lichaamsfuncties en lichaamsstructuren, en de aandacht voor omgevingsfactoren was beperkt.

Hoofdstuk 3 beschrijft de kwalitatieve studie, waarin belangrijke aspecten van functioneren werden geïdentificeerd vanuit het perspectief van volwassenen met CP, door zowel volwassenen met als zonder een verstandelijke beperking. We hebben zes focusgroepen uitgevoerd met volwassenen zonder een verstandelijke beperking en zeven interviews met volwassenen met verstandelijke beperking of hun proxies. Transcripten werden onderverdeeld in thema's, die vervolgens gelinkt werden aan ICF categorieën. Volwassenen met CP gaven diverse problemen aan die verwijzen naar veelvoorkomende stoornissen en beperkingen in activiteiten waarvan bekend is dat ze verband houden met CP, zowel fysiek als mentaal. Producten voor mobiliteit en persoonlijk gebruik in het dagelijks leven werden genoemd als belangrijke ondersteuning bij functioneren, evenals de gezondheidszorg en ondersteuning van familie. Bij volwassenen met een verstandelijke beperking kwamen problemen met mentale functies vaak ter sprake, die ook van invloed waren op de taal, gerelateerd aan hun verstandelijke beperking.

In **hoofdstuk 4** beschrijven we de resultaten van een internationale studie onder zorgverleners en onderzoekers om vanuit hun perspectief relevante gebieden van functioneren van volwassenen met CP te identificeren. Deze experts hadden minimaal twee jaar ervaring in het werken met volwassenen met CP. In totaal hebben 126 experts uit 32 landen de enquête ingevuld, waarbij alle werelddelen vertegenwoordigd waren. De experts identificeerden een grote diversiteit aan ICF categorieën, zoals pijn, spiertonus, mobiliteit en werk, die de heterogeniteit van CP en de gevolgen weerspiegelen. Ook werden in deze studie veel omgevingsfactoren geïdentificeerd, zoals de toegankelijkheid van openbare en private gebouwen en producten voor mobiliteit, waarin de rol van de omgeving bij het functioneren van volwassenen met CP wordt erkend.

In **hoofdstuk 5** onderzochten we veelvoorkomende problemen bij volwassenen met CP met en zonder verstandelijke beperking die in de afgelopen drie jaar de gezondheidscentra hadden bezocht, vanuit een internationaal perspectief. In totaal werden 101 volwassenen met CP uit Nederland, Zweden, Thailand en de Verenigde Staten geïncludeerd, waaronder 69 volwassenen zonder verstandelijke beperking en 32 volwassenen met een verstandelijke beperking. Semigestructureerde interviews werden uitgevoerd met behulp van een op maat gemaakte versie van de ICF checklist 2.1a. De ICF checklist 2.1a bevat 123 ICF categorieën die door de Wereldgezondheidsorganisatie als belangrijk worden beschouwd. Deze checklist werd aangepast naar 106 items om deze specifieker te maken voor het functioneren van volwassenen met CP. Van de 106 items werden er 104 frequent gerapporteerd, waaronder 27 lichaamsfuncties, 4 lichaamsstructuren, 53 activiteiten en participatie en 20 omgevingsfactoren. Een breed scala alsook een hoge frequentie van problemen in het functioneren en ondersteunende en belemmerende factoren werden aangegeven. Moeilijkheden bij activiteiten en participatie werden het meest gerapporteerd, bijvoorbeeld mobiliteit en werk, vooral bij volwassenen met een verstandelijke beperking. Omgevingsfactoren werden vaker genoemd als ondersteunend dan als belemmerend.

Hoofdstuk 6 beschrijft het consensus proces om de meest relevante categorieën van functioneren van volwassenen met CP te selecteren. Er werd bewijs verzameld tijdens de vier voorbereidende studies, de systematische literatuurstudie, de kwalitatieve studie, de expertenquête en de klinische studie. Dit resulteerde in een lijst van 154 unieke ICF categorieën. Een online consensus proces werd toegepast om de meest relevante categorieën bij volwassenen met CP te selecteren. Voor dit proces werden 25 internationale experts vanuit verschillende professionele achtergronden op het gebied van volwassenen met CP geïncludeerd, die alle werelddelen vertegenwoordigden. Door de COVID-19 pandemie was dit proces uniek door zijn online uitvoering, met plenaire sessies, werkgroepen en stemrondes. Uiteindelijk resulteerde dit proces in een uitgebreide ICF Core Set, bestaande uit 120 ICF categorieën: 33 lichaamsfuncties, 8 lichaamsstructuren, 50 activiteiten en participatie en 29 omgevingsfactoren. De meest essentiële categorieën, 33 in totaal, werden geselecteerd voor de korte ICF Core Set. Voorbeelden van categorieën die werden opgenomen in de Core Sets zijn intellectuele functies, pijn, spiertonus (*lichaamsfuncties*), structuur van de bovenste en onderste extremiteit (*lichaamsstructuren*), mobiliteit, zelfverzorging (*activiteiten en participatie*), producten voor mobiliteit, en gezondheidszorg (*omgevingsfactoren*). Deze ICF Core Sets zullen de basis vormen in het proces naar universele en gestandaardiseerde verzameling van gegevens in de klinische praktijk en onderzoek. De volgende stap is het valideren en implementeren van de ICF Core Sets om ervoor te zorgen dat het wereldwijd toepasbaar is in verschillende sociale, culturele en economische contexten, alsook in midden- en lage-inkomenslanden.

In het tweede deel van dit proefschrift (**hoofdstuk 7**) beschrijven we een systematische review en meta-analyse van bloeddruk en hypertensie bij volwassenen met CP. Potentiële datasets werden geïdentificeerd door een literatuurstudie naar studies die tussen 2000 en 2017 zijn gepubliceerd, en door experts in het veld. We hebben gegevens van individuele deelnemers verkregen uit zes gepubliceerde en vijf niet-gepubliceerde studies, waardoor in totaal 444 volwassenen met CP met een mediane leeftijd van 29,0 jaar en woonachtig in Noord-Amerika, Europa of Afrika werden geïncludeerd. De gemiddelde bloeddruk was 124,9/79,9mmHg en de prevalentie van hypertensie was 28,7%. Onze bevindingen suggereren dat de bloeddruk en de prevalentie van hypertensie relatief hoog zijn in deze vrij jonge groep van volwassenen met CP. Hogere bloeddrukwaarden of een hogere prevalentie van hypertensie werden gevonden bij volwassenen met CP boven de 40 jaar, evenals bij mannen, personen met een spastische vorm van CP of degenen die in Afrika wonen. Risicofactoren geassocieerd met bloeddruk of hypertensie waren body mass index, hartslag in rust en alcoholgebruik. Onze bevindingen onderstrepen het belang van screening op bloeddruk bij personen met CP vanaf jongvolwassen leeftijd.

Hoofdstuk 8 bevat de algemene discussie. De belangrijkste resultaten van dit proefschrift worden geïnterpreteerd en bediscussieerd in de context van de huidige literatuur. Daarnaast bespreken we methodologische overwegingen en klinische implicaties en geven we aanbevelingen voor toekomstig onderzoek.

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Curriculum Vitae

Suzie Noten was born in Bergeijk, the Netherlands on February 27th, 1990. After finishing high school (VWO) in Eersel in 2008, she started her study Human Movement Sciences at the VU University, Amsterdam. She obtained her Bachelor degree in Human Movement Sciences (specialization: Health) in 2011. In 2013, she successfully finished the Research Master Fundamental and Clinical Human Movement Sciences.

She then started working as a researcher at the University of Antwerp (Belgium), for 1.5 years. This research focused on factors that influence mobility, pain, functioning and disease prognosis in patients with adhesive capsulitis of the shoulder.

In November 2016 she started as a PhD candidate at the Department of Rehabilitation Medicine at Erasmus MC University Medical Center, Rotterdam and Rijndam Rehabilitation, Rotterdam. Her PhD involved the development of the ICF Core Sets for adults with cerebral palsy (CP), including four preparatory studies and an international consensus process, which were performed in close collaboration with the ICF Research Branch. In addition, she worked on a meta-analysis of individual participant data on blood pressure in adults with CP, in close collaboration with 11 investigators worldwide. She was also a member of the Cerebral Palsy Team of the Dutch Patient Organization CP Netherlands, in which she was committed to organizing activities and information days with adults with CP.

Currently, she is working as a researcher at the Academic Collaborative Center (ACC) Care for Older Adults of Tranzo, the scientific center for care and wellbeing of the Tilburg School of Social and Behavioral Sciences of Tilburg University. The focus of this research is on the consequences of restrictive measures because of the COVID-19 pandemic, on loneliness and social needs of residents, informal caregivers and volunteers in nursing homes.

List of publications

This thesis is based on the following international peer-reviewed publications

Noten S, Rodby-Bousquet E, Limsakul C, Tipchatyotin S, Visser F, Grootoonk A, Thorpe DE, van der Slot WMA, Selb M, Roebroeck ME. An international clinical perspective on functioning and disability in adults with cerebral palsy. Submitted

Noten S, Selb M, Troenosemito LAA, Thorpe DE, Rodby-Bousquet E, van der Slot WMA, Roebroeck ME. International consensus on ICF Core Sets for adults with cerebral palsy: A basis for standardized assessment of functioning. Submitted

Noten S, van den Berg-Emons RJG, Thorpe DE, Heyn PC, Marciniak CM, McPhee PG, Lamberts RP, Langerak NG, Verschuren O, Salokivi T, Morrison KM, Peterson MD, Limsakul C, Stam HJ, Papageorgiou G, Versmissen J, van der Slot WMA. Blood pressure in adults with cerebral palsy: a systematic review and meta-analysis of individual participant data. J Hypertens. [Epub 2021 Jun 7]

Noten S, Troenosemito LAA, Limsakul C, Selb M, de Groot V, Konijnenbelt M, Driessen DMF, Hilberink SR, Roebroeck ME, on behalf of ICF Core Set for adults with cerebral palsy study group. Development of an ICF Core Set for adults with cerebral palsy: capturing their perspective on functioning. Dev Med Child Neurol. 2021; 63(7):846-852.

Limsakul C, **Noten S**, Selb M, Stam HJ, van der Slot WMA, Roebroeck ME. Developing an ICF Core Set for adults with cerebral palsy: A global expert survey of relevant functions and contextual factors. J Rehabil Med. 2020; 52(4):jrm00049.

Benner JL*, **Noten S***, Limsakul C, Van Der Slot WMA, Stam HJ, Selb M, van den Berg-Emons RJG, Roebroeck ME. Outcomes in adults with cerebral palsy: systematic review using the International Classification of Functioning, Disability and Health. Dev Med Child Neurol. 2019; 61(10): 1153-1161. ***Joint first author**

Other international peer-reviewed publications by the author

van Gorp M, Hilberink SR, **Noten S**, Benner JL, Stam HJ, van der Slot WMA, Roebroeck ME. Epidemiology of cerebral palsy in adulthood: A systematic review and meta-analysis of the most frequently studied outcomes. Arch Phys Med Rehabil. 2020; 101(6): 1041-1052.

Mus-Peters CTR, Huisstede BMA, **Noten S**, Hitters MWMGC, van der Slot WMA, van den Berg-Emons RJG. Low bone mineral density in ambulatory persons with cerebral palsy? A systematic review. Disabil Rehabil. 2019; 41(20): 2392-2402.

Noten S, Struyf F, Lluch E, D'Hoore M, van Looveren E, Meeus M. Central pain processing in patients with shoulder pain: a review of the literature. Pain Pract. 2017; 17(2): 267-280.

Reijneveld EA, **Noten S**, Michener LA, Cools A, Struyf F. Clinical outcomes of a scapular-focused treatment approach in participants with shoulder pain: a systematic review. Br J Sports Med. 2017; 51(5): 436-441.

Noten S, Meeus M, Stassijns G, Van Glabbeek F, Verborgt O, Struyf F. Efficacy of different types of mobilization techniques in patients with primary adhesive capsulitis of the shoulder: a systematic review. Arch Phys Med Rehabil. 2016; 97(5): 815-825.

Meeus M, Nijs J, van Wilgen CP, **Noten S**, Goubert D, Huijnen I. Moving on to movement in patients with chronic joint pain. International Association for the Study of Pain: Clinical Updates, 2016; 24(1): 1-8.

Baert IA, Lluch E, Mulder T, Nijs J, **Noten S**, Meeus M. Does pre-surgical central modulation of pain influence outcome after total knee replacement? A systematic review. Osteoarthritis Cartilage. 2016; 24(2): 213-223.

Struyf F, Geraets J, **Noten S**, Meeus M, Nijs J. A multivariable prediction model for the chronification of non-traumatic shoulder pain: a systematic review. Pain Physician. 2016; 19(2): 1-10.

Coppieters I, Ickmans K, Cagnie B, Nijs J, De Pauw R, **Noten S**, Meeus M. Cognitive performance is related to central sensitization and health-related quality of life in patients with chronic whiplash-associated disorders and fibromyalgia. Pain Physician. 2015; 18(3): E389-401.

Struyf F, Lluch E, Falla D, Meeus M, **Noten S**, Nijs J. Influence of shoulder pain on muscle function: implications for the assessment and therapy of shoulder disorders. Eur J Appl Physiol. 2015; 115(2): 225-234.

IJmker T, **Noten S**, Lamoth CJ, Beek PJ, van der Woude LH, Houdijk H. Can external lateral stabilization reduce the energy cost of walking in persons with a lower limb amputation? Gait Posture. 2014; 40(4): 616-621.

Contributions to international conferences

Noten S, van der Slot WMA, Thorpe DE, Heyn PC, Marciniak CM, McPhee PG, Lamberts RP, Langerak NG, Verschuren O, Salokivi T, Morrison K, Papageorgiou G, vd Berg-Emons HJG**.** Determining blood pressure levels in adults with cerebral palsy: a systematic review and meta-analysis of individual participant data. Oral presentation at 74th AACPDM Annual Meeting, New Orleans, Louisiana, USA (virtual). September 23-26, 2020.

Noten S, Rodby-Bousquet E, Limsakul C, Visser F, Tipchatyotin S, de Groot V, Grootoonk A, Konijnenbelt M, Meuzelaar- Kiezebrink FEM, van der Slot WMA, van den Berg-Emons HJG, Selb M, Roebroeck ME. An international clinical study on impairments and disability in adults with cerebral palsy as a base for developing an ICF Core Set. Oral presentation at 74th AACPDM Annual Meeting, New Orleans, Louisiana, USA (virtual). September 23-26, 2020.

Noten S, Benner JL, Limsakul C, Van Der Slot WMA, Stam HJ, Selb M, van den Berg-Emons RJG, Roebroeck ME. A state-of-science on adults with cerebral palsy as a base for developing an ICF Core Set. Oral presentation at Combined 73rd AACPDM Annual and 2nd IAACD Triannual Meeting, Anaheim, California, USA. September 18-21, 2019.

Noten S, Troenosemito LAA, Selb M, de Groot V, Konijnenbelt M, Driessen DMF, van Eeghen AM, Stam HJ, van den Berg-Emons HJG, Hilberink SR, Roebroeck ME. Developing an ICF Core Set for adults with CP: Which areas of functioning do these adults consider important? Poster presentation at Combined 73rd AACPDM Annual and 2nd IAACD Triannual Meeting, Anaheim, California, USA. September 18-21, 2019.

Noten S, Benner JL, Limsakul C, Van Der Slot WMA, Stam HJ, Selb M, van den Berg-Emons RJG, Roebroeck ME. Developing an ICF Core set for adults with cerebral palsy. Oral presentation at 31st EACD Annual Meeting ‘Innovation for participation’, Paris, France, May 23-25, 2019

Noten S, Benner JL, Limsakul C, Van Der Slot WMA, Stam HJ, Selb M, van den Berg-Emons RJG, Roebroeck ME. Developing an ICF Core set for adults with cerebral palsy: study design and preliminary results. Poster presentation at the 3rd International symposium – ICF Education, Hamburg, Germany. April 13, 2018

Awards

Nominated for Gayle G. Arnold Award, AACPDM 2020: **Noten S**, Rodby-Bousquet E, Limsakul C, Visser F, Tipchatyotin S, de Groot V, Grootoonk A, Konijnenbelt M, Meuzelaar-Kiezebrink FEM, van der Slot WMA, van den Berg-Emons HJG, Selb M, Roebroeck ME. An international clinical study on impairments and disability in adults with cerebral palsy as a base for developing an ICF Core Set.

AACPDM Student Travel Scholarship, AACPDM 2019

PhD Portfolio

Summary of PhD training and teaching activities

Name PhD student: Suzie Noten	PhD period: 2016-2020
Erasmus MC Department: Rehabilitation Medicine	Promotor: Prof. Dr. H.J. Stam
Research School: NIHES	Supervisors: Dr. H.J.G. van den Berg-Emons, Dr. W.M.A. van der Slot, Dr. M.E. Roebroeck

1. PhD training	**Year**	**Workload Hours (ECTS)**
General courses		
Systematic literature search (Endnote, Pubmed and other databases), Medical library, Erasmus MC, Rotterdam	2017	28 (1)
Research Integrity, Erasmus MC, Rotterdam	2017	8 (0,3)
BROK Course ('Basiscursus Regelgeving Klinisch Onderzoek'), NFU	2017	30 (1,1)
CPO Course Patient Oriented Research: design, conduct and analysis, Erasmus MC, Rotterdam	2018	8 (0,3)
English Biomedical Writing and Communication, Erasmus MC, Rotterdam	2019	84 (3)
Specific courses		
EpidM V30 Regressietechnieken	2018	42 (1,5)
Seminars and workshops		
Lezing 'Ouder worden met CP' – Wilma van der Slot, Merem, Hilversum	2017	3 (0,1)
Symposium 'Impact van cerebrale parese op volwassen leeftijd', Rijndam Revalidatie, locatie Westersingel, Rotterdam	2018	8 (0,3)
VvBN PhD day, Erasmus MC, Rotterdam	2017	8 (0,3)
VvBN Symposium 'Move around', Utrecht	2018	8 (0,3)
VvBN Symposium 'Super Human', Utrecht	2019	8 (0,3)
VvBN Symposium 'COVID-19 en bewegen', Utrecht (virtual)	2020	8 (0,3)
Symposium BOSK, Utrecht	2017	8 (0,3)
Symposium BOSK, Utrecht	2018	8 (0,3)
Symposium CP Nederland (voorheen BOSK), Utrecht	2019	8 (0,3)
Postdoc Network Erasmus MC Workshop 'Negotiation'	2018	4 (0,1)
VENA workshop 'Succesvol zichtbaar worden'. Persoonlijk profileren door onzichtbare beïnvloeding. Zabeth van Veen, Imagomatch, Rotterdam	2019	2,5 (0,1)
VENA workshop 'De magie van communicatie'. Rik Rottier, Speech Republic, Rotterdam	2020	2,5 (0,1)
Presentations		
Poster presentation: 3rd International symposium ICF Education, Hamburg, Germany - ICF Core set design and preliminary results	2018	8 (0,3)

	Year	Workload Hours (ECTS)
Oral presentation: 31st EACD Annual Meeting 'Innovation for participation', Paris, France - ICF Core set design and preliminary results	2019	10 (0,4)
Oral presentation: Combined 73rd AACPDM Annual and 2nd IAACD Triannual Meeting, Anaheim, California, USA – ICF Core set: systematic review	2019	10 (0,4)
Poster presentation: Combined 73rd AACPDM Annual and 2nd IAACD Triannual Meeting, Anaheim, California, USA – ICF Core set: qualitative study	2019	8 (0,3)
Oral presentation: 74th AACPDM Annual Meeting, New Orleans, Louisiana, USA (virtual) – ICF Core Set: empirical study	2020	10 (0,4)
Oral presentation: 74th AACPDM Annual Meeting, New Orleans, Louisiana, USA (virtual) – Blood pressure	2020	10 (0,4)
Oral presentation: webinar Indian Academy of CP – ICF Core Set	2021	10 (0,4)
Oral presentations: several topics. Research meetings department of Rehabilitation Medicine, Erasmus MC, Rotterdam	2017-2020	28 (1)
Conferences		
29th EACD Conference, Amsterdam (volunteer)	2017	28 (1)
3rd International symposium ICF Education, Hamburg, Germany	2018	28 (1)
31st EACD Conference, Paris, France	2019	28 (1)
Combined 73rd AACPDM Annual and 2nd IAACD Triannual Meeting, Anaheim, California, USA	2019	28 (1)
74th AACPDM Annual Meeting, New Orleans, Louisiana, USA (virtual)	2020	28 (1)
Other		
Organizing member VvBN PhD day Human movement sciences, Erasmus MC, Rotterdam	2017	10 (0,4)
Organizing Symposium BOSK / CP Nederland	2017-2019	60 (2,1)
Organizing VvBN Symposium	2018-2020	30 (1,1)
Participating in weekly research meetings department of Rehabilitation Medicine, Erasmus MC, Rotterdam	2016-2020	160 (6)
2. Teaching		
Lecturing		
Minor Rehabilitation Medicine for medical students – Blood pressure	2019	10 (0,4)
Minor Rehabilitation Medicine for medical students – Blood pressure	2020	10 (0,4)
Supervising Master's theses		
Supervising master thesis in Medicine (1 student)	2018-2019	28 (1)
Other		
Supervising internship Bachelor students HBO Physical Therapy (4 students)	2018	10 (0,4)
Supervising internship Bachelor students HBO Nursing (2 students)	2018	10 (0,4)
Supervising internship MD in residency (1 student)	2018-2020	14 (0,5)
TOTAL		852 (31,3)