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# Comparing Neurophysiological Methods to Functional Therapy in Treatment of Cerebral Palsy from Newborn to Adolescents

A literary review

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## Abstract:

**Title:**

Comparing Neurophysiological Methods to Functional Therapy in Treatment of Cerebral Palsy from Newborn to Adolescents

**Investigative questions:**

What are the scientifically proven advantages of Neurophysiological Methods and Functional therapy, respectively?

In what situations would one treatment approach be more beneficial than the others?

**Background:**

Cerebral palsy is the most prevalent of the chronic childhood motor disability disorders, with a prevalence of approximately 2 in every 1000 live born. Definitions and classifications have been varying for the last 150 years, leading to a great deal of confusion and controversy in this field of paediatric medicine, resulting in varying recommendations in terms of therapy. In complex cooperative therapy team is necessary in each individual, and in terms of physiotherapeutic treatment, two big and very distinct blocks of treatment philosophies are found, namely the Neurophysiologic Method and the Functional Therapy. Previously, no definite recommendations towards therapy has been provided, and many studies simply conclude that the field of cerebral palsy, despite centuries of attention, still lacks substantial parts of information to conclude with anything in particular. The purpose of this thesis is to evaluate and compare the Neurophysiological Methods to functional therapy in physiotherapeutic treatment of children with cerebral palsy.

**Methods:**

The thesis is a literary review, reviewing books, journals and articles retrieved in the period from autumn 2010 to spring 2012. Articles relating to the topic of the thesis have been searched for on the databases of PubMed, the Cochrane Library and BioMed Central.

**Conclusion:**

History has shown that any clear conclusions regarding the vast medical field of cerebral palsy has been hard to make. Even though this thesis also found that no overall recommendations were possible to extract to whether one approach served as more beneficial for the entire population of cerebral palsy, it serves to hypothesise several general guidelines, and offers recommendation for future research in the field.

Due to the nature of intervention, it is assumed that the Method of Reflex Locomotion by Vojta possesses clear advantages when treating preverbal children, children with cerebral palsy accompanied with learning disabilities (mental retardation, U.S. use) and with a high degree of motor impairment.

Bobath's approach were found to present good results in overall gross motor function, especially immediately after therapy intervention and particularly in shorter periods of high intensity treatment. The therapeutic window of improved bodily functions seen as an immediate result of Bobath therapy is believed to be an important factor that physiotherapists should take advantage of in planning treatment of children with cerebral palsy.

The group of functional therapy is demonstrating a good accomplishment of special functional goals. There consists conflicting evidence to whether achievements of these goals are beneficial towards attaining other, unpractised functional goals, despite the fact that an overall improvement of gross motor function is seen after intervention of functional therapy.

Major gaps are found in the contemporary research of cerebral palsy, and suggestions are made for further research. It is believed, based on findings in present research that no definite approach would benefit the whole population of children with cerebral palsy as a whole. The varying characterizations of the condition must be respected, and the individual child must be treated accordingly. It is also believed that no clear recommendations would be present even in the future, due to these factors. There is however an urgent need for future research in the field of cerebral palsy in order to optimize the current therapy regimen.

**Keywords:**

Cerebral Palsy, Treatment, Neurodevelopmental Therapy, Method of Reflex Locomotion by Vojta, Bobath Treatment, Functional Therapy

## Abstrakt:

**Název:**

Srovnání neurofyziologických metod s funkční terapií v léčbě dětské mozkové obrny od novorozenců po dospělé

**Hlavní otázky:**

Jaké jsou vědecky dokázané výhody neurofyziologických metod a funkční terapie?

V jakých situacích by byla jedna léčebná metoda lepší než ty ostatní?

**Výchozí informace:**

Mozková hybná porucha (dětská mozková obrna) je nejrozšířenější dětskou chronickou motorickou poruchou, jež postihuje přibližně 2 z 1000 novorozenců. Odlišující se definice a klasifikace v posledních 150 letech vedly k výrazným zmatkům a diskusím na poli pediatrické medicíny, což vyústilo v různá doporučení léčby. Ve spolupracujícím léčebném týmu je nutné, aby byly v každém jednotlivém případě, na základě fyzioterapeutické léčby, brány v potaz dva zásadní a výrazné typy léčby, tj. neurofyziologická metoda a funkční léčba. V minulosti nebyla k dispozici žádná určitá doporučení týkající se léčby a mnoho studií jednoduše došlo k závěru, že oblast dětské mozkové obrny, i přes staletí výzkumů, stále postrádá značné informace, jež by dopomohly dobrat se konkrétních závěrů. Účelem této práce je zhodnotit a porovnat neurofyziologické metody s funkční léčbou ve fyzioterapeutické léčbě dětí s mozkovou obrnou.

**Metody:**

Tato práce vychází z knižních zdrojů, studia knih, časopisů a článků v období podzimu 2010 až jara 2012. Články vztahující se k tématu práce byly vyhledány v databázi PubMed, Cochrane Library a BioMed Central.

**Závěr:**

Minulost ukázala, že bylo velice obtížné stanovit jakékoli jasné závěry vztahující se k rozsáhlé lékařské oblasti dětské mozkové obrny. I když tato práce mimo jiné objevila, že nebylo možné získat žádná celková doporučení, jestli jeden přístup byl přínosnější pro veškerou populaci s mozkovou obrnou než ty ostatní, slouží jako hypotéza několika obecných zásad a nabízí doporučení k budoucímu výzkumu v této oblasti.

S ohledem na podstatu intervence se předpokládá, že metoda reflexní lokomoce dle Vojty se vyznačuje jasnými výhodami při léčbě kojenců, dětí s mozkovou obrnou doprovázenou poruchami učení (mentální retardací) a vysokým stupněm motorického postižení.

Koncept neurovývojové terapie dle Bobatha přinesl dobré výsledky v celkové hrubé motorické funkci, obzvláště okamžitě po léčbě a především v kratších obdobích intenzivnější léčby. Terapeutické okno zlepšených tělesných funkcí, jakožto okamžitý výsledek Bobathovy

terapie, je považováno za důležitý faktor, že fyzioterapeuté by měli využít plánování léčby dětí s mozkovou obrnou.

Skupina funkční terapie ukazuje dobrý výsledek speciálních funkčních cílů. Sestává z rozdílných důkazů, zda výsledky těchto cílů jsou přínosné k získání dalších, nepraktikovaných funkčních cílů, přestože celkové zlepšení hrubé motorické funkce je viditelné až po zásahu funkční terapie.

V současném výzkumu dětské mozkové obrny se objevily velké mezery a byly stanoveny návrhy pro další výzkum. Je zřejmé, že na základě závěrů současného výzkumu neexistuje žádný určitý přístup, jenž by byl přínosný pro celou populaci dětí s mozkovou obrnou. Různící se charakteristiky okolností musejí být respektovány a každé dítě musí být takto léčeno. Je také zřejmé, že na základě těchto faktorů neexistují žádná jasná doporučení do budoucnosti. Avšak je více než nutné započít budoucí výzkum na poli dětské mozkové obrny pro optimalizaci současného léčebného režimu.

**Klíčová slova:**

Dětská Mozková Obrna, Léčba Neurovývojových Poruch, Metoda Reflexní Lokomoce dle Vojty, Koncept Neurovývojové Terapie dle Bobatha, Funkční terapie

## Declaration:

I hereby declare that the contents of this thesis are my own, individual work with knowledge attained from various books, journals, articles, consultations and seminars. Under no circumstances, has any work been copied, forged or changed. I also declare that I am by no means biased, as I have never received any training of any of the approaches dealt with in this thesis.

Prague, March 2012

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# I. Introduction

The phenomenon of cerebral palsy has been widely discussed ever since the early attempts of classification and diagnosis, some 150 years ago. The lack of any clear guidelines and definite descriptions have puzzled aetiologists, epidemiologists, researchers, physicians and other health care workers for decades. Despite the long history of investigations and scientific researches, new improvements in diagnostics, treatment and prevention are still done. This intriguing fact is the basis of the choice of topic in this thesis, in an attempt to further improve knowledge about the effects of treatment of this large group of severely impaired children. The problems attempted to be solved in this paper regards the physiotherapeutic interventions of the youngest age groups suffering from this often life limiting condition.

In general one could divide the physiotherapeutic procedures in two parts, namely the so-called neurodevelopmental procedures aiming to increase the functional base, and the functional therapy aiming to increase the functionality of the already existing base. In other words, the neurophysiological methods aims to increase the quality of the movement repertoire, whereas the functional therapy approach are more interested in achievement of functional goals, regardless of the execution. Both procedures are undoubtedly effective, but little information exists in regards to what situations the different applications are more useful. In order to compare the groups, a definition of a successful therapy has to be mentioned. In this comparison the successfulness of therapy is judged after the criterions that increase the child's overall state, meaning increasing quality of life by means of a higher individuality, functionality, and decreasing pain and physical obstacles in everyday life. According to today's view, the function of the child within a family unit is also emphasized.

Rather than concluding with one method being better than the other, it would be more useful, in this case to compare the strengths and weaknesses/advantages and disadvantages using the different therapeutic measures in different stages of the therapy and according to the progression of unwanted symptoms.

A wide range of different definitions, classification systems and inclusion and exclusion criteria has been offered in connection with this condition, causing difficulties in researching this topic. However, as the question of interest in this thesis was not based on the definitions and classifications the paper was not suffering, despite this fact.

Despite this, it was felt necessary to clarify certain areas that have been known to cause quite a bit of confusion in the literature. In this thesis is based on the definition compiled by an executive committee in April 2004. This is now widely recognised as the most descriptive description as for today and states:

*"Cerebral palsy (CP) describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to nonprogressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication, and behaviour, by epilepsy, and by secondary musculoskeletal problems."* (1 p. 9)

Further on a sub-categorization based on the type of motor deficit is chosen. This subdivision includes the subgroups of *spastic, ataxic, athetoid/dyskinetic* and *hypotonic* forms of cerebral palsy. This has been evaluated to be the best way of dividing in to specific sub-categorization, from a physiotherapeutic point of view (2) (3).

## II. Objectives and research methods

Investigative questions:

What are the scientifically proven advantages of Neurophysiological Methods and Functional therapy, respectively?

In what situations would one treatment approach be more beneficial than the others?

Inclusion criteria:

- Research performed in Europe, Australia or Northern America
- Journals, articles and books published in Europe, Australia or Northern America
- Journals and articles under medical field of Physiotherapy, Paediatrics or Neurology
- Researches performed on a population from 0-20 years of age
- Physiotherapeutic approach on chosen therapy

Exclusion criteria:

- Studies and articles where cerebral palsy was not the primary diagnosis
- Research performed on adult population (above 20 years of age)
- Research with pharmacological intervention
- Research with orthopaedic or surgical intervention

In order to come to any conclusions, a literary review has been chosen as a research method. Based on the inclusion and exclusion criteria mentioned above, the work on this thesis lasted from autumn 2010 to spring 2012, and all data was collected in this time period.

The first part of the thesis involves a general description of the concept of cerebral palsy with definitions and sub-categories used. Even though this does not exactly correspond with the aim of the thesis itself, it is important as an introduction to the topic, especially since the great variation of terms and definitions used in the study literature. It would also help to further understand the complex condition of cerebral palsy, and is felt necessary in order to draw any conclusions, that could be made evaluating the nature and characterization of cerebral palsy. It was also done in respect of the priceless and without doubt crucially important research preformed within the area for the last one and a half century, which without, little would be known about the subject.

The second part is devoted to the different assessment methods used in order to plan treatment and to predict the future possible state of the child. The assessments included are tools often used in cerebral palsy research, and the ones that are widely used in available literature. It is also attempted to include those assessment measures that include testing of motor development, preferably in children with cerebral palsy. An introduction to a traditional evaluation of infants, based on motor development and infant reflexes, also seemed necessary, as it plays an important part in paediatric neurology assessment.

The third, part of the thesis deals with the therapeutic interventions chosen, with an emphasis on the effects of neurophysiological, and functional approaches. Due to global and local popularity approaches according to the philosophies of Bobath and Vojta has been chosen respectively, for the neurophysiological approaches. The functional therapy is defined by what is believed to be common consensus by advocates of the approach, and is defined as: *The approach should emphasise the active promotion of functional skills in a familiar environment which is meaningful to the child and the parents. The desired outcome of therapy is the achievement of a set of pre-determined functional goals through repetitive practice with the child being the active problem-solver and the therapist as a facilitator.*

The remaining of the thesis deals with the scientific evidence available to the area of cerebral palsy. It is listed and explained in the chapter named “Results” and compared and discussed in the chapter of “Discussion”. The latter is also the basis for the “Conclusion”, and together they should be regarded as the most important parts of the thesis.

At the very back of the thesis, a list of appendixes is attached, and the respective appendix is referred to in the text.

# 1. Cerebral Palsy

## 1.1. Introduction

A clear and concise definition of cerebral palsy has been proven hard to set, due to the complexity of the condition, and attribution of other neurological damages. The term "Cerebral Palsies" were first described 150 years ago, but discussions have been made regarding which symptoms and pathology should be taken into consideration when describing the term (4), ever since. The condition itself is believed to be recognized for much longer. Ancient Egyptian monuments and figures are formed in a way that gives signs that the disease was known already at that period of time (5). Although several scientists tried to explain the correlation between cerebral atrophy and congenital paralysis in the early 19th century (4) (5), it was not before the English surgeon William Little concluded with the correlation of joint contractures and deformities resulting from long-standing spasticity and paralysis. These are the earliest traces of what we today know as cerebral palsy. In his work Little clearly stated that the cause of spasticity and paralysis was often damage to the brain during infancy, and especially in cases of preterm birth and perinatal asphyxia. (4) Little then stated: "*...in many instances the spasmodic affection is produced at the moment of birth or within a few hours or days of that event... The subjects were born at the seventh month, or prior to the end of the eighth month of utero gestation. In two cases the birth occurred at the full period of gestation, but owing to the difficulty and slowness of parturition the individuals were born in a state of asphyxia, resuscitation having been obtained, at the expiration of two and four hours, through the preserving efforts of the acoucheurs* [sic]" (5 p. 5). Following these statements the modern concepts of cerebral palsy is widely based on his discoveries, and even though different scientists at the same time had many of the same discoveries, cerebral palsy was previously also known as Little's disease (6), as a homage to the person who first gave in an adequate description, a description that has since then been heavily debated.

In the late 19th century, the first attempt of a classification of cerebral palsy based merely on clinical findings was started. It was made by a young Sigmund Freud (5), and although he had a background in neuropathology, he insisted in only using clinical findings in classification and diagnosing cerebral palsy on the background that the body's own repair mechanism would hamper a classification based on the initial lesion (4). He then suggested that the cause of cerebral palsy was of prenatal origin and that a difficult birth, in some cases, was only to be

looked upon as a symptom that influences the development of the foetus. (7). Sigmund Freud later lost interest in the field of cerebral palsy, and later developed his theory of psychoanalysis.

Based on aforementioned Little's philosophy of the progression of the condition, a U.K. based group, known as "the Little Club", formed a definition to match the simplicity of his theory, stating that: *"Cerebral palsy is a permanent but not unchanging disorder of movement and posture appearing in the early years of life and due to a non-progressive disorder of the brain, the result of interference during its development"* (8 p. 27). This definition met a lot of criticism, especially because it attempted to subdivide different groups leading to a necessity to change between the groups as the symptoms of the disease progressed (4). A revised definition was therefore offered by the existing members of the Little group stating: *"Cerebral Palsy is a disorder of posture and movement due to a defect or lesion of the immature brain"* (9 p. 295) and for practical purposes disorders of short duration, due to progressive disease or due solely to mental deficiency were excluded. This definition was frequently used in the following years, leading to a further revision in an attempt create a single internationally accepted definition by an international multidisciplinary group in 2004, updating the definition to recognize that the key motor deficit is often accompanied by other neurological impairments (4), which later has served as the closest thing to an universally accepted definition to the concept of cerebral palsy, and is described into more details at the end of this chapter.

Over the following years a lot of researchers investigated further into cerebral palsy, and tried to divide it into several subgroups based on, among others, clinical description, aetiology , pathology, mental and physical ability, anatomical site of the brain lesion, degree of muscle tone, topography, therapeutic requirement, severity of the disease and epidemiology (4). The main problem was dividing it into several subgroups did not offer a clear definition of the condition, and the classification did not give clear universal inclusion and exclusion criteria used for diagnostic and therapeutic purposes. Based on the available information at the time the first global definition was attempted as following: "*Cerebral palsy is a symptom complex arising from non-progressive brain lesion.* " (10 p. 841)

As this definition did not take into consideration the heterogeneity of the condition a further revised definition that underlined the previous one was performed from 1987-1990 (4) stating that: "....*Cerebral palsy is an umbrella term covering a group of non-progressive, but often*

*changing, motor impairment syndromes secondary to lesions or abnormalities of the brain arising in the early stages of development."* (11 p. 547)

Following this last attempted definition the Surveillance of Cerebral Palsy in Europe (SCPE) made standardized diagnostic tools in order to properly diagnose children with cerebral palsy. Their definition was largely based on the definition stated by Mutch et al., and included 5 key-points (4).

1. An umbrella term
2. Is permanent and not changing
3. Involves a disorder of movement and/or posture and motor functions
4. Is due to a non-progressive interference, lesion, or abnormality
5. The interference, lesion, or abnormality is in the immature brain.

As a result of over 150 years of discussions, debates and arguments, a single, universal definition accepted by scientists and health-care workers worldwide does not yet exist. In this thesis the updated definition by Bax et al., and later revised and explained by an Executive Committee in April 2006; "with the intent of providing a common conceptualization of CP for use by a broad international audience" (1 pp. 1,), is taken into consideration along with the five [5] key points set by SCPE based on the aforementioned definition for simplification purposes.

*"Cerebral palsy (CP) describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to nonprogressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication, and behaviour, by epilepsy, and by secondary musculoskeletal problems."* (1 p. 9)

It is also important to note that saying that a child has cerebral palsy simply concludes that there is a motor impairment from a static brain lesion, and says nothing about the aetiology of the condition. That is why some authors refer to the conditions in the plural form of cerebral palsies (2). The term "Cerebral Palsy" would be used exclusively in all cases throughout this thesis.

## 1.2. Epidemiology

Because the wide range of different causes and varying definitions, sub-categories and exclusion/inclusion criteria, as discussed in the previous chapter, the results found in various epidemiological researches vary to a certain degree, and any exact conclusion is hard to draw. Reasons for these slight differences might be varying standard of health care, difficulties in discovering mild cases, and different interpretations of definitions. In a research article compiled Odding et al., states that: *"It must be concluded that an important aspect of scientific knowledge about CP is missing in rehabilitation literature",* (12 p. 183) when discussing the epidemiology of cerebral palsy. With that kept in mind, clear indications suggest that the prevalence of the condition is remarkably similar worldwide with the differences explained by a faulty counting and different interpretations of exclusion and inclusion criteria (2). Based on the findings, an estimated prevalence of cerebral palsy is believed to be around 2 in every 1000 live births (2) (4) (7) (12), with a slight lower prevalence in China, compared to Europe and America (2). This makes it the most prevalent of the chronic childhood motor disability disorders (13).

Following the classification made by SCPE in the late 1990's prevalence rates for six European countries were published, showing a prevalence of below 2 per 1000 live births in the 1970's to a prevalence above 2 per 1000 live births in the 1990's in the participating European nations (12), but in this case it is important to keep in mind the different definitions in the diagnostics and the progression of the paediatrics medical care during the latter part of last century, together with the believed increase in general health care to the vast majority of the population, during the same time span. Another interesting finding in this period of time is that even though the overall total prevalence of liveborns with cerebral palsy has remained more or less stable over the past 4 decades, a remarkable increase of surviving newborns with low and very low birthweight leading to cerebral palsy has been found (14). This leads to another notable and usual finding in recent literature, suggesting a higher prevalence of cerebral palsy in preterm births accompanied by a low birthweight. (12) (15) (16). A Swedish research made on 241 children diagnosed with cerebral palsy indicates that 36% were born at a gestational age (GA) of less than 28 weeks. Detailed information extracted even showed a 25% prevalence of births of 28-32 weeks of GA, 2.5% of 32-38 weeks of GA, and 28.5% of non-preterm births (15). The relatively high percentage of cerebral palsy among term infants found in this study must be seen in connection with the higher prevalence of term deliveries

among the 241 infants included in the investigation. Joseph et al. (17) compared two large population based studies leaving no doubt. With a GA of less than 28 weeks the ratio was 63.9 per 1000 liveborns, with the ratio of liveborns with a GA of more than 37 weeks were 0.9 per 1000 (17) as opposed to the collected ratio of 2:1000.

A large, population based study from Norway aids further interesting data regarding the length of GA and prevalence of cerebral palsy. It shows that children born after 40 weeks of GA have the lowest prevalence of cerebral palsy with 0.99 per 1000 liveborns. Children born with 41, 42 and 43 weeks of GA show a gradual increase of prevalence with 1.08, 1.36 and 1.44 per 1000 liveborns respectively (18).

When considering birth weight, research indicates that newborns weighing less than 2500 grams at birth constitute 50 % of all causes of cerebral palsy (12). Several studies conclude with a higher prevalence of cerebral palsy among low birthweight children, compared to normal birthweight children (12). Studies have been made to compare normal birthweight (NBW $\geq$2500 g), low birthweight (LBW 1500-2499 g) and very low birthweight (VLBW $\leq$ 1500 g). The group of liveborns with a birthweight below 2500 g (LBW and VLBW) shows a prevalence of 16.85 per 1000 liveborns. The collected, overall prevalence of cerebral palsy in this study was 2.51 per 1000 births, leaving the prevalence of NBW to 1.55 per 1000 births. If we look into more detail, it shows a higher prevalence of newborns with very low birthweight, 57.45 per 1000 liveborns, than newborns with low birthweight, 10.77 per 1000 liveborns, in this UK based study (19). An increase of prevalence of cerebral palsy with VLBW rose from 29.8 per 1000 liveborns in 1964 to 74.2 per 1000 liveborns in 1993 and the incidence of neonatal survivors rose from 3.9 to 11.5 per 1000 in the group of children with LBW within the same time span (12), indicating, among other things, an increase of neonatal care in this period of time. Contributing to the tendency of a better neonatal care is manifested by several sources suggesting a shift toward diplegia and spastic quadriplegia and away from hemiplegia and athetosis in the period from the 1970's to the 1990's (2) (12). Explanations for this shift slightly increased prevalence is increased medical care and attention including better obstetric care and a higher survival rate of preterm births (12).

A higher incidence of an increased or decreased maternal age is also present. Children born to mothers with a maternal age of 12-19, or 35+ have an increased chance of developing cerebral palsy (20). Multiple births are known to increase the incidence-rate of cerebral palsy (2) (7),

with a prevalence per pregnancy for singles at 0.2%, twins 1.5%, triplets 8.0%, and quadruplets 43% (2) (3).

It is also found that an increased prevalence with a lower social and social-economic class in researches made on epidemiological studies in Great Britain and in the US (3) (12). In the American study 54,000 pregnant women from 12 urban teaching hospitals were studied between 1959 and 1966. Among the 38,533 children born, 202 met the criteria of cerebral palsy, or a ratio of 5.2:1000 children, as opposed to around 2:1000 in the general population (3). Patients in these urban areas, attending the teaching hospital, had a lower socio-economic status (SES) than the average population. Great controversy arises when comparing correlation between a socio-economic gradient and the incidence rate of cerebral palsy. A large population based study from Sweden compiled by Hjern et al. (20) adds important information in this epidemiologic field, and backs the findings in the British and American researches. It concluded with a higher rate of incidence of cerebral palsy in rural districts compared to other metropolitan or urban areas. Children born with a lower maternal SES had a significant higher rate of incidence compared to mothers classified to have a higher SES. The same tendency was found, as expected, with a lower level of maternal education. It also concluded with a significant increase of cerebral palsy in children born into families that received social welfare (20), but the research does not conclude whether the family was receiving social welfare prior to the delivery of a child with cerebral palsy, or if the change of occupational status was as a result of the new family situation.

Boys have a higher ratio of cerebral palsy collectively, with a boy to girl ration of 2.05:1.50 per 1000 liveborns (20). Findings also conclude with higher incidence for cerebral palsy in births in the summer months (12), explained by the effect of infectious agents, which may vary seasonally.

All these factors discussed above offers important information, and could be used in planning therapy, but also to a certain degree prevent the prevalence where intervention is possible.

### 1.3. Aetiology and risk factors

When discussing the term of aetiology in cerebral palsy, it is important to keep in mind that the definition of cerebral palsy stating that it is an umbrella term based on clinical signs, and that diagnosing a child with cerebral palsy is only indicating some form of motor impairment and does not take the aetiology into consideration (2) (21). In other words, determining the aetiology does not help the actual management of treatment of the impairment as the original cause of development of the condition does not matter (2).

In many cases of cerebral palsy, only the risk factors of the prenatal, perinatal or postnatal period can be identified, and in most cases, there are more than one causative factor leading to the condition (5). This distinct classification was offered already in the late 19$^{th}$ century, by Sigmund Freud, when he distinguished three separate groups of causal factors as [1] maternal or idiopathic congenital; [2] perinatal causes; and [3] post-natal causes (4). Aetiology is however of great importance when diagnosing and for a prognosis, in order to determine whether the child is following the expected course of maturation and development, and it aids with important information to parents crucial for future pregnancies (2). It is even said to help with reducing parental guilt (22). The therapist should however, in all cases, be familiar with the child's medical history, if data are available. It is also important to pay attention to the fact that not all cases of cerebral palsy have any clear aetiology. Different researches have been made on this particular field, and figures of cerebral palsy without any specific, identifiable, aetiological cause vary between 42-44% (5).

Even though any exact aetiological data have proven to be hard to extract, figures roughly suggest that 30% of cases of cerebral palsy are associated with brain malformation, 40% with prematurity, 20 % with neonatal encaphalopathies, and 10% of different postnatal causes (22). Another way to categorize the aetiology suggest prenatal events to be responsible for 75% of the cases, perinatal causes 6-8% and postnatal causes are thought to be responsible for the remaining 10-18% of the cases (3). Yet again other sources estimate the percentage of prenatal events to constitute for 70-80 % of the cases (23), and postnatal causes to 10-25% of the cases (2).

In general, the overall most prevalent risk factors for cerebral palsy include; low birthweight, intrauterine infections and multiple gestation (12). Having said that, it is important to mention that according to research, 60 % of children diagnosed with cerebral palsy were not classified

as having an especially high risk profile, and 97% of children classified with a high risk profile were never diagnosed with cerebral palsy (24).

As mentioned previously risk factors are some of the key components used in order to determine the aetiology of the motor impairment seen in cerebral palsy. With respect to what is already mentioned previously, it is necessary to look into the specific risk factors connected with cerebral palsy. For simplification I have chosen to divide these risk factors in 3 separate groups, namely the prenatal, perinatal, and postnatal period. It is important to keep in mind that several risk factors coincide, increasing the possibility of the incidence of cerebral palsy.

The prenatal period

From the prenatal period the maternal factors are obviously proven to be of great importance when discussing the subject of cerebral palsy. If the mother has irregularities of the menstrual cycle, such as delayed onset of menstruation, irregular menstruation, or long intermenstrual intervals, it is believed to increase the chances of cerebral palsy. If the mother's intervals between pregnancies are either abnormally short or abnormally long, if she has a parity of three or more, or has experiences with three or more miscarriages, the risk of cerebral palsy is increased (3). Maternal risk factors during the pregnancies could also be drug and alcohol abuse, learning disabilities (mental retardation U.S. use), hyperthyroidism, epilepsy, or congenital infections in the $1^{st}$ or $2^{nd}$ trimester, such as herpes simplex, toxoplasma gondii, rubella or cytomegalovirus (3) (5).

Other prenatal risk factors include maternal use of other tetratogenic agents, maternal iodine deficiency, and a vascular event, such as hypoxia, ischemia and thrombosis, especially in middle cerebral artery (3) (5). Conditions such as pre-eclampsia and poor intrauterine growth are also considered as major risk factors during the pregnancy (3).

Paternal causes such as advanced age, and motor deficits in one or more siblings also increase the prevalence of cerebral palsy (3).

Other prenatal risk factors include chorioamnionitis, which is seen in 50% of women delivering prematurely (23). Intrauterine infections are the most important risk factor of cerebral palsy in VLBW infants (12), and are also a strong risk factor in full term infants with NBW (23).

The perinatal period

In the perinatal period, the moment of delivery is of great importance. If complications occur, such as an obstructed labour, antepartum haemorrhage or an umbilical cord prolaps, the neonate might develop neonatal encephalopathy, which greatly increases the risk of cerebral palsy (3). Other risk factors in the perinatal period occur of a premature birth, CNS infections, hypoglycaemia, untreated jaundice, and neonatal stroke of the middle cerebral artery (3) (5). One of the most common risk factors of cerebral palsy in this period is excessive neonatal anoxia or asphyxia (3) (5) (16). This would instantly lead to a decreased oxygen level of the circulation, causing a brain lesion due to hypoxic-ischemic encephalopathy. Other risk factors thought to trigger a cytokine cascade resulting in damage to the developing brain are death of co-twin, placental abruption and cerebral ischemia (12).

The postnatal period

The postnatal period includes the documented cases occurring after the neonatal period where the child is thought to be developing normally before the event, and includes incidences such as near-drowning accidents, encephalitis and complications after surgery (25). In developed countries postnatal infections are believed to be responsible for most cases of cerebral palsy in the post natal period (26). Even though the postnatal risk factors make up the smallest group of risk factors, they are important due to the fact that these are the easiest to prevent (27).

Metabolic encephalopathy is one of the major risk factors of cerebral palsy in the postnatal period, together with infections, such as meningitis, septicaemia and malaria, especially in developing countries (3). The prevalence of cerebral palsy is 3 times higher in term infants with encephalopathy with an additional birth defect, than of those with encephalopathy with no additional birth defects (12). Injuries such as hypoxia due to a near-drowning incidence or other types of suffocation, cardiac arrest or child abuse such as “shaken baby syndrome”, or a blunt trauma leading to a skull fracture are also among the risk factors of the postnatal period (2) (3) (5).

### 1.4. Classification of subgroups of Cerebral Palsy

Similar to the definition of cerebral palsy, a classification of the condition has been discussed since scientists first caught interest of the topic in the early 19th century, with different attempts to classify the several manifestations of the impairment. Through history several prominent people have concluded with the difficulties in such a task, with Bax stating that: "*It is impossible to proceed definitely with classifying cerebral palsy* (9 p. 295), and Sigmund Freud concluding that the task of separating congenital from acquired causes impossible, and sometimes even unhelpful (4). The last statement has later been challenged by the technological development of precise diagnostic measures, such as ultrasound and MRI. It has been estimated that 70-90% of all infants diagnosed with cerebral palsy has some kind of brain abnormalities found in MRI scans (3).

The first attempt to make any concrete classification followed William Little's very first definition of cerebral palsy in 1843, acknowledged as the first scientific definition of cerebral palsy. Little compared the clinical presentation and the birth history of a large portion of his patients, and grouped the clinical presentations found to match his newly formed definition of cerebral palsy as either [1] hemiplegic rigidity affecting one side only, although a lesser impairment of the uninvolved limb was often seen, [2] paraplegia affecting lower extremities more than the upper extremities, and [3] generalized rigidity (4).

At the end of the 19th century, further discussions regarding the classifications of cerebral palsy arose. On one side a group of scientists, lead by Sachs and Peterson, stated that a classification should include special reference to the pathology of the disease. This was based on post-mortem examinations of selected specimens to determine the aetiology of the condition, and simply concluded that in Little's classification, all three groups could be a result of a variety of causes, and thereby considering the classification as useless. Saying so, they did not construct any other classification system to back up their statement. On the other side a young Sigmund Freund dismissed the theory by Sachs and Peterson, with the explanation that in a post-mortem examination the findings would not be purely related to the clinical presentation of the cerebral palsy itself, as the findings would most likely be a result of the initial lesion, and the repair process later in life, making such post mortem examination useless and misleading. Instead he wanted a classification system based merely on clinical findings. His classification was simple and included the term diplegia for the previous categorized bilateral disorders, and hemiplegia for unilateral disorders. He even identified

three separate groups of causative factors as maternal and idiopathic congenital, perinatal causes, and post natal causes, but said it was difficult to determine whether later problems resulted from birth trauma, or whether it in fact were predisposing factors that may have caused these infants to have a difficult birth (4).

In the 1920's another view of the classification system was published, this time by the American orthopaedic surgeon Winthrop Phelps. Despite his profession he was conservative with the approach of surgery as the cornerstone of treatment and wanted a classification based on a functional basis, including both mental and physical abilities. As a result of this he completed a classification system where he grouped all movement disorders under the term dyskinesia with sub-categories grouped into spasticity, athetosis, overflow or synkinesia, incoordination or ataxia, and tremor (4). Even though he made a distinct separation classified in five sub-categories he noted that these varieties rarely manifested themselves in a pure form. This was the first classification made, similar to the most frequently used in today's practice.

Despite the numerous attempts of classifying cerebral palsy for about 100 years, great confusion persisted regarding the subject in the 1940's and 1950's. Myer Perlstein then developed a system classifying children according to anatomical site of the brain lesion, clinical symptoms, degree of muscle tone, severity of involvement, and aetiology. This system was later backed by Minear, based on a survey of the members of the American Academy of Cerebral Palsy in 1953. Minear classified the impairment as a listing of the clinical symptoms with categories for motor impairment, topography, aetiology, neuro-anatomical factors, functional capacity and therapeutic requirements. A similar system was also developed in the UK, by Evans, Asher and Schonell (4).

Later on in the 1950's the aforementioned Little Club classified cerebral palsy by use of the term spastic, with subcategories of hemiplegia, double hemiplegia, and diplegia, accompanied by 5 other categories, namely dystonic, choreo-athetoid, mixed, ataxic and atonic (4), which is a basis for the categorization used later in this thesis. However, at that time the term spastic was used inconsistent throughout various countries, leading to the group concluding with that it is impossible to proceed definitively with classifying cerebral palsy (4) (9)

Due to the urgent need of a global classification system in the late 1980's for epidemiological purposes, Evans developed a system that gained a lot of popularity due to its simplicity. He

categorized cerebral palsy after recorded details of central motor deficits in terms of the neurological type to hypotonia, hypertonia (including stiffness, spasticity, and rigidity) dyskinesia and ataxia. He then subdivided the groups according to where the impairments were prominent, with details for each limb, head and neck separately (4). In many ways this system is similar to the one developed by members of the Little Club some decades previously, but it has excluded some of the groups, and it is especially important to note that the mixed group is removed, and rather compensated by descriptions of multiple groups when needed, leading to a better description in each individual case. This, however, was likely to cause confusion in epidemiologic researches.

As for the definition of cerebral palsy, there still is no universally accepted method of classifying cerebral palsy. The following list of sub-groups are based on work by the Little group (8), and by Evans (28), and seems to be the most used classification in terms of sub-groups of cerebral palsy. This classification of type of motor disorder with attribution of a description of anatomical distribution is thought to be the best way of classifying from a physiotherapeutic point of view (2) (3), and is believed to be the classification system most frequently used in publications included in the inclusion criteria for this thesis. Such an anatomical classification includes the forms of spastic type, ataxic type, atheoid/dyskinetic type, and hypotonic type of cerebral palsy, which will be described into further detail in the following chapters. The mixed group is left out, even though the occurrence of more than one sub-group in a single individual is respected. In those cases, the predominant sub-group prevails. The explanation on the following pages serves to describe the characterizations of the different subtypes of cerebral palsy, hence a separate description of the mixed form of cerebral palsy seems unnecessary.

Common for all these different classifications is the subdivision of which part of the body is being affected. This topographic classification is believed to be useful in order to further classify the different sub-groups of cerebral palsy. Diplegia describes the cases where both extremities are involved symmetrical, with the primary involvement of the lower extremities, even though affection of the upper extremities might occur (2) (3) (5) (29). Hemiplegia describes children with involvement of half the body, with one arm and one leg on the same side being affected (2) (3) (29). At last quadriplegia, sometimes referred to as tetraplegia, involves all four limbs and in some cases even the trunk, with the involvement more pronounced in the lower extremities compared to the upper extremities (2) (3) (5) (29). In

general, one can say that children presenting diplegic and hemiplegic patterns are able to perform an independent locomotion with assistive devices when needed, whereas children with a quadriplegic pattern are wheelchair bound (2). This may of course vary.

In some children the clinical manifestation does not strictly fit in under the classifications of diplegia, hemiplegia or quadriplegia. Other name suggestions, such as double hemiplegia, triplegia, monoplegia and pentaplegia has been prompted to describe these rare incidences, which adds quite a bit of confusion in the literature as the terms does not seem to have any clear universal definition. It is, however, believed that double hemiplegia describes the individuals with upper and lower extremity involvement of both side, with a remarkable higher involvement on one side. Triplegia has hemiplegic pattern of the upper extremity and diplegic pattern of the lower extremity. Monoplegia would be, as the name suggest, involvement of one single limb, either on the upper or the lower extremity. Finally, individuals that are described as pentaplegic are used for the most severe cases. It manifests itself in the same manner as quadriplegia, but in these cases, the person is not even able to control the head or neck (2).

### 1.4.1. Spastic Form of Cerebral Palsy

The spastic form of cerebral palsy is the most dominant type, making up the highest percentage of all cases of cerebral palsy. Numbers of incidence varies and different authors suggest different outcomes, but an average suggests a percentage about 70% of all cases of cerebral palsy (3). Other sources offer a slightly higher percentage. For example an epidemiological research made in western European countries, the US and Australia from the late 1970's to the mid 1990's had numbers varying from 76-93% of all cases of cerebral palsy, with an average of 85% (30). With this research, however, it is important to keep in mind the change of definition seen in this time span. Different exclusion and inclusion criteria and different physicians setting the diagnosis vary with both geographical area and the time periods when the diagnosis were set could also affect epidemiological findings. It is important not to blindly accept these data, but rather use them as a relative estimation of the rate of incidence. It is however an universal agreement that the spastic form of cerebral palsy, without doubt, is the most predominant of all cases of cerebral palsy (2) (3) (30). It is also suggested that spasticity is more prevalent in the bilateral types of cerebral palsy, namely diplegia, quadriplegia and tetraplegia, in both preterm and infants born after a complete gestational age (31).

Spasticity itself is motor disorder characterized by a velocity-dependant increase in the tonic stretch reflex (31) (32), accompanied by an unusual increased muscle tone, and increased tendon reflexes leading to an abnormal movement and position of body in both postural and phasic movements, and it is commonly known that spasticity in a growing child would lead to deformities due to muscle contractures leading to joint dislocations (5) (31). Spasticity leads from a lesion in the upper motor neuron in the spinal cord or the brain and presents itself with either negative features, such as loss of power, decreased fine motor control and sensory deficit, or positive features, such as spasticity, involuntary movements and epileptic seizures, depending of the site of the lesion (31).

Spastic form of cerebral palsy could be further subdivided into the clinical manifestation of the spasticity, as in which parts of the body are being affected. Spastic diplegic type affects both legs more, with little or no affection of the upper extremity (3) (5). It is said that the aetiology of spastic diplegia is always congenital, with a high percentage of the neonatal survivors having a low birth weight, less than 1500 g, and a gestational age of less than 32 weeks (5). The percentage of spastic diplegia is estimated to an average of 33% of all cases of

spastic type of cerebral palsy in a research comparing a number of epidemiological surveys performed in western Europe, the Americas and Australia from the late 1970's to the late 1990's and the numbers are believed to be persistent even today (30). Contractures are often seen in the muscle groups of hip flexors, adductors and the hamstrings, and usually also in the triceps surrae accompanied with a tight Achilles tendon that might require surgery if severely hampering the locomotion. The muscle contractures could develop into an internal rotation of the acetabulofemoral joint and anteversion of pelvis typically leading to the characteristic crouch gait seen in many patients with spastic diplegia (33). The gait is also characterized by an excessive movement of the head, neck, trunk and upper extremities in order to compensate for the lack of mobility in the lower extremity (28). Spastic diplegia is also highly connected to learning disabilities (mental retardation U.S. use), and it is found in 15% of patients born prematurely and 45% born at full gestational age (5). A connection has also been seen between the spastic diplegic type of cerebral palsy and seizures, with occurrence ranging from 16-27 % of all children in this subgroup (34).

Spastic hemiplegia is characterized by spasticity in the arm, leg and trunk on one side of the body, and presents itself with equinusvarus of the foot and ankle, flexion of elbow, wrist and fingers, and adduction of the thumb (33) (35). In general, nearly all children with the spastic hemiplegic type of cerebral palsy are able to walk independently, but often use assistive devices for everyday locomotion (33). Despite this fact only approximately 50% of children with this form of cerebral palsy are able to walk independently by the age of 18 months (35). The spastic hemiplegia is one of the most common types of cerebral palsy, accounting 38% of all the cases of the spastic type of cerebral palsy (30). In terms of cerebral palsy, a distinction between congenital causes and acquired forms should be made. The congenital form is defined by the fact that the lesion provoking the hemiplegia occurs within the end of the neonatal period, until the first four weeks of life. This accounts for about 70-90% of all the cases of spastic hemiplegic type of cerebral palsy. On the other hand, the acquired form is determined by the lesion provoking the hemiplegia occurs within the first 3 years of life. This accounts for 10-30% of all cases of childhood hemiplegia (36). Almost 30% has some kind of seizure disorder, and about 50% some degree of learning disabilities (mental retardation U.S. use) accompanied by attention deficit, learning or behaviour disorders (35).

A further subdivision has been made to categorize children with spastic hemiplegia in order to plan the treatment and especially surgical intervention. This subdivision has been made into four separate groups (35).

Type I: This subdivision of spastic hemiplegia is characterized by weakness of the tibialis anterior and no tightness or spasticity of the triceps surrae group of the posterior calf. This manifests itself with a foot drop and a steppage gait with the plantar flexion disappearing during the stance phase (35). The weakness and the spasticity demonstrated also manifests itself in a falling/dropping foot, easily observed in the swing phase of the gait, leading to the initial contact with the floor being either flatfooted or on the toes (36).

Type II: This is by far the most common form of spastic hemiplegia in cerebral palsy (36). Unlike in the type 1, this sub-category demonstrates a weakness of the tibialis anterior and spasticity of the triceps surrae group, and sometimes even the tibialis posterior. This leads to an equinovarus deformity of the foot and ankle which persist during the whole gait cycle and could ultimately lead to a hyperextension of the knee in the late stance phase to allow individual bipedal locomotion (35). This ultimately leads to a slower gait speed than seen in type I (36).

Type III: In this group both the tibialis posterior and the triceps surrae group are spastic and in contraction, sometimes even with involvement of the group of hamstring muscles and the rectus femoris (35). This produces a knee stiffness of the gait, due to the spasticity of muscles around the knee joint, with a limited flexion of the knee during the swing phase (36).

Type IV: The clinical picture of children demonstrating this type of gait would be equinovarus, knee flexion, hip flexion, and anteversion of the pelvis in the sagital plane, with an increased lumbar lordosis at the end of the stance phase. In the frontal plane, hip adduction is found, together with internal rotation of the hip in the horizontal plane (36). This sub-group has the same characterization as the type III subgroup, with the additional involvement of the muscle groups of hip-flexors and the adductors, and therefore also requires the same treatment as type III with additional emphasis of especially the iliopsoas and the hip adductors (35). The gait pattern is similar to the one seen in spastic diplegia, but as the condition is unilateral, clear asymmetries can be seen, such as horizontal translation of the pelvis, with an increased incidence of hip sub-luxation (36).

The children grouped under the term spastic quadriplegia are considered the worst affected ones, and does rarely manage individual, erected locomotion, and usually requires assistive devices to move. Most children with quadriplegic cerebral palsy are in general wheelchair bound, but in some cases children manage bipedal locomotion with help of assistive devices. A great deal of confusion arises in the literature describing this subgroup, and terms such as double hemiplegia, tetraplegia, tetraparesis and quadriparesis are also names that are used to describe individuals of this subgroup. In the continuation of this text, the term quadriplegia would be used, as this term is deeply entrenched in the literature and tradition.

Individuals with spastic quadriplegic form of cerebral palsy have all four limbs involved, although the upper limbs are usually most affected (28), thus presenting a lack of coordination or voluntary movements of the hands and arms (33), which in turn might complicate activities of daily living and decrease the degree of individuality by the patient, making personal hygiene and difficulties in feeding an issue with an additional requirement of excessive care-giving in most of the children (34). This is further complicated by the high incidence of learning disabilities (mental retardation U.S. use) seen in children in this subgroup (16), making these children one of the most difficult and time consuming of all cases of cerebral palsy. The incidence of severe learning disabilities (IQ of less than 50) was seen in 100 % of children with spastic quadriplegia in an epidemiological study by Odding et al. (12) out of a total incidence of 30-41% of individuals with all subgroups of cerebral palsy combined. These numbers must be seen with some degree of error, as there are no definite connection between spastic quadriplegia and severe learning disabilities. However clear correlation can be seen, and in the pioneering Ingram series (37) it is concluded that no child in the study were educable (34). Others suggest a division of learning disabilities as 25% severely involved, 50 % moderately involved and 25% mildly involved, without specifying criteria for the division, also making a combined percentage of 100% of involvement of learning disabilities (38). Spastic quadriplegics with severe mental disabilities are also prone to experience complications due to epileptic seizures, with epilepsy seen in 94% of the cases in this group of children (12). Other common impairments in are hip dislocations and spinal curvatures. 60 % of individuals that are not able to walk independently are believed to have one or both hips dislocated by the age of 5, with numbers increasing throughout the life time, and 70% experience some kind of spinal curvatures, such as hyperkyphosis, hyperlordosis or scoliosis, that could be present already in early childhood, and develops well into adolescence (33).

### 1.4.2. Ataxic Cerebral Palsy

The ataxic form is one of the least common types of cerebral palsy, and authors estimate the prevalence being around 5-10% of all cases of cerebral palsy (33) (34). The aetiology is usually leading from a congenital cerebellar malformation (2), which is associated with a dysfunction of the cerebellum, ultimately leading to difficulties in maintaining balance while standing and walking and when performing skilled voluntary movements (39), such as writing, feeding or turning the pages in a book. The ataxic cases present loss of orderly muscle coordination with movements preformed with an abnormal force, rhythm and accuracy (40). Despite the fact of difficulties in maintaining balance, most children in this subgroup are able to walk independently (38), although usually with an increased support base and their feet wide apart to avoid falling (29). Typically an infant with pure ataxic type of cerebral palsy develops normally, until the age of 12 months, when the lack of stable sitting and standing worries parents and paediatricians. It is also important to keep in mind that ataxia is associated with other neurological deficits that have to be excluded in order to classify it as an ataxic form of cerebral palsy (26).

The individual bipedal locomotion is also markedly delayed as a result of difficulties in maintaining equilibrium, and usually does not occur within the 3 first years of life. When it occurs it shows clear signs of ataxia, and especially in the middle of the childhood, when a big growth spurt occurs, further challenging the child's ability to maintain balance (2).

The disturbance in balance leads from poor stabilisation in the head, trunk, shoulder and pelvic girdle, leading to overcompensation by arms (16), and swaying back and forth to maintain the balance (29). Voluntary movements are possible, but are often described as uncoordinated and clumsy (16). In addition to ataxia, hypotonia is also often seen in these children (41), with excessive flexibility of joints and poor muscle power (16), adding to the unsteady gait demonstrated by these children. The child tends to overreach or underreach objects, also known as dysmetria. Intentional tremors might also occur, adding to the poor quality of fine motor control (16). Despite the sometimes quite dramatic appearance with ataxic movement and speech dysarthria of children affected with ataxic cerebral palsy, intelligence is usually not impaired (42), although intellectual impairments may exist, especially if severe auditory or visual impairments are present (16). As there is nothing to do to repair the malformation and dysfunction of the cerebellum, therapy is usually focused on

education in how to fall without causing further injury, and for the child to recognize when he is about to fall with body awareness exercises (2).

Ataxia is also sometimes used to describe posture and gait patterns in other forms of cerebral palsy, without being classified as ataxic cerebral palsy. A pure form of ataxia is rarely seen in individuals with this diagnosis and is usually a part of a mixed type of spasticity and ataxia or hypotonia and ataxia. It is however diagnosed as ataxic form of cerebral palsy if the ataxia is predominant.

### 1.4.3. Athetoid/dyskinetic Cerebral Palsy

This group has a lower rate of incidence than for example the spastic type, but it is suggested to be found in 10-20% of all the cases of cerebral palsy (43) (44), however rarely in a pure form, and often combined with the spastic type and thereby also often termed under this group. It is believed to be the second most common form of cerebral palsy (44).

In the athetoid type, the lesion is found in the basal ganglia, which leads to a severe disorganized movement pattern, which might be totally disabling (45). The movement patterns are present in the whole body, and even in the face and tongue (16), but are more common in the distal parts of the extremities, such as foot, toes, hand and fingers (31). These disorganized movement patterns, are bizarre, purposeless movements, which may be uncontrollable, in a writhing, jerky, tremor or swinging patterns, and sometimes even with no distinct pattern at all (16). The involuntary movements are often increased when the child is influenced by some emotional response, such as fright or excitement (16) (35), and are induced by a voluntary effort, which in some cases could be as remote as the wish to speak (2). This in turn makes locomotion a difficult issue, and a great part of children with the athetoid type of cerebral palsy are bound to a wheelchair for this reason. On the other hand, factors that are believed to decrease the outbreak of the involuntary movements are fatigue, drowsiness, sleep, prone position lying and keeping the child's attention (16). This is a fact that must be kept in mind in a therapeutic setting.

A special type of gait arises in some individuals with the athetoid form of cerebral palsy. These children are unable to maintain the weight on their feet, and continually withdraw their feet in either an upward or upward or outward direction. This is referred to as an athetoid dance and is a result of a conflict between grasp and withdrawing reflexes. In turn this leads to a quicker pace of the gait, and children that are athetoid usually run before they walk steadily (16). It presents itself with a specific set of motor symptoms, including difficulties in maintaining a symmetric supine posture, decreased upper extremity forward extension, limited neck and trunk stability, and inability to achieve sitting balance at the expected developmental age (44).

A typical clinical history of children with an athetoid form of cerebral palsy is hypotonia in the first year of infancy. Then between 12 to 24 months of age the child starts to ambulate more voluntarily with the underlying hypotonia, which is resolved between 2-4 years of age

and develops into a generalized increased tone to modulate their movements. Ultimately, by the age of 5, a full expression and clinical presentation of the motor disorder is usually present (2).

Previously this type of cerebral palsy accounted for a greater number of incidences of cerebral palsy, and was responsible for approximately 25% of all cases (35), but due to a better paediatric health care in the last couple of decades, the risk factors have been decreased markedly, and thereby also decreasing it's prevalence.

Children with athetoid cerebral palsy often also meet some difficulties in terms of communication, however only rare cases are found with impaired mental abilities in individuals with a pure form of athetoisis (2). If the involuntary movements are present in the face, it might hamper the child's ability to speak, similar troubles are also seen in feeding, as involuntary movements in upper limbs and face might make this difficult to perform (46). Children with athetoid cerebral palsy are also connected with a higher incidence of impairment of hearing (44), which further challenges the communicative skills, and must be taken into consideration as an obstacle during therapy. Difficulties in respiration also often accompany the impairment (16).

Another condition that in some cases accompanies the athetoid/dyskinetic form of cerebral palsy, and thereby hampers the condition dramatically is dystonia. Dystonia is a phenomenon of increased general muscle tone, distorted postures and abnormal positions (35), leading from strong muscle contractions with major recurrent movement patterns (2). These movement patterns cannot be voluntarily controlled (2) (35). The condition could be present in a single joint, or a limb, or in a generalized form which affects the whole body (2).

SCPE uses a sub-categorization for the athetoid/dyskinetic form of cerebral palsy, which is quite interesting. They term the group dyskinetic cerebral palsy for cases that present involuntary, uncontrolled, recurring, and occasionally stereotyped movements. The primitive reflex patterns predominate, and the muscle tone is varying. Their sub-division is into a dystonic form and a choreo-atheotic form. The dystonic form is dominated by abnormal postures (may give the impression of hypokinesia) and hypertonia (tone fluctuating, but easily elicited tone increase). It is characterised by involuntary movements, distorted voluntary movements and an abnormal posture. The choreo-atheotic type is dominated by hyperkinesias and hypotonia (tone fluctuating, but mainly decreased). Chorea is then further defined as a

state with rapid involuntary, jerky, often fragmented movements, and the athetosis as slower, constantly changing writhing, or contorting movements. If a sub-categorization is impossible to make, the term dyskinetic cerebral palsy is recommended (40).

### 1.4.4. Hypotonic Cerebral Palsy

Hypotonic type of cerebral palsy is characterized by generalized muscular hypotonia that persists beyond two to three years with no connection to a disorder of the muscle or peripheral nerve (34). It occurs with a less frequent incidence rate than the spastic form, being one of the rarest forms of cerebral palsy in its true form, but it is still not uncommon, and hypertonia itself is a normal condition experienced by many children with cerebral palsy. Many infants are born hypotonic, which later, after the first 2-3 years of life, develops into spasticity as a compensatory mechanism in an attempt to maintain joint stability, or to ataxia (2) (35). In true form of hypotonic cerebral palsy occurs when the hypotonia persists throughout life, and it is always connected with learning disabilities (mental retardation U.S. use) (47). Despite this, it is a field within the field of cerebral palsy in which scientists have shown little interest (2). Rates of incidence vary with different epidemiological researches, but are believed to be in a predominant form, from 1-5% of all cases of cerebral palsy, but only occur in its pure form on rare occasions (48). Perinatal asphyxia is only responsible for about 5 % of the cases of hypotonic cerebral palsy, and causes are suggested to be as a result of an extremely late brain development (34) and due to an aetiology that leads from congenital lesions (2).

In the periphery, muscles are the primary structure affected in children as a result of the hypotonic form of cerebral palsy. The muscles are often thin and gracile, and lack the ability to generate great force compared to a normal child upon examination. As a result of this, in many cases, joint hypermobility occurs, together with osteopenia and osteoporosis. Collectively, this in turn leads to difficulties in maintaining a stable equilibrium, hampering the child’s posture and gait (2).

## 2. Diagnosis

As discussed in the previous chapters, the difficulties in defining the concept of cerebral palsy with its sub-groups has proven to be a difficult task, which again leads to difficulties when diagnosing a child. Therefore no exact criteria have to be met in order to set the diagnosis. Usually a failure to reach developmental milestones in stipulated time, persistency of primitive reflexes, and significant abnormalities and impairment of motor functions are usually enough, as long as it matches with the criteria of being permanent and non-progressive (2). However, great care should be taken when diagnosing a child with cerebral palsy and classifying it into one of the subgroups, and paediatricians are usually restrictive with setting such diagnose before the child reaches 12 months of age. This is due to the high plasticity of the CNS in this early period of life (3). A diagnosis could be set before 1 year of age, if the clinical signs and disabilities are severe and well recognisable (2), and to meet the demands of an early treatment intervention of children in the risk group (49). However, some authors even suggest waiting for up to 2 years by setting a diagnosis in cases where the clinical manifestations are not clear, in order to exclude the chances of a faulty diagnosis (2).

The diagnostic measures are developed in order to optimize the diagnosing assessment, aiding the treatment and calculating a better prognosis and the further development of the child's general state of health. A selection of these methods is described into more detail in the following pages.

In the late 1980's the first steps of an individual classification system for children with cerebral palsy was made. With the introduction of Gross Motor Function Measure (GMFM) the limitations of the present measurements were highlighted (50). After this a wide range of different gross motor function measures have been developed, including Test of Infant Motor Performance (TIMP), Alberta Infant Motor Scale (AIMS) and Pediatric Evaluation of Disability Inventory (PEDI). Some of them are described into more detail in the following pages. Assessment methods created as a direct answer to the GMFM was also conducted, namely the "Gross Motor Function Classification System (GMFCS) and "Manual Ability Classification System (MACS)", which are also included in the following chapters.

The Bayley Scale of Infant Development (BSID) and the Peabody Developmental Motor Scales (PDMS) are also assessment tools with a long history of early infant development

assessment. Together with a widespread popularity and use, and high rates of reliability and validity, they are included for a more specific explanation in this thesis.

The assessment methods described in more detail in the following pages are a group of hand-picked, early infant development assessments that are often found in researches evaluating the effect of treatment. Infant reflexes have always been of importance in the field of paediatric neurology, a selection of widely tested reflexes is provided. Guidelines of what is described as normal infant motor development are also included, as this is the cornerstone of a holistic paediatric evaluation. It is, however, important to keep in mind, that these are just guidelines, and a failure to reach a certain developmental milestone at the "correct" age, does not necessarily impale a developmental disturbance. A thorough explanation of these methods was felt necessary to avoid any future confusion, and in order to be able to make any conclusion regarding the effectiveness of treatment.

## 2.1. Infant motor development

When assessing a child with a suspected neurodevelopmental disorder four domains are usually evaluated, namely motor, speech and language, social-emotional and cognitive abilities (51). In this chapter, the infant motor development and developmental kinesiology is looked at in particular, as that is the main aim of a physiotherapeutic intervention in children with cerebral palsy.

The human infant development is of a particular interest, as a human baby is one of the most immature newborns on the planet (52). Where newborns of other species are able to walk and run within a few hours after birth, the human baby needs months of development in order to acquire this skill (28). In order to reach an erect bipedal locomotion, the normally developing child passes through a set of motor milestones on the way. These motor milestones are, of obvious reasons, the first developmental domain that could be recognized in a child and are therefore of great importance in paediatric care and early diagnostics. A child reaches certain motor milestones at certain ages, and a disturbance in obtaining these motor milestones at a correct age might indicate a motor delay (51). A delay in obtaining of motor milestones is also a typical finding in children with cerebral palsy (53).

Characteristics of human development are determined by different principles. Human development is a continuous process of change, to a greater or lesser degree, throughout the life span (54). The development also involves a sequential change, with one acquired skill is followed by the next (55). Development is also related to, but not necessary dependent on, age (54).

Other specific principles that are important to take into consideration when assessing human infant motor development includes: (i) Gross motor development progresses in a so-called cephalo-caudal direction, whilst fine motor development progresses from the midline to lateral, also referred to as proximo-distal development. (ii) The loss of primitive reflexes should occur at an appropriate time. (iii) The development should progress as the child gets older, from generalized and reflexive responses to more voluntary and purposeful movements (51). Having said that, the assessing of the individual child is thought to be of more importance than labelling and classifying with cerebral palsy, as the clinical manifestation and motor abilities vary widely in each individual child (53). Some even point out that even

though the child present an unusual motor behaviour and a different sequence of motor development should not be considered pathophysiological, as the child might fully develop in a normal way (28).

The traditional theory of infant motor development consists motor milestones that follow patterns stored in the brain, and are as a result of evolution, i.e., the child does not have to be told how to perform the movement (52). The main motor milestones are head control, rolling, creeping, independent sitting, and walking, which normally should occur at or around 4, 6, 7, 8 and 12 months respectively (55). In the first year, the main motor milestones are related to change in posture (54). The development of motor milestones from birth to independent walking is described below.

The first period after birth is dominated by spontaneous movements and infant reflexes, that are of a subcortical origin (56). This period is also completely controlled by the tonic muscular system (52). The infant also automatically assume a flexed position of the extremities, regardless in what position they might be put, as a physiologic flexor tone dominates the brain (55). This leads to an unbalanced posture in both prone and supine lying, with the centre of gravity in the sternal and umbilical region, offering no support points with the whole body resting on the surface (52). If the infant is placed in a prone position, it lays on one half of the body from cheek to chest and all the way to the umbilicus. The upper and lower extremities are in flexion, with the pelvis in anteversion, creating a highly unstable posture (52). The next chapter will focus more on this early period of infant reflexes.

After 4 weeks, the infant starts with the first voluntary elicited movements, with slight voluntary movements of hands, head and eyes (56). Between the $4^{th}$ and $6^{th}$ week after delivery optic fixation appears, allowing the infants orientation in space, resulting in the initiation of holding the head against gravity (52). Even though it is indicated that visual perception is not the only factor that controls the infant movement and posture (54), it is proven absolutely necessary in future motor milestones, such has recognition of own body, reaching and grasping that happens after about 2-3 months (55). The head control develops in the following weeks (56), first by lifting the head to one side and then by lifting the head in the midline when strength of the neck and trunk extensors is sufficient (55). The reason for this need of muscle strength is due to the relatively bigger size ratio between head and body (56), and due to the biomechanical properties of the existing posture of the child in the prone position (55). Raising the head, immediately leads to a whole new, and more stable posture

for the infant, with support by the forearms, and the centre of gravity moved from the sternal area towards the symphysis (52). At 3 months, the infant is fully supported on forearms (55), with clear support points on elbows and symphysis (52).

A critical time in regards of infant motor development occurs after 4 months of age when the posture and movement gradually changes from being roughly asymmetrical to a more coordinated and symmetric form (55). This coincidence with the stabilization in the sagital plane, as a result of balance has been challenged in previous developmental stages, and resulting in achievement in later developmental milestones, such as rolling, sitting, creeping and walking (52). At this point, the child is able to fully control the head in a midline position, lifting the head to above 45 ° from a prone position, and bringing hands to the midline in a supine position (55). At this age the infant is able to grasp an object when prone lying, lifting the head, the grasping arm and shoulder work against gravity, demonstrating a typical support pattern. This support pattern is of a triangular shape with support points on stationary elbow, ipsilateral anterior superior iliac spine and contralateral medial condyle of a double flexed lower extremity (52).

Even though the infant is unable to perform any form of locomotion at 4 months, it starts to perform small pelvic movements (55). In supine position the infant lifts the pelvis from the surface, maintaining the posture by shifting the centre of gravity to the thoraco-lumbar junction (52), or starts to perform bridges (55), that are important for future locomotion.

Soon after this the infant starts rolling, first from prone to supine, followed by rolling from supine to prone a few weeks later (56). This is allowed when the infant is able to perform trunk rotation of a straight spine (52). Infants start to log roll, i.e. a primitive form of turning over with the head and body rolling as one unit without segmental rotation, from 4-6 months. The so-called segmental rolling occurs between 6 and 8 months and includes a rolling with separate rotation in the upper and lower trunk (55). Furthermore it includes the ability to turn the head to one side, shift the body weight to the opposite side, while lifting a shoulder or a leg off the floor to turn around the body axis (57).

The next important developmental milestone first occurs around 5 months which is attaining of a sitting position (56). At this point, the position is supported by hands. This type of sitting, called propped sitting, is consisting of the child's two hands and his buttocks, creating a tripod for better balance (3). After 8 months the infant is able to sit independently, defined as the

ability to sit alone when placed (55). This is made possible because the infant now possesses the ability of controlling the upper trunk, keeping the body erected allowing the infant to free both hands for manipulation of objects (28). This has in turn been proved beneficial for the development of the eye-hand coordination due to the completely new perspective for the child (56). Some children even develop a form of locomotion from this position, using the feet to move on the surface, scooting on the buttocks, in a process referred to as hitching (3).

Up until this point the infant has been rather stationary, without any real possibilities of voluntary self-locomotion. This is about to change over the next months with the development of crawling, creeping, standing, cruising and ultimately walking. Attaining of previous motor milestones, such as lifting head in prone lying and voluntary control of separate extremities are pre-requisite in order to be able to perform independent locomotion (54).

The first forms of voluntary infant locomotion are crawling and creeping. However highly variable, crawling normally starts around 7 months of age with similar crawling attempts prior to this age is believed to be of a reflexive origin (56), although some authors suggest crawling being present as early as 3 months of age (3). The first sign of creeping also starts at around 7 months of age. Saying that, it is important to note that the classical path of development of individual locomotion is crawling, creeping and ultimately erected, bipedal locomotion (58). There exists considerable confusion in available literature regarding the terminology used for creeping and crawling (28) (56), and they are often used interchangeably. It is believed to be absolutely crucial that the terms are used with consistency in paediatric health care to avoid confusion (3). In general one can say that both crawling and creeping occur when all four limbs are in contact with the surface. During crawling the infant's chest and stomach is also in touch with the surface whereas in creeping only the hands and knees are in contact with the surface (54). This definition would be used in the remaining of this thesis. At this point it is also important to point out that although creeping and crawling is often looked upon as two distinctive motor milestones, many infants will not perform crawling, whereas a small percentage will not perform creeping but rather find other means of locomotion. This does not necessarily indicate a delayed, or faulty, motor development (28).

The next, and probably the most important step of motor developmental milestones is the process of verticalization and upright locomotion. It is usually initiated by the child pulling himself to standing and holding on to a stable object at around 10 months (3). This is followed by cruising, normally present anywhere from 7 to 12 months of age. In this process the child

performs small sideways steps in order to have both hands free for stabilization at the same object (28). Around 11 months the child has enough stability to walk with minimal assistance, i.e. holding a parents hand, and by 12 months the child is able to walk independently (56), although it would not be considered delayed until after 18 months of infancy. The first steps are typically provided with a wide base made by abducted and externally rotated hips, and by hands held in a high position to maintain balance (55). It then takes several months for the infant to perform a controlled and fluent gait. Progressing over the next couple of weeks, the infant starts to walk with a heel to toe pattern, width of the strides decrease and a greater mobility are seen, allowing longer strides (28). In the beginning there is no arm swing, but the child gradually adapts trunk rotation and early forms of arm swing (54). Developing until the age of 5, research suggest that the child's gait slowly matures, meaning a greater fluency with higher velocity of the steps and shorter time period where both feet are in contact with the surface (56).

## 2.2. Infant reflexes

As discussed in the previous chapter, the human infant is born into this world completely vulnerable and dependent of caretaking. Not yet able of sufficient voluntary muscle control, the first 4 months of infancy is dominated of a movement repertoire consisting of reflexes triggered by certain stimuli (56). Traditionally these early infant reflexes have been assessed to determine the maturation of the nervous system (55). Being age specific, severe deviations from the normal time frame may indicate neurological dysfunction, alerting the paediatrician that additional testing might be needed (56).

A definition of the terms is needed regarding these infant reflexes as several different terms occur in the available literature. Different authors offer subdivisions into primitive (56), survival (59), tonic (55) and postural (56) reflexes, with similar reflexes being present in several groups, but in general the classification are based on the following principles. Primitive reflexes are believed to be suppressed by about 6 months of infancy (56) when higher brain centres inhibit them by voluntary muscle control (59). However, a group of scientists promote a new view of the disappearing of infant reflexes. Advocates of the Dynamic Systems Theory (DST) explain the shift from a reflexive infant to voluntary movement is happening through self-solution, replacing one motor behaviour with a more effective one (60). The traditional view of the neurodevelopmentalists is explained in this thesis.

The primitive reflexes are also described as being absolutely crucial to survival (56), thereby also constituting with the reflexes included in the subgroup of survival reflexes (59), and also to some degree the tonic reflexes. The tonic reflexes are described as related to the brain stem, influencing the muscle tone of the infant (55). Postural reflexes on the other hand is believed to be connected to the future voluntary movement in some way, by facilitating higher brain centres, and is with few exceptions not present from birth (56). However, any definite sub-categorisation is thought unnecessary, and the term infant reflexes are chosen for the remaining of this thesis. A selection of the many infant reflexes observable is listed and explained below.

One of the first reflexes encountered in the neonate is the palmar grasp reflex. It is evident from birth to a maximum of 4 months of age (61), and is even developed prenatally (62). Tactile stimulation is elicited to the infants hand and leads to closing of the hand by flexion of

the fingers (56). The reflex should be inhibited by higher brain centres at around 4 months, when voluntary muscle control carries out the movement (55), and a persistence of the reflex over these 4 months might indicate a cerebral dysfunction (61). In the first few days of life, the reflex is strong enough to support the baby's weight, which is believed to lead from the day the newborn had to cling onto the mother, as seen in the animal kingdom (62). Another of these so-called primitive reflexes is the rooting or search reflex. It is evident from birth to 3 months of age (56), and it is elicited by a gentle, tactile touch to the cheek (62), and the healthy infant will turn its head towards the stimulated side with opening of the mouth (61). One should take into consideration that the reflex is harder to elicit when the infant has just been fed (62). The rooting/searching reflex is accompanied by the sucking reflex, which completes this triad of reflexes. This reflex is preset from birth and usually diminishes around 3 months of infancy (56). It is elicited by insertion of a nipple or a clean finger into the infant's mouth, and is responded with a strong and rhythmical sucking (3).

Another reflex universally (61) tested is the Moro reflex, or the Moro response. It is mostly evident from birth to about 4 months of age, when it slowly diminishes within the $6^{th}$ month of infancy (56). It could be elicited by any, unexpected vestibular stimulation (62), but in neurological assessment, the infant is usually held by the examiners hand under the torso and neck before the child is rapidly lowered towards a surface (61). The wanted response is an extension of the fingers, arms and legs (56). The response is most sensitive in the first days after birth (62), and a failure to elicit in this time period might indicate a CNS disturbance (56). Further on, an asymmetry of the response can indicate a hemiparetic disorder (61). At around 6 months of infancy the Moro response should normally be diminished and replaced by the so-called Startle response which is more mature and involves higher brain centres (62). This response however involves the flexion of fingers, arms and legs upon an unexpected vestibular stimulation (56). If the Moro response is still present at this stage, it is also a sign of neurological dysfunction, and will vastly hamper the progression of other motor milestones (56), often making locomotion impossible to carry out.

The next reflex is universally accepted to be an important part of a neurological assessment (55). The Babinski reflex, or the Babinski sign, is normally present in the infant from birth to about 4 months of age (56). To elicit it, the examiner strokes the lateral part of the foot with a sharp object from the heel to the base of the toes (62). The immediate response of a positive Babinski sign is dorsiflexion of the big toe and fanning of the remaining toes (34). If the

positive Babinski sign fails to diminish at the appropriate time, it is a trustworthy sign of a lesion in the corticospinal tract (56).

The palmar mandibular reflex or the Babkin reflex is also an infantile reflex usually tested and is present the first 3 months of infancy. It is elicited by simultaneously applying pressure to both palms (54), and the wanted response is opening of the mouth, closing of the eyes, flexion of the neck and tilting of the head forward (56).

The following reflexes are believed to be more connected to posture. An often described reflex in this part is the stepping reflex, also referred to as newborn stepping, walking reflex or automatic gait. Stepping reflex will be used in the remaining of this thesis. It is of particular interest due to the possible relation to the future, voluntary walking (54). A bit of confusion consists regarding when the physiological disappearance of the reflex occurs. Suggested periods are from the first few weeks to fifth or sixth month (56), where others suggest a time-span from birth to about 2 months (3), 4 months (61) or 5 months (63). The revolutionary work on infant reflexes conducted by Esther Thelen et al. (64) in the early 1980's suggest that the reflex is not inhibited during the first few months, but rather decreased due to the increased body weight of the infants lower limbs, making it difficult to perform the reflex stepping, suggesting it would just fuse into a pattern of voluntary walking by the time the infant has sufficient motor control (56). This is seen as an important finding by promoters of the Dynamic Systems Theory (DST). The reflex itself is elicited by holding the infant under the armpits with the feet barely touching the surface (52). This triggers a movement of lifting and descending the lower limb (56), causing a triple flexion in the ankle, knee and hip (52) in a motion that resembles voluntary walking (56).

Another reflex thought to be of great importance in the development of posture is the so-called parachute reflexes. Available literature offers different ways of performing the reflex, all involves tipping the infant off balance to elicit the wanted response of protection (56). This could be performed in a sideway, backward, or forward manner (65), whereas the latter seems to be the one most frequently used in a neurological assessment of infants. A forward elicited parachute control is performed by holding the infant in prone position in the air, and suddenly lowering it towards the surface (35). The wanted effect includes a reaching of the arms towards the approaching surface, as if to break the fall (65). An asymmetric movement of the arms during this response might be an early indicator of a lesion of the pyramidal tract (66).

Different literature offer different age of appearing, but it ranges from 4 (56), via 7 (65) to 12 (35) months of infancy.

Similar to the parachute reflex, the labyrinthine reflex is also believed to be in strong connection with attaining an upright posture. It is a reflex possible to elicit between 2 and 12 months of infancy, and is triggered by tilting the infant to either side. Physiological response is tilting of the head to the opposite side, as if to maintain head in a straight position (56). It is of great importance that this response is not confused with the tonic labyrinthine reflex, which is a highly abnormal reflex, not seen in any human under normal circumstances, and indicates an association with spasticity or intermittent spasms (67). It is manifested by an increased extensor tone throughout the body when the child is put in a supine position, and vice versa, an increased flexor tone when child is in supine (55).

Other reflexes of a tonic origin related to the tonic labyrinthine reflex are the asymmetric tonic neck reflex (ATNR) and the symmetric tonic neck reflex (STNR). Both responses are present from birth, and are normally diminishing after 3 (56) to 6 (35) months. The ATNR is elicited by turning the child's face to either side (56) and is followed by extension of the limbs on the facial side (the side in which the face is turned towards) and flexion of the limbs on the occipital side (the contralateral side) (3) resembling a fencer, or someone using a bow and arrow. ATNR is believed to facilitate the development of body dissociation (56), demonstrating the infant's inability to move the head without moving arms, or moving limbs separately when the response is possible to elicit (3). The STNR on the other hand has a symmetrical response of the extremities, as the name implies. It is performed by extension of the neck, followed by extension of the upper limbs and flexion of the lower limbs, or by flexion of the neck, followed by flexion of the upper limbs and extension of the lower limbs (35). Persistence of this reflex over the 6 months indicated is thought to severely hamper future motor abilities, especially the voluntary control of head (56)

## 2.3. Gross Motor Function Measure (GMFM)

In order to meet the increasing demands of classifying the ever present need of a gross motor function assessment in children with cerebral palsy, the Gross Motor Function Measure (GMFM) was created in the late 1980's and early 1990's (68) (69). It has been validated for assessing children with cerebral palsy from 5 months to 16 years (70). The process of measuring the gross motor function in children with cerebral palsy is complex and has a lot of variables to keep in mind. The maturity of motor function develops to a lesser or greater extent, motoric milestones may regress, the child may reach a plateau for motor development, or develop atypical or unfavourable substitution mechanisms to perform a motor task, depending on the individual child. This was just some of the obstacles the developers of the GMFM had to take into consideration during its development. Even so, the GMFM is regarded as the "gold standard" when it comes to test gross motor function in children (71).

The GMFM is a clinical measure designed to evaluate changes over time in gross motor function in children with cerebral palsy. It was originally an 88 item measure, but has later been narrowed down to a 66 item measure, abbreviated by GMFM-88, and GMFM-66 respectively. GMFM is constructed to measure quantitative measures, taking into consideration how much the child can do, rather than the quality of the movement (72). The measure is based on a four point scoring system for each item. The scoring is evaluated in correspondence with the user manual and points and percentages could be calculated for each of the five dimensions separately, namely lying and rolling; sitting; crawling and kneeling; standing and walking; and running and jumping (50) (68). For information about the score sheets and calculations, see Appendix II at the very end of this thesis.

Being such a ground breaking and pioneering measurement tool, the need of proper research of its validity, stability and reliability was soon present. A large study was compiled and proved GMFM to be a valuable and very much valid measure in order to predict the future level of gross motor function in children with cerebral palsy (73). This also provides the possibility to plan interventions and evaluate progress of therapy over time (72). The initial developers have on several (68) occasions published researches underlining the reliability, validity and stability of the GMFM, but more interesting is the findings of independent research groups (74) concluding with the same, stating that GMFM is both useful and reliable for assessing motor function and treatment outcome in cerebral palsy. (75). A longitudinal research compiled by Josenby et al. (76) concludes that both GMFM-88 and GMFM-66 were

valid for revealing changes in gross motor function when evaluating the total scores. Together with the widespread use and the several different measure tools based on its principles (GMFCS, MACS and CFCS), it is fair to conclude that the GMFM is a reliable, valid and stable method of measuring the change of gross motor function in children diagnosed with cerebral palsy over time.

For practical purposes, even abbreviated versions of the originals have been made, and proven both valid and reliable (71), and sometimes even more suitable for a clinical setting, as a normal assessment by a professional paediatric therapist takes approximately 1 hour (50). These abbreviated versions are not believed to be sufficient enough for research protocols, but are shown to be useful in a clinical setting.

## 2.4. Gross Motor Function Classification System (GMFCS)

A universally accepted method of measuring the overall situation of motor function is the Gross Motor Function Classification System (GMFCS). It is widely used internationally (77), and it is a special system, initially developed by Palisano et al. in 1997 (78), and later expanded and revised in 2007, to classify children from birth to 18 years of age (79), with the aim of classifying children with cerebral palsy into 5 clinically meaningful levels (3). The GMFCS is based on self-initiated movements, emphasising on trunk stability and walking. Criteria for classification of the level of motor functions are based on functional limitations, with the need of additional assistive devices for locomotion, such as walkers, crutches, canes and wheelchairs. It also, to a lesser extent, takes the quality of the movement into consideration (78).

It was developed by Palisano et al. over a period of time in the 1990's, and was based on parts from already existing classification systems for children with cerebral palsy, from videotapes of children with cerebral palsy already classified by their respective physiotherapist and after extensive discussions with other authors (3). Initially being created as a supplement for ill-defined terminology of the GMFM, it has later served as building blocks for other classification systems, such as the Manual Ability Classification System (MACS) (80) and the Communication Function Classification System (CFCS) (77).

The GMFCS aims to classify children into 5 levels of severity in different age groups. It respects the fact that the gross motor function is dependent on age, especially in the early stages of the motor development. The focus of the GMFCS is on determining which level is best representing the child's present abilities and limitations in motor function. That is why emphasis is usually put on performance in a home, or school environment, or other daily life settings, rather than in a fixed setting at a physiotherapy clinic, with a stable and fixed floor and an even surface (79). The classification criteria are attached as Appendix III at the very back of this thesis.

According to the developers of the classification system, emphasis is to be put on the child's abilities and not the limitations (78) (79). This should be kept in mind when retrieving a child's gross motor function using the GMFCS. A child does not necessarily fulfil all the criteria for the respective level, thus in reality making the child's level of motor function worse in some domains.

The clinical significance of GMFCS has been proven through a number of different research programs during the last decades, and has mainly been used in observational research or experimental research (81). In observational researches comparing larger groups of children with cerebral palsy, based on their GMFCS score has been useful in researches in the field of functional limitations. It has been shown that state of mobility, dexterity, speech, vision, hearing and cognition is associated with the level of GMFCS (82). GMFCS levels have also been associated with the diagnosis, aetiology, intellectual capacity, epilepsy and visual impairment (83). In terms of experimental researches, the GMFCS has been proven a vital device in assessing either progress in therapy, or in comparing effectiveness of two therapeutic methods. (81). Many studies have actively used GMFCS as a way of creating homogeneity between two randomized groups.

Being such a relatively new classification system, a need for evidence of the reliability, stability and validity soon occurred. Now, almost 15 years after the initial publication of the GMFCS we can see some long term lines after the use of the classification system, and thereby discuss the reliability. First of all, the world wide use of the system could be a good indicator of the quality of the system. The widespread use and rapid expansion of the system was demonstrated by a small fraction of the initial developers. Morris et al. stated that in 2004, 7 years after the initial publication of the classification system, GMFCS was found in 102 citations in various languages, with an increasing frequency throughout the years, indicating an increasing popularity (81). Studies have been made to validate the GMFCS's ability to predict future gross motor function (84). The same study even proved high test-retest reliability and a high interrater reliability. A multicenter study was compiled in 2004 with the main aim of investigating the relationship between GMFCS and other well known and universally reliable methods of establishing the level of severity, concluding with a moderate to strong relationship between GMFCS and other existing outcome tools (85).

In order to determine the stability, and thereby also the validity of the GMFCS, Palisano et al. compiled a report stating that: "*The results of this study provide evidence of the stability of the GMFCS in children with CP"* (86 p. 428). The aim of this report was according to the authors to assess the stability of the GMFCS by examining whether the children with cerebral palsy stayed in the same level of motor function over time. The validity of this report must be considered carefully, as it was compiled by the developers of the system, hence the authors might be biased, but by the way the results were found and by linking to other assessment

tools grading motor functions like the Gross Motor Function Measure (GMFM) (50), the findings are worthy of inclusion. After testing the total amount of 610 children diagnosed with cerebral palsy with a mean testing frequency of 4.3 times over a long term testing period a total of 73% stayed in at the same level throughout the whole testing period.

Interesting sub findings were also found in this research. Children initially classified in level I or V had the lowest changing rate throughout the testing period. Possible explanations offered for this finding is that children in these groups have the most distinct characterizations, making assessment easier for the therapist. Another possible explanation is that these groups are on both ends of the scale, making it possible to change groups in one direction only, hence lowering the chance of any change at all.

On the other hand, children initially classified in the levels II-IV had a higher rate of interchanging between the levels throughout the testing period. Possible reasons for these findings might be explained by the greater variability in terms of possibilities in mobility of children in these groups. The characterization are neither that distinct, making the assessment by the examiner relatively harder.

Other findings indicate that infants and children under the age of two years have a relatively higher chance of changing groups than older children. Gorter et al. therefore recommends classifying children under 2 years, but states a need of reclassification at the age of 2, to avoid any faultiness in the classification (87).

But despite some small differences in findings, the consistency of 73% of the children throughout the testing period shows a remarkable stability taking into consideration all the different factors of which are able to interfere with the development. It also proves the accuracy of the classification system, but maybe most importantly, it is an important tool in order to calculate a prognosis and the expected level of gross motor function in the future, which must be a much sought after possibility for health care workers, parents and other care takers. Some even claim that: *"The GMFCS has clearly established itself as the principal classification system of functional ability for children with CP."* (81 p. 61).

In order for GMFCS to be used in a broader spectre and in a bigger population, members of the original developers of the system constructed a family questionnaire for families and care takers to provide the classification on a private basis. Questions were asked regarding the

reliability of the use of this questionnaire, but research shows an excellent agreement in the GMFCS questionnaire compared to the classification made by primary health care workers in a study comparing both methods (88). The results were later supported by another research group (89), making the GMFCS a highly reliable method of measuring gross motor function in children with disabilities, and even offering aid in providing larger, population based epidemiological studies with the use of a minimum of resources. It is also believed to help the parents or other caretakers in highlighting everyday problems, seeing the real obstacles and problems for children with CP, and has established itself as a valid tool of gross motor classification and gross motor function prediction.

## 2.5. Manual Ability Classification System (MACS)

The Manual Ability Classification System (MACS) was developed to classify how children diagnosed with cerebral palsy use their hands in handling objects in everyday situations, and to evaluate the collaboration between both hands. It has been validated for use in children with cerebral palsy from 4 to 18 years of age (90). The system was developed as a direct answer to the GMFCS in order to have a more precise measuring tool for the fine motor control in manual manipulation of objects with both hands in order to "*broaden the functional perspective of CP beyond gross motor issues"* (80 p. 549). It has been looked upon as a major step forward in order to classify hand function, and how children handle objects in daily activities (91). During the work of verifying its reliability, it was suggested that it was absolutely crucial to independently classify fine and gross motor function, as there is no parallel between these abilities in children with cerebral palsy (80), and that a classification of merely the gross motor function would not provide the entire clinical picture of the child. The structure of the MACS has purposefully been based on the structure of GMFCS in order to make it clinically meaningful (92). It follows the definition of Penta et al. on manual ability as: " *the capacity to manage daily activities that require the use of the upper limbs, whatever the strategies involved, which can be observed from activity performance in the person's everyday context"* (93 p. 1627). It also just take into consideration the activities that are relevant and age appropriate to a child, such as eating, dressing, playing and writing (80).

The process of validation of the classification system was started immediately after the publication of the system. The developers presented preliminary versions of the system at various conferences in Canada, Sweden and Norway in 2002 and 2003 (80), to collect opinions and to increase the quality. They requested opinions from a wide spectre of health care providers to optimise their system. One of the developers, Öhrvall, investigated whether the concept was meaningful for the parents of children with cerebral palsy (94), and parents responded positive to this question, and even expressed that MACS was built in a useful way to describe their child's hand function (80). Another research group came to the conclusion that the classification system offers a valid and reliable method of communicating about the manual ability of children with cerebral palsy, after comparing parent's reports with those made by health care providers, such as paediatricians, physiotherapists and occupational therapists (92).

The system seems to be of great value in assessing fine motor skills, a field that has traditionally belonged to occupational therapy. It also seems to be a great asset in order to compare traditional therapy of the neurophysiologic approach to the functional approach. Despite this, I have encountered few articles using MACS as an assessment tool, and that is something that should be considered in future research programs. Being such a relatively newly developed assessments tool, the usage of might increase in the future.

Appendix IV offers further information of practical use of MACS.

## 2.6. Paediatric Evaluation of Disability Inventory (PEDI)

The Paediatric Evaluation of Disability Inventory (PEDI) was originally developed for a clinical assessment of selected key function capabilities and performance of children (32), and is validated to measure adaptive functions in children from 6 months to 7 years of age (16). It was designed in a way to both describe the child's current performance, and in order to compare changes of performance over time (32). The developers suggested that PEDI could be used to: *(a) detect whether a functional deficit or delay exists,(b) determine the extent and content area of an identified delay or deficit, (c) monitor individual or group progress in pediatric rehabilitation programs, and (d) evaluate pediatric rehabilitation services or therapeutic programs in educational settings* (95 p. 264). Limited information exists upon whether or not it is in fact a reliable testing tool for measuring its complete and intended purpose (28).

PEDI measures the ability of performing activities of daily living (ADL) through standardized structured interviews (33). Even though the test is not especially designed for cerebral palsy, or any other condition with developmental delay for that matter, it is often used as an evaluator in testing the functional ability in these children. This is done by comparing the assessed child with a normally developing child, assessing the functional limitations (16). It has also been validated to identify disabilities in larger populations (32), and is a useful tool to do so, as it is possible to collect date for the system by interviews with parents, direct observation by a caregiver, teacher or therapist, or by professional judgement by the child's therapist and/or teacher (95).

PEDI measures the adaptive functions of children in three domains, namely: self care, mobility and social functions (16). A Functional Skill Scale is then produced from these 3 domains. In addition to this, a Caregiver Assistance Scale is produced from a set of 20, complex functional activities, and a Modification Scale is calculated from the level of modification needed to perform the tests performed in the Caregiver Assistance Scale (28). These scores are again calculated into so-called normative standard scores, where the age of the child is taken into consideration, and scaled scores, where the effort is scaled on a scale from 0-100 without consideration to the child's age (3), thus giving the possibility to evaluate the child with comparison to the age of his peers, and to evaluate the relative ability level independent of age.

Several trials have been conducted in order to check the reliability and validity of the evaluative measure showing a remarkable high inter-interviewer reliability (3) (28). Studies have also concluded that PEDI sufficiently discriminates between a disabled and a non-disabled group of tested children (96), making it an appropriate assessment tool for children with cerebral palsy. It is also said to be a useful tool when describing functional delay in children with cerebral palsy and was found sensitive to functional change (97).

## 2.7. Bayley Scales of Infant Development (BSID)

The Bayley Scales of Infant Development (BSID) is based on the work of Nancy Bayley with colleagues, and the current version, the BSID-III (98) is a revision of Bayley's earlier work (3). The assessment tool is aiming to assess an infant's strengths and weaknesses in five important domains: cognitive, language, motor, social-emotional and behaviour (99) . BSID is said to measure infants as young as 15 days, up until 42 months, in order for an early diagnosis to start treatment as soon as possible for children with developmental delay (100), as seen in children with cerebral palsy.

Early traces of the scales were published as early as 1933, when Bayley published a measurement for the mental development of the infant. Some years later, in 1936, the motor component was created, and in 1969 the mental and motor scales were joined together to one assessment tool, together with scales for behavioural development, and has since the first edition in 1969 been considered by many as the best measure for assessment of infant developemt (28). The newest revision, BSID-III also includes two additional and separate scales, one for language skills, and one for the social-emotional development (100).

The main focus of the following paragraphs will be on the motor skill assessment, which has proven to be to most accurate when testing validity (3), stability, reliability (28), and predictability (101). It is also the part I feel covers the aim of this thesis, and the physiotherapists view in a child with cerebral palsy the best. It has also been concluded that consideration should be taken when using the cognitive scale for measuring intellectual abilities in children with cerebral palsy using the BSID (99) (100), because intellectual deficiency is far from a hallmark in children with this condition.

The motor scale aims to evaluate both fine and gross motor skills, and postural and ambulatory abilities by testing axial muscles when sitting, standing and walking, coordination of large muscle movements, and ability to perform fine manipulations using fingers and hands (100). It consists of a total of 138 items, divided in a 66 item fine motor assessment, and a 72 item gross motor assessment (99). This is an increase from the 111 item motor scale previously used in the BSID-II (101).

Even though the motor assessment part of the BSID is acknowledged as a very much valid tool for assessing a child's motor development, it has also been criticized for not containing

milestones that are usually agreed upon to be a major part of infant motor development, and that the tool has too few items to truly investigate the entire picture of such a complex field as the infant motor development, with rapid and sometimes individual changes in a relative short period of time (102). BSID has also been criticized for not including items assessing primitive reflexes, muscle tone and equilibrium responses, by many considered crucial for evaluation of infants with disabilities (28). It has also been argued that the system requires a considerable knowledge of infant development in order to adequately carry out the assessment (28).

Having said that, the BSID has been used by clinicians all over the world, for an extensive period of time, and it rates among the most popular assessment tools when assessing the human infant development. It has been standardized on a large group of infants (103) and is believed to adequately represent the normal infant development, except for some weaker validity results on the behaviour scale, and to assess deviations from this (24). Administering the system takes about 45 minutes by a trained examiner (3), and thereby serves as a relatively rapid way of assessing an infant's development. A form of continuity and familiarity is also seen, as different items containing similar devices in the different domains, making the assessment significantly easier, both for the examiner, and the child.

## 2.8. Peabody Developmental Motor Scales (PDMS)

The Peabody Developmental Motor Scales (PDMS) aims to assess early childhood motor development, from birth to 83 months (104). The current version was published in 2000 and is known as PDMS-2 (3) based on the original version of the PDMS published in 1983 by Folio and Fewell (95). The PDMS is a standardized, norm-references assessment tool, aiming to assess both the fine and the gross motor development of children in the mentioned age group (28) with individual scales for fine and gross motor development (104). A full assessment takes about 45-60 minutes to complete, with approximately and an equal time spent on the two scales (28). The fine motor developmental scale consists of 112 items divided into 16 age levels and covers tests for grasping, hand use, eye-hand coordination and finger dexterity. The gross motor developmental scale consists of 170 items, divided into 17 age levels testing the quality of reflexes, locomotor and non-locomotor abilities, balance, and receipt and propulsion of objects (104). It is provided norms for each skill category at each age level, and for total scores (3). Each item is scored according to a three-point system divided into the levels of: (A/2 points) Child is able to perform the skill, (B/1 point) Child can almost master or the skill is emerging, (C/0 points) The skill is clearly beyond the child's reach (104).

The administration of PDMS should begin one age level under the child's motor age (usually estimated after the child's chronological age). If the child is evaluated to score a 0 or 1 score in two or more items, the examiner steps down one age level. The basal motor age is then the first level where the child scores 2 on all items. The ceiling level, on the other hand, is the level under the level in which the child is only able to score 0 or 1 on the items (one score of 2 points is accepted) (95). The child's motor age is then estimated between the basal and the ceiling level.

The standardization of the PDMS was made on a large group of children, considered to be representative for the American population in terms of geographic region, race, and gender. The test-retest reliability and the inter-observer reliability both scores 0.99, indicating an excellent stability of the assessment tool (3). Another recent study evaluating PDMS-2 showed that the measure is an adequate measure to evaluate motor skills and motor development changes over time for young children with cerebral palsy. The same study also supports the excellent test-retest reliability, and compliments the systems sensibility to change over time after application of interventions (105). The authors of the assessment measure

initiated a series of tests to confirm the reliability and stability immediately after the initial publication of the original version of the PDMS, and found exceptionally high outcomes on both domains (95), it is important to keep in mind, however, that the user manual in some cases does not offer any specific device, for example in order to draw the tested child's attention to an object, for some of the items. This could hamper the standardization, as different objects could trigger different responses in different individuals (3). I high test-retest reliability could be attained by using the very same environmental settings, as performed in the studies mentioned above. There is reason to believe that assistive devices are not universally similar. The Peabody Motor Development Chart is attached as Appendix V at the very back of this thesis.

## 3. Treatment

Therapy and treatment for children with cerebral palsy is a complex process, requiring a strong collaboration between a wide spectre of different health care providers, including physicians, pharmacologists, occupational therapists, speech and language therapists, special education teachers, and the main aim of this thesis, physiotherapists (2) (5). The intercommunication of the multidisciplinary treatment team is believed to be of high importance in order for a successful treatment to occur (31). Physiotherapy encompasses a central role in managing the condition by focusing on function, movement and optimal use of the child's potential (106). The physiotherapeutic field focuses mainly on gross motor function, such as walking, running and range of motion (2), but in some situations their tasks overlap with areas traditionally belonging to the occupational therapists, involving fine motor control, like feeding, manipulation of objects and function of facial muscles.

An early intervention is proven absolutely crucial (28) (107), due to the relatively high plasticity of the central nervous system from a young age (2) (100). Several treatment approaches are made with different advantages and disadvantages. The majority of the treatment procedures available today could be divided into two major divisions, namely the Neurophysiological Methods (NPM) and Functional Therapy (FT). The blocks have been defined with the first group being with emphasis put on the normalization of the quality of the movement, whereas the latter emphasises on achievement functional activities (108). They are heavily built upon the traditional theory of maturation of the nervous system, and the Dynamic Systems Theory (DST) respectively. This is the basis of the differentiation used in this thesis.

Another way to describe the different therapy philosophies often found in literature, are into the concepts of child-focused approach and the task/context-focused approach. A child-focused approach, like the NPM, aims to change the body function and structure in the child by remediation of the CNS (109). It is, however, important to keep in mind that the original lesion causing the motor impairment in cerebral palsy is static, and can never be reversed, the approaches are rather a way to teach, or trick, the child's central nervous system to work around the lesion (2). The task/context-focused approach, on the other hand, works on a specific functional goal that has been identified through the cooperative work of the family, the child and the therapist (109). It has been suggested that a general shift in therapy

approaches from the child-focused approach to the task/context focused approach is recognized (110), but only inconclusive evidence exist to the efficiency comparing these two therapy approaches.

The Neurophysiological Methods are represented by the treatment philosophies developed by Vojta and the Bobath's (also known as Neurodevelopmental treatment). They are similar in the way that they focus primarily on remediation of body function and structure in the children.

The Functional therapy on the other hand is characterized by activity focused, goal oriented therapy. In other words it is a highly specific training on the activity the individual child needs to manage, often with substitution mechanisms, and not necessarily with correction of what is traditional viewed as an abnormal motor performance. The definition of functional therapy used this thesis is based on the available literature, and are as follows: "*An approach that emphasis the active promotion of functional skills in a familiar environment which is meaningful to the child and the parents. The desired outcome of therapy is the achievement of a set of pre-determined functional goals through repetitive practice with the child being the active problem-solver and the therapist a facilitator."*

### 3.1. Neurophysiological methods

This group of therapeutic intervention focus heavily on the normalisation of the quality of movement of children with cerebral palsy. Although it is consisting of a larger amount of therapy approaches, I have chosen to focus on the Bobath approach (also known as neurodevelopmental treatment) and therapy based on Vojta's principles. The decision is based on global and domestic popularity of the respective treatment methods.

Neurophysiological methods follow the so-called neuromaturational theory, assuming that a child acquires more complex motor skills as a result of the maturation of the CNS. This happens when higher centers inhibit and control lower centers in order to allow voluntary movement, as the child matures. Cerebral palsy has been seen as the lack of inhibition of these lower centers, leading to abnormal postures and movements (108). Further on, the neuromaturationalists also believe that certain basic motor skills are not learned through environmental experience, but are rather as a result of the maturation of the CNS (111). In other words, inability to perform these basic motor skills are not due to the lack of practice, but instead because of the child's immature CNS, or its maldevelopment. Following this hierarchical unfolding of predetermined patterns one can make a diagnosis of developmental motor dysfunction, such as cerebral palsy, by evaluating if the predetermined patterns are unfolding at the right time (112).

In a practical setting, neurophysiological methods are following the so-called child-focused approach. Remediation of the child's ability is aimed to be achieved through changing body function or structure in order to develop more normal motor patterns that will ultimately lead to assist the child in reaching the functional goal (109). The actively participating therapist uses therapeutic techniques to improve the child's bodily functions and structures through exercises focusing on strength, coordination, balance, quality of movement and range of motion (110).

### 3.1.1. Method of Reflex Locomotion by Vojta

Vaclav Vojta was a Czech born neurologist that developed a revolutionary new concept for children with cerebral palsy and delayed motor development in the 1950's and 1960's (16). Vojta contradicted the common, contemporary view of human motor development when he established a set of global motor patterns found in newborns, stating that: "*... even a newborn must have reached a certain maturity of postural ontogenesis"* (49 p. 76). During the observation of children with cerebral palsy, he noted that they would respond to certain stimuli in a given body position with recurring motor reactions of the trunk and the extremities (113). The contemporary medicine and neurology were heavily influenced by Cartesian dualism (114) and the neurologists of the 1950's found Vojta's new explanations of human motor development hard to digest, and was only later recognised as a part of human development and ontogenesis (115) . The dualistic view of a clear-cut division between the physical body and the spiritual soul (116), was contradicting Vojta's concept of preset, global movement patterns. After emigrating to the Federal Republic of Germany in 1968 he published his first book: ""Die zerebralen Bewegungsstörungen im Säuglingsalter – Frühdiagnose und Frühtherapie" (115), that roughly could be translated into "Cerebral Palsy in Infancy- early diagnosis and treatment". There exists no English translation of this book.

The Method of Reflex Locomotion by Vojta (hereinafter referred to as "Vojta concept", or similar) is heavily based on the neuromaturational principal, aiming to activate the postural ontogenesis which is claimed to be blocked or inhibited during the early human motor development in cases of a CNS disturbance (28). Vojta explain the theory of the ontogenetic blockage with the fact that he was able to provoke previously unachievable movement patterns in children with spasticity following repeated stimulation (113), and thereby bypassing the blockage or inhibition. Vojta stated that an ideal motor function is congenital, with a normal developing child passing through innate motor milestones (5). He based the theory of a set of preset motor milestones inherited from previous generations and present at birth on the fact that he was able to activate these respectable movement patterns at a much earlier stage than contemporary human developmentalists (113). Early motor patterns found in newborns are of a subcortical origin, and can be provoked in older children with cerebral palsy (28). To come to this conclusion, Vojta observed movement patterns in older children with cerebral palsy and recognised the same patterns in infants with a suspected CNS disturbance. He placed the tested children with certain body postures in prone, supine and side

lying positions, and observed that reproducible global movement patterns were triggered by this handling (115). This allegedly allowed an early detection and subsequent treatment of children in the risk group of being diagnosed with cerebral palsy (49). Advocates of the Vojta theory means that this offers a unique possibility of an early diagnosis of a suspected CNS disturbance by assessment of spontaneous movement patterns, postural responses and the infant reflex development (113). This met the criteria of Vojta's opinion of the necessity of an early introduction of treatment for these children (16) and researches have also showed that the best effect of the Vojta therapy is gained during the first 2 years of life (2), even though it was initially developed for adolescents with a fixed cerebral palsy (117). By using the principals of the Vojta theory, it is claimed to be possible to diagnose and initiate appropriate treatment in infants within the first 6 months of infancy (113).

The goal of the therapy provided by "Internationale Vojta Gesellschaft" is said to be: "*..to activate and maintain physiological patterns of movement, as well as to reduce non-established abnormal patterns of movement and to integrate them into normal motor processes, all the way to complete mastery of conscious motor activity."* (118). The idea of the concept is that in a child with cerebral palsy, both the beginning and the end of a movement pattern is done in an abnormal posture, sending faulty afferent information back to the CNS, establishing this abnormal movement repertoire. It is believed that, through guidance and facilitation of the beginning and end of the movement, the CNS is able to substitute the previously stored abnormal movement pattern, with this new corrected one (5). Unlike other comparable treatment techniques, therapy according to the Vojta principal does not aim to realize typical motor milestones such as grasping, rolling and walking through practice, but rather through gaining accessibility by facilitating the CNS (118). A description of the main principles of the treatment follows.

The cornerstone of therapy according to Vojta's principles is the so-called reflex locomotion (5). Reflex locomotion is described as present in all newborns, but the patterns persist in children with cerebral palsy, or motor delay (16). The therapeutic use of reflex locomotion enables the therapist to activate basic movement patterns in children with an impaired CNS (118). Vojta described reflex locomotion as a performed motor pattern that is not of a spontaneous origin, but rather as a result of tactile stimulation in the periphery (49). The term "reflex" in these circumstances is intended to cover situations where a certain stimuli trigger a specific motor activity leading to an automatic movement (115). They involve partial

movement functions thought to represent the normal postural development in a child, and are characterized by the fact that they are controlled by the CNS, are constant, and are possible to reproduce (52). A basic principle in the clinical administration of treatment according to the Vojta concept and reflex locomotion is the administration of goal-directed, (118) tactile stimulation (28) on proprioceptive triggerpoints genetically determined (52) on the trunk and the extremities to initiate reflex movements which produce the desired movements (2). Ten different zones of stimulation are described in the literature (16). The simulative points are sites on the body of a great number of muscular and ligament attachments, high in the relative number of receptors (52), and are carried out with the child either in a prone, supine or side lying position (119). This tactile stimulation can provoke two possible results, namely reflex rolling and reflex creeping, which are initial positions the child is placed into in order to provoke an involuntary muscle activity (52).

The reflex creeping includes the most fundamental components of human locomotion, and aims to promote postural control, activation of uprighting and extension mechanisms and to introduce goal directed stepping movements of arms and legs. Movements occur in a so-called crossed pattern, where left leg and right arm, or vice versa, move simultaneously. The therapist performs adequate counter-pressure when the child initiates the turning of the head, in order to increase the muscle activity throughout the body, as a prerequisite for the uprighting (119).

Reflex rolling, on the other hand, is a sequence that starts in supine lying, continues via side lying through a prone creeping position. Reflex rolling could be further subdivided into two phases, where the first phase is with the child supine, and the second phase is with the child in a side lying position. Desired reactions following reflex rolling are, among others, extension of the spine, flexion of hip, knee and ankles, coordinated activation of the abdominal muscles and stabilization of the head in a side lying position (119).

These two movement complexes are so-called artificial creations, as they do not spontaneously occur in human beings. Their global occurrence is only as a result of a correct starting position and specific stimulation, and would not occur without these methods of triggering (115).

The 3 different positions of reflex creeping and reflex rolling have 30 different variations, and by changing the combination of stimulation zones, force and direction of applied pressure and

joint angles, the therapy is highly adaptable to every individual child (119). When the therapist combines more zones for the wanted effect, as an initially inactive zone turns active if combined with stimulation of another reflex zone (49). It is also crucial that the stimulation elicited is performed in a correct direction and with a varying intensity (52). By these possible differentiations in varying intensity and the number of stimulated points, the concepts elicit motor activity through temporal and spatial summation, respectively (49). *The available literature does not offer any recommendations of the stimulation, and a successful therapy is thought by the author to be through experimenting in each individual case, based on previous knowledge of developmental kinesiology and the occurrence the of wanted reactions.*

The therapy is suggested to be carried out with a daily frequency of application by parents with several short, but intensive sessions, lasting for approximately 15 minutes (2) (5) (16). The parents are looked upon as laymen, with the therapist alone determining the treatment plan and approach, and educating the parent accordingly, in a one way direction (120). The treatment often induces crying by the children, and many parents find this disturbing (16). Some even suggest this could be a possible contributor to a damaged parent-child relationship (5). No scientific research supports this view, however, and the crying is thought to be a desirable response, manifesting the success of treatment. Crying is further on believed to be the non-verbal infant's way of responding to an unaccustomed activity. This is explained by the fact that the child is not crying so forcefully after the initial acclimatisation of the new treatment, and stops rather immediately after completion of therapy, and by the fact that older, verbal children do not cry during therapy (118).

On the other hand a detailed report of the fatal outcome of Vojta therapy of a 3 months old baby exists. The casualty was due to bleeding into the adventitia of both vertebral arteries causing ischemia of the caudal brain stem with subarachnoid haemorrhage. Symptoms occurred after forced active rotation of the head (121). No other reports on instant death due to Vojta therapy are found in medical journals, but general contraindications of treatment are acute fever or inflammatory states, recent vaccinations, ongoing pregnancy and certain disorders such as osteogenesis imperfecta and heart diseases (118).

Due to the relatively limited geographic expansion of the Vojta method, few newer researches are available in the English language. This is also manifested by the fact that the web page of the "Internationale Vojta Gesellschaft", www.vojta.com, was only recently translated into English.

### 3.1.2. Bobath's method (neurodevelopmental treatment)

One of the most remarkable couples in the field of cerebral palsy is without a doubt the Bobath's. Karel and Berta Bobath were both born in the beginning of the 20th century in Berlin, Germany. He was a trained medical doctor, and she a remedial gymnast, and later on an educated physiotherapist (122). Husband and wife working together, developed the framework of what today is known as Neurodevelopmental Treatment (NDT) (2). In existing literature, the Bobath concept and NDT are used interchangeably. It is said that practitioners of the more modernized NDT are bound to be influenced in their work by the framework originally stated by the Bobath's by means of handling techniques (123). For that reason, the Bobath concept (or similar) will be used from now on, to minimize confusion, and as a homage to the initial developers.

The Bobath concept was originally developed for individuals with pathology of the CNS, and especially for children with cerebral palsy and hemiplegic adults (3). It has from the very beginning been described by the Bobath's as a living concept (2), with the intention of a continuous development as research was done in neurology, and the medical field as a whole (3). Prior to the development of the Bobath concept, CNS pathology was typically treated orthopedically, with splinting and surgery. During work with a patient, unsatisfied with the conventional treatment, Mrs. Bobath discovered that muscle tone was changing by handling the patient in certain ways, and she saw the possibility for a functional recovery of the motor impairment. This was not only a major advancement in neurorehabilitation, but with the Bobath concept, physiotherapy as a profession was also more acknowledged as a science, adopting a huge group of patients from medical prescription (122).

As mentioned above the Bobath concept is a living concept, meaning it will develop according to recent research, always aiming to be up to date. Although it has been suggested that the development of the approach has not necessarily kept pace with the recent advances in evidence based medicine, following the death of the Bobath's in 1991. Saying that, the very same review concluded with a higher percentage of parameters favouring the Bobath concept in newer studies, using contemporary techniques (124). Later researchers also support the finding of better results achieved through recent approaches of Bobath therapy. I refer to the sections of results for further information on this field.

When the concept was founded in the 1940's it was a hypothetical model based solely on clinical observations, validated by the available research at the time, often based on animal experimentation (122). Since then, major advances have been made in clinical neurophysiology, and advanced diagnostic and imaging tools have been made. Below is a short summary of the history of the development of the Bobath concept thought to be of great importance in order to fully grasp the concept of the Bobath approach to treatment of cerebral palsy.

In the early years of the development of the Bobath philosophy the concept was focused to a high degree on reflexes. The Bobath's stated that the fundamental difficulty in cerebral palsy was lack of inhibition of reflex patterns of the posture and movement, with the hypertonicity found in many cases explained by overaction of tonic reflex activity, leading to an abnormal posture and movement patterns (16). Dr. Bobath first described the theory as a hierarchical model, with descending control from the cortex to the primitively organized spinal cord. In other words, movement in early childhood was thought to be elicited solely through stimulation of primitive reflexes in the spinal cord. Development of the more mature movement system was explained by inhibition of these primitive reflexes by higher centres. This meant that a lesion of these higher centers would cause a disturbance in this all important inhibition, manifesting itself in a motor deficit (122).

Over the years, the cornerstone of the Bobath concept, the book "*The Motor Deficits in Children with Cerebral Palsy"* (later retitled " *A Neurophysiological Basis for the Treatment of Cerebral Palsy"*) was published in 1966 and 1980 respectively, with the latter version reprinted in a virtually untouched form, several times after the death of the Bobath's in 1991. This underlines the fact that the original philosophy is the building block for further development of the concept, explaining the long lasting popularity of the Bobath approach. Karel Bobath was even cited on several occasions saying: "*The Bobath Concept is unfinished, we hope it will continue to grow and develop in years to come"* (122 p. 3). A fundamental change in the concept is found between the two publications, however. In the early days of the concept, the child was placed in so-called reflex-inhibiting postures. Even though these postures reduced the spasticity to a certain degree, there was a poor carryover into functional movement. The approach was changed to a more functional setting, where the therapist rather than performing therapy to the relatively passive child, changed to inhibit abnormal patterns

of movement, and facilitate normal movement while the child was performing the given activity (124).

Today, some practitioners of the Bobath concept follows the principles of the so-called Neuronal Group Selection Theory (NGST), to explain why positive changes are present after the treatment intervention (3). The NGST is a relatively new concept, serving as a fusion between the existing neuromaturational theories and the Dynamic System Theory (DST). It is explained by the existence of cortical and subcortical systems, interconnected by thousands of neurons to one neuronal group as a functional unit, which deals with a specific type of motor behaviour (111). Development of this system is believed to start with primary neuronal repertoires, with each repertoire consisting of multiple neuronal groups, evolutionary set in the organism, inherited from forefathers over generations. During life the secondary repertoire appears, as a result of the afferent information, modifying the synaptic and intraneuronal relations, allowing a more situation-specific selection of neuronal groups (112), thereby putting an end to the everlasting "nature-nurture" debate, stating that the human development, and especially the motor development consists of inborn genetic factors and acquired environmental conditions (111).

In terms of the clinical administration of the treatment it is important to emphasise from the very beginning, the fact that the Bobath treatment is just a concept, and not a set of fixed exercises easily reproducible in a clinical setting. It is more a wider understanding of the developmental process of motor control, and motor components necessary to perform a functional task (3). Physiotherapists are educated in the Bobath philosophy, and each individual therapist modifies the techniques used according to practical experience and personal preference. This leads to a different administration of the Bobath approach in different countries, regions and even clinics (16). This is due to the clinical variety of children with cerebral palsy and similar motor deficits, and no rigid and standardized set of exercises would be adequate to cover the needs of all these children. Some general and flexible guidelines do exist and are described briefly in the following paragraphs.

In the first phase of treatment according to the Bobath concept, the therapist performs the preparatory work with the child, normalizing tone and elongating contracted muscles (16). This is done in order for the child to perform a selected movement task as self-initiated as possible, by optimizing the child's chances of succeeding (3). The self-initiated functional activities are broken down to movement components for the child to experience a normal tone

and sensation (16). The therapist only facilitates and guides the child in a normal movement pattern (3), encouraging the active use of appropriate muscles, while excluding use of muscles evaluated to be unnecessary to perform the movement pattern (2) . It is important for the concept that the movement and the sensory process are linked together, and you need to address both the systems for a successful treatment (3).

Bobath stated that: "*A child, whether normal or abnormal, can only use what he has experienced before. The normal child will use and modify his normal motor patterns, by practice, repetition and adaptation. The child with cerebral palsy will continue to use, and by repetition, reinforce abnormal patterns."* (67 p. 26), stressing the importance of reducing the undesirable outcome of a faulty movement pattern, as this is thought to further increase the functional limitations, by building on an abnormal base (3). This concludes that the Bobath Concept is not just a treatment intervention, but also represents a framework allowing interpretation and problem-solving in each individual child (122), matching the child's ability level, age and cognitive function (3), in order to tailor-make a therapy regime to each individual child.

The concept consists of the principle of the so-called all-day management, supplementing therapeutic sessions with a Bobath coached physiotherapist, where functional tasks are carried out at a domestic basis to increase the amount of therapy received by the child in a natural setting (16), making parents an important part of the daily therapy, involving them in the trehatment. This individualization is further highlighted by the fact that the examinations and evaluations serve to prioritize what the individual child needs based on impairments and limitations, and by functional goals that the child and parents find meaningful in an everyday basis (3).

The ultimate aim for the Bobath treatment is to reach the highest level of independence possible, according to his/her age and level of ability (3), and prepare the child for an as normal adolescent and adult life as possible (125).

### 3.2. Functional therapy

As the functional approach to treatment of cerebral palsy does not seem to have a universal definition, it is necessary to start with a description of what is considered functional therapy in this thesis based on what seems to be the common consensus among practitioners of functional therapy in the field of cerebral palsy. The approach should emphasise the active promotion of functional skills in a familiar environment which is meaningful to the child and the parents. The desired outcome of therapy is the achievement of a set of pre-determined functional goals through repetitive practice with the child being the active problem-solver and the therapist as a facilitator (108) (127) (128).

Functional therapy is in other words heavily based on the so-called task/context focused approach (109). In this approach the therapist should not correct a child's motor behaviour through handling, but rather facilitate the motor development through preparing the environment in such a way that the child is stimulated to perform self initiated actions within naturally occurring restraints (110). These goal-limiting restraints are important for this concept and could be found in the child, the task or the environment, and must be identified by the therapist, and then decided if they should be removed, modified or changed in order for the child to achieve the functional task (109). To identify these restraints, a strong collaboration between therapist, parents and other caretakers is necessary in order to best meet the individual child's needs (110).

The strong collaboration with the family links the functional approach tightly to the so-called family-centred service (FCS). Such a family-centred approach follows the principles that every family is unique and different, that primary caregivers best know their child's abilities and needs, and want the best for their child and that the child is functioning optimally in a supportive family and community setting (129). Parents are educated in the principles, and intervention is carried out by the parents in a home environment, to provide a stable environment for the child, which is believed to optimize the performance (128). It also takes the strengths and needs of all family members into consideration (129) in order to constitute a thorough concept for therapy. Family-Centred Functional Therapy (FCFT) is based on FCS and Dynamic Systems Theory (DST), and aims to achieve a functional task identified by the family as important to the child with adaptations encouraged and effective movement patterns considered more important than normal movement patterns, with tasks constructed to fit into the family routines (128).

Besides FCFT, DST also highly influences the task/context focused approach, (16) (109), and should be explained into more detail as it is thought to be of high importance throughout the field of functional therapy in cerebral palsy.

DST is a relatively new explanation of human development, following a non-linear, rather than hierarchical organization of infant development (130). More and more developmentalists now recognize the idea that human development is not merely as a result of the unfolding of innate programs, embracing the theory behind the DST (112). The theory is based on the assumption that human beings are complex systems, put together by individual elements, open to change from the environment (130). This system is under a continuous dynamic process where all the specific parts constituting the system are both influencing, and are influenced by each other, i.e. the physical structures of the body, such as bones and muscles are transforming and thereby changing the conditions of performing a motoric action throughout the lifespan (60) cf. Thelen et al.'s research on the disappearing reflex (64) .

What differentiates DST from the traditional views of the neuromaturationalists is that they dismiss the explanation of a gradually maturing nervous system, orchestrated by a pre-set and latent program of motor development similar in every child. Smith et al. (130) uses creeping as an example to explain their views. This early form of locomotion enables the child to move around when strong and coordinated enough to obtain a hands and knees position, but still too weak to maintain upright locomotion. Instead of the neuromaturational explanation of an ever evolving nervous system, advocates of DST stresses that infant creeping manifests an event of a self organized problem solving, allowing the child to achieve his goal of moving across the floor as the best solution. Later this form of locomotion would be replaced with a more advanced form of motor activity of erected bipedal locomotion. The self organization works together and interacts with multiple other factors, such as body weight, muscle strength, joint configuration, mood of the infant, specific environmental conditions and brain development (112).

Rather than assessing whether a child merely has the knowledge or ability to perform an action or not, the DST aims to question how all the separate elements cooperate in order to perform a specific action, and if unsuccessful, what the reason is for the non-achieved goal (60). That gives the system an advantage in a practical setting, thus not restricting the area of therapy to the child's movement apparatus strictly, but also allowing intervention to be performed through manipulation of constraints also in the environment. Critiques however,

point out the relative neglect of the role of the CNS, stating that when dealing with a child of an impaired movement apparatus, the CNS plays a substantial role (112).

According to the activity based principle of the functional approach in treatment of cerebral palsy, a new trend of that stresses continuous activity as an important mantra for further development of cerebral palsy (131). Activity focused therapy assumes that the child acquires important movement repertoires through an active motor learning (132). Such an approach was found in Sorsdal et al. (133), where sessions of high intensity, activity-focused and goal directed physiotherapy were carried out over a shorter period of time. This research is also following the trend of a family centred practice of intervention as explained above.

# 4. Results

The following chapters summarize scientific results found in available literature, investigating the effectiveness of treatment of cerebral palsy from newborn to adolescence. Many of the investigative findings are evaluated by assessment methods already explained in earlier chapters, and for a better understanding of the different methods used I am referring to these chapters. No specific definition is set to how to determine a so-called successful therapy, but evaluation is based on what seems to be the common consensus of researchers, namely a higher level of independence, higher level of gross and fine motor function and a better functioning within the family as a unit. This seems to be a collective goal of the two otherwise conflicting therapy systems. Results are also evaluated according to what was the aim of the respective studies.

The following chapters serve to contain research results for neurophysiological methods and functional therapy respectively. In cases where two such interventions were compared the results are presented under the chapter of its respective experimental group. In other cases, the research would be referred to under both chapters.

## 4.1. Results Neurophysiological methods

As previously discussed, the Vojta therapy has a limited prevalence worldwide, hence has few researches compiled in the English language. An often cited research written in English was compiled by Kanda et al. (134). Unfortunately I was unable to access it in its full form. However, the abstract indicates a finding of children with spastic diplegia receiving Vojta therapy from an early age was walking from an early age than previously expected. A follow-up cohort study was later performed by Kanda et al. (135). The aim was to evaluate the long-term effects of early onset Vojta therapy to infants with spastic diplegia. Of the 10 infants in the original study sample, 5 completed full-course therapy. Of the 5 children receiving full-course therapy, 4 were standing or walking after consistent Vojta therapy for a mean duration of 52 months, as opposed to none in the group that received insufficient therapy, or did not receive therapy at all. Unfortunately, I have been unable to retrieve full access to the article, but study results were confirmed by a review made by Blauw-Hospers et al. (107) , that came to the conclusion that the experimental group showed significantly better results compared to the control group. Despite this, Blauw-Hospers et al. concludes that there are no evidence available supporting the practice of Vojta therapy.

With the lack of published and available literature in English, it is necessary to look at the nature of the Vojta concept. As discussed previously it is enabling an early onset intervention of children in the risk group of later being diagnosed with cerebral palsy. Vojta therapy is said to be applicable already to newborn infants (118), and with respect to this it has been stated that Vojta therapy has a great advantage when it comes to an early onset of intervention, preventing the further development of a more serious CNS disturbance of so called risk infants (136). Vojta himself published results of impressive numbers. He treated 207 of the so-called risk infants with Vojta therapy. This subsequently lead to a discharge of 199 (96%) of the children after have being assessed to possess normal motor and mental abilities (137) . These results have to be considered carefully due to the relatively high chance of bias. Preferably these results should be confirmed by an independent researcher in a study of high methodological value. It is important to point out that the infants in the study had yet to be diagnosed with cerebral palsy, but was just termed as risk-infants. However, it is reasonable to believe that the group would encompass a number of possible cases of cerebral palsy, as it was compiled of infants under circumstances that were previously proven to increase the prevalence, such as complications during birth, premature delivery, increased maternal age,

multiple births and a high number of gestations. Questions should also be asked regarding the practical carry-over of the findings to the field of cerebral palsy. It is important to keep in mind the nature of cerebral palsy, being a static lesion of the central nervous system, so being discharged at an early age with no motor deficit, does not mean that the child will not encompass difficulties related to cerebral palsy at a later stage in life, or that they simply did not have cerebral palsy. It also indicates that a large portion of the original number of 207 children would not present with a CNS disturbance, even without the intervention, although milder forms of central coordination disorders (CCD) might have been prevented, or even cured to a certain degree.

Bobath therapy, or NDT, is one of the absolutely most widely used forms of therapy for children with cerebral palsy worldwide (2), and being the preferred treatment of the condition in the United Kingdom (123) and in North America (126) the need of validation has resulted in a wide variety of different researches over the years.

An often cited work in this case was the large evidence report compiled by Butler et al. (124) evaluating research done on the effect of the Bobath concept from 1956 to April 2001, appointed by the American Academy for Cerebral Palsy and Developmental Medicine (AACPDM). It concluded that no consistent evidence is present towards change of abnormal motoric responses, slowing down or preventing contractures or an overall improvement of motor development of functional motor activities were present in combination with Bobath based therapy. This dramatic conclusion was met with scepticism among supporters of the concept, arguing that the Bobath approach is not a specified intervention for children with cerebral palsy, but rather a method assisting children in reaching functional tasks. It also stated that the assessment tools used in a lot of the researches, like the Bayley Scales of Infant Development and the Denver Development Screening Test did not necessarily evaluate positive changes expected after administration of the Bobath approach (138). As an answer to these accusations, Adams challenged the sceptics to develop and validate an assessment tool that would include the areas thought not to be covered by traditional assessment tools, in the spirit of contemporary research (139). It also has to be taken into consideration that AACPDM evidence reports are based purely on existing results, simply listing them schematically, based on their already existing conclusions (124). Although criticism arises around some aspects of the evidence report, both sides agree that the study is a vast piece of

work and it is worth to look into it in more detail. Important findings of the evidence report are highlighted below.

The study subdivided results into categories commonly believed to be of importance for cerebral palsy. A small advantage was found in favour of the Bobath approach in terms of motoric responses in the form of immediate dynamic range of motion. A short term improvement of contractures and deformities are clearly favouring the Bobath treatment, whereas similar results on the long term improvement of contractures and deformities did not differentiate Bobath treatment from the control treatment. Motor development was not found to favour either the Bobath approach or the control treatment. It also concludes that there exists no evidence that therapy carried out with a higher frequency would be more beneficial. Neither was any other socio-emotional benefits found, such as improved parent-child relations, greater parent satisfaction, better home environment or improvement of the domains of language and cognitive development. Interestingly the more recent studies show a significantly higher amount of positive results with regards to motor impairment and motor activity, than earlier studies, indicating an improvement of the contemporary Bobath approach. The author of the evidence report also concluded that there still exist substantial gaps in the fields of evidence that need to be addressed before either promoting or dismissing Bobath therapy as the preferred therapy in cerebral palsy.

Webb (123) conducted a similar review of the evidence of the effectiveness of Bobath therapy, appointed by the National Public Health Service for Wales. Although basing a lot of the conclusion of the aforementioned AACPDM evidence report, it has the advantage of a later publication date and thereby also including more recent researches. It found 8 studies were the Bobath approach was used. One study provided positive results when compared to the control group, in six studies the experimental group and the control group did not differ, the last study reported a worse outcome of the Bobath group when compared with the control group. The conclusion of the report was that: "*Despite the widespread use of NDT/Bobath in children and adolescents with CP the existing published evidence, does not provide support for the effectiveness of the NDT/Bobath treatment approach."* (123 p. 10)

A more detailed analysis of particularly the newer studies seems to be needed in order to get any clear conclusions in terms of the Bobath approach, and especially studies performed after April 2001, and thereby not included in the AACPDM Evidence Report. This is true to the

nature of the Bobath concept, being an ever evolving philosophy aiming to be up to date with the newest research available.

Tsorlakis et al. (140) compiled such a research. Aiming to evaluate the effectiveness of intensive versus non-intensive administration of treatment according to the Bobath theory, he presented remarkable findings. In both the intensive and the non-intensive group 30 out of 34 subjects showed an improved GMFM score after 16 weeks of treatment, with a greater effect seen in the intensive group receiving treatment 5 times weekly, as opposed to 2 times weekly in the non-intensive group. This study is of special interest due to the fact that is has 2 homogenous groups with respect to sex, GMFCS level, distribution of impairment and with only small differences in age. (See Table 1 in Appendix I) Two groups of 17 children were randomly extracted from an original group of 114 children and assigned to their respective groups according to the aforementioned criteria. The improvement in GMFM was significant in both groups, with the biggest improvement shown in the intensive groups comparing the pre-intervention assessment to the post-intervention assessment. The difference between the intensive group and the non-intensive group was calculated to be of a large effect size, and improvements were especially big when evaluating the GMFM-66 score. (See Table 2 and Table 3 respectively in Appendix I). This questions the statement from Butler et al. (124) saying that no indications were found supporting a high intensity application of intervention. The researchers also extracted data that the biggest improvement of GMFM was shown in the youngest age group. This is known to have a possible cause of natural development in the specific child, and should be taken into consideration. Even though the test results as presented in the study are impressive, a few things need to be highlighted and discussed in more detail. Studies of low versus high-intensity treatment have previously shown an immediate advantage of the latter with a gradual subsequent regress in results. To avoid this, a follow-up assessment should have been preformed after a certain time period to confirm the stability over time. Another thing that request caution in this study is the impressive homogeneity provided between the two groups. A strive to create such an environment might hamper with a natural randomization that are absolutely crucial for result of high methodological value. The study also only consists of children with spastic forms of cerebral palsy, with a relatively mild impairment of gross motor functions with GMFCS levels between I-III, hence does not represent the full spectre of the condition. Having said that, this randomized controlled trial concludes with profound advantages in gross motor improvement of the Bobath approach in general, and with using high intensity in particular. On the other

hand, questions must be asked towards whether an intensive application of intervention of 50 minutes, 5 times weekly for 16 weeks is practically feasible.

Another study supporting the short term improvement leading from therapy according to the Bobath philosophy was put together by Knox et al. (141) showing a significant improvement as a result of a 6 weeks intervention in a Bobath therapeutic unit, administered by a Bobath educated physiotherapist. The child was tested in the baseline period when receiving therapy from a local physiotherapist, at the start of Bobath intervention, at the end of Bobath intervention and 6 weeks after finishing Bobath intervention by means of GMFM, PEDI and a parent questionnaire. Interestingly, the Bobath educated physiotherapists were instructed to construct 3 functional goals in cooperation with the respective parents, linking the aim of therapy closely to what is seen in several researches of functional therapy. These functional goals were not directly practiced during intervention.

Results of interventions shows that 75% of the goals set were achieved through intervention (see Table 4 in Appendix I). A significant improvement in the mean value of GMFM is also seen comparing baseline test results to the post-intervention assessment in all items. The scores also remain relatively stable in the follow-up assessment (see Table 5 in Appendix I). The PEDI showed improvement after Bobath intervention to the domain of self-care in the functional skills dimension, and improvement mobility and total scores of the dimension of caregivers assistance. The other domains also showed improvement, but this did not differ from the improvement seen in the baseline assessments, and could therefore not be credited to the Bobath intervention (See Table in Appendix I). The assigned parent questionnaire resulted in positive feedback, with most parents stating that their child's overall independency level improved following the 6 weeks Bobath intervention.

This clearly give us an understanding of the possible effects of the Bobath approach, even though the study sample in this research was relatively small, consisting of 15 children completing the program, out of 20 children in the beginning. However, the children were covering a wider spectre of cerebral palsy then seen earlier, containing children diagnosed with different levels of spastic, athetoid and ataxic forms of cerebral palsy. All levels of GMFCS were also covered. The follow-up assessment was conducted only 6 weeks after end of therapy, and is thought to be a too short time period to rule out the possibility of regression of results, and immediate improvement following Bobath intervention, reported earlier.

Blauw-Hospers et al. (107) conducted a review evaluating the effect of early intervention in children with a suspected delayed motor development as seen in cerebral palsy, concluding with no clear evidence indicated for techniques where passive handling played a key role in treatment, and stating that therapy based on the Bobath principles was not recommended. Their view was later supported by a follow-up review, indicating findings of no new evidence supporting the practice of Bobath therapy on neither motor nor cognitive development (142). However, it concluded with beneficial results in therapy programmes aiming to stimulate the child's own sense of exploration and active motor behaviour. This is contradicting itself as, therapy based on Bobath principles contain both passive handling, but maybe to a greater degree, the child's own self initiated movements. It also has to be added that the study was not focused solely on children diagnosed with cerebral palsy.

Anttila et al. (106) concluded in their recent review with mostly limited evidence in Bobath interventions addressed to children with cerebral palsy, with conflicting evidence towards the effectiveness. Although not as profound as Butler et al. (124) , it still opens up for the need of well designed trials on neurophysiological interventions, and all other interventions, for that matter, in the field of cerebral palsy.

## 4.2. Results Functional Therapy

*As explained in the part describing the functional therapy in an earlier chapter, there is no clear guidelines to what is considered a functional therapy, but rather a set of different theories the therapist practicing what is considered to be under the umbrella term "Functional Therapy" work within. The evidence for the use of functional therapy in cerebral palsy is based on researches and literature using the elements of the definition found in the introduction to this chapter.*

Ahl et al. (127) compiled a pilot study evaluating functional, goal directed therapy in daily life settings with pre-set functional goals, true to the principles of functional therapy. Intervention was performed with a preparatory course for all caregivers, followed up by a five month period of therapy in the children's home environment, supplemented by weekly group sessions with other children. They reported a successful achievement of the preset goals to 77%, with 19 % being partially achieved. The authors also report a significantly improved gross motor function shown by an improved GMFM score. The PEDI evaluation showed improved scoring in all three domains tested (self-care, mobility and social functions) mainly in functional scales, but also in the caregivers assistance (See Table 7 in Appendix I), altogether concluding with: "*Children with CP benefited from a functional goal-directed training approach in their development of gross motor function and everyday activities"* and "*The study adds to the growing knowledge that efficacy of treatment lies within the child's day-to-day environment"* (127 p. 618). However, it has to be taken into consideration that the sample group was small, consisting of only 14 children, and that training specific skills might overlap with the tested items seen in the GMFM measure that was seen to increase after this therapy, and thereby artificially increasing this score. The fact that the sample groups seemed to increase their social functions measured by PEDI came as a positive side effect, and might be due to the fact that the intervention was performed partly in a group setting. Despite this, the reported findings are impressive, and this research could serve as a pilot study for a similar research of a larger scale that would be necessary in order to classify it as being of high methodological value.

Another study evaluating therapy according to the principles of functional therapy was performed by Ketelaar et al. (108). The study aimed to investigate the effectiveness of physiotherapy with emphasis on practicing functional activities (FT) versus physiotherapy aimed to improve the quality of movement (NPM). In this study, 55 children diagnosed with

spastic cerebral palsy were evenly distributed according to sex, age, distribution of impairment and severity, into 2 groups. Of these, 28 received functional therapy as described above and 27 were in the referral group, continuing to receive their previous therapy, predominantly by means of Bobath's therapy and Vojta or other methods facilitating the normalization of movement. All subjects were tested before onset of intervention, and after 6, 12 and 18 months according to GMFM and PEDI (See Table 8 and Table 9 in Appendix I, respectively). Both the functional therapy group and the referral group proved increasing results throughout the intervention period on the GMFM, and no statistically significant difference was found between the two groups. The PEDI also showed improved ratings in both groups but to a greater degree in the functional therapy group, and especially for the caregiver assistance scale score of self-care that was evaluated to be of large effect size calculating difference between last follow up assessment to pretest measurements. Compared to the previous research compiled by Ahl et al. (127), Ketelaar et al. showed a large sample group with a randomized block design of two more or less homogenous groups of children with universally accepted and scientifically reliable assessment methods in GMFM and PEDI. The sample group was purely of children classified as having a form of spastic cerebral palsy, and does thereby not take into consideration the other sub-groups of the condition. It was also limited to cases of relatively mild forms of cerebral palsy. Due to the fact that the referral group continued to receive the same therapy as previous, and the experimental group saw a change of therapy, one could question if the children in the referral group had reached some kind of plateau in their current therapy, and that the children in the experimental group benefited from a shift in approach.

A recent study by Sorsdahl et al. (133) investigated the change in basic motor abilities following a short term intensive intervention of therapy matching the definition of functional therapy. During this 22 children received intensive, goal-directed and activity-focused physiotherapy in a group setting for three hours, five days a week for a 3-week period were 3 baseline and 2 follow-up assessments were performed. GMFM remained relatively stable during the baseline testing, and improved significantly following the 3 week intervention time, increasing with a mean percentage of 4.5, calculated as a great improvement. (See Table 10 in Appendix I) Other noteworthy results were found in PEDI with significant improvements of the domain of self-care (both dimensions) and mobility and social functions (caregivers assistance) (See table 11 in Appendix I). Other domains of PEDI were of no statistical importance. The study also assessed the experimental group by other assessment

tools, but findings did not show any statistical difference after therapy intervention. (See Table 10 in Appendix I) The study suffers, however, from the fact that the sample group was not randomly assigned, but rather families that wanted intensive training. It is not necessarily true that this therapy program would benefit every family, as the load for both caregivers and child were substantial. The study did neither compare the finding to a reference group receiving control treatment. Due to the fact that the intervention was performed in an intensive manner, it is reasonable to believe that it did just not measure the effect of functional therapy alone but also the effect of intensive, short-term intervention.

Bower et al. (143) compiled a randomized control trial investigating that question, and concluded that the advantage seen in gross motor function following a short-term intensified therapy is of little effect, and is believed to be lost over the subsequent 6 months if therapy reverts to its previous frequency and duration. This view is supported by Ödman et al. (144). Another follow-up assessment of Sorsdahl et al. would be beneficial to rule out the regression of gross motor abilities as seen by Bower et al. and measuring the true effectiveness of the functional therapy alone. Apart from that, the improvement seen in GMFM and PEDI should be taken into consideration. It should also be mentioned that such a therapy regime, with an intervention period of 45 hours in just 3 weeks is not practically feasible.

Lammi et al. (128) researched the effectiveness of Family-Centred Functional Therapy (FCFT) as described in a previous chapter. They compiled a study with intervention true to the principles of FCFT and carried out a sample group of 3 children previously diagnosed with cerebral palsy, under GMFCS III and being between 3 years and 3 years and 6 months. Parents were instructed to establish 3 functional goals seen as difficult to perform, of which intervention was provided towards two of them, with the third just being monitored. The children were also evaluated through PEDI. In the post intervention assessment evaluated through the Canadian Occupational Performance Measure (COPM), significant positive changes were seen in the two functional tasks being targeted through intervention, but no significant change was seen on the third task that was only monitored (See Table 12 in Appendix I). This is demonstrating a poor carry-over of the approach to a functional setting. The post intervention assessment of the PEDI showed a significant increased score in the child's self-care in both the functional scale and in caregivers assistance (See Table 13 in Appendix I). The other domains and dimensions did not have any statistical change, and for one child the domain of social functions in caregivers assistance dramatically declined in the

post intervention assessment. Being a study conducted around just 3 children of a very limited population with cerebral palsy, this study might not seem too reliable, but is important due to the fact that its findings do not correspond to what is previously being stated after an intervention of functional therapy, and is therefore inclusion worthy.

## 5. Discussion

Concluding with anything in particular in the vast field of cerebral palsy has historically been proven difficult. As discussed in the introduction to this thesis, it took almost 150 years from the first description of cerebral palsy for a more or less universal definition to be accepted, let alone the many different sub-categorizations I have encompassed during my work. But this journey through the decades serves as a reminder for what cerebral palsy really is. It is a highly diverse set of symptoms leading from a static disturbance to the immature central nervous system, presenting many different characterizations of the condition. This might explain, despite numerous attempts since the dawn of modern medicine, no single universal accepted treatment philosophy or even general guidelines exists for how to best treat this group of children. Although cerebral palsy is inevitably a complex condition, the answer is most probably easier than one should suspect. When dealing with such a complex condition as this, one should keep in mind that you are not really treating cerebral palsy. You are rather treating the set of different symptoms that are caused by a static lesion of the central nervous system, a lesion which is permanent, and does not have a cure. Trying to find a concept of rehabilitation for all cases of cerebral palsy might therefore be wrong, as the symptoms of each individual child is the cause of concern. However, the decades of tireless research by dozens of highly skilled researchers are not in vain, but serve as important bits and pieces in how to understand the condition to a better extent. In the following pages I will discuss some important findings with the necessity of being highlighted, explaining in which situations a certain approach seems more effective than the other, and the advantages of the respective treatment approach, extracted from the scientific evidence presented in previous chapters. This is according to the investigative questions of this thesis.

Before a discussion on this topic of the effectiveness of treatment of cerebral palsy could be started, a few general considerations need to be made. First of all, in a field experiment evaluating the effect of one treatment approach to the other, it is close to impossible to recruit a homogenous treatment and control group of any reasonable size without risking the randomization of the study sample, due to the many different characteristics of the condition. Also, a finding of a non-statistically significant improvement, especially in a long term study, could in many ways be taken as a sign of a successful treatment, due to the natural history of decreased motor function expected to be found in a child with cerebral palsy. On the other hand, a natural development of motor function is also present in certain age groups, and

increased values of certain assessments such as GMFM, GMFCS, PDMS, PEDI and BSID could be obtained as a result of natural development. And at last, when two treatment interventions are evaluated against each other, a finding of no difference between intervention groups could simply indicate that both interventions have proven to be effective, or on the contrary, that none of them were proven effective at all. With these three considerations in mind, a discussion on the topic of effectiveness of the treatment of cerebral palsy could be made.

It immediately becomes evident that rather than two different treatment approaches as seen in the neurophysiological methods and functional therapy, there are two distinguished philosophies of human motor development. The neurophysiological method follows the traditional and hierarchical system of the neuromaturationalists promoting the normalization of movement, where higher brain centres inhibit lower centres in a process of maturation orchestrated by innate programs. On the other hand, the advocates of functional therapy are more concerned with the presence of the functional execution of a specific task, following principles of the Dynamic Systems Theory (DST). This non-linear maturation of movement leaves the child to realize the most effective way of performing a movement through experience. Until definite evidence promotes one philosophy over the other it is hard to recommend one type of therapy over the other. This ongoing debate of whether motor abilities are innate or achieved, are compromised in the newly developed Neuronal Group Selection Theory (NGST), aiming to put an end to this "nature-nurture" debate. In theory however, a merger between these two concepts are not feasible. Where the functional therapy does not intervene to correct a child's movement pattern when performed in what is traditionally viewed as an abnormal movement pattern. This is looked upon as fundamentally wrong in the views of the neurophysiological group. Vojta stressed that if the beginning and end of a movement was carried out with an abnormal pattern, the faulty afferent and efferent interconnection produces a faulty movement repertoire. This is supported by the Bobath's, stating that: "*A child with cerebral palsy will continue to use, and by repetition, reinforce abnormal patterns".* (67 p. 26) The question is; does it matter whether the explanation behind the concept is correct, as long as the treatment shows positive results in the end of the day? In order to answer that question, it is necessary to look at some protruding findings of the previously discussed results.

A secondary condition that often accompanies cerebral palsy is learning disability (mental retardation, US use). Learning disability is said to be present in 30-41% of all children with cerebral palsy. There is however a big difference in specific subgroups, with higher prevalence in spastic diplegia, and in practically all cases of spastic quadriplegia and hypotonic form of cerebral palsy.

This creates certain demands towards the therapy plan and the therapy approach. In many cases, communication with children having learning disabilities will be severely difficult, or in severe cases, impossible. Due to this fact, instructions given and the subsequent problem solving that is the basis for functional therapy would suffer, and would require major adaptations. To a certain degree, treatment according to the Bobath approach would also be hampered, due to the nature of the application. Vojta's approach on the other hand, does not require any communication between the child and the person that is carrying out the treatment, being the therapist or the parent. Given that the approach itself is effective, this gives a major advantage to the Vojta therapy, especially for those children found to have a form of learning disability.

Taking those very same factors into consideration, another group of children would benefit from a pure child-focused approach as demonstrated by the Vojta approach, namely the youngest children. In this group of non-verbal children, difficulties would arise in application of a task-focused approach due to difficulties in communication. Given this fact, functional therapy looses out on the possibility of a valuable early onset of therapy, described as being of absolute importance when dealing with children with a CNS disturbance. On the other hand, the Vojta therapy is applicable already from birth, due to the fact that it does not require any cooperation from the child, and thereby possess a great advantage. Having said that, in many cases a diagnosis of cerebral palsy is impossible to set before 2 years of age. In other words, early onset of physiotherapy in the field of cerebral palsy is hard to evidentially prove to be effective, as it is not guaranteed that the entire study group has cerebral palsy. However, as long as the therapy does not cause harm or unnecessary stress to the infant, a practice of early onset of Vojta therapy could be defended, following the principle of better safe than sorry. There exists no evidence that Vojta therapy causes unnecessary stress to the infant, despite several accusations. The incidence of fatality followed by Vojta therapy discussed previously is not believed to be caused by the application of therapy as such, but rather due to an underlying secondary condition, and an unfortunate coincidence.

The nature and characterization of subgroups of cerebral palsy must also be taken into consideration. Present studies on the field are predominately of children with spastic forms of cerebral palsy, mostly with a relatively mild level of impairment according to GMFCS. Especially the studies evaluating the functional therapy lacks the full spectre of GMFCS levels, which immediately raises some questions. Would functional therapy be effective for children with spastic quadriplegia? Apart from being heavily connected to learning disabilities, as noted above, it also creates very strong constraints within the child, making voluntary movement difficult. The same is the situation with children in the group of ataxic and athetoid/dyskinetic cerebral palsy. These children have problems with coordination, and this is often worsened by initiating voluntary movement. Even though the need of functional practice is high, no scientific evidence exists to whether the functional therapy approach would benefit these children, and this should be considered during therapy of any approach. Another thing that should be thought through in the case of athetosis, is that these children often turn spastic to prevent these violent movements. A therapist should be careful in reducing spasticity in these children. In all forms of interventions when dealing with a child with athetoid patterns, certain factors might decrease the outbreaks of involuntary movements. Fatigue, prone position lying and keeping the child's attention are said help the child reduce the violent movements. By modification, all of the evaluated treatment approaches could follow these principles.

With these considerations taken towards the nature of the therapy approaches and the different characterizations of cerebral palsy itself, it is appropriate to evaluate the existing evidence.

Vojta therapy suffers greatly from the absence of studies compiled in the English language. The evaluated researches were of either a very low sample number, or of high chances of bias. Effectiveness is evaluated according to the nature of the application. Studies of a higher methodological value, or translated copies of existing researches of other languages are needed in order to make any definite conclusion regarding Vojta therapy.

The existing evidence is, however, unanimously positive. Kanda et al. presented two studies indicating that children with spastic diplegia had higher chances of walking from an earlier time, or had a higher chance of walking at all following the application of early onset Vojta therapy. The other study was conducted by Vojta himself, showing a remarkable recovery rate of the so-called risk infants. As discussed previously, these results must be considered carefully, due to the nature of cerebral palsy a complete recovery is impossible. In these cases,

the therapist was simply not dealing with cerebral palsy. However, proven that the reported evidence is true, it shows a great advantage to the risk infants with a suspected central coordination disorder (CCD). The carry-over to cerebral palsy, however, remains unknown.

What immediately becomes evident when looking into the Bobath approach is the several review reports conducted on the effectiveness of the Bobath therapy in children with cerebral palsy. These review articles are of a predominantly negative nature. The most comprehensive study conducted on the field is the AACPDM evidence report concluding that no consistent evidence is present favouring the Bobath therapy in treatment of cerebral palsy. This view is supported by 3 more review articles, concluding with similar statements, or that limited evidence is available in order to recommend Bobath therapy over other approaches in cerebral palsy.

These evidence reports need to be evaluated carefully, as they rarely conclude with studies with a more beneficial outcome of the compare treatment group, but rather that Bobath therapy and control therapy did not differ in outcomes, either positive or negative, or the advantage of the Bobath treatment was not statistically significant. This indicates that even though the review articles concluded with an overall negative view on Bobath therapy, it in fact also shows that it is proved to improve the overall state of children after Bobath intervention. What also needs to be stressed is that many of the studies included in the review articles are of old age, often with sometimes outdated Bobath therapy. An increase in positive findings were also found in the most recent studies evaluated, indicating the possibility of an increased effectiveness of contemporary Bobath therapy.

An interesting finding when evaluating available researches becomes evident when comparing the researches by Knox et al. (141) to Ahl et al. (127), due to the overlapping assessment tools evaluating the results (see Table 14 in Appendix I for more information). Practically no difference was shown in the achievement of functional goals set before onset of intervention, even though the Bobath therapy had a significantly shorter intervention period. Despite the similar percentage, it serves as an advantage to the Bobath approach, as the preset functional goals were not directly targeted through the intervention. Both therapy interventions showed significant improvement of the GMFM scores, with the functional therapy study producing a higher percentile improvement. This would be expected, due to the difference in the intervention periods, so the results are to be considered thereafter. The last assessment tool to be compared is the PEDI. Functional therapy showed increased scores in

all domains and dimensions, whereas the Bobath therapy study only periodically shows improvements in certain domains and dimensions.

This trend of improved PEDI results could be traced to other studies of functional therapy. Several studies show significant improvements of PEDI results, and especially in the domain of self care. This could indicate an increased level of independence after application of therapy. Another interesting sub-finding when evaluating PEDI results in functional therapy is that in studies where children receive parts of therapy in a group setting, the domain of social functions greatly improved. In studies where no group therapy is performed, the children either remain unchanged in this domain, or the score decreases after therapy. For a comparison of PEDI Scores in evaluated research, see table 15 in Appendix I.

Another possibility to explain the increased PEDI scores following a functional therapy intervention lies within the application of the method. PEDI is evaluated through a standardized structured interview of the parents. Due to the fact that one of the main pillars of functional therapy is the education and involvement of parents in an everyday therapy setting, it might greatly influence the PEDI scores for several reasons. A higher parental involvement might lead to the parents realizing the full potential of their children simply through handling them in problematic situations. The risk of the parents reporting slightly biased results, as they in a way are evaluating their own work, is also present. For these reasons, all though thoroughly validated in large population based studies, PEDI might not be the best way of measuring the functional level of children receiving therapy that involves a high degree of parental involvement as seen in functional therapy. These same problems would probably not occur in a neurophysiological therapy setting. As discussed previously, in Vojta therapy parents are seen merely as laymen, carrying out the instructions from the therapist. The Bobath concept also has a lower degree of parental influence on the course of the therapy, and might explain the lack of unanimously positive PEDI scores, as seen for functional therapy.

Traditionally, advocates of functional therapy have criticised the neurophysiological methods for the poor functional carry-over to the daily lives of the children. The functional therapy approach aims to practice a specific functional task, and shows an overall significant improvement (See Table 16 in Appendix I). However, in one of the studies, just two out of the three functional goals were targeted, showing that these untargeted goals did not improve noteworthy. This might indicate that the functional carry-over of functional therapy is not

better than seen in neurophysiological methods. It must be taken into consideration the relatively small sample size in this research.

Another trend of several studies is that the conductors see the need of an introductory educational course for therapists before the intervention period starts. This is to structure the study best possible, but it also serves as a reminder of what the 3 compared intervention programs really are. Rather than techniques, they are treatment philosophies, with different interpretations and execution varying from therapist to therapist. A variable when comparing these methods is the level of skill of the therapist, which might indicate why the experimental group usually prevails in results to the comparison group. Where the first group usually get a thorough introduction and education of the intervention of investigation, the latter has not been seen to receive that at any point, indicating that the level of skill would be different, and not purely measuring the effectiveness of the given treatment approach.

## 6. Conclusion

As previously indicated, any conclusion in this vast field of paediatric rehabilitation is a very complex process to make, and sometimes straightforward wrong. Several researchers before me have concluded that any conclusion towards therapy recommendations in cerebral palsy is impossible due to lack of, or insufficient evidence. The aim of this thesis was to evaluate the effectiveness of neurophysiological methods and functional therapy in treatment of cerebral palsy, and highlight advantages of the chosen approaches in given situations. Although no overall recommendations seem possible to extract from a review of the available literature, the evaluation of the therapy approaches and the nature of cerebral palsy itself, serves to hypothesise certain general guidelines. As these conclusions are based merely on a theoretical evaluation of literature, these of course would have to be scientifically proven.

Based on the previously discussed factors, it seems to be reasonable to conclude that Vojta therapy demonstrates clear advantages in early intervention of preverbal children with a suspected CNS disturbance, hereunder possible causes of cerebral palsy. Due to the nature of the application of intervention, it also points towards an advantage in terms of children with cerebral palsy accompanied with severe learning disabilities (mental retardation U.S. use) and children with a high degree of motor impairment, manifested by a high GMFCS score. In order to conclude with anything on the effectiveness of the approach itself, new researches need to be conducted in the English language that corresponds to newer editions of assessment tools, in order to assess the contemporary Vojta therapy. A translation of researches compiled in other languages is also desirable.

Even though a number of reviewers have already concluded that no evidence is consistent enough to recommend the Bobath approach over any other treatment approach, I have yet to find any study of high methodological value that completely dismisses Bobath therapy as a successful treatment intervention in the treatment of cerebral palsy. This rather serves as another indicator to the absence of evidence in this field of medicine. In fact, several sub-findings indicate a rather dramatic improvement of gross motor function, especially after high intensity therapy over shorter periods of time. It is stated on several occasions that the Bobath approach leads to an immediate effect after intervention, but that the results regress rapidly. This period of increased range of motion and a decrease of contractures and deformities opens up a therapeutic window where intervention is believed to be more effective. This period should be taken advantage of in a therapeutic setting, as the child is more receptive for applied

therapy. This might also explain the successful results seen following an intensive therapy, and put further stress on the necessity of everyday treatment. A temporary relief of contractures and deformities also serves as a short recess from the pain experienced by many children, and is therefore desirable merely due to this fact.

Functional therapy arguably show significant improvements of the intervened functional goals set. Of the evaluated researches, a mean value of 75.3% is found of the complete achievement of these functional goals following therapy based on the principles of functional therapy. However, no evidence is present to which practice of these functional goals has a functional carry-over to other activities of daily living, and some findings even indicate the opposite, even though a marked improvement of gross motor functions are generally found. However, carefully set goals might increase the child's independence significantly, if the skill is mastered. The only fear is that a lengthy therapy intervention is necessary in order to acquire different types of the numerous movement repertoires needed to accomplish just the most basic of activities of daily living. Consistent findings in PEDI indicates that this is not a desirable measuring tool for assessing the effect of functional therapy, as there is a high risk of parental bias. Another finding with PEDI and functional therapy was that intervention partially set in a group setting, seemed to increase the domain of social function. It is reasonable to believe the therapy in a group setting would enhance social skills, regardless of the therapy intervention.

All in all, none of the evaluated therapy approaches points out as the most favourable treatment of all cases of cerebral palsy. Contrary to previous reviews, I read this as a sign that all the evaluated approaches are in fact found to be effective. This is based on the overall positive findings found in the evaluated studies, taken into consideration the expected decrease of gross motor function seen in cerebral palsy. Under no circumstances, the mean scores of the investigated groups decreased after application of the therapy.

However, major gaps in available literature is present and should be further investigated in studies of high methodological value, preferably by independent researchers, as otherwise might risk the accuracy of findings. As requested before, studies of Vojta therapy would be beneficial to be conducted in the English language, or even translated versions of already compiled reports in other languages. It would also be interesting to investigate the hypothesis that Vojta is to be preferred in preverbal children, children with learning disabilities (mental retardation U.S. use) and a high level of motor impairment. Studies should also be performed

of the contemporary Bobath approach, preferably with the treatment intensity practically feasible. It would also be beneficial to see the possibility to take advantage of the therapeutic window demonstrated immediately after Bobath application, also in combination with other physiotherapeutic means. Desired evidence of the functional therapy is regarding the carry-over of the practiced functional goal to other activities of daily living, together with an independent evaluation of PEDI. These interviews should be performed with the parent not in charge of therapy, if ethically possible, in order to avoid the chances of incorrect scoring.

Generally, evidence is missing towards different level of GMFCS levels, age and subtypes of cerebral palsy. This is seen as absolutely crucial, given the wide range of characterization seen in children termed under the umbrella-term; cerebral palsy.

Based on the previous evaluation and discussion, it is reasonable to assume that no definite treatment approach would benefit the entire population of cerebral palsy. A lot of the therapy in child neurology is based on trial and error, until you find a beneficial method of helping one individual child. One should also take into consideration that the skills and experience of the single therapist could vary significantly, which might cause internal errors in experiments. These factors indicate that not even in the future, any clear, universal recommendation towards physiotherapeutic therapy in the field of cerebral palsy would be available. Saying that, further researching is absolutely crucial in order to optimize the already existing selection of therapy approaches present.

## Abbreviations

AACPDM= American Academy for Cerebral Palsy and Developmental Medicine
ADL= Activities of daily living
AIMS= Alberta Infant Motor Scale
ATNR= Asymmetric Tonic Neck Reflex
BSID= Bayley Scale of Infant Development
CCD= Central Coordination Disorder
Cf.= Confer, meaning *referring to*
CFCS = Communication Function Classification System
CNS= Central Nervous System
COPM= Canadian Occupational Performance Measure
CP= Cerebral Palsy/ies
DST= Dynamic Systems Theory
Et al.= et alii (lat.), meaning *and others*
FCS= Family-Centred Service
FCFT= Family-Centred Functional Therapy
FT= Functional Therapy
GA = Gestational age
GMFCS = Gross Motor Functioning Classification System
I.e. = Id est (lat.), meaning *that is*
GMFM = Gross Motor Function Measure
LBW= Low birthweight (1500-2499 g)
MACS = Manual Ability Classification System
MRI= Magnetic Resonance Imaging
NBW= Normal birthweight ($\geq$ 2500 g)
NDT= Neurodevelopmental Treatment
NGST= Neuronal Group Selection Theory
NPM= Neurophysiological Methods
PDMS= Peabody Developmental Motor Scales
PEDI= Paediatric Evaluation of Disability Inventory
SCPE= Surveillance of Cerebral Palsy in Europe
SES= Socio-economic status
STNR= Symmetric Tonic Neck Reflex
TIMP= Test of Infant Motor Performance
VLBW= Very low birthweight ($\leq$ 1500 g)

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# Appendix

## Appendix I –Tables



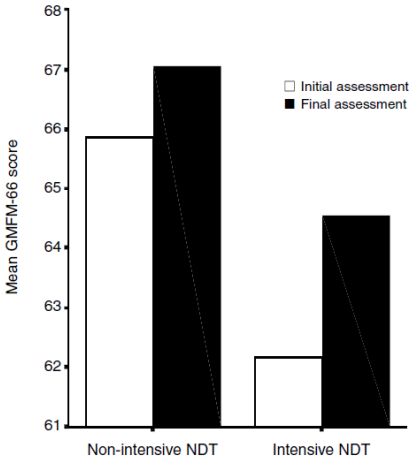
**Table 1 Matched pairs for age, sex, and distribution of impairment**

| *Matched pairs* | *Sex* | *GMFCS level* | *Distribution of impairment* | *Age (y)* | |
|---|---|---|---|---|---|
| | | | | *Group A* | *Group B* |
| 1 | Males | I | Hemiplegia | 6 | 7 |
| 2 | | II | Hemiplegia | 7 | 8 |
| 3 | | II | Diplegia | 4 | 3 |
| 4 | | I | Diplegia | 6 | 7 |
| 5 | | III | Diplegia | 3 | 4 |
| 6 | | I | Diplegia | 9 | 9 |
| 7 | | II | Diplegia | 3 | 3 |
| 8 | | III | Quadriplegia | 5 | 6 |
| 9 | | III | Quadriplegia | 14 | 13 |
| 10 | | III | Quadriplegia | 11 | 11 |
| 11 | | III | Quadriplegia | 5 | 4 |
| 12 | Females | II | Hemiplegia | 5 | 3 |
| 13 | | I | Hemiplegia | 6 | 8 |
| 14 | | I | Hemiplegia | 10 | 12 |
| 15 | | II | Diplegia | 5 | 4 |
| 16 | | III | Quadriplegia | 9 | 10 |
| 17 | | III | Quadriplegia | 14 | 14 |

Group A, non-intensive treatment; Group B, intensive treatment.

(140)

**Table 2 Mean change in GMFM-66 scores for both groups between initial and final assessment**




(140)

**Table 3 Descriptive Statistics**

| Group | Assessment | GMFM-88 | | | | GMFM-66 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *Mean* | *SD* | *Min.* | *Max.* | *Mean* | *SD* | *Min.* | *Max.* |
| A | Before treatment | 80.31 | 15.15 | 52.46 | 98.65 | 65.85 | 14.47 | 45.91 | 87.99 |
| | After treatment | 82.00 | 14.54 | 53.68 | 98.93 | 67.04 | 14.24 | 46.91 | 89.70 |
| B | Before treatment | 77.36 | 15.89 | 44.43 | 97.07 | 62.17 | 12.24 | 44.03 | 84.05 |
| | After treatment | 79.99 | 15.80 | 46.93 | 97.58 | 64.54 | 12.86 | 45.32 | 85.23 |

GMFM, Gross Motor Function Measure (Russell 2002). Min, minimum; Max, maximum. Group A, non-intensive; Group B, intensive.

(140)

**Table 4 Goals set related to test dimensions and domains**

| *Child* | *Total number of goals* | *Goals in GMFM dimension or PEDI domain* | *Goals achieved* | *Number of other goals* | *Goals achieved* |
|---|---|---|---|---|---|
| 1 | 3 | Walk and Mobility[a] | + | 1 | + |
| | | Social | + | | |
| 2 | 3 | Stand and Walk[a] | + | 2 | ++ |
| 4 | 3 | Stand | + | | |
| | | Walk and Mobility[a] | + | | |
| | | Self care | + | | |
| 5 | 5 | Sit | + | 2 | +− |
| | | Stand | + | | |
| | | Walk and Mobility[a] | + | | |
| 6 | 3 | Lying and Sitting[a] | + | 1 | + |
| | | Self care | − | | |
| 7 | 3 | Walk | + | | |
| | | Self care | + | | |
| | | Mobility | + | | |
| 8 | 3 | Sit | + | 1 | + |
| | | Sit | − | | |
| 9 | 3 | Sit | − | 1 | + |
| | | Stand | − | | |
| 11 | 3 | Sit | + | 1 | + |
| | | Sit | + | | |
| 12 | 3 | Sit | + | 1 | NR |
| | | Self care | − | | |
| 13 | 7 | Sit | + | 2 | + NR |
| | | Sit | NR | | |
| | | Crawl | + | | |
| | | Self care | + | | |
| | | Mobility | + | | |
| 14 | 4 | Sit | NR | 2 | + NR |
| | | Stand and Mobility[a] | + | | |
| 16 | 4 | Lying | + | 1 | + |
| | | Sit | + | | |
| | | Self care | + | | |
| 17 | 3 | Stand | − | 2 | ++ |
| 19 | 3 | Stand and Self care[a] | + | 1 | + |
| | | Walk and Mobility[a] | NR | | |

[a]Goals that fell into more than one dimension/domain. + achieved, − not achieved, NR. result not recorded.

(141)

**Table 5 Gross Motor Function Measure- Group Mean Values (SD) (n=15)**

| *Dimension* | *Test 1* | *Test 2* | | *Test 3* | *Test 4* |
|---|---|---|---|---|---|
| Lying | 83.06 (18.88) | 83.08 (20.48) | B[a] | 86.46 (15.76) | 86.11 (19.13) |
| Sitting | 70.91 (34.72) | 73.02 (36.43) | | 74.83 (34.75) | 75.14 (34.11) |
| Crawl/kneeling | 61.47 (46.58) | 59.96 (46.78) | O | 63.21 (45.78) | 62.99 (46.92) |
| Standing | 42.31 (35.52) | 47.86 (36.40) | B | 49.79 (39.00) | 48.49 (37.60) |
| Walking | 29.75 (31.92) | 29.16 (29.75) | A | 33.79 (34.04) | 34.95 (34.09) |
| Total | 57.80 (31.76) | 58.56 (32.67) | | 61.20 (32.19) | 60.80 (32.50) |
| Goal total | 47.22 (25.44) | 48.77 (25.88) | T | 55.80 (25.78) | 55.16 (25.23) |
| Non goal total | 62.64 (37.68) | 62.74 (38.59) | H | 63.73 (37.67) | 64.10 (38.69) |
| GMFM-66 | 54.71 (13.99) | 55.09 (14.72) | | 56.94 (14.40) | 55.59 (13.97) |

[a]Denotes 6-week period of Bobath intervention.

(141)

**Table 6 Pediatric Evaluation of Disability Inventory- Group Mean Values (SD) (n=15)**

| *Domain* | *Test 1* | *Test 2* | | *Test 3* | *Test 4* |
|---|---|---|---|---|---|
| Skills | | | | | |
| Self care | 61.17 (16.01) | 60.60 (17.96) | B[a] | 62.40 (17.82) | 62.94 (16.98) |
| Mobility | 60.06 (17.83) | 61.53 (19.14) | O | 63.28 (19.57) | 65.52 (18.22) |
| Social function | 70.34 (17.41) | 70.70 (20.21) | B | 73.27 (18.53) | 74.37 (17.86) |
| Total Skills | 191.58 (44.67) | 192.83 (51.91) | A | 198.96 (51.74) | 202.84 (48.73) |
| Caregiver assistance | | | T | | |
| Self care | 58.84 (17.40) | 55.63 (24.61) | H | 56.42 (24.94) | 61.26 (17.66) |
| Mobility | 61.24 (18.34) | 62.21 (16.98) | | 64.48 (17.82) | 64.72 (19.33) |
| Social function | 71.31 (24.88) | 71.31 (24.25) | | 72.30 (22.96) | 71.76 (22.70) |
| Total Caregiver | 191.40 (55.48) | 189.15 (62.12) | | 193.21 (62.60) | 197.75 (55.77) |

[a]Denotes 6-week period of Bobath intervention.

(141)

**Table 7 Change in PEDI: Functional skills score and Caregivers assistance score**


Figure 4: *Change in Pediatric Evaluation of Disability Inventory (PEDI; Haley et al. 1992) functional skill scores (n=14). Boxplots represent 25th, 50th, and 75th centile. Whiskers represent minimum and maximum values. White boxplots indicate assessments before intervention and black boxplots assessments after intervention. [a]p<0.001, [b]p<0.01 (Wilcoxon). PEDI evaluates through a structured interview if a child is able or unable to perform 197 skills (score 1 or 0) in everyday life situations.*

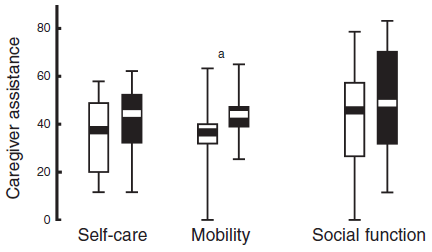



Figure 5: *Change in Pediatric Evaluation of Disability Inventory (Haley et al. 1992) caregiver assistance (n=14). Boxplots represent 25th, 50th, and 75th centile. Whiskers represent minimum and maximum values. White boxplots indicate assessments before intervention and black boxplots assessments after intervention. [a]p<0.001 (Wilcoxon). Caregiver assistance is evaluated in 20 different activity areas using a 6-point scale. A score of 5 indicates independence and a score of 0 complete dependence on assistance.*

(127)

**Table 8 Mean Scores and Standard Deviations of GMFM**

| | GMFM (%) | | | | | | | | Effect | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pretest | | Follow-up 1 | | Follow-up 2 | | Follow-up 3 | | Time | | Group | | Group × Time | |
| | $\bar{X}$ | SD | $\bar{X}$ | SD | $\bar{X}$ | SD | $\bar{X}$ | SD | *df*[a] | F | *df* | F | *df*[a] | F |
| Standing | | | | | | | | | | | | | | |
| Referral group | 81.2 | 20.3 | 87.1 | 12.5 | 87.6 | 11.2 | 90.8 | 6.6 | 1.5 | 15.93[b] | 1 | 0.01 | 1.5 | 0.45 |
| Functional physical therapy group | 82.8 | 15.7 | 85.9 | 12.9 | 88.5 | 12.3 | 90.6 | 10.5 | | | | | | |
| Walking, running, and jumping | | | | | | | | | | | | | | |
| Referral group | 70.8 | 24.4 | 76.3 | 20.9 | 82.1 | 17.1 | 84.8 | 15.5 | 1.7 | 79.94[b] | 1 | 0.04 | 1.7 | 0.59 |
| Functional physical therapy group | 70.2 | 18.2 | 76.7 | 16.4 | 84.1 | 13.4 | 86.5 | 12.8 | | | | | | |

[a] Adjusted degrees of freedom using Greenhouse-Geisser epsilon statistic.
[b] $P<.01$.

(108)

**Table 9 Mean Scores and Standard Deviations of: Functional Skills & Caregivers Assistance**

| | PEDI Functional Skills Scale Scores | | | | | | | | Effect | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pretest | | Follow-up 1 | | Follow-up 2 | | Follow-up 3 | | Time | | Group | | Group × Time | |
| | $\bar{X}$ | SD | $\bar{X}$ | SD | $\bar{X}$ | SD | $\bar{X}$ | SD | *df* | F | *df* | F | *df* | F |
| Self-care | | | | | | | | | | | | | | |
| Referral group | 67.3 | 10.1 | 70.3 | 12.7 | 71.7 | 9.9 | 76.5 | 12.1 | 3 | 61.60[b] | 1 | 0.64 | 3 | 2.72[c] |
| Functional physical therapy group | 68.3 | 14.9 | 71.9 | 14.9 | 76.7 | 15.0 | 79.7 | 14.4 | | | | | | |
| Mobility | | | | | | | | | | | | | | |
| Referral group | 75.8 | 11.6 | 76.7 | 10.6 | 79.9 | 9.1 | 81.2 | 7.5 | 2.1[a] | 36.74[b] | 1 | 3.29[c] | 2.1[a] | 3.13[c] |
| Functional physical therapy group | 78.2 | 11.3 | 80.4 | 10.9 | 86.1 | 11.9 | 88.1 | 10.2 | | | | | | |

| | PEDI Caregiver Assistance Scale Scores | | | | | | | | Effect | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pretest | | Follow-up 1 | | Follow-up 2 | | Follow-up 3 | | Time | | Group | | Group × Time | |
| | $\bar{X}$ | SD | $\bar{X}$ | SD | $\bar{X}$ | SD | $\bar{X}$ | SD | *df* | F | *df* | F | *df* | F |
| Self-care | | | | | | | | | | | | | | |
| Referral group | 59.2 | 11.6 | 60.6 | 12.3 | 66.5 | 10.2 | 68.3 | 11.4 | 3 | 71.86[b] | 1 | 0.79 | 3 | 4.14[b] |
| Functional physical therapy group | 58.7 | 13.7 | 63.0 | 15.3 | 71.4 | 17.4 | 73.9 | 15.1 | | | | | | |
| Mobility | | | | | | | | | | | | | | |
| Referral group | 74.0 | 15.7 | 77.7 | 13.2 | 81.9 | 12.7 | 84.4 | 12.6 | 2.2[a] | 54.11[b] | 1 | 0.42 | 2.2[a] | 2.96[c] |
| Functional physical therapy group | 72.7 | 13.7 | 78.8 | 13.3 | 86.4 | 12.2 | 88.7 | 11.6 | | | | | | |

[a] Adjusted degrees of freedom using Greenhouse-Geisser epsilon statistic.
[b] $P<.01$.
[c] $P<.05$.

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**Table 10 Change in test scores from baseline to follow up**

| Measure | *n* | Baseline | | | | | Follow up | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | PreTest1 | PreTest2 | Change PreTest1 to PreTest2 | PreTest3 | Change PreTest2 to PreTest3 | PostTest1 | Change PreTest3 to PostTest1 | PostTest2 | Change PreTest3 to PostTest2 |
| | | Mean (SD) Min-max | Mean (SD) Min-max | Mean (SD) | Mean (SD) Min-max | Mean (SD) | Mean (SD) Min-max | Mean (SD) | Mean (SD) Min-max | Mean (SD) |
| GMFM-66[1)] | 22 | 61.4 (17.4) 23.4-89.7 | 61.1 (17.0) 24.7-89.7 | -0.3 (2.8) | 61.8 (17.4) 23.4-89.7 | 0.7 (3.0) | 65.6 (18.2) 28.0-92.1 | 3.8 * (4.0) | 66.3 (19.4) 25.3-100.0 | 4.5 * (4.0) |
| GMPM(A1) | 20 | | 58.0 (13.4) 12.0-72.3 | | 59.2 (12.2) 16.0-72.3 | 1.2 (3.8) | 59.5 (12.3) 15.3-70.9 | 0.3 (3.7) | 59.9 (14.1) 12.0-76.7 | 0.7 (4.6) |
| GMPM(A2) | 20 | | 58.1 (18.5) 12.0-83.2 | | 57.4 (19.9) 12.0-90.2 | -0.7 (5.6) | 58.5 (18.6) 12.0-84.1 | 1.1 (6.8) | 58.8 (18.8) 12.0-84.1 | 1.4 (6.5) |
| QUEST(A1) | 20 | | 63.8 (23.6)8.3-93.6 | | 65.9 (22.1) 8.3-96.1 | 2.1 (11.6) | 69.8 (21.4) 22.7-96.0 | 3.9 (11.6) | 68.8 (25.0) 0.0-97.1 | 2.9 (11.5) |
| QUEST(A2) | 20 | | 68.3 (24.9) 4.2-97.8 | | 68.4 (25.5) 4.2-97.1 | 0.1 (6.1) | 71.6 (24.8) 2.8-96.9 | 3.2 (7.9) | 71.7 (24.0) 11.1-96.7 | 3.3 (6.8) |

[1)]Post hoc paired comparisons. Paired t-tests with Bonferroni ajustments of alfa level. * $p < 0.01$.
GMFM: Gross Motor Function Measure, GMPM: Gross Motor Performance Measure, QUEST: Quality of Upper Extremity Skills Test
A: assessor

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**Table 11 Test scores of PEDI (scale 0-100) at pre-and posttest (n=21)**

| PEDI dimensions and domains | PreTest<br>Mean<br>(SD)<br>Min-max | PostTest<br>Mean<br>(SD)<br>Min-max | Change<br>Mean1)<br>(SD) |
|---|---|---|---|
| FUNCTIONAL SKILLS | | | |
| Self-care | 56.9<br>(15.9)<br>11.8 – 81.4 | 60.9<br>(18.0)<br>11.8 – 100.0 | 4.0 *<br>(4.5) |
| Mobility | 64.7<br>(21.9)<br>6.1 – 100.0 | 67.0<br>(19.6)<br>15.2 – 94.2 | 2.3<br>(3.8) |
| Social Function | 60.7<br>(11.6)<br>31.6 – 89.1 | 62.7<br>(13.1)<br>32.9 – 96.3 | 2.0<br>(4.4) |
| CAREGIVER ASSISTANCE | | | |
| Self-care | 52.4<br>(27.0)<br>0.0 – 100.0 | 59.2<br>(26.4)<br>0.0 – 100.0 | 6.7 *<br>(10.9) |
| Mobility | 69.1<br>(25.0)<br>0.0 – 100.0 | 72.4<br>(25.3)<br>0.0 – 100.0 | 3.4 *<br>(4.6) |
| Social Function | 68.1<br>(24.2)<br>11.3 – 100.0 | 72.3<br>(26.9)<br>0.0 – 100.0 | 4.2<br>(7.7) |

1) Wilcoxon signed rank test, p-level adjusted for inter correlation in scales, * $p < 0.01$ (2-tailed)

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**Table 12 Pre-& post-intervention scores for all participants for the COPM**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Child 1** | | | | | | |
| 1. Donning pants | 1 | 2 | 6 | 8 | 5 | 6 |
| 2. Self-feeding | 2 | 2 | 8 | 9 | 6 | 7 |
| 3. Donning shoes | 2 | 2 | 4 | 6 | 2 | 4 |
| **Child 2** | | | | | | |
| 1. Independent play | 2 | 1 | 6 | 5 | 4 | 4 |
| 2. Self-feeding | 5 | 5 | 9 | 10 | 4 | 5 |
| 3. Donning pants | 1 | 1 | 2 | 1 | 1 | 0 |
| **Child 3** | | | | | | |
| 1. Self-feeding | 5 | 2 | 6 | 5 | 1 | 3 |
| 2. Donning jacket | 2 | 4 | 5 | 5 | 3 | 1 |
| 3. Pencil use | 3 | 4 | 3 | 4 | 0 | 0 |

Note: Perf. = performance; satisf. = satisfaction.
Change score of 2 or more points is considered clinically significant.

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**Table 13 Caregiver assistance scale of the PEDI**

| Domain | Pre-Intervention Scores | Post-Intervention Scores |
|---|---|---|
| **Child 1** | | |
| Self-care | 12 | 17 |
| Mobility | 15 | 16 |
| Social Function | 15 | 16 |
| **Child 2** | | |
| Self-care | 11 | 19 |
| Mobility | 16 | 23 |
| Social Function | 14 | 11 |
| **Child 3** | | |
| Self-care | 6 | 15 |
| Mobility | 15 | 15 |
| Social Function | 25 | 25 |

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**Table 14 Extract of evidence from Knox et al. and Ahl et al.**

| | **Knox et al.** (141) | **Ahl et al.** (127) |
|---|---|---|
| Study sample | 15 children | 14 children |
| Intervention duration | 6 weeks | 20 weeks |
| Achievement of functional goals | 75 % | 77% |
| GMFM Improvement | Significant | Significant |
| PEDI- Functional Improvement | Significant (self-care) | Significant (all domains) |
| PEDI-Caregivers assistance Improvement | Significant(mobility + total) | Slight (all domains) |

**Table 15 Comparing PEDI in Functional Therapy**

| | **Ahl et al.** (127) | **Ketelaar et al.** (108) | **Sorsdahl et al.** (133) | **Lammi et al.** (128) |
|---|---|---|---|---|
| **Study sample** | 14 | 28(55)[1] | 22 | 3 |
| **Group therapy** | Yes | No | Yes | No |
| **Functional Scale** | | | | |
| Self care | Significant | Slight | Significant | Significant |
| Mobility | Significant | Significant | N/S | N/S |
| Social function | Significant | N/A | N/S | N/S |
| **Caregivers Assistance** | | | | |
| Self-care | Slight | Slight | Significant | Significant |
| Mobility | Significant | Slight | Significant | N/S |
| Social functions | Slight | N/A | Significant | N/S/Decrease[2] |

[1]Number in experimental group vs. whole sample-[2] Parts of sample group showed decreased improvement- Significant=significant improvement- Slight=slight improvement- N/A= not available/not tested- N/S Not statistically important

**Table 16 Functional goal achievement following functional therapy**

| | **Ahl et al.** (127) | **Sorsdahl et al.** (133) | **Lammi et al.[1]** (128) | **Lammi et al.[2]** (128) |
|---|---|---|---|---|
| **Number of goals** | 98 | 53 | 6 | 9 |
| **% of successful achievement** | 77% | 66% | 83% | 66 % |
| **Study sample** | 14 | 22 | 3 | 3 |
| **Intervention period** | 5 months | 3 weeks | 61 days | 61 days |

[1] Results without functional tasks not practiced [2] Results with functional tasks not practiced

Appendix II- Gross Motor Function Measure Score Sheet

# GROSS MOTOR FUNCTION MEASURE (GMFM)
# SCORE SHEET (GMFM-88 and GMFM-66 scoring)

Version 1.0

Child's Name: _____ ID #: _____

Assessment date: _____ year / month /day

Date of birth: _____ year / month /day

Chronological age: _____ years/months

GMFCS Level [1]

☐ I ☐ II ☐ III ☐ IV ☐ V

Testing Conditions (eg, room, clothing, time, others present)

Evaluator's Name: _____

_____

_____

_____

The GMFM is a standardized observational instrument designed and validated to measure change in gross motor function over time in children with cerebral palsy. The scoring key is meant to be a general guideline. However, most of the items have specific descriptors for each score. It is imperative that the guidelines contained in the manual be used for scoring each item.

**SCORING KEY**
0 = does not initiate
1 = initiates
2 = partially completes
3 = completes
NT = Not tested [used for the GMAE scoring*]

***It is now important to differentiate a true score of "0" (child does not initiate) from an item which is Not Tested (NT) if you are interested in using the GMFM-66 Ability Estimator Software.***

*The GMFM-66 Gross Motor Ability Estimator (GMAE) software is available with the GMFM manual (2002). The advantage of the software is the conversion of the ordinal scale into an interval scale. This will allow for a more accurate estimate of the child's ability and provide a measure that is equally responsive to change across the spectrum of ability levels. Items that are used in the calculation of the GMFM-66 score are shaded and identified with an asterisk (*). The GMFM-66 is only valid for use with children who have cerebral palsy.

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[1] GMFCS level is a rating of severity of motor function. Definitions are found in Appendix I of the GMFM manual (2002).

**Check (✓) the appropriate score:** if an item is not tested (NT), circle the item number in the right column

| | Item | A: LYING & ROLLING | SCORE | | | | NT |
|---|---|---|---|---|---|---|---|
| | 1. | SUP, HEAD IN MIDLINE: TURNS HEAD WITH EXTREMITIES SYMMETRICAL | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 1. |
| * | 2. | SUP: BRINGS HANDS TO MIDLINE, FINGERS ONE WITH THE OTHER | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 2. |
| | 3. | SUP: LIFTS HEAD 45° | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 3. |
| | 4. | SUP: FLEXES R HIP AND KNEE THROUGH FULL RANGE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 4. |
| | 5. | SUP: FLEXES L HIP AND KNEE THROUGH FULL RANGE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 5. |
| * | 6. | SUP: REACHES OUT WITH R ARM, HAND CROSSES MIDLINE TOWARD TOY | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 6. |
| * | 7. | SUP: REACHES OUT WITH L ARM, HAND CROSSES MIDLINE TOWARD TOY | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 7. |
| | 8. | SUP: ROLLS TO PR OVER R SIDE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 8. |
| | 9. | SUP: ROLLS TO PR OVER L SIDE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 9. |
| * | 10. | PR: LIFTS HEAD UPRIGHT | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 10. |
| | 11. | PR ON FOREARMS: LIFTS HEAD UPRIGHT, ELBOWS EXT., CHEST RAISED | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 11. |
| | 12. | PR ON FOREARMS: WEIGHT ON R FOREARM, FULLY EXTENDS OPPOSITE ARM FORWARD | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 12. |
| | 13. | PR ON FOREARMS: WEIGHT ON L FOREARM, FULLY EXTENDS OPPOSITE ARM FORWARD | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 13. |
| | 14. | PR: ROLLS TO SUP OVER R SIDE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 14. |
| | 15. | PR: ROLLS TO SUP OVER L SIDE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 15. |
| | 16. | PR: PIVOTS TO R 90° USING EXTREMITIES | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 16. |
| | 17. | PR: PIVOTS TO L 90° USING EXTREMITIES | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 17. |

**TOTAL DIMENSION A** ☐

| | Item | B: SITTING | SCORE | | | | NT |
|---|---|---|---|---|---|---|---|
| * | 18. | SUP, HANDS GRASPED BY EXAMINER: PULLS SELF TO SITTING WITH HEAD CONTROL | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 18. |
| | 19. | SUP: ROLLS TO R SIDE, ATTAINS SITTING | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 19. |
| | 20. | SUP: ROLLS TO L SIDE, ATTAINS SITTING | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 20. |
| * | 21. | SIT ON MAT, SUPPORTED AT THORAX BY THERAPIST: LIFTS HEAD UPRIGHT, MAINTAINS 3 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 21. |
| * | 22. | SIT ON MAT, SUPPORTED AT THORAX BY THERAPIST: LIFTS HEAD MIDLINE, MAINTAINS 10 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 22. |
| * | 23. | SIT ON MAT, ARM(S) PROPPING: MAINTAINS, 5 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 23. |
| * | 24. | SIT ON MAT: MAINTAINS, ARMS FREE, 3 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 24. |
| * | 25. | SIT ON MAT WITH SMALL TOY IN FRONT: LEANS FORWARD, TOUCHES TOY, RE-ERECTS WITHOUT ARM PROPPING | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 25. |
| * | 26. | SIT ON MAT: TOUCHES TOY PLACED 45° BEHIND CHILD'S R SIDE, RETURNS TO START | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 26. |
| * | 27. | SIT ON MAT: TOUCHES TOY PLACED 45° BEHIND CHILD'S L SIDE, RETURNS TO START | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 27. |
| | 28. | R SIDE SIT: MAINTAINS, ARMS FREE, 5 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 28. |
| | 29. | L SIDE SIT: MAINTAINS, ARMS FREE, 5 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 29. |
| * | 30. | SIT ON MAT: LOWERS TO PR WITH CONTROL | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 30. |
| * | 31. | SIT ON MAT WITH FEET IN FRONT: ATTAINS 4 POINT OVER R SIDE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 31. |
| * | 32. | SIT ON MAT WITH FEET IN FRONT: ATTAINS 4 POINT OVER L SIDE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 32. |
| | 33. | SIT ON MAT: PIVOTS 90°, WITHOUT ARMS ASSISTING | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 33. |
| * | 34. | SIT ON BENCH: MAINTAINS, ARMS AND FEET FREE, 10 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 34. |
| * | 35. | STD: ATTAINS SIT ON SMALL BENCH | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 35. |
| * | 36. | ON THE FLOOR: ATTAINS SIT ON SMALL BENCH | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 36. |
| * | 37. | ON THE FLOOR: ATTAINS SIT ON LARGE BENCH | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 37. |

**TOTAL DIMENSION B** ☐

| Item | | C: CRAWLING & KNEELING | SCORE | | | | NT |
|---|---|---|---|---|---|---|---|
| | 38. | PR: CREEPS FORWARD 1.8m (6') | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 38. |
| * | 39. | 4 POINT: MAINTAINS, WEIGHT ON HANDS AND KNEES, 10 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 39. |
| * | 40. | 4 POINT: ATTAINS SIT ARMS FREE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 40. |
| * | 41. | PR: ATTAINS 4 POINT, WEIGHT ON HANDS AND KNEES | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 41. |
| * | 42. | 4 POINT: REACHES FORWARD WITH R ARM, HAND ABOVE SHOULDER LEVEL | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 42. |
| * | 43. | 4 POINT: REACHES FORWARD WITH L ARM, HAND ABOVE SHOULDER LEVEL | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 43. |
| * | 44. | 4 POINT: CRAWLS OR HITCHES FORWARD 1.8m (6') | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 44. |
| * | 45. | 4 POINT: CRAWLS RECIPROCALLY FORWARD 1.8m (6') | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 45. |
| * | 46. | 4 POINT: CRAWLS UP 4 STEPS ON HANDS AND KNEES/FEET | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 46. |
| | 47. | 4 POINT: CRAWLS BACKWARDS DOWN 4 STEPS ON HANDS AND KNEES/FEET | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 47. |
| * | 48. | SIT ON MAT: ATTAINS HIGH KN USING ARMS, MAINTAINS, ARMS FREE, 10 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 48. |
| | 49. | HIGH KN: ATTAINS HALF KN ON R KNEE USING ARMS, MAINTAINS, ARMS FREE, 10 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 49. |
| | 50. | HIGH KN: ATTAINS HALF KN ON L KNEE USING ARMS, MAINTAINS, ARMS FREE, 10 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 50. |
| * | 51. | HIGH KN: KN WALKS FORWARD 10 STEPS, ARMS FREE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 51. |

**TOTAL DIMENSION C** ☐

| Item | | D: STANDING | SCORE | | | | NT |
|---|---|---|---|---|---|---|---|
| * | 52. | ON THE FLOOR: PULLS TO STD AT LARGE BENCH | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 52. |
| * | 53. | STD: MAINTAINS, ARMS FREE, 3 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 53. |
| * | 54. | STD: HOLDING ON TO LARGE BENCH WITH ONE HAND, LIFTS R FOOT, 3 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 54. |
| * | 55. | STD: HOLDING ON TO LARGE BENCH WITH ONE HAND, LIFTS L FOOT, 3 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 55. |
| * | 56. | STD: MAINTAINS, ARMS FREE, 20 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 56. |
| * | 57. | STD: LIFTS L FOOT, ARMS FREE, 10 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 57. |
| * | 58. | STD: LIFTS R FOOT, ARMS FREE, 10 SECONDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 58. |
| * | 59. | SIT ON SMALL BENCH: ATTAINS STD WITHOUT USING ARMS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 59. |
| * | 60. | HIGH KN: ATTAINS STD THROUGH HALF KN ON R KNEE, WITHOUT USING ARMS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 60. |
| * | 61. | HIGH KN: ATTAINS STD THROUGH HALF KN ON L KNEE, WITHOUT USING ARMS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 61. |
| * | 62. | STD: LOWERS TO SIT ON FLOOR WITH CONTROL, ARMS FREE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 62. |
| * | 63. | STD: ATTAINS SQUAT, ARMS FREE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 63. |
| * | 64. | STD: PICKS UP OBJECT FROM FLOOR, ARMS FREE, RETURNS TO STAND | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 64. |

**TOTAL DIMENSION D** ☐

| Item | | E: WALKING, RUNNING & JUMPING | SCORE | | | | NT |
|---|---|---|---|---|---|---|---|
| * | 65. | STD, 2 HANDS ON LARGE BENCH: CRUISES 5 STEPS TO R | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 65. |
| * | 66. | STD, 2 HANDS ON LARGE BENCH: CRUISES 5 STEPS TO L | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 66. |
| * | 67. | STD, 2 HANDS HELD: WALKS FORWARD 10 STEPS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 67. |
| * | 68. | STD, 1 HAND HELD: WALKS FORWARD 10 STEPS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 68. |
| * | 69. | STD: WALKS FORWARD 10 STEPS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 69. |
| * | 70. | STD: WALKS FORWARD 10 STEPS, STOPS, TURNS 180°, RETURNS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 70. |
| * | 71. | STD: WALKS BACKWARD 10 STEPS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 71. |
| * | 72. | STD: WALKS FORWARD 10 STEPS, CARRYING A LARGE OBJECT WITH 2 HANDS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 72. |
| * | 73. | STD: WALKS FORWARD 10 CONSECUTIVE STEPS BETWEEN PARALLEL LINES 20cm (8") APART | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 73. |
| * | 74. | STD: WALKS FORWARD 10 CONSECUTIVE STEPS ON A STRAIGHT LINE 2cm (3/4") WIDE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 74. |
| * | 75. | STD: STEPS OVER STICK AT KNEE LEVEL, R FOOT LEADING | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 75. |
| * | 76. | STD: STEPS OVER STICK AT KNEE LEVEL, L FOOT LEADING | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 76. |
| * | 77. | STD: RUNS 4.5m (15'), STOPS & RETURNS | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 77. |
| * | 78. | STD: KICKS BALL WITH R FOOT | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 78. |
| * | 79. | STD: KICKS BALL WITH L FOOT | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 79. |
| * | 80. | STD: JUMPS 30cm (12") HIGH, BOTH FEET SIMULTANEOUSLY | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 80. |
| * | 81. | STD: JUMPS FORWARD 30 cm (12"), BOTH FEET SIMULTANEOUSLY | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 81. |
| * | 82. | STD ON R FOOT: HOPS ON R FOOT 10 TIMES WITHIN A 60cm (24") CIRCLE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 82. |
| * | 83. | STD ON L FOOT: HOPS ON L FOOT 10 TIMES WITHIN A 60cm (24") CIRCLE | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 83. |
| * | 84. | STD, HOLDING 1 RAIL: WALKS UP 4 STEPS, HOLDING 1 RAIL, ALTERNATING FEET | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 84. |
| * | 85. | STD, HOLDING 1 RAIL: WALKS DOWN 4 STEPS, HOLDING 1 RAIL, ALTERNATING FEET | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 85. |
| * | 86. | STD: WALKS UP 4 STEPS, ALTERNATING FEET | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 86. |
| * | 87. | STD: WALKS DOWN 4 STEPS, ALTERNATING FEET | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 87. |
| * | 88. | STD ON 15cm (6") STEP: JUMPS OFF, BOTH FEET SIMULTANEOUSLY | 0 ☐ | 1 ☐ | 2 ☐ | 3 ☐ | 88. |

**TOTAL DIMENSION E** ☐

Was this assessment indicative of this child's "regular" performance? YES ☐ NO ☐

COMMENTS:

## GMFM RAW SUMMARY SCORE

| DIMENSION | CALCULATION OF DIMENSION % SCORES | GOAL AREA (indicated with ✓ check) |
|---|---|---|
| A. Lying & Rolling | $\frac{\text{Total Dimension A}}{51} = \frac{\quad}{51} \times 100 = \quad\%$ | A. ☐ |
| B. Sitting | $\frac{\text{Total Dimension B}}{60} = \frac{\quad}{60} \times 100 = \quad\%$ | B. ☐ |
| C. Crawling & Kneeling | $\frac{\text{Total Dimension C}}{42} = \frac{\quad}{42} \times 100 = \quad\%$ | C. ☐ |
| D. Standing | $\frac{\text{Total Dimension D}}{39} = \frac{\quad}{39} \times 100 = \quad\%$ | D. ☐ |
| E. Walking, Running & Jumping | $\frac{\text{Total Dimension E}}{72} = \frac{\quad}{72} \times 100 = \quad\%$ | E. ☐ |

**TOTAL SCORE =** $\frac{\%A + \%B + \%C + \%D + \%E}{\text{Total \# of Dimensions}}$

$= \frac{\quad + \quad + \quad + \quad + \quad}{5} = \frac{\quad}{5} = \quad\%$

**GOAL TOTAL SCORE =** $\frac{\text{Sum of \% scores for each dimension identified as a goal area}}{\text{\# of Goal areas}}$

$= \frac{\quad}{\quad} = \quad\%$

### GMFM-66 Gross Motor Ability Estimator Score [1]

GMFM-66 Score = _____ _____ to _____ 95% Confidence Intervals

previous GMFM-66 Score = _____ _____ to _____ 95% Confidence Intervals

change in GMFM-66 = _____

[1] from the Gross Motor Ability Estimator (GMAE) Software

## TESTING WITH AIDS/ORTHOSES

Indicate below with a check (✓) which aid/orthosis was used and what dimension it was first applied. (There may be more than one).

| AID | | DIMENSION | ORTHOSIS | | DIMENSION |
|---|---|---|---|---|---|
| Rollator/Pusher | ☐ | ____ | Hip Control | ☐ | ____ |
| Walker | ☐ | ____ | Knee Control | ☐ | ____ |
| H Frame Crutches | ☐ | ____ | Ankle-Foot Control | ☐ | ____ |
| Crutches | ☐ | ____ | Foot Control | ☐ | ____ |
| Quad Cane | ☐ | ____ | Shoes | ☐ | ____ |
| Cane | ☐ | ____ | None | ☐ | ____ |
| None | ☐ | ____ | Other | ☐ | ____ |
| Other | ☐ | ____ | | | |

_____ (please specify)

_____ (please specify)

## RAW SUMMARY SCORE USING AIDS/ORTHOSES

| DIMENSION | CALCULATION OF DIMENSION % SCORES | GOAL AREA (indicated with ✓ check) |
|---|---|---|
| F. Lying & Rolling | $\frac{\text{Total Dimension A}}{51} = \frac{\quad}{51} \times 100 = \quad\%$ | A. ☐ |
| G. Sitting | $\frac{\text{Total Dimension B}}{60} = \frac{\quad}{60} \times 100 = \quad\%$ | B. ☐ |
| H. Crawling & Kneeling | $\frac{\text{Total Dimension C}}{42} = \frac{\quad}{42} \times 100 = \quad\%$ | C. ☐ |
| I. Standing | $\frac{\text{Total Dimension D}}{39} = \frac{\quad}{39} \times 100 = \quad\%$ | D. ☐ |
| J. Walking, Running & Jumping | $\frac{\text{Total Dimension E}}{72} = \frac{\quad}{72} \times 100 = \quad\%$ | E. ☐ |

**TOTAL SCORE =** $\frac{\%A + \%B + \%C + \%D + \%E}{\text{Total \# of Dimensions}}$

$= \frac{\quad + \quad + \quad + \quad + \quad}{5} = \frac{\quad}{5} = \quad\%$

**GOAL TOTAL SCORE =** $\frac{\text{Sum of \% scores for each dimension identified as a goal area}}{\text{\# of Goal areas}}$

$= \quad = \quad\%$

### GMFM-66 Gross Motor Ability Estimator Score [1]

GMFM-66 Score = _____ _____ to _____ 95% Confidence Intervals

previous GMFM-66 Score = _____ _____ to _____ 95% Confidence Intervals

change in GMFM-66 = _____

[1] from the Gross Motor Ability Estimator (GMAE) Software

Appendix III- Gross Motor Function Classification System

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# GMFCS – E & R
# Gross Motor Function Classification System
# Expanded and Revised


Robert Palisano, Peter Rosenbaum, Doreen Bartlett, Michael Livingston


Robert Palisano, Peter Rosenbaum, Stephen Walter, Dianne Russell, Ellen Wood, Barbara Galuppi
(Reference: Dev Med Child Neurol 1997;39:214-223)

## INTRODUCTION & USER INSTRUCTIONS

The Gross Motor Function Classification System (GMFCS) for cerebral palsy is based on self-initiated movement, with emphasis on sitting, transfers, and mobility. When defining a five-level classification system, our primary criterion has been that the distinctions between levels must be meaningful in daily life. Distinctions are based on functional limitations, the need for hand-held mobility devices (such as walkers, crutches, or canes) or wheeled mobility, and to a much lesser extent, quality of movement. The distinctions between Levels I and II are not as pronounced as the distinctions between the other levels, particularly for infants less than 2 years of age.

The expanded GMFCS (2007) includes an age band for youth 12 to 18 years of age and emphasizes the concepts inherent in the World Health Organization's International Classification of Functioning, Disability and Health (ICF). We encourage users to be aware of the impact that **environmental** and **personal** factors may have on what children and youth are observed or reported to do. The focus of the GMFCS is on determining which level best represents the **child's or youth's present abilities and limitations in gross motor function**. Emphasis is on usual **performance** in home, school, and community settings (i.e., what they do), rather than what they are known to be able to do at their best (capability). It is therefore important to classify current performance in gross motor function and not to include judgments about the quality of movement or prognosis for improvement.

The title for each level is the method of mobility that is most characteristic of performance after 6 years of age. The descriptions of functional abilities and limitations for each age band are broad and are not intended to describe all aspects of the function of individual children/youth. For example, an infant with hemiplegia who is unable to crawl on his or her hands and knees, but otherwise fits the description of Level I (i.e., can pull to stand and walk), would be classified in Level I. The scale is ordinal, with no intent that the distances between levels be considered equal or that children and youth with cerebral palsy are equally distributed across the five levels. A summary of the distinctions between each pair of levels is provided to assist in determining the level that most closely resembles a child's/youth's current gross motor function.

We recognize that the manifestations of gross motor function are dependent on age, especially during infancy and early childhood. For each level, separate descriptions are provided in several age bands. Children below age 2 should be considered at their corrected age if they were premature. The descriptions for the 6 to 12 year and 12 to18 year age bands reflect the potential impact of environment factors (e.g., distances in school and community) and personal factors (e.g., energy demands and social preferences) on methods of mobility.

An effort has been made to emphasize abilities rather than limitations. Thus, as a general principle, the gross motor function of children and youth who are able to perform the functions described in any particular level will probably be classified at or above that level of function; in contrast, the gross motor function of children and youth who cannot perform the functions of a particular level should be classified below that level of function.

## OPERATIONAL DEFINITIONS

**Body support walker –** A mobility device that supports the pelvis and trunk. The child/youth is physically positioned in the walker by another person.

**Hand-held mobility device** – Canes, crutches, and anterior and posterior walkers that do not support the trunk during walking.

**Physical assistance –** Another person manually assists the child/youth to move.

**Powered mobility –** The child/youth actively controls the joystick or electrical switch that enables independent mobility. The mobility base may be a wheelchair, scooter or other type of powered mobility device.

**Self-propels manual wheelchair –** The child/youth actively uses arms and hands or feet to propel the wheels and move.

**Transported –** A person manually pushes a mobility device (e.g., wheelchair, stroller, or pram) to move the child/youth from one place to another.

**Walks –** Unless otherwise specified indicates no physical assistance from another person or any use of a hand-held mobility device. An orthosis (i.e., brace or splint) may be worn.

**Wheeled mobility –** Refers to any type of device with wheels that enables movement (e.g., stroller, manual wheelchair, or powered wheelchair).

## GENERAL HEADINGS FOR EACH LEVEL

| | | |
|---|---|---|
| **LEVEL I** | - | Walks without Limitations |
| **LEVEL II** | - | Walks with Limitations |
| **LEVEL III** | - | Walks Using a Hand-Held Mobility Device |
| **LEVEL IV** | - | Self-Mobility with Limitations; May Use Powered Mobility |
| **LEVEL V** | - | Transported in a Manual Wheelchair |

## DISTINCTIONS BETWEEN LEVELS

**Distinctions Between Levels I and II -** Compared with children and youth in Level I, children and youth in Level II have limitations walking long distances and balancing; may need a hand-held mobility device when first learning to walk; may use wheeled mobility when traveling long distances outdoors and in the community; require the use of a railing to walk up and down stairs; and are not as capable of running and jumping.

**Distinctions Between Levels II and III -** Children and youth in Level II are capable of walking without a hand-held mobility device after age 4 (although they may choose to use one at times). Children and youth in Level III need a hand-held mobility device to walk indoors and use wheeled mobility outdoors and in the community.

**Distinctions Between Levels III and IV -** Children and youth in Level III sit on their own or require at most limited external support to sit, are more independent in standing transfers, and walk with a hand-held mobility device. Children and youth in Level IV function in sitting (usually supported) but self-mobility is limited. Children and youth in Level IV are more likely to be transported in a manual wheelchair or use powered mobility.

**Distinctions Between Levels IV and V -** Children and youth in Level V have severe limitations in head and trunk control and require extensive assisted technology and physical assistance. Self-mobility is achieved only if the child/youth can learn how to operate a powered wheelchair.

## Gross Motor Function Classification System – Expanded and Revised (GMFCS – E & R)

### BEFORE 2ND BIRTHDAY

**LEVEL I:** Infants move in and out of sitting and floor sit with both hands free to manipulate objects. Infants crawl on hands and knees, pull to stand and take steps holding on to furniture. Infants walk between 18 months and 2 years of age without the need for any assistive mobility device.

**LEVEL II:** Infants maintain floor sitting but may need to use their hands for support to maintain balance. Infants creep on their stomach or crawl on hands and knees. Infants may pull to stand and take steps holding on to furniture.

**LEVEL III:** Infants maintain floor sitting when the low back is supported. Infants roll and creep forward on their stomachs.

**LEVEL IV:** Infants have head control but trunk support is required for floor sitting. Infants can roll to supine and may roll to prone.

**LEVEL V:** Physical impairments limit voluntary control of movement. Infants are unable to maintain antigravity head and trunk postures in prone and sitting. Infants require adult assistance to roll.

### BETWEEN 2ND AND 4TH BIRTHDAY

**LEVEL I:** Children floor sit with both hands free to manipulate objects. Movements in and out of floor sitting and standing are performed without adult assistance. Children walk as the preferred method of mobility without the need for any assistive mobility device.

**LEVEL II:** Children floor sit but may have difficulty with balance when both hands are free to manipulate objects. Movements in and out of sitting are performed without adult assistance. Children pull to stand on a stable surface. Children crawl on hands and knees with a reciprocal pattern, cruise holding onto furniture and walk using an assistive mobility device as preferred methods of mobility.

**LEVEL III:** Children maintain floor sitting often by "W-sitting" (sitting between flexed and internally rotated hips and knees) and may require adult assistance to assume sitting. Children creep on their stomach or crawl on hands and knees (often without reciprocal leg movements) as their primary methods of self-mobility. Children may pull to stand on a stable surface and cruise short distances. Children may walk short distances indoors using a hand-held mobility device (walker) and adult assistance for steering and turning.

**LEVEL IV:** Children floor sit when placed, but are unable to maintain alignment and balance without use of their hands for support. Children frequently require adaptive equipment for sitting and standing. Self-mobility for short distances (within a room) is achieved through rolling, creeping on stomach, or crawling on hands and knees without reciprocal leg movement.

**LEVEL V:** Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At Level V, children have no means of independent movement and are transported. Some children achieve self-mobility using a powered wheelchair with extensive adaptations.

### BETWEEN 4TH AND 6TH BIRTHDAY

**LEVEL I:** Children get into and out of, and sit in, a chair without the need for hand support. Children move from the floor and from chair sitting to standing without the need for objects for support. Children walk indoors and outdoors, and climb stairs. Emerging ability to run and jump.

**LEVEL II:** Children sit in a chair with both hands free to manipulate objects. Children move from the floor to standing and from chair sitting to standing but often require a stable surface to push or pull up on with their arms. Children walk without the need for a hand-held mobility device indoors and for short distances on level surfaces outdoors. Children climb stairs holding onto a railing but are unable to run or jump.

**LEVEL III:** Children sit on a regular chair but may require pelvic or trunk support to maximize hand function. Children move in and out of chair sitting using a stable surface to push on or pull up with their arms. Children walk with a hand-held mobility device on level surfaces and climb stairs with assistance from an adult. Children frequently are transported when traveling for long distances or outdoors on uneven terrain.

**LEVEL IV:** Children sit on a chair but need adaptive seating for trunk control and to maximize hand function. Children move in and out of chair sitting with assistance from an adult or a stable surface to push or pull up on with their arms. Children may at best walk short distances with a walker and adult supervision but have difficulty turning and maintaining balance on uneven surfaces. Children are transported in the community. Children may achieve self-mobility using a powered wheelchair.

**LEVEL V:** Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At Level V, children have no means of independent movement and are transported. Some children achieve self-mobility using a powered wheelchair with extensive adaptations.

## BETWEEN 6TH AND 12TH BIRTHDAY

**Level I:** Children walk at home, school, outdoors, and in the community. Children are able to walk up and down curbs without physical assistance and stairs without the use of a railing. Children perform gross motor skills such as running and jumping but speed, balance, and coordination are limited. Children may participate in physical activities and sports depending on personal choices and environmental factors.

**Level II:** Children walk in most settings. Children may experience difficulty walking long distances and balancing on uneven terrain, inclines, in crowded areas, confined spaces or when carrying objects. Children walk up and down stairs holding onto a railing or with physical assistance if there is no railing. Outdoors and in the community, children may walk with physical assistance, a hand-held mobility device, or use wheeled mobility when traveling long distances. Children have at best only minimal ability to perform gross motor skills such as running and jumping. Limitations in performance of gross motor skills may necessitate adaptations to enable participation in physical activities and sports.

**Level III:** Children walk using a hand-held mobility device in most indoor settings. When seated, children may require a seat belt for pelvic alignment and balance. Sit-to-stand and floor-to-stand transfers require physical assistance of a person or support surface. When traveling long distances, children use some form of wheeled mobility. Children may walk up and down stairs holding onto a railing with supervision or physical assistance. Limitations in walking may necessitate adaptations to enable participation in physical activities and sports including self-propelling a manual wheelchair or powered mobility.

**Level IV:** Children use methods of mobility that require physical assistance or powered mobility in most settings. Children require adaptive seating for trunk and pelvic control and physical assistance for most transfers. At home, children use floor mobility (roll, creep, or crawl), walk short distances with physical assistance, or use powered mobility. When positioned, children may use a body support walker at home or school. At school, outdoors, and in the community, children are transported in a manual wheelchair or use powered mobility. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports, including physical assistance and/or powered mobility.

**Level V:** Children are transported in a manual wheelchair in all settings. Children are limited in their ability to maintain antigravity head and trunk postures and control arm and leg movements. Assistive technology is used to improve head alignment, seating, standing, and and/or mobility but limitations are not fully compensated by equipment. Transfers require complete physical assistance of an adult. At home, children may move short distances on the floor or may be carried by an adult. Children may achieve self-mobility using powered mobility with extensive adaptations for seating and control access. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports including physical assistance and using powered mobility.

## BETWEEN 12TH AND 18TH BIRTHDAY

**Level I:** Youth walk at home, school, outdoors, and in the community. Youth are able to walk up and down curbs without physical assistance and stairs without the use of a railing. Youth perform gross motor skills such as running and jumping but speed, balance, and coordination are limited. Youth may participate in physical activities and sports depending on personal choices and environmental factors.

**Level II:** Youth walk in most settings. Environmental factors (such as uneven terrain, inclines, long distances, time demands, weather, and peer acceptability) and personal preference influence mobility choices. At school or work, youth may walk using a hand-held mobility device for safety. Outdoors and in the community, youth may use wheeled mobility when traveling long distances. Youth walk up and down stairs holding a railing or with physical assistance if there is no railing. Limitations in performance of gross motor skills may necessitate adaptations to enable participation in physical activities and sports.

**Level III:** Youth are capable of walking using a hand-held mobility device. Compared to individuals in other levels, youth in Level III demonstrate more variability in methods of mobility depending on physical ability and environmental and personal factors. When seated, youth may require a seat belt for pelvic alignment and balance. Sit-to-stand and floor-to-stand transfers require physical assistance from a person or support surface. At school, youth may self-propel a manual wheelchair or use powered mobility. Outdoors and in the community, youth are transported in a wheelchair or use powered mobility. Youth may walk up and down stairs holding onto a railing with supervision or physical assistance. Limitations in walking may necessitate adaptations to enable participation in physical activities and sports including self-propelling a manual wheelchair or powered mobility.

**Level IV:** Youth use wheeled mobility in most settings. Youth require adaptive seating for pelvic and trunk control. Physical assistance from 1 or 2 persons is required for transfers. Youth may support weight with their legs to assist with standing transfers. Indoors, youth may walk short distances with physical assistance, use wheeled mobility, or, when positioned, use a body support walker. Youth are physically capable of operating a powered wheelchair. When a powered wheelchair is not feasible or available, youth are transported in a manual wheelchair. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports, including physical assistance and/or powered mobility.

**Level V:** Youth are transported in a manual wheelchair in all settings. Youth are limited in their ability to maintain antigravity head and trunk postures and control arm and leg movements. Assistive technology is used to improve head alignment, seating, standing, and mobility but limitations are not fully compensated by equipment. Physical assistance from 1 or 2 persons or a mechanical lift is required for transfers. Youth may achieve self-mobility using powered mobility with extensive adaptations for seating and control access. Limitations in mobility necessitate adaptations to enable participation in physical activities and sports including physical assistance and using powered mobility.

Appendix IV- Manual Ability Classification System

**Information for users**

The Manual Ability Classification System (MACS) describes how children with cerebral palsy (CP) use their hands to handle objects in daily activities. MACS describes five levels. The levels are based on the children's self-initiated ability to handle objects and their need for assistance or adaptation to perform manual activities in everyday life. The MACS brochure also describes differences between adjacent levels to make it easier to determine which level best corresponds with the child's ability to handle objects.

The objects referred to are those that are relevant and age-appropriate for the children, used when they perform tasks such as eating, dressing, playing, drawing or writing. It is objects that are within the children's personal space that is referred to, as oppose to objects that are beyond their reach. Objects used in advanced activities that require special skills, such as playing an instrument are not included in this considerations.

When establishing a child's MACS level, choose the level that best describes the child's overall usual performance, in the home, school or community setting. The child's motivation and cognitive ability also affect the ability to handle objects and accordingly influence the MACS level. In order to obtain knowledge about how a child handles various everyday objects it is necessary to ask someone who knows the child well. MACS is intended to classify what the children usually do, not their best possible performance in a specific test situation.

MACS is a functional description that can be used in a way that is complement to the diagnosis of cerebral palsy and its subtypes. MACS assesses the children's overall ability to handle everyday objects, not the function of each hand separately. MACS does not take into account differences in function between the two hands; rather, it addresses how the children handle age-appropriate objects. MACS does not intend to explain the underlying reasons for impaired manual abilities.

MACS can be used for children aged 4–18 years, but certain concepts must be placed in relation to the child's age. Naturally there is a difference in which objects a four-year old should be able to handle, compared with a teenager. The same applies to independence –a young child needs more help and supervision than an older child.

MACS spans the entire spectrum of functional limitations found among children with cerebral palsy and covers all sub-diagnoses. Certain sub-diagnoses can be found at all MACS levels, such as bilateral CP, while others are found at fewer levels, such as unilateral CP. Level I includes children with minor limitations, while children with severe functional limitations will usually be found at levels IV and V. If typically developed children were to be classified according to MACS, however, a level "0" would be needed.

Moreover, each level includes children with relatively varied function. It is unlikely that MACS is sensitive to changes after an intervention; in all probability, MACS levels are stable over time.

The five levels in MACS form an ordinal scale, which means that the levels are 'ordered' but differences between levels are not necessarily equal, nor are children with cerebral palsy equally distributed across the five levels.

E-mail:ann-christin.eliasson@ki.se; www.macs.nu

Eliasson AC, Krumlinde Sundholm L, Rösblad B, Beckung E, Arner M, Öhrvall AM , Rosenbaum P. The Manual Ability Classification System (MACS) for children with cerebral palsy: scale development and evidence of validity and reliability Developmental Medicine and Child Neurology 2006 48:549-554

# Manual Ability Classification System for Children with Cerebral Palsy 4-18 years

**MACS classifies how children with cerebral palsy use their hands to handle objects in daily activities.**

- MACS describes how children usually use their hands to handle objects in the home, school, and community settings (what they do), rather than what is known to be their best capacity.
- In order to obtain knowledge about how a child handles various everyday objects, it is necessary to ask someone who knows the child well, rather than through a specific test.
- The objects the child handles should be considered from an age-related perspective.
- MACS classify a child's overall ability to handle objects, not each hand separately.

2005, updated 2010

## What do you need to know to use MACS?

The child's ability to handle objects in important daily activities, for example during play and leisure, eating and dressing.

In which situation is the child independent and to what extent do they need support and adaptation?

I. **Handles objects easily and successfully.** At most, limitations in the ease of performing manual tasks requiring speed and accuracy. However, any limitations in manual abilities do not restrict independence in daily activities.

II. **Handles most objects but with somewhat reduced quality and/or speed of achievement.** Certain activities may be avoided or be achieved with some difficulty; alternative ways of performance might be used but manual abilities do not usually restrict independence in daily activities.

III. **Handles objects with difficulty; needs help to prepare and/or modify activities.** The performance is slow and achieved with limited success regarding quality and quantity. Activities are performed independently if they have been set up or adapted.

IV. **Handles a limited selection of easily managed objects in adapted situations.** Performs parts of activities with effort and with limited success. Requires continuous support and assistance and/or adapted equipment, for even partial achievement of the activity.

V. **Does not handle objects and has severely limited ability to perform even simple actions.** Requires total assistance.

### Distinctions between Levels I and II

Children in Level I may have limitations in handling very small, heavy or fragile objects which demand detailed fine motor control, or efficient coordination between hands. Limitations may also involve performance in new and unfamiliar situations. Children in Level II perform almost the same activities as children in Level I but the quality of performance is decreased, or the performance is slower. Functional differences between hands can limit effectiveness of performance. Children in Level II commonly try to simplify handling of objects, for example by using a surface for support instead of handling objects with both hands.

### Distinctions between Levels II and III

Children in Level II handle most objects, although slowly or with reduced quality of performance. Children in Level III commonly need help to prepare the activity and/or require adjustments to be made to the environment since their ability to reach or handle objects is limited. They cannot perform certain activities and their degree of independence is related to the supportiveness of the environmental context.

### Distinctions between Levels III and IV

Children in Level III can perform selected activities if the situation is prearranged and if they get supervision and plenty of time. Children in Level IV need continuous help during the activity and can at best participate meaningfully in only parts of an activity.

### Distinctions between Levels IV and V

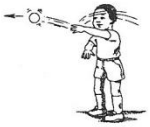
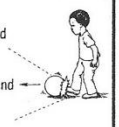
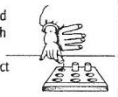
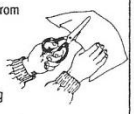
Children in Level IV perform part of an activity, however, they need help continuously. Children in Level V might at best participate with a simple movement in special situations, e.g. by pushing a button or occasionally hold undemanding objects.

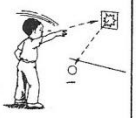
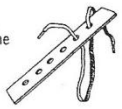
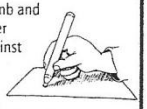
Appendix V- Peabody Motor Development Chart

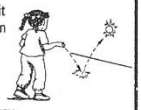
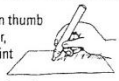
# Peabody Motor Development Chart

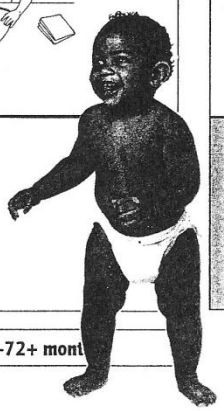
| | 0–2 months | 3–5 months | 6–8 months | 9–11 months |
|---|---|---|---|---|
| **GROSS MOTOR** | | | | |
| Locomotion | • Lying on back, bends and straightens legs (alternately or together) twice<br>• Rolls to back from both right and left sides<br>• Bends and straightens arms (alternately or together)<br>• When held in standing position, bears weight with knees flexed and feet flat<br>• Elevates head and upper trunk 45 degrees, bearing weight on forearms or hands | • Maintaining midline head and body posture, brings both hands to the midline while lying on back<br>• Elevates head and upper trunk 45 degrees, bearing weight on forearms to see toy<br>• Rolls from back to left and right sides with opposite arm crossing the midline<br>• Lying on stomach, extends arms and legs (alternately or together) off surface<br>• Brings both feet to mouth for play or grabs feet with hands while lying on back<br>• Raises arms and legs (alternately or together) in smooth, fluid movements | • From stomach, raises upper trunk, shifts weight to side, lifts free arm, and reaches toward toy<br>• Grasps both feet and holds them<br>• From stomach, elevates head and stomach, bearing weight on palms<br>• Lying on back, shifts weight to side and supports self with arm while extending opposite arm to reach for toy<br>• Rolls from back to stomach<br>• Rolls from back to stomach, leading with hips and thighs, followed by stomach and then shoulders<br>• Uses arms to move forward 3 feet | • Raises and bears weight on hands and knees and rocks back and forth twice<br>• Creeps 5 feet on hands and knees with opposite arms and legs moving together<br>• Maintains sitting posture and uses hands and legs to scoot forward 3 feet<br>• Using stable object for support, raises to standing position<br>• Creeps completely over adult's legs<br>• Lowers from standing to a sitting position without falling<br>• Takes 4 alternating steps in place or forward with trunk support<br>• Frees hand and body from support and maintains balance in standing position for 5 seconds<br>• Takes 4 alternating steps in place or forward |
| Stationary | • Lifts and turns head so opposite cheek touches surface<br>• Holds back in rounded position when sitting<br>• Holds head so that at least 45-degree angle exists between chin and chest<br>• Holds head so that 45-degree angle exists between back of head and back<br>• Holds head in midline through more than 75% of movement cycle<br>• Raises head at midline and holds it in alignment when suspended vertically<br>• Holds head in midline for 2 to 3 bounces | • Holds head in alignment when tilted sideways<br>• Holds trunk off legs when sitting<br>• Holds head aligned while rotating head to follow toy<br>• Maintains balance while sitting | • Maintains balance while moving hands and arms to grasp toy<br>• Pulls up to sitting position holding adult's fingers<br>• Sits unsupported<br>• Retrieves toy, returns to upright sitting, and maintains balance | • Maintains balance while sitting and manipulating toy<br>• Pulls up from lying on back to sitting position using chair for support<br>• Lying on stomach, raises to sitting position to reach toy |
| Reflexes & Object Manipulation | • Lifts one foot, then the other in walking movement | • Does not move his or her arms and legs when head is turned | • Raises head above horizontal plane, extends trunk, and symmetrically raises hips and legs into full extension<br>• Extends arms, straightens elbows, and bears weight on palms when tilted forward<br>• Breaks fall by extending arm and supporting self with open palm when tilted to one side<br>• Breaks fall by extending one or both arms and supporting self with open palm when tilted forward | • Extends arms and head forward to recover balance and returns to upright sitting position when pulled backward<br>• Stops fall by extending arm(s) backward and supporting weight on open palm(s) when pushed backward |
| **FINE MOTOR** | | | | |
| Visual–Motor | • Lying on back, tracks rattle 90 degrees from midline to each side<br>• Tracks rattle to midline on both sides<br>• Places open hand on table<br>• Lying on back, turns head to avoid approaching rattle<br>• Looks at hands for 3 seconds<br>• Tracks small ball beyond midline on both sides<br>• Lying on back, head turned to side, tracks rattle through midline on both sides | • Lying on back, extends straight arms toward rattle<br>• Lying on back, moves hand within 4 inches of midline to reach for toy<br>• Lying on back, engages fingers in mutual touching | • Sitting, brings hands together to secure block<br>• Lying on back, extends straight arm toward rattle while other arm remains stationary<br>• Picks up 2 cubes and retains both<br>• Transfer cube to other hand and picks up 2nd cube with original hand<br>• Touches pellet with fingers<br>• Bangs cup on table<br>• Pokes finger in hole of pegboard | • Brings 2 cubes together at midline<br>• Claps hands<br>• Extends hand toward 3rd cube while holding cube in each hand<br>• Secures string to retrieve out of sight attached toy<br>• Removes 3 pegs from pegboard<br>• Releases cube into adult's hand<br>• Removes both socks<br>• Picks up pellet with thumb and index finger and drops it into cup<br>• Places 3 to 7 cubes in cup |
| Grasping | • Closes finger in tight grasp<br>• Secures in hand cloth hanging from adult's arm<br>• After holding rattle for 5 seconds, drops rattle within 3 seconds<br>• Grasps rattle<br>• Holds rattle for 30 seconds | • Moves rattle 15 degrees<br>• Picks up rattle<br>• Grasps string, pulls it, and obtains toy<br>• Secures paper<br>• Grasps and holds cube | • Moves rattle through 90-degree arcs<br>• Grasps cube with thumb and 1st and 2nd fingers with space visible between cube and palm<br>• Using a raking motion, secures 2 pellets at once<br>• Crumples paper with palms (1 or 2 hands)<br>• Grasps pellet with thumb against side of curled index finger | • Grasps pellet with pad of of thumb and pad of index finger, with hand, wrist, and arm off table<br>• With hand approaching from top, grasps cube with thumb opposed to 1st and 2nd finger pads with space visible between cube and palm |
| | 0–2 months | 3–5 months | 6–8 months | 9–11 months |

M. Rhonda Folio
Rebecca R. Fewell

| | 12–14 months | 15–18 months | 19–24 months | 25–30 months |
|---|---|---|---|---|
| **GROSS MOTOR** | | | | |
| Locomotion | • From sitting cross-legged on floor, stands without turning body more than 20 degrees<br>• Uses alternating steps to walk 8 feet while holding adult's hand<br>• Walks unaided for 5 steps<br>• Picks up toy, returns to standing, and takes 3 steps without losing balance<br>• Creeps up 2 steps on hands and knees<br>  <br>• Walks 10 feet with narrow base of support, heel–toe gait, using reciprocal pattern for 5 feet | • Creeps backward down 3 steps without support<br>• Walks up 4 steps without support (may place 1 or both feet on each step)<br>  <br>• Walks 10 feet quickly<br>• Walks backward 5 steps (may pull toy)<br>• With support only from adult's finger, walks down 4 steps (may place 1 or both feet on each step)<br>• Walks backward 5 steps | • Runs forward 10 feet<br>• Stands on 2-inch line with 1 foot in front of other; toe of back foot is within 3 inches of front foot<br>• Walks sideways for 10 feet, leading with same foot<br>• Walks with 1 foot on 4-inch line for 6 feet<br>• Jumps forward 4 inches without falling<br>• With feet together, jumps up 2 inches<br>  <br>• Jumps down 1 step without assistance (1 foot may lead)<br>• Walks up 4 steps without support from wall or rail (may place 1 or both feet on each step) | • Walks down 4 steps without support (may place 1 or both feet on each step)<br>• Walks backward 10 feet without heels touching toes<br>• Jumps up and touches line 2 inches above standing reach<br>• With hands on hips and without heels touching toes, takes 3 steps forward on 4-inch line<br>  <br>• Placing 1 foot on each step, walks up 4 steps (may use wall or rail for support)<br>• Jumps down from object 16 in. high without assistance (1 foot may lead)<br>• With hands on hips and without heels touching floor, walks on tip-toes for 5 steps<br>• Runs 30 feet |
| Stationary | • In kneeling position, maintains balance while rotating head<br>  |  | | |
| Reflexes & Object Manipulation | • Without losing balance, corrals 8-inch ball with arms and/or hands<br>  <br>• Using hand/arm contact, rolls 8-inch ball forward<br>• Throws 3-inch ball in any direction by extending arm at shoulder or elbow | • Lifts foot and contacts 8-inch ball<br>• Maintaining balance, throws 3-inch ball by extending arm<br>  | • Kicks ball forward 3 feet<br>• Throws small ball overhand 3 feet forward before it touches floor<br>• Throws small ball underhand 3 feet forward before it touches floor<br>  | • Presenting extended arms directly in front, palms facing upward or facing each other, attempts to catch 8-inch ball by bending arms toward chest<br>• Initiates overhand throw by moving arm upward and back; small ball travels 7 feet before touching floor<br>  <br>• Initiates underhand throw by moving arm down and back; small ball travels 7 feet before touching floor<br>• Using opposing arm and leg movements and initiating kick by extending leg back with bent knee, kicks ball forward 6 feet |
| **FINE MOTOR** | | | | |
| Visual–Motor | • Opens book<br>• Stirs spoon in cup<br>• Turns bottle over and dumps out pellet<br>• Places 7 cubes in cup<br>• Places 3 pegs in pegboard<br>• Taps cup horizontally with spoon<br>  <br>• Places 1 shape into correct hole in formboard<br>• Puts pellet in bottle<br>• Makes at least 1 scribble more than 1 inch long on paper | • Stacks 2 to 3 cubes<br>• Places 2 shapes into correct holes in formboard<br>  | • Turns 3 pages in book, 1 at a time<br>• Places 3 shapes int correct holes in formboard<br>• Stacks 4 to 6 cubes<br>• Draws vertical line<br>  | • Removes screw-on lid from bottle<br>  <br>• Stacks 8 to 10 cubes<br>• Cuts paper in 1 place<br>• Draws horizontal line<br>• Bends paper, producing crease<br>• Using 4 cubes, aligns 3 cubes and positions top cube on one end<br>• Strings 2 to 4 beads |
| Grasping | • Picks up 2 cubes with 1 hand and holds them<br>  | • Grasps marker with thumb and 1st finger toward paper and remaining fingers around marker<br>  | | |
| | 12–14 months | 15–18 months | 19–24 months | 25–30 months |

| | 31–36 months | 37–42 months | 43–48 months |
|---|---|---|---|
| **GROSS MOTOR** | | | |
| Locomotion | • Using 2-footed takeoff and landing, jumps forward 24 inches<br>• Jumps down from object 18 inches high without assistance using 2-footed takeoff and landing<br>• Using 2-footed takeoff and landing, jumps over string 2 inches off floor without tripping<br>• With hands on hips and without heels touching floor, walks on tip-toes 8 feet on 4-inch line<br>• Placing 1 foot on each step, walks up 4 steps without support<br>  | • Runs 15 yards in 6 seconds or less<br>• Using 2-footed takeoff and landing, jumps forward 26 inches<br>• With hands on hips and without heels touching toes, walks forward 4 feet on 4-inch line without stepping off<br>• Runs with arms moving back and forth across body and below waist, balls of feet used to push forward, toes pointed forward, a high knee and heel lift, and trunk leaning forward<br>  <br>• With hands on hips, without heels touching toes, and without swaying more than 20 degrees, walks forward 8 feet on 4-inch line without stepping off | • Placing 1 foot on each step, walks down 4 steps without support from wall or rail<br>  <br>• Without letting other foot touch floor, jumps forward 6 inches on 1 foot<br>• Jumps up and touches line 3 inches above standing reach<br>• Runs and stops without falling<br>• With hands on hips and without heels touching toes, walks backward 4 feet without stepping off 4-inch line<br>• Using 2-footed takeoff and landing, jumps forward at least 30 inches<br>• Hops forward on 1 foot, then hops forward on other foot |
| Stationary | • With hands on hips, stands on 1 foot for 3 seconds | • With hands on hips, stands on 1 foot for 5 seconds | • With arms held overhead and without moving feet, stands on tiptoes<br>• With hands on hips and without swaying more than 20 degrees, stands on 1 foot<br>  |
| Reflexes & Object Manipulation | • Catches 8-inch ball with arms extended<br>  | • Using upper trunk rotation, arms and legs moving in opposition, and initiating overhand throw by moving arm up and back, throws small ball 10 feet forward<br>• Using an underhand toss, hits target with small ball<br>• With arms bent at 45 to 90 degrees at elbows and palms up or facing each other, catches 8-inch ball with hands, securing it to chest if necessary<br>  | • Using an overhand toss, hits target from 5 feet<br>  <br>• Using upper trunk rotation and moving arms and legs in opposition, throws small ball underhand 10 feet |
| **FINE MOTOR** | | | |
| Visual–Motor | • Builds bridge of 3 blocks<br>• Draws circle<br>• Builds wall of 4 blocks<br>  | • Cuts paper into 2 pieces<br>• Laces 3 holes<br>• Cuts within 1/2 inch of line for entire length of line<br>  <br>• Draws a cross<br>• Puts 10 pellets in bottle<br>• Traces horizontal line | |
| Grasping | | • Grasps marker with thumb and pad of index finger, other 3 fingers are secure against palm, upper portion of marker rests between thumb and index finger, child moves hand as unit when drawing<br>  <br>• Unbuttons 3 buttons | • Buttons and unbuttons 1 button<br>  |
| | 31–36 months | 37–42 months | 43–48 months |

| | 49–54 months | 55–60 months | 61–72+ months |
|---|---|---|---|
| **GROSS MOTOR** | | | |
| Locomotion | • With hands on hips and with toes touching heels, walks backward 5 steps without stepping off 4-inch line<br>• Completes forward roll without turning more than 15 degrees to either side<br>• With weight transferred smoothly and evenly, gallops 10 feet<br>• Using 2-footed takeoff and landing, jumps forward 36 inches<br>• With hands on hips and body not swaying more than 20 degrees, jumps and turns so feet land in opposite direction from starting position<br>• Hops 3 feet on 1 foot, changes feet, and hops back | • Using 2-footed takeoff and landing, jumps over string 10 inches off floor without tripping<br>• Runs 10 ft., picks up a can, and returns to starting line without tripping or dropping can<br>• Maintaining balance, using opposing arm and leg movements, and using alternating feet, skips 8 steps<br>• With hands on hips, with feet together, and without touching line or pausing between jumps, jumps back and forth across line taped on floor<br>  | • Maintaining balance and rhythm, using opposing arm and leg movements, and using alternating feet, skips 10 feet<br>• Without losing balance or letting free foot touch floor, hops 20 feet in 6 seconds or less<br>  |
| Stationary | • With arms held overhead, without moving feet, and without swaying more than 20 degrees, stands on tip toes<br>• With hands on hips and without swaying more than 20 degrees, stands on 1 foot, then stands on other foot | • Accurately imitates arm positions<br>• With hands on hips and without swaying more than 20 degrees, stands on each foot for 10 seconds<br>• Completes 3 sit-ups<br>  | • Completes 5 sit-ups<br>• Performs 8 push-ups<br>  |
| Reflexes & Object Manipulation | • Using an overhead toss, hits target from 12 feet<br>• Bounces small ball so it bounces once and then hits wall from 5 feet<br>• With arms bent and using hands only, catches small ball thrown from 5 feet away<br>  | | • Using opposing arm and leg movements and initiating kick by extending leg back with bent knee, kicks ball so it travels 12 feet in air<br>• Bounces and catches small ball<br>  |
| **FINE MOTOR** | | | |
| Visual–Motor | • Draws a square<br>• Cuts out circle printed on paper<br>• Builds steps of 6 blocks<br>• Connects dots by drawing straight line<br>• Cuts out square printed on paper<br>• Builds pyramid of 6 blocks<br>  | • Folds paper in half lengthwise with edges parallel<br>• Colors between vertical lines<br>  | • Folds paper in half twice with edges parallel<br>  |
| Grasping | • Grasps marker between thumb and pad of index finger, marker rests on first joint of middle finger<br>• Touches each finger to thumb<br>  | | |
| | 49–54 months | 55–60 months | 61–72+ mont |





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Appendix VI- Cited literature in alphabetical order


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