SHORT TERM EFFECTS OF RIDING THERAPY ON GAIT IN CHILDREN WITH CEREBRAL PALSY

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ABSTRACT

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The purpose of this study was to investigate the short term effects of an intensive riding therapy program on gait in children with cerebral palsy. The research method was single-subject design. The walking skill was assessed before and after a three-week riding therapy phase.

The functional, quantitative, change in gait of four subjects was studied with temporal and stride parameters (velocity, stride length, and cadence). The gait parameters were measured in a 15,5 meter walkway with a digital stopwatch and a tapeline. This method is considered valid and highly reliable way to assess functional status of persons with motor disabilities.

The results show that two boys with diplegia spastica type cerebral palsy clearly improved their walking when compared the performance after the riding therapy phase with the baseline measurements before it. They mainly improved their gait velocity by increased stride length. A positive change in gait of a girl with athetoid type of cerebral palsy was detected. She improved her gait velocity evenly by increased cadence and stride length. All three showed similar slopes after riding therapy indicating fatigue just after the riding therapy phase, and recovery and improvement in gait during the following days.

One girl with mild ataxia, and with only minor problems in gait, showed only a small percentile increase in her gait parameters. Also the slope was different to the others showing a downward trend. No positive conclusions could be drawn about her functional status of walking when compared the state after riding therapy phase with the situation before it.

Additional subjective information about the qualitative changes in gait explaining the functional improvement was received by observing the gait from videotape recordings. Observable improvement in the quality of walking could be detected in the gait of the two boys with diplegia.

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1. INTRODUCTION

This study derived its origin from the experiences in a riding camp for children with cerebral palsy in autumn 1990. Before the camp began I was sure that five days of intensive riding (twice a day) would certainly kill off the fun of this kind of recreation. This attitude was due to the previous experience I had in riding of children with cerebral palsy, and knowing how hard work it can be. What I found was that all the children remained enthusiastic and seemed to improve their skill in riding. The most amazing observation was that a multiply handicapped boy with quadriplegia, who was to a considerable degree hypotonic, gained erect posture while riding and even was able to ride without assistance for a short while. This took place in the latter part of the camp, and after refraining from the excessive supporting of the child. I realized that in order to stick the child on the horseback we held him so strongly that he certainly did not fall, but neither did he benefit from riding. I concluded two things: there might be positive functional outcome of horseback riding; and one has to know how to manipulate the child and the horse in order to achieve any results. True expertise is required if horseback riding is to be called therapy.

After that camp I had a closer look in riding of children with cerebral palsy, since I had a chance to assist in riding therapy. It raised further questions in my mind of the possible effects (or supposed effects) of therapeutic horseback riding. Observing, for example, the improvement of postural and balance reactions while riding, and the possible transfer to overall motor function and activities of daily living were interesting topics. Also the motivational aspects of riding in relation to the expected positive treatment outcome seemed to be worth of thinking, but difficult to scientifically verify.

For the children with cerebral palsy the skill of walking is evidently of great importance from a functional point of view. Since riding therapy is supposed to influence in walking in various ways, it became one major topic of interest from the beginning. I was astonished to find out that in fact what seems to happen immediately after riding, is that even the children with severe impairment who will never attain to the walking skill were enthusiastic to walk supported. They even did that with relatively good quality when compared with the gait before riding. The walking pattern seemed to sustain after riding.

People who are involved in the riding therapy, the patients, parents, therapists and the persons assisting in therapy are often at least to some degree emotionally part of the process. The horse is a symphatetic and respected animal, and cooperation with a horse is usually boosting some mental processes in people: excitement, attachment, fear, honoring and so forth. Positive mental outcome in regards of therapy is usually strong motivation towards riding.

What kind of therapeutic value is there in riding? Many questions are answered, if one gets involved in the process of therapy. This so called "face validity" is enough for the therapist, but not for the professionals prescribing therapies or the instances financing it. The question has to be answered keeping the interpretations apart from the emotions. There is, I believe, unconscious need in everybody involved in riding therapy to see most of the positive changes as an outcome of riding. True professionals may avoid this pitfall, but still objective studies are desperately needed instead or in addition to subjective individual observations.

The scientific proof is needed to officially justify the therapy or treatment. This is especially true with those treatments derived from sports and, thus, are easily considered as leisure activities. "As expected some have attempted to demonstrate therapeutic value in sports such as 'hippotherapy' and 'therapeutic horseback riding for cerebral-palsied children'. These attempts are perhaps the natural outgrowth in countries with liberal medical care insurance schemes - an indirect approach to finance recreation for children whose parents cannot afford it" (Bleck 1987, 169).

Many scientific problems require research designs with a "big n" and control group to meet the needs of validity. In many cases this is not possible, practical or necessary to arrange. Well-designed single subject research may give even more valid and reliable information than the traditonal group designs. This study is assessing the effects of riding therapy on gait of four children with cerebral palsy. It is a single subject study of intensive riding therapy program designed to improve the gait of the children. The short term outcome is measured with temporal and stride parameters.

2. CEREBRAL PALSY

2.1. Definition and clinical classification

Cerebral palsy is caused by a central nervous system lesion before or during delivery or in infancy and it leads to motor dysfunction. The damage in the brain is nonprogressive. The motor impairment is the major component of cerebral palsy, but there usually occurs other problems caused by dysfunctioning nervous system. They are such as: sensory and perceptual dysfunction, seizures and cognitive deficits. There may be also problems in behavior, learning and emotion. (Bleck 1982; Ingram, 1966; Low & Downey 1982; Scherzer & Tscharnuter 1982, 8; Shapiro, Palmer, Wachtel & Capute 1983.)

The collective term "cerebral palsy" as a hospital discharge diagnosis, gives us no information about the variability of etiology, clinical features, and course of cerebral palsy, thus is lacking practical value (Low & Downey 1982). The diagnosis, quoting Low & Downey (1982), "should be classified according to type and severity, and probably also qualified by the listing of associated conditions." The classification of cerebral palsy has confusingly not just one exact form of presentation in the literature, but various more or less alike approaches. Also the terminology is somewhat varying in different sources. (see Bleck 1982; Bobath & Bobath 1991, 22; Ingram 1966; Low & Downey 1982; Scherzer & Tscharnuter 1982, 8-11.)

Minear developed (for the American Academy of Cerebral Palsy in 1956) the clinical classification system often used as a basis of current presentations. This system is based on the physiology of the motor dysfunction and the number of limbs involved. (Gage 1991, 2; Scherzer & Tscharnuter 1982, 9-11.) According to Gage (1991, 2-7) a more complete description of the patient's condition should include: functional capacity, associated problems, and etiologic and risk factors if they can be identified. By functional capacity Gage (1991, 2) means severity of cerebral palsy, and it is estimated in a three degree scale with six items (Table 1): gross motor function I (overall), gross motor function II (ambulation), fine motor function, IQ, speech, overall function (need of assistance) .

TABLE 1. Severity of cerebral palsy (Gage 1991, 2)

Gross motor	Gross motor	Fine motor	IQ	Speech	Overall
Mild	Independent walker	Unlimited function	>70	2 words	Independent function
Moderate	Crawl or supported walk	Limited function	50-70	Single words	Needs assistance
Severe	No locomotion	No function	<50	Severely impaired	Total care

The Table 1 is not presenting a categorical definition of the severity of cerebral palsy. One has to notice, for example, that even with severe problems in gross motor and fine motor performance an individual with cerebral palsy may have normal intelligence. Anyhow, the children with more global involvement of the central nervous system are more likely to have mental retardation than the ones with mild cerebral palsy (Gage 1991, 4).

2.1.1. Physiological classification

According to the physiological classification there are three major types of motor dysfunction in cerebral palsy: spastic, dyskinetic and ataxic. In addition to these there are also mixed types of motor dysfunction.

Spasticity is motor disorder that is not possible to comprehensively define because the neurobiology of motor system is not fully understood, but it is "characterized by velocity dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyperexitability of the stretch reflex, as one component of the upper motor neuron syndrome" (Young 1994). Gage (1991, 2) is defining spasticity as "increased stretch reflex determined by passively flexing and extending muscle groups across a joint". Spasticity differs from rigidity, which refers to increased muscle tone even at rest, (spasticity occurs only during muscle stretch) and there are usually no abnormal tendon reflexes and the plantar reflex is normal (in spasticity they are increased) (Young 1994). Spasticity will lead into contractures in muscles when a child is growing and the spastic muscles become shorter. This may cause deformities in spine, limbs and pelvis (Bleck 1982, 61.)

Dyskinesia implies to involuntary movements and involuntary changes in muscle tone. Two major types of dyskinesia exists: athetosis, which is the most common type, and dystonia. Characteristic to athetosis is slow writhing movements affecting the distal part of the limbs and is most evident in the fingers and wrists, but usually involve all extremities. Dystonia is also a slow writhing movement but affecting the proximal part of the limbs and the trunk. Since the tongue, lips, palate and individual face muscles are often affected in dyskinesias a high proportion has severe speech defects. (Ingram 1966; Low & Downey 1982.)

Yokochi, Shimabukuro, Kodama, Kodama & Hosoe (1993) studied the motor function of 35 athetoid infants with cerebral palsy (5-8 months of age). They found out that the most specific motor symptoms in athetoid cerebral palsy are: difficulty in keeping symmetric supine posture, limited forward extension of the upper extremity, poor stability of the neck and trunk, and excessive opening of the mouth. These symptoms are useful for making diagnosis in infancy,

Ataxia means functional disturbances in coordination of voluntary movements due to muscle dyssynergia (Gage 1991, 3). Poor kinesthetic sence and balance induce problems in standing and walking (Bleck 1982; Sherrill 1986, 552). Often children with ataxia tend to be hypotonic for the first years of life but the muscle tone gradually increases with age, but it will never become normal (Gage 1991, 3; Ingram 1966). There is functional improvement when growing older since people are able to compensate ataxia if it is not severe (Low & Downey 1982).

2.1.2. Topographical classification

According to the amount of limbs affected the division is: hemiplegia, diplegia, quadriplegia (or tetraplegia) are the major types; and rarely occurring monoplegia, paraplegia and triplegia. Topography is depending on the location of the lesion in the central nervous system. (Bleck 1982; Gage 1991, 2; Low & Downey 1982; Scherzer & Tscharnuter 1982, 9-11.)

Hemiplegia indicates that neuromuscular disorder involves one half of the body in the frontal plane while the other side is normal or near normal (Winters et al. 1987). Spastic hemiplegia is the most common type but sometimes there is additional distal athetosis (Bobath & Bobath 1991, 22). In most cases the upper extremity is more involved. The affected limbs are not usually developing normally: they may grow thinner and shorter than the healthy one's with smaller hand or foot. (Low & Downey 1982.) Motor dysfunction is often noticed rather early (from one month on) because of the clear functional asymmetry: the child is reaching and grasping with only the other hand, and cannot sit straight. If the hemiplegia is mild, it is sometimes difficult to make exact diagnosis. (Bobath & Bobath 1991, 42.)

Diplegia affects the whole body but lower limbs more than upper limbs, which are mildly affected. All the children with diplegia belong to the spastic group and the distribution of spasticity is more or less symmetrical. Impairment does not usually affect speech, and the control of the head is fairly good. Most of the low birth weight babies, many of them preterm, with motor deficit will show this type. (Bobath & Bobath 1991, 22-23; Low & Downey 1982.) Even though these children are slowly developing, the progress is close to normal, and the diagnosis is seldom made before the age of nine months (Bobath & Bobath 1991, 23).

Quadriplegia affects the whole body. In spastic type all limbs are equally affected, and in athetotic quadriplegia usually the upper body is more affected than the lower limbs. If impairment is clearly asymmetrical when comparing body halves (sagittal plane), the posture and movements will become asymmetrical too. Control of the head is poor and there are problems in speech and swallowing. All the athetoid and ataxic children are in this group. (Bobath & Bobath 1991, 22.) Spastic quadriplegia is a severely disabling condition with strong spasticity or rigidity often from first weeks after birth, and there are usually many associated conditions too. An infant has a total loss of head control, erected and stiff spine, elbows are drawn backwards, and lower limbs are in adduction and in excessive extension. Contractures may develop very early. (Bobath & Bobath 1991, 78.)

2.2. Developmental aspects and the importance of assessment

Most behavioral changes during the first three months after birth represent development from reflexes into voluntary actions. At the end of that stage most of the primary motor and sensory areas of cortex are matured to function. Period until about six years of age is the time for neurological development and it gives a basis for future motor learning. Motor activities (Table 2) become more and more complex as they develop from reflexes and fundamental movements into skills that allow culturally determined actions as different plays and sports. (Fisher & Lazerson, 1984, 18).

TABLE 2. Components of motor activity (Johnston 1976)

Elements	Functions	Skills
	Postural stability	Sitting
Tone	Movements	Walking
Control	Coordination	Running
Strength	Balance	Reaching
		Manipulating

The basic elements underlying specific motor functions, which in turn combine and interact to develop certain skills

The early assessment of a child's motor development and detecting the possible symptoms of cerebral palsy is very important. It is due to the fact that early intervention gives a better prognosis for future development because the therapy should start during the first year of life (Bobath & Bobath 1991, 21; Fiorentino 1972, 60; Low & Downey 1982; Eiben & Crocker 1983). Motor abnormalities will appear along with maturing nervous system: spasticity, athetosis and especially ataxia may emerge relatively late (Scherzer & Tscharnuter 1982, 23). Making diagnosis before the age of six months is very difficult especially if the impairment is mild; sometimes diagnosis is not made until 18 months when a child should be able to walk. Despite these difficulties it should be taken care of that the best age for motor learning is not lost. (Bobath & Bobath 1991, 15-16.)

The therapists must be aware of those many remarkable changes in motor development of the child with cerebral palsy. These changes take place when the child tries to develop compensatory skills to cover those that are defected: he or she has to learn to function despite the impairment. Spastic child reaches the peak of his abnormal motor development at the age from six to nine years. The development of an athetotic or an ataxic child can continue until 15 years of age. The motor development is not only dependable on the location and the severity of the lesion in the central nervous system, but also on the level of intelligence of the child. (Bobath & Bobath 1991, 21.)

Observations often focus on and diagnosis is made according to certain well known milestones of motor, linguistic, adaptive and social development: this gives information about the nature, extent and severity of the neurological impairment, and it has also some value in making prognosis (Ingram, 1966). The developmental milestones of a child with cerebral palsy and abnormal patterns of movement are possible to predict to a some extent as is the case in a development of a normal child. The difficulty is that the patterns vary according to the type of cerebral palsy, and after all they are not very well known. The reason that a child with cerebral palsy does not reach certain milestones is not only a question of retardation but symptom of a neurological deficiency, which can be seen in various forms of abnormal tonus. (Bobath & Bobath 1991, 14.)

Although Bobath and Bobath (1991, 12-15) accept the concept of developmental milestones they state that comparison of normal motor milestones with abnormal development in cerebral palsy is inadequate and unsatisfactory, as regards making diagnosis or planning treatment. They warn that comparing normal and abnormal motor development strictly as milestones may lead into a situation where physiotherapists concentrate on reinforcing only one or two groups of motor patterns at a time. They state that this biased therapy may block the development of some other equally important patterns that should be part of the same developmental stage, and the ones reinforced will become dominant. The motor development process, normal or abnormal, is a dynamic process between developing patterns of movement, where different patterns appear and disappear in various kinds of combinations affecting each other (reinforcing or competing) (Bobath & Bobath, 1991, 12-15).

Harris (1990) considers that it is important to assess motor functions such as muscle tone, primitive reflexes, and postural or automatic reactions, and not only concentrate on developmental milestones. In assessing these neurological behaviors it should be borne in mind how they may interfere with the child's function: can the abnormal motor characteristics be used to increase the child's functional abilities or do they have negative effect on these abilities (Harris 1990).

Even though the abnormal motor development is not the only problem of a child with cerebral palsy, it is the major focus of assessment and intervention especially in the infancy. In the sensorimotor period (until about two years of age) learning has not differentiated yet into motor, cognitive and social learning (Fisher & Lazerson, 1984, 20). In this period of cognitive development an infant knows things only by touching, seeing, or hearing them (Fisher & Lazerson, 1984, 20). Fisher and Lazerson (1984, 20) state that "the sensorimotor skills during the first two years strongly affect a child's entire psychological life". The results of Rodrigues (1990) give a reason to emphasize the importance of early motor stimulation of children with cerebral palsy in order to achieve improvement in perceptual skills development.

Several other secondary consequences exist due to the motor dysfunction in cerebral palsy. The nutritional status often relates to the severity of the neurological problem. Poor oromotor function and dependence on help for adequate food supply affect the proper food intake. Chronic undernutrition influences growth, immunological factors, functional and physiological capacity, and also behavior and learning. (Stallings, Charney, Davies & Cronk 1993a and 1993b.)

In this perspective it is important to know the quantity and the quality of the child's problems. It is vital in order to be able to plan the therapy and education in early childhood and, thus, to prevent further unnecessary complications in sensorimotor and other areas of development.

There is a lack of norm-referenced, standardized tests of motor development suitable for neuromotor disabilities. These tests would give comparable information about the developmental level of children and also data that would serve as a baseline for measuring developmental progress with therapeutic intervention. Anyhow, a number of neuromotor assessment instruments that can at least be administered in a standardized manner exist. (Harris 1990, 164-5.)

2.3. Treatment

There is not sufficiently enough scientific knowledge about the training effect on motor abilities of children with cerebral palsy. Because the neurological nature of motor problems is varying in different types of cerebral palsy, it can be presumed that the learning process requires individually planned strategies. (Rintala 1988, 107.) Since the motor control system has various functions, the success of a therapy depends on the localization of the neurological deficit of a patient. The primary problem may be in planning a motor activity, transforming the motivation into action, executing motor tasks, or biomechanical restriction. (Sandström 1994a.)

Since cerebral palsy is by definition due to fixed and permanent pathology in the brain, treatment can never cure the condition. Even though it is non-progressive syndrome there may be some changes in the clinical picture with age; and if proper intervention will not be initiated early and carried on, spasticity will develop fixed deformities and functional capacity may become worse. Considering motor functions from this non curative basis the two goals are set: to prevent the handicap from increasing, and to increase or improve function. (Low & Downey 1982.)

Bleck (1987, 142-3) remarks that when planning a treatment for a person with cerebral palsy, it is in fact better to talk about the "management" instead of "treatment" because all the remedial efforts are unsuccessful since cerebral palsy is incurable. He sets goals of management focusing on the optimally independent living based on the needs of an adult with cerebral palsy. The goals are as follows in order of priority:

1. Communication (need to express wants, thoughts and feelings).
2. Activities of daily living (need to care for oneself).
3. Mobility (essential for independence and social integration).
4. Walking, since the independence and social integration needs have become predominant for an adult (although it is often considered the highest priority for children with cerebral palsy).

(Bleck 1987, 142-3.)

Many different methods and approaches in treatment of cerebral palsy exist. There are scientifically proved results, and often high "face value" of positive treatment outcome that should not be underestimated. Nevertheless, many of the therapies are rather controversial, if their effectiveness is critically examined, and many medical operations seem to have at least their pros and cons, especially, if they are not based on careful assessment and planning. There is lack of objective evaluation of treatment in the field of therapeutic profession: the systematic assessment of treatment outcome is still missing to a great extent. (e.g., Bleck 1987, 148-66; Ekenberg &

Erikson 1994; Fetters & Kluzik 1996; Harris 1990; Harris 1996; Hazlewood, Brown, Rowe & Salter 1994; Hesse, Jahnke, Shreiner & Mauritz 1993; Low & Downey 1982; Martin & Epstein 1976; Michels 1982; Palmer et al. 1988; Richards, Malouin & Dumas 1991; Soderberg 1990; von Wendt 1994.) According to Zahrádka (1993), it is difficult to interpret the outcome of a treatment that aim to improve the coordination, balance or posture, or especially complicated to analyze the combination of all these factors when a patient is learning to walk.

Harris (1996) in her article "How should treatments be critiqued for scientific merit" calls for criticism when new physical therapy treatments are introduced. The decision to adopt a specific treatment approach should be based on careful examination of the theoretical backround and the scientific value of the therapy in question. She gives tools for estimating the basis and rigour of a new treatment or technique before taking it into practice. It should meet the following six criteria:

1. The theories underlying the treatment approach are supported by valid anatomical and physiological evidence.
2. The treatment approach is designed for a specific type of patient population.
3. Potential side effects of the treatment are presented .
4. Studies from peer-reviewed journals are provided that support the treatment's efficacy.
5. Peer-reviewed studies include well-designed, randomized, controlled clinical trials or well-designed single-subject experimental studies.
6. The proponents of the treatment approach are open and willing to discuss its limitations.

(Harris 1996, 179.)

Physical therapy is an entity with many schools of therapy with different approaches and methods. Physiotherapists often use a combination of methods in CP-therapy. The most commonly used are for example: Ayres Sensory Integrative Therapy, Conductive Education (Petö), Doman-Delacato, Vojta Method, and Bobath Neurodevelopmental Treatment (NDT) which is predominant in Finland. (Bleck 1987, 151; von Wendt 1994.)

The Bobaths have contributed a great deal to the management of children with cerebral palsy worldwide, and the NDT-trained physiotherapists have a status of special professional expertise (Scherzer & Tscharnuter 1982, 63-64). NDT program is consisting of passive positioning in order to reduce spasticity, and facilitation of automatic righting reactions (sensation of normal movements) (Bleck 1987, 153). According to von Wendt (1994), the noticeably great amount of passive exercises and emphasizing strongly the "right patterns of movement" in the expense of functionality, may be considered the weak points of NDT. Although there are some weaknesses, " the Bobath-NDT is the therapy that seems to be in the best harmony with current neurophysiological trend of thought." There are scientific studies made, and at least some of them indicate the usefulness of this method. (von Wendt 1994.)

Orthopaedic surgeries (e.g., muscle transfers, releases and lenghtenings) in children with cerebral palsy are used in order to prevent disabling structural changes of the limbs and trunk, and to improve function, especially ambulation. **Orthotics** (braces and orthoses) are used to prevent structural changes, control movements or support foot when walking. **Plaster casting** is supposed to help in reducing muscle hypertonicity by immobilization (inhibitive casts). **Drug therapy** promotes for muscle relaxation in cerebral palsy. The goal of **biofeedback therapy** is that the patient with a help of some device is able to monitor or receive information of the action performed and learns to control one's motor performance. (Bleck 1987, 148-97.) There are nowadays also other therapies for children with cerebral palsy such as **occupational therapy**, and therapies derived from sports such as **riding therapy**.

3. GAIT IN CEREBRAL PALSY

Human walking is the most common of all human movements. It is very complex biomechanical process and difficult to learn, but when once learned it becomes almost subconscious. Our limited understanding of gait is revealed only when walking is disturbed for some reason. (Olsson 1990, 89.)

3.1. Neurological basis of human movement

In order to understand the pathologies in cerebral palsy one has to have an adequate knowledge of the mechanisms by which the central nervous system carries out motor control. This control system is extremely complex (Gage 1991, 37). The following is a presentation of basics.

Moving and balancing are automatic, mostly subconscious but learned skills acquired through maturation and experiences. Motor development depends on the programming of the subcortical part of the central nervous system. The quality of executing motor tasks depends on the stored programs and how they can be transformed into action in the motor cortex. (Blum 1993.)

The motor cortex is responsible for voluntary movements. It can be subdivided into three areas: the primary motor cortex, the premotor area, and the supplemental motor area. Typical for **primary motor cortex** function is that a single neuron is very specifically controlling one muscle or even a portion of muscle. It is concerning especially the motor tasks of the hands and of speech. **The premotor cortex** is preparing the motor action ("motor set" function) and selecting the mode of action. It causes patterns of movement involving groups of muscles that perform a specific task. **The supplemental motor area** is responsible for programming complex movements as rotation of hands or vocalization. It is active while new movements are learned, or when skills are executed in new situations. The supplemental motor area is not active during the movements that have become automatic. (Gage 1991, 44-6; Sandström 1994a.)

The primary motor cortex is able to initiate movements, but the two other are necessary in motor tasks to provide patterns of movement that are involving groups of muscles. The **basal ganglia** help the cortex to execute correctly the complex patterns of movement that have become automatic, moreover control their intensity and direction. The major function of **cerebellum** is the rapid timing of consecutive motor activities. It has an active role in the interplay between agonists and antagonist muscle groups. The **brainstem**, regarding motor control, provides maintenance of axial body tone that is necessary to erect posture. To maintain balance continuous modification of the different directions of this tone has to take place. Equilibrium requires constant feedback from the vestibular system. In the **spinal cord** there are programs of local patterns of movement for all muscle areas of the body. These include, for example, rhythmical reciprocal back and forth limb movements during gait. The preprogrammed activities in the spinal cord can be brought into action or inhibited by higher levels of motor control. (Gage 1991, 47-51.)

The transmission of motor signals take place directly from the cortex to the spinal cord through the pyramidal or corticospinal tract, and indirectly through multiple accessory pathways that involve the basal ganglia, the cerebellum and various nuclei of the brainstem (Gage 1991, 46; Sandström 1994b). In the spinal cord motoneurons are clustered into medial and lateral groups. The medial groups innervates the axial muscles in the neck and trunk. The lateral group is innervating the extremities and it is organized somatotopically. The dorsolateral part consist of motoneurons that innervate the distal parts of the limbs. The ventromedial part is innervating the proximal parts of the limbs and the gridle muscles (in shoulder and hips). (Sandström 1994b.)

The motor control system can be divided into **lateral and medial motor systems** according to the descending tracts. The lateral system controls fine movements, particularly of the fingers and the hands. The medial motor system controls the muscles of the eyes, the neck, the trunk, and the proximal parts of the limbs, thus controlling the posture and balance. This recent classification is replacing the traditional one, that there are two independent systems controlling movement which has proved to be incorrect. (Sandström 1994b.) The traditional division into pyramidal and extrapyramidal systems is still used widely (e.g., Gage 1991, 54; Sherrill 1993, 263).

The motor control system is receiving information about displacements of the body from the sensorimotor, vestibular, and visual systems. This information is vital for postural control and equilibrium. There are two main systems to maintain erect posture and balance: feed forward control and feedback control. Preprogrammed, feed forward, postural reactions help to maintain stability by adjusting posture. They take account of voluntary movements before they begin. Experience modifies these preprogrammed postural reactions. Corrective reactions are automatic and based on sensory input and feedback of body position when balance is already lost. Corrective reactions can be learned. Normal control of posture and movement will not emerge if: the neuronal system responsible for movements is damaged; there are problems in processing sensory information; the biomechanical abilities are decreased. The learning process of impaired regulation system is not continuing in normal tracks so it has to detect compensating ways to deal with the gravity. (Sandström 1994c; Sandström 1994d.)

Improving a certain motor task or learning a new skill is based on many other motor abilities already mastered. Differentiated movements require control of one muscle, but also coordinated function of several muscles. Walking is possible only after the balance and posture are achieved in lower positions. Neurological restriction in cerebral palsy makes the process even more complicated clustering the problems in motor learning. (Blum 1993.)

3.2. Main features of normal gait

Term "normal" has often many pitfalls. That is true when human gait is described: variation within the limits of normal gait that has to be borne in mind. There are changes that occur with wide range of ages, and differences in extremes in body geometry and due to sex. It is vital to understand normal gait in order to be able to study and analyze pathological gait.

Important is also to know the terminology that relates to human gait. (Sutherland 1984, 14; Whittle 1991, 48.)

What is walking and how it differs from the concept of gait? According to Whittle (1991, 49) most people, including himself, tend to use the words gait and walking interchangeably. "However, there is a difference: the word gait describes the manner or style of walking, rather than the walking process itself." Whittle (1991, 49) also considers that it may be pointless to attempt shortly define walking so that it would apply to all cases (also pathological).

Human gait is bipedal. If compared to quadrupedal gait of many animals, it is less efficient and not as stable. The center of mass is located above the base of support. The trunk musculature cannot be used as extensively in bibedal gait. This means constrained stride lenght and speed. That is into small extent compensated with human pelvic rotations. (Gage 1991, 61.)

In normal walking the gait cycle (Figure 1) begins with heel strike (heel contact), continues as stance phase, followed by swing phase and it ends with heel strike of the same foot. The timing of the cycle consists of two periods of single support when only right or left foot is on the ground, and two periods of double support when both feet are on the ground. (Gage 1991, 73; Smidt 1990; Soderberg 1990; Sutherland 1984, 10; Whittle 1991, 53-4.) The cycle can be devided into smaller major events (Figure 1 B). The following division is presented according to Whittle (1991, 53):

-Stance phase includes:

1. heel strike, 2. foot flat, 3. mid stance, 4. heel off (and toe off)

-Swing phase covers:

5. toe off, 6.mid swing (and heel strike)

Motion of the pelvis (Table 3) and spine are important factors of human gait. There is slight movement in the sagittal plane, and rotations in the transverse and frontal plane. Stance phase is a critical point of the cycle when the abductors must be active in order to prevent the opposite side of pelvis from dropping. Upper trunk rotates on the opposite direction when compared to pelvis. The whole trunk rises and falls twice during the cycle (total range of about 50 mm). Upper limbs move in correlation with the trunk, acting together as a balance mechanism. (Soderberg 1990; Whittle, 1991, 58.)

The hips and knees are extending and flexing during the cycle as presented in the Table 3. The ankle and foot are varying the angle from plantarflexion to dorsiflexion, and changing from pronation to supination. The maximal dorsiflexion is about 10 degrees in late mid stance and early heel off, and maximal plantarflexion of about 15 degrees takes place just before foot flat. Usually the heel is slightly inverted during the stance phase. (Whittle 1991, 57-71.)

According to Gage (1993), in normal gait leg muscles physiologically work as accelerators (concentric contraction), decelerators (exentric c.) or as stabilizers (isometric c.). Well-controlled gait is dependent on synergistic muscle activity that controls the movement: the synergy is conserving energy by transferring efficiently potential and kinetic energy between the body segments (Khodadadeh 1993; Sutherland & Davids 1993).

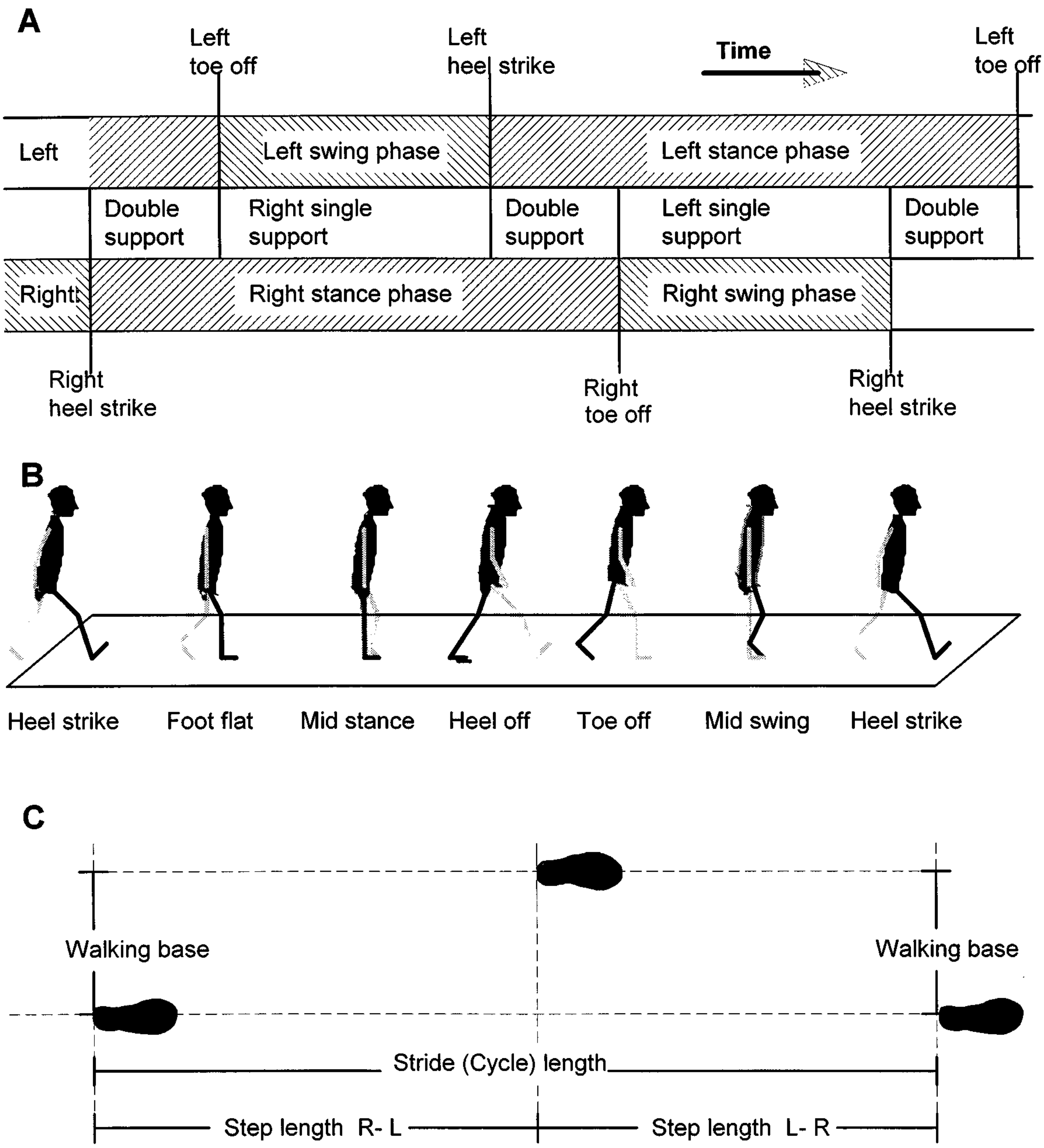

FIGURE 1. Gait cycle (B), timing of single and double support during a single gait cycle (A), and distance factors (C). (Applied from Whittle 1991, 53-55)

TABLE 3. Major events of gait cycle, and function of lower extremity and pelvis (applied from Browne & Hodge 1990, and Whittle 1991)

Cycle	Phase	Event (% / cycle)	Hip/knee (angle ***)	Pelvis	Time
GAIT CYCLE	STANCE	**1. Heel strike** (8 %)	hip flex. (25 - 20) knee flex. (2 - 7)	lateral tilt	
		2. Foot flat (22 %)	hip flex. (20 - -3)* knee flex. (13 - 3)	max. posterior tilt	
		3. Mid stance (16 %)	hip ext. (3 - 13) knee ext. (-0 - -5)**	inward rotation	
		4. Heel off (14 %)	hip ext. (13 - 17) knee flex. (5 - 45)	backw. rotation	
	SWING	**5. Toe off** (20 %)	hip flex. (-10 - 30) knee flex. (45 - 70)	lateral tilt forward rotation	
		6. Mid swing (20 %)	hip flex. (32 - 26) knee flex. (55 - 0)	outward rotation	
		(Just before 1.)	hip flex. (26) knee ext. (+0 - -1)	max. anterior tilt	
		1. Heel strike			

*flexion turning to extension (change from + to -) **full extension of the kneeis 0 degrees (in practice slightly over)

***In parenthesis the first figure is the degree of the angle in the beginning of the event, second figure is the highest or lowest degree of the event depending on the slope

The development of gait is depending on maturation of the central nervous system and on learning. An infant acquires the ability to walk without support at around the age of one year (Sutherland 1984, 14). In the beginning a child walks with wide base of support and without reciprocal arm swing (arms are in abduction), there is hyperflexion of the hips and knees which are relatively stiff, and there is flat foot strike without heel strike (Sutherland 1984, 14-15; Gage 1991, 61; Wyatt 1990, 161-2). There is immature timing in antagonist leg muscles until the age of five years (Berger, Altenmueller & Diez 1984); although Leonard, Hirschfeld and Forssberg (1991) have shown that after achieving independent locomotion EMGs of children are beginning to share similarities with the normal adult gait pattern.

The cocontraction of muscles is normal for children who are learning to walk, but it is also typical for many pathologies (e.g., spastic cerebral palsy): cocontractions are causing mechanical inefficiency because the muscles are working against each other (Winter 1990, 115; Gage 1993). Insufficient neuromuscular control of infant makes it possible for him or her to take only short steps, and in order to increase walking velocity a child must increase cadence (Sutherland, Olssen, Cooper and Woo 1980b; Sutherland 1984, 15).

Most features of mature gait, for example reciprocal arm swing and heel strike, emerge at very early age. Many of them are at present from two years on. The walking skill in general is completed at the age of five years. (Sutherland et al. 1980b.) The EMG pattern of normal gait after six years of age is not visibly different from that recorded in adults (Berger, Qintern & Diez 1982). Sutherland et al. (1980b) found that there are only minor differences when compared seven-year-olds with adults, focusing on temporal and stride measurements and movements in pelvic area.

Sutherland (1984, 25-7) names five strong determinants that are very informative considering gait and the state of its maturation:

-duration of single-limb stance

-walking velocity

-cadence

-step length

-the ratio of pelvic span to ankle spread

According to Gage (1991, 61) normal walking has five major attributes which are frequently lost in pathological gait:

-stability in stance

-sufficient foot clearance during swing

-appropriate prepositioning of the foot

-an adequate step length

-energy conservation.

3.3. Pathologies of gait in cerebral palsy

The pathological gait is in general characterized by comparatively large variations in all the gait parameters such as velocity, stride length, and height of centre of mass. Much of energy is wasted when abnormal conditions of the hip, knee, or foot are overcome. The abnormal gait patterns may result in excessive fatigue. (Khodadadeh 1993.)

The primary cause of the motor problems of cerebral palsy is the central nervous system lesion, but the secondary reasons as spasticity and contractures across joints, lead to observable gait abnormalities (Gage 1991, 101; Sutherland & Davids 1993, 140-1). According to Gage (1991, 101) typical features of gait in cerebral palsy are:

-loss of selective muscle control

-difficulties with balance

-abnormal muscle tone

-agonist and antagonist imbalance

-dependence on using primitive reflexes for ambulation

Because there is considerable variance in individuals with cerebral palsy, these named features may be more or less presented (Gage 1991, 101). Although abnormal reflexes, spasticity, contractures, etc., are in their part responsible for difficulties in ambulation, the standing equilibrium reactions are the most important determinants for functional walking of a child with cerebral palsy: there may be good prognostic signs for walking but still the child may remain dependent on external support because of the poor balance (Bleck 1987, 124-5). Walking prognosis depends on the type and severity of cerebral palsy. A great many children with diplegia will attain ambulation while majority of spastic quadriplegics will not. The good potential for walking of children with hemiplegia is widely accepted. (da Paz, Burnett & Braga 1994; Schultz-Hurlburt & Tervo 1982.)

In their study da Paz et al. (1994) found that there are some developmental milestones indicating good locomotor prognosis: achievement of head balance by nine months of age (poor after 20 months), crawling at 30 months (poor at 61), and sitting by 24 months (poor by 30). Also the findings of Baddell-Ribera (1985) and Bottos, Puato, Vianello, and Facchin (1995) confirm the importance of the age of first crawling. Exeption is ataxic type of cerebral palsy: children with ataxia can learn independent walking without achieving any form of locomotion before the age of three years (Baddell-Ribera 1985). According to Watt, Robertson and Grace (1989) persistence of primitive reflexes as tonic, labyrinth, ATNR, STNR and Moro reflex, and absence of postural reactions had a statistically significant correlation with non-ambulatory status.

Gait analysis organized by Skrotzky (1983) revealed reduced stride length in children with cerebral palsy, which was concluded to be the main factor (rather than decreased cadence) of slower gait velocity. The length of stride related to severity of neuromuscular dysfunction. She also found asymmetry in gait components and also abnormality in movement patterns: overall decrease in amplitude, a lack of normal flexion and extension pattern in lower limbs and hips, and the absence of a normal 2-wave pattern in dorsi-flexion and extension of the ankle.

Berger et al. (1982) found striking intra-subject irregularity of the gait cycle when he was studying EMG records of children with spasticity. They also found that the amplitude of EMG signals from all muscles was very small, and in some patients the leg muscle activity persisted throughout the cycle; hence, records were not comparable with averaged EMG data of normal children. Skrotzky also (1983) noticed the high intra-subject variability in children with cerebral palsy when analysing temporal and stride parameters of the gait cycle.

A common consequence of spastic cerebral palsy is the inefficiency of gait, when compared with normal gait. That is since energy is wasted on unnecessary cocontraction of muscles, especially of hamstrings and quadriceps at mid-swing phase of gait cycle. (Berger et al. 1982; Gage, Perry, Hicks, Koop & Wernz 1987; Gage 1993; Winter 1990, 115.) The energy required for ambulation in cerebral palsy may be three- to four-fold (Sutherland & Davids 1993).

When studied EMG activity in lower extremities, it has been noticed that the locomotor pattern of older children with cerebral palsy resembles the one of normal infant gait in early stages of development (Berger et al. 1984; Leonard et al. 1991). Since concurrent agonist-antagonist contractions make it impossible to generate appropriate accelerations in joints (Gage 1993), and furthermore because of the immature regulation of gait, there is only a limited chance to increase walking velocity (Berger et al. 1984).

3.4. Characteristics of gait in different types of CP

Hemiplegic gait pattern (Appendix 1) is typically where upper limb is internally rotated at the shoulder, in flexion at the elbow and wrist, and the foot of the same side is in equinus ("tiptoe-") position (Gage 1991, 133-4). There is a loss of fine distal movements and increased muscle tone in the affected upper extremity and distal weakness in the calf and dorsiflexors of the hemiplegic leg. The step length is reduced since there is a loss of calf propulsion and failure of maximum knee extension at the end of swing phase on the hemiplegic side, because of tight hamstrings, spastic quadriceps or rectus femoris. The foot usually does not show a good heel strike: the initial contact is either foot flat, on toe followed with heel rocker, or there is persistent equinus throughout stance phase. (Brown, Rodda, Walsh & Wright 1991.)

If knee flexion is limited, it causes difficulty with foot clearance in swing and is usually compensated by vaulting on the contralateral side or circumducting the hip on the hemiplegic side. In the severest form of hemiplegic gait, there is flexion and adduction contracture in the hips. The limited hip motion is compensated through the use of increased lumbar lordosis in terminal stance (after mid stance). These people walk reciprocating primitive flexion and extension patterns. (Gage 1991, 135-43). If there is not associated ataxia, most children with hemiplegia will walk at around 20 months (Brown et al. 1991).

Diplegic gait patterns (Appendix 1) are generally same type with spastic quadriplegia: they differ mainly in the severity of impairment. Typical features of gait are: adducted thighs that are internally rotated and flexed, flexed knees, and feet that are often in equinus position. Walking is mostly toe-toe or toe-heel gait. The extension-flexion rate in knees is clearly constricted and there is pelvic drop during swing phase. This creates difficulties with clearance of the foot in swing phase and it may contact the floor during swing and be twisted either internally or externally. (Gage 1991, 152-3; Whittle 1991, 127.)

To get over the primary problems of gait a diplegic person may generate "coping responses". Difficulties in foot clearance may be tried to overcome by circumduction of the swing limb, hip abduction on the stance limb to fit the pelvis on the swing side, or vaulting on the stance side. The restriction of knee extension reduces the step length in diplegic gait and there is instability in stance phase due to the abnormal foot positioning. Since the motor control in the upper body and the more proximal joints is better, so the trunk, pelvis and hips are usually used to generate compensations. (Gage 1991, 152-3.) These coping responses will often lead into deformities in spine (e.g. "compensatory lordosis" or scoliosis), pelvic area and/or in hips (Bobath & Bobath 1991, 39; Bottos et al. 1995).

Even though diplegic children are flexed in the hips and bent forwards, they tend to fall backwards when standing. That is since they do not have normal balance reactions in ankles and toes. When the center of gravity shifts behind over the base of support there should be dorsal flexion in feet and toes, but instead there is extension spasticity pushing the feet against the floor, and hence the child falls backwards. (Bobath & Bobath 1991, 40-41.)

When a child with mild spastic diplegia learns to walk the walking is possible in the beginning since there is only little spasticity (because of the reduced speed). There is also a wide base of support. When the child is becoming more experienced the gait velocity is gradually increasing and so is the spasticity. Then the child starts tiptoeing, bends forward with hips in flexion, the base of support is diminishing, and he or she is encountering with great difficulties in maintaining balance. (Bobath & Bobath 1991, 40-

41.) According to da Paz et al. (1994) almost all of the children with diplegia will attain ambulation, but the majority of the quadriplegics will not.

Athetotic gait is possible only for those who are mildly or moderately affected. It is difficult to achieve standing balance and walking is sometimes not learnt before fifteen years of age. First steps without help are often too high and the balance is lost, or they collapse because of flexion spasms, but gradually the child learns his or her individual manner of walking. Athetotics are regularly using pathological reflexes in getting on their feet, standing, and walking. In order to maintain standing balance athetotic person has to keep hands together in front of the body elbows extended. To be able to do this a person has to push the head and chin forward, or push the chin down against chest. Typical features of athetotic gait are also: broad walking base, weight on medial side of the feet, and jerking and very asymmetrical movements. (Bobath & Bobath 1991, 74-77.)

Ataxic gait (Appendix 1) can be described as "sailor walk". Ataxic person is lacking balance and sense of position in space, and the movements are uncoordinated. The person holds his arms in abduction in order to maintain balance and the walking base is wide. (Bleck 1982, 65: Whittle 1991, 112.) Children with ataxia may sometimes achieve walking rather late at five to six years of age, or very late (up to nine years) if there is mental retardation (Bottos, Puato, Vianello & Facchin 1995).

3.5. Walking aids

Assistive devices are commonly recommended when a patient has problems such as poor equilibrium, pain, joint instability, muscular weakness, excessive skeletal loading, fatigue, and cosmesis. The gait abnormalities are evaluated by physical therapist in order to identify the form of assistive device to be used and type of assisted gait to be learned. (Smidt & Mommens 1980.)

Walking aids can be classified into three categories: canes, crutches and frames. These devices distribute the weight more or less equally to the legs and arms, and broaden the base of support whichs makes it easier to maintain stability. (Whittle 1991, 114.)

The cane, or walking stick, is the simplest form of aid. Using two canes to improve balance is usual. The load is on the rather weak muscles of wrist and hand, so the fatigue may restrict their use for long distances. The main difference between canes and crutches is that the latter is fixed to the body at two points (instead of one). (Whittle 1991, 114-5.)

There are two types of crutches, forearm and axillary crutches, and three major ways to walk with the two crutches (Appendix 2). A person uses three-point swing-through or three-point swing-to gait when the both legs can not support the body weight separately and take steps. Swing-to gait has shorter swing, and the legs advance together behind the line of crutches, when in swing-through gait the legs land in front of the line. Four-point gait is closer to normal walking but with extra help. One crutch (or cane) is moved at a time in a pattern: left crutch - right leg - right crutch - left leg. (Sherrill 1993, 280; Whittle 1991, 117-20.)

The most stable devices are the anterior or posterior walkers. They are frames that enable the person to have wide base of support around him or her. Persons who have deficient equilibrium reactions to all directions will need a walker (Bleck 1987, 125). The traditional, rollator type, walker was positioned in front of the child, but more recently posterior walkers that move behind have been advocated because they facilitate more upright posture and therefore allow ambulation that is closer to normal (Greiner, Czerniecki & Deitz 1993).

Using assistive devices may modify the gait pattern considerably: it increases for example the complexity of the sequencing and timing of floor contact in walking (Smidt & Mommens 1980; Whittle 1991, 113). Smidt and Mommens (1980) studied the influence of ambulatory aids on gait with 25 normal adults. When comparing the temporal and stride parameters of normal gait with walking with assistive devices they found that:

1) the subjects walked slower with ambulatory aids
2) assisted gaits tended to have similar measurements, if they had the same number of floor-contact events (counts) in one cycle
3) reciprocal swing and stance times were symmetrical for all types of gait studied
4) double stance and step times tended to be symmetrical for all types except the three-count assisted gaits
5) vertical accelerations were disproportionately elevated for most assisted gaits

3.6. Gait analysis

Improving the ambulation in children with cerebral palsy is a great challenge, but there has not been a total consensus about the means of treatment among the professionals. In addition to this, a clinical evaluation does not always give sufficient information to plan a treatment correctly in as complex conditions as is the case in cerebral palsy. Sometimes, for example, a surgery that improves the walking ability of one child, instead generates additional problems to another child who seems to have similar problems. (Gage 1991, xiii.) Understanding the walking in cerebral palsy is increased through gait analysis, which is not just an academic discipline, but has also important practical value (Whittle 1991, 201).

The application of the gait analysis can be divided into two main categories: clinical and scientific gait analysis. Scientific gait analysis has the aim to improve our understanding of gait, and clinical gait analysis aims to help individual patient directly. It has to be borne in mind that the clinical gait analysis is not neccesserily unscientific, and scientific does not mean that it has no clinical value. (Whittle 1991, 174.)

Clinical gait analysis can be used preoperatively to assess critically the pathologies of the patient. This information can be used in planning the treatment to improve ambulation. Postoperatively gait analysis provides assessment of treatment outcome. It gives feedback information about successfulness of therapeutic programs, as well as accurate critique of surgeries. (Gage 1993; Law & Minns 1987; Rose, Ounpuu & DeLuca 1991; Sutherland, Cooper & Daniel 1980a.) Through gait analysis it has been established that cerebral palsy or its subtypes are noninclusive terms in regards of pathologies of gait: there are variety of homogenous patterns of gait that may be separated and identified, and optimal treatment protocols for each pattern type developed. (Gage 1993, 126.)

It has been published significantly more papers on scientific gait analysis than on the clinical applications of the techniques. According to Whittle (1991, 174) this is due to the fact that clinicians are often involved in solving problems of individual patients, which at best can be published as case studies, whereas scientists are focusing on studying some aspect of subject in depth, and deriving publishable conclusions. Clinical analysis may aim to document the current status of a patient, or be one step of continuing process, such as the planning of treatment or the monitoring of progress over a period of time. There is generally not as great technical requirements and need of accuracy as in scientific gait analysis: practical, time saving measurement and data processing procedures are often more useful. (Whittle 1991, 175.)

In the assessment of the child with cerebral palsy, the use of gait analysis does not negate or replace the information gained from clinical examination. The anamnesic data of the subject is the basis of any gait analysis. Knowing the medical history of the subject is vitally important in order to understand the present status, plan the treatment, and interpret the results of gait analysis. (Gage 1991, 12; Whittle 1991, 135.)

3.6.1. Qualitative observational analysis

Observational gait analysis is most often used in clinical settings. Qualitative descriptions of ambulation through observation provide the clinician with general information about the child's walking pattern. Attention is paid to stability and balance, velocity and control, symmetry and movements of the upper and lower extremities and trunk, weight transfer, foot placement, deformities such as hind foot varus, and the influence of assistive devices. Even though systematic scoring systems have been developed the reliability of visual analysis can be questioned. (Olsson 1990; Patla, Proctor & Morson 1987; Rose et al. 1991; Skrotzky 1983.)

Whittle (1991, 130) names four serious limitations of visual analysis:

1. It is transitory, giving no permanent record
2. The eye cannot observe high-speed events
3. It is only possible to observe movements, not forces
4. It depends entirely on the skill of the individual observer

Videotape analysis is neither an objective method, since it does not provide quantitative data in the form of numbers. However it provides valuable permanent record, and reduces number of walks a subject needs to do. Consistency of observation improves markedly if slow motion and stop-frame facilities are imployed. Still, accurate assessment can not be done with videotape alone. (Gage 1991, 22; Law & Minns 1987; Whittle 1991, 133.) This statement is supported by Krebs, Edelstein and Fishman (1985), who found that both interrater and intrarater reliability of observational gait analysis is only moderate even in highly trained clinicians using stop-motion video recording. They studied ratings of three expert observers who were analysing gait kinematics of 15 children with lower limb disability. Interater intraclass correlation coefficient was .73; intrarater Pearson product-moment correlation averaged .60.

3.6.2. Quantitative analysis

Well-defined and clinically meaningful parameters of gait have to be measured and analyzed in quantitative values (Olsson 1990). Although visual gait analysis using videotape is subjective, there are rather simple methods to simultaneously derive objective, quantitative, data from general gait patterns as velocity, cadence, and stride length. It is also possible to use computer based videotape digitizers in order to measure joint angles. There is though a major limitation and source of error associated with attempting to measure joint angles directly from a screen. That is the incapability of 2-dimensional representation to account for 3-dimensional, out-of-plane, movements. (Whittle 1991, 134-5; Rose et al. 1991.) Nowadays there is available advanced practical as well as more complicated instrumentation and methods that are reliable and can be used to assess human walking (Olsson 1990).

3.6.2.1. Temporal and stride analysis

Almost every gait variable changes with changed walking velocity: therefore, information is useful only when considered in relationship to walking speed. This important fact makes walking speed a compulsory gait variable to measure. The self selected speed of walking is a measure of overall effectiveness. It has a strong correlation to qualitative and subjective findings. (Olsson 1990.)

Velocity, stride length, cadence and cycle time can be measured on a marked walkway using stopwatch, tapeline, and powder on the feet or ink footprints. From footprints can be derived additional information about ratio of left/right and right/left step lengths, walking base, and toe-out angle. (Holden, Gill, Magliozzi & Piehl-Baker 1984; Rose et al. 1991; Shores 1980; Whittle 1991, 134) Validity and reliability of the temporal and stride analysis and this type of setting is discussed in chapter 6.6.3.

There are number of automatic systems to measure the gait parameters and timing of the gait cycle. These may be divided into two main classes: footswitches and instrumented walkways. If footswitches are mounted on both feet and fixed beneath the heel and forefoot, then it is possible to measure the timing of the heel strike, foot flat, heel off and toe off, and the duration of the stance phase. They are usually connected through a trailing wire to a microcomputer, or alternetively radio transmitter is used to transfer the data to the measuring equipment. (Whittle 1991, 139.)

A footswitch is exposed to very high forces. That may cause problems with reliability especially with such patient populations as with cerebral palsy, who have difficulties in obtaining adequate foot clearance during swing phase. The footswitches may share off, or remain active throughout swing phase, if the person drags his feet. (Gage 1991, 23.)

A common arrangement in gait laboratory is a conductive walkway that is covered with an electrically conductive substance such as sheet metal or conductive rubber. The system requires electrical contacts on the shoes to complete an electrical circuit. A less common system requiring no trailing wires is walkway with large number of switch contacts. The instrumented walkway is providing essentially the same information as the footswitches. (Whittle 1991, 140.)

Time-distance measures are good indicators of overall function. Anyhow, it has to be borne in mind that they are descriptors of an end product and do not provide information about the component segments that interact to produce these measures. (Rose et al. 1991.)

3.6.2.2. Electromyography

Electromyography (EMG) is the measurement of electrical activity of a contracting muscle (Whittle 1991, 149). In gait analysis it presents the activation of a sceletal muscle during movement: mode, timing, and the intensity of timing can be determined from the EMG record (Gage 1991, 26-7; Olsson 1990). EMG data is collected by using either surface or indwelling electrodes (Gage 1991, 26; Rose et al. 1991).

Surface electrodes are fixed to the skin over the muscle. Elecrical activity is caused by the muscle action potential and reaches the surface electrodes through the intervening layers of fascia, fat, and skin. EMG is recorded as the voltage difference between two electrodes. Indwelling electrodes are introduced directly into the muscle. (Whittle 1991, 149.) The surface electrodes are easier to use but they are not as discriminating as indwelling electrodes, which are more definite in terms of sampling activity from a particular muscle. Insertion process of indwelling electrodes may be painfull, and cause increase in muscle tone and spasms. This induce a problem particularly when children are concerned. (Bleck 1987, 76; Gage 1991, 26.)

Obtaining information about changes in muscle activity during different phases of gait cycle may be the most relevant application of EMG analysis. Phasic data allows the clinician to determine whether a certain muscle's activity is normal, out of phase, continuous, or clonic. This information can help in evaluating the cause of movement abnormality and aid in planning surgical operations such as tendon transfers. (Rose et al. 1991.)

The correct interpretation of EMG data is very difficult, since there may be intruding factors affecting the signal. The EMG signal can be affected for example by: electrode location, size and shape, inter-electrode distance, the amount of fat tissue interposed, and the cross-sectional area of the muscle in question. (Winter 1987, 38-9.) The EMG is not a measure of mechanical activity, thus, it cannot be used to distinquish between eccentric, concentric and isometric contractions (Whittle 1991, 149). Although EMG amplitude under some conditions has been shown to be correlated with force (Rose et al. 1991, 963), one must be cautious with the interpretations, since the nature of relationship has not been well established (Rose et al. 1991; Whittle 1991, 149).

Interpretation is more vulnerable, if the EMG data is analyzed alone: the muscle activity may be abnormal or in response to the demands placed on the joint. For example, if a person with cerebral palsy walks in crouched position (with knees in flexion), muscle activity in quadriceps femoris is required throughout the stance phase to prevent falling (as would be the case also with nondisabled person). Studying only EMG, this might lead to incorrect conclusion that muscle activity persists due to abnormal spastic response. (Rose et al 1991.) Coupling the EMG data to the kinematic, kinetic, and clinical data will give better basis for understanding the causes of the abnormalities in gait (Gage 1991, 27; Rose et al. 1991; Sutherland 1984, vii).

3.6.2.3. Kinematics

Kinematics is the measurement of movement, describing geometrically motion in such terms as angular displacements of joints, angular velocities, and accelerations of limb segments (Rose et al. 1991, 964; Whittle 1991, 161). Before the automated motion analysis systems were introduced the kinematic data were collected using film and manual digitization techniques (Sutherland 1984, 1-10). The high-speed cine cameras are still used in settings outside the laboratory for practical reasons, dispite the fact that the manual digitizing of the data is time consuming process (Gage 1991, 27; Whittle 1991, 161).

Computerized motion analysis may be made either two-dimensional with a single camera, or three-dimensional with two or more cameras. Common feature to these analysis is the use of some type reference system, such as, markers in specific anatomical landmarks. Kinematic data do not provide any information about the cause of movements. (Rose et al. 1991; Whittle 1991, 163.)

Two-dimensional analysis with single camera has a limited use in kinematic analysis. It can be used to measure joint angles in sagittal plane. The problem is that the measured angles are projections of three dimensional-angles onto a two-dimensional plane, and what occurs out of that plane is ignored. Distances may be approximately measured if some form of calibration is used. (Whittle, 1991, 163.) These limitations are a particular concern in patients with cerebral palsy, since they have abnormal motion in coronal and transverse planes. Three-dimensional analysis involving some form of calibration are used to achieve reasonable accuracy and account for motion in all planes. (Rose et al. 1991.)

The most sophisticated methods of kinematic analysis involve optical tracking systems. They track the displacement of markers placed in anatomical landmarks. There are two different categories into which the optical systems generally fall: active and passive marker system. Active markers require some form of energy source; usually the subject has to wear power pack for illuminator in marker that is emitting light for camera detection. The passive markers do not require connection to a power source, since they are reflective and the light source is located at the camera. (Gage 1991, 27; Rose et al. 1991.) The markers placed externally to the body are most practical, but there is error due to the skin movement that is difficult to quantify (Rose et al. 1991).

3.6.2.4. Kinetics

Kinetics studies are used to detect and explain the factors that cause or control movement. In gait analysis the joint kinetic patterns, moments and forces, are the topic of interest. They refer to the ground reaction or external forces and the internal forces within the joints, and also the kinetic energy of the body and body segments. (Gage 1991, 29; Olsson 1990, 31; Rose et al. 1991.)

Ground reaction forces are a direct reflection of the accelerations of the body applied to the ground through the foot: equal in magnitude and opposite in direction. External forces are caused by the weight of the body, the ground reaction force acting on the foot, and the acceleration and deceleration of the limb segments. Internal forces act to balance the external forces. They are generated by active muscle contraction, ligamentous forces, and joint contact forces. Vertical ground reaction forces can be measured directly with force plate. The recording instrument can be attached to the foot (risk of disturbing the subject's normal gait), but most often it is mounted on the floor. (Olsson 1990.)

Interpreting the information recieved from kinetics analysis is more complex than analyzing the joint kinematic patterns. The complexity of calculations increases if the force plate data and three-dimensional kinematic analysis are combined, but the capability to explain movement multiplies. (Rose et al. 1991; Whittle, 1991, 172.) In addition to this, the best equipped gait laboratories also have facilities for dynamic electromyography. It is included as an equally valuable part of analysis, since the EMG signal represents the muscles producing the force. (Gage 1991, 29; Whittle 1991, 173.)

Combining the different analysis may decrease the risk involved in estimating the forces transmitted by and accross the various structures of joints. A large number of unknown factors such as the internal moment generated by the different muscles, and the extent of any simultaneous cocontraction by antagonist threathens the reliability of results. (Whittle 1991, 173.)

3.6.2.5. Energy expenditure

In normal gait the energy is conserved by optimized movements resulting efficient conversion between potential and kinetic energy. In impaired gait, abnormal patterns may result in excessive fatigue, hence the measurement of energy change during walking can be an important element in scientific analysis. The measurement of energy variation combines different factors underlying the pathological gait, producing a single indicator of the degree of the defect. (Khodadadeh 1993.)

The most accurate but impractical way of measuring energy consumption is "whole body calorimetry," in which the subject is kept in an insulated chamber from which the heat output of the body can be measured (Whittle 1991, 153). Another direct and more practical way to measure energy expenditure is based on body's oxygen consumption (Olsson 1990; Rose et al. 1991; Whittle 1991, 153). This method requires an analysis of the subjects exhaled breath. One can calculate the "respiratory quotient," if the volume of air exhaled is measured and content of oxygen and carbon dioxide is analysed. This provides information about the metabolism that is taking place. (Olsson 1990: Whittle 1991, 153.)

There are also less direct methods. Monitoring the heart rate is a good substitute for measurement of oxygen uptake, since it is accurate enough and easier to perform (Whittle 1991, 154). Another method is to calculate the mechanical work required for walking. According to Khodadadeh (1993), "the ratio of the kinetic energy variation to potential energy variation can provide a mean to calculate the degree of patient disability and an indication of the benefits of prostheses, surgery, or the use of orthotic equipment." Anyhow, it is a rather unsatisfactory way to measure the total metabolic energy consumed in as a complex motor performance as walking: for example, the co-contraction that is frequently noted in patients with cerebral palsy will be unaccounted, if the mechanical work is calculated alone (Rose et al 1991; Whittle 1991, 154).

4. RIDING THERAPY

The combination of health and horseback riding has a long, but not very well known history. Already the ancient Greeks and Romans were known to have adopted riding in medicine. Some novel writings can be found in the literature from the sixteenth century on about the therapeutic value of the horse. (Purjesalo 1991, 25-26.) The often mentioned historical key point of modern therapeutic riding can be drawn back in time to year 1943 in Denmark where a girl named Liz Hartel became wheelchair-bound because of polio. In 1952 she won a silver medal in dressage at the Olympic games in Helsinki, Finland. This was perhaps the main inspiration for beginning to organize and develop riding for the people with special needs in many countries. In addition to recreation, the aspect has most often been rehabilitative. (e.g., DePauw 1986; Haskin, Erdman, Bream & Mac Avoy 1974; Mayberry 1978.)

The conceptions, terminology, and definitions of therapeutic hoseback riding have varied nationally and internationally. There seems to be no definite division of different approaches and consensus what is included in the context of riding for the people with special needs. Defining different approaches, medical versus recreational, and drawing the line between therapeutic and rehabilitative riding has not been settled. For example, the term ' therapeutic riding' has been used as an umbrella term (as is the case in this study) to cover all activities in this context, but also used specifically referring to a professionally designed and carried out rehabilitation program. (Purjesalo 1991, 19.)

According to riding therapist Anne Rautio-Honkavaara (1996), only lately it has become some clarity in definitions and practice in Finland. Solution had to be found, since it was important for the professionals especially in the therapeutic field to get an official legitimation from the instances and authorities deciding for example on funding. This became actual after the schooling of riding therapists in Finland was begun in 1989. (Rautio-Honkavaara 1996.)

The main goal of next chapters is to describe the theoretical basis of the proposed effects of riding therapy as a neurological treatment approach. Anyhow, it is also important to understand the multidimensional concept of the riding therapy as a whole. The following presentation enlightens the Finnish system, division and terminology, although the basic principles and proposed effects of the riding therapy are universal.

4.1. Concepts of therapeutic riding

The riding therapy can be defined broadly as a professional use of a horse as a tool to achieve variety of therapeutic goals: physical, psychological, social, behavioral and educational. A variety of methods exist to accomplish these goals. Both the therapist and the horse contribute to the therapeutic effect. (Rautio-Honkavaara 1996.)

A riding therapist is a professional with an official education in riding therapy arranged by Finnish Rehabilitation Association in cooperation with Finnish Horse Institute. Requirements for being accepted to the schooling are: a basic education in the fields of teaching, health care or social welfare; at least two years experience of working in the profession; sufficient riding skill and knowledge of horses. There is an examination that has to be passed to be qualified. The education is multi-formal, sequenced into course periods, and consisting of approximately 600 hours (17 weeks of 40 hours' studying). (Lindroos 1996.)

Riding therapy is prescribed by a physician and costs are covered by National Health Insurance (sometimes other instances as private insurance companies or associations). The patient has to fulfill a certain criterion based on the type and the severity of impairment in order to get the costs covered from the public funds. The riding therapy for patients with motor disabilities is usually prescribed as a support for physiotherapy, but can also be carried out as an independent therapy. It may be given for an intensive period, or as a long-term treatment. (Lindroos 1996; Rautio-Honkavaara 1996.)

Apart from the riding therapy is defined the riding for the disabled, which includes the recreational activity. The goal is equestrian skills and control of the horse. The riding for the disabled is instructed or coached by specialized riding instructor or teacher. Finnish Riding Association is responsible for this area of riding. (Lindroos 1996; Rautio-Honkavaara 1996.)

When comparing the theoretical division commonly used in Central Europe and the Finnish one (figure 2), there is a difference in defining the medical approach. In Central Europe, especially in Germany and Switzerland, there is a clear division between the hippotherapy (Hippotherapie) and pedagogic riding and vaulting (Heilpedagogisches Reiten und Voltigieren). The Finnish model of riding therapy education is including elements from both of these schools. (Lindroos 1996; Rautio-Honkavaara 1996.)

Hippotherapy is a special form of physiotherapy using the movement (gait) of a horse. It is neurophysiological treatment for patients with neurolgical disorders. Hippotherapy is based on the therapeutic effects transferred to the patient on a horseback. It is prescribed by a physician and given by physiotherapist specialized in hippotherapy. Hippotherapy is considered a strictly therapeutic maneuver far from riding in a traditional sense. (Kuprian 1986; Strauss 1991, 24-26; Ölsböck 1992.) In pedagogic riding and vaulting the emphasis is on education and psychosocial development of a child with problems in behavior or learning. The psychology of the contact with the horse is considered important, as well as riding and exercises on the horse. It is employed by specialized psychologists or pedagogues. (Gäng 1983, 9-11; Kuprian 1986; Strauss 1991, 24-26; Thun-Hohenstein 1992.)

The Finnish model is more flexible (without any priorities). The type of impairment of the patient and the basic education of the riding therapist is influencing the decision what strategy to emphasize in therapy. For example, for the children with neurological disorders as cerebral palsy is prescribed riding therapy, which is given by physiotherapist. The treatment is emphasizing the methods close to hippotherapy but also try to benefit of the possibilities of the motivating situation with the horse in regards of psychomotor exercising. For patients with behavioral problems the basic strategy is closer to pedagogy. (Rautio-Honkavaara 1996.)

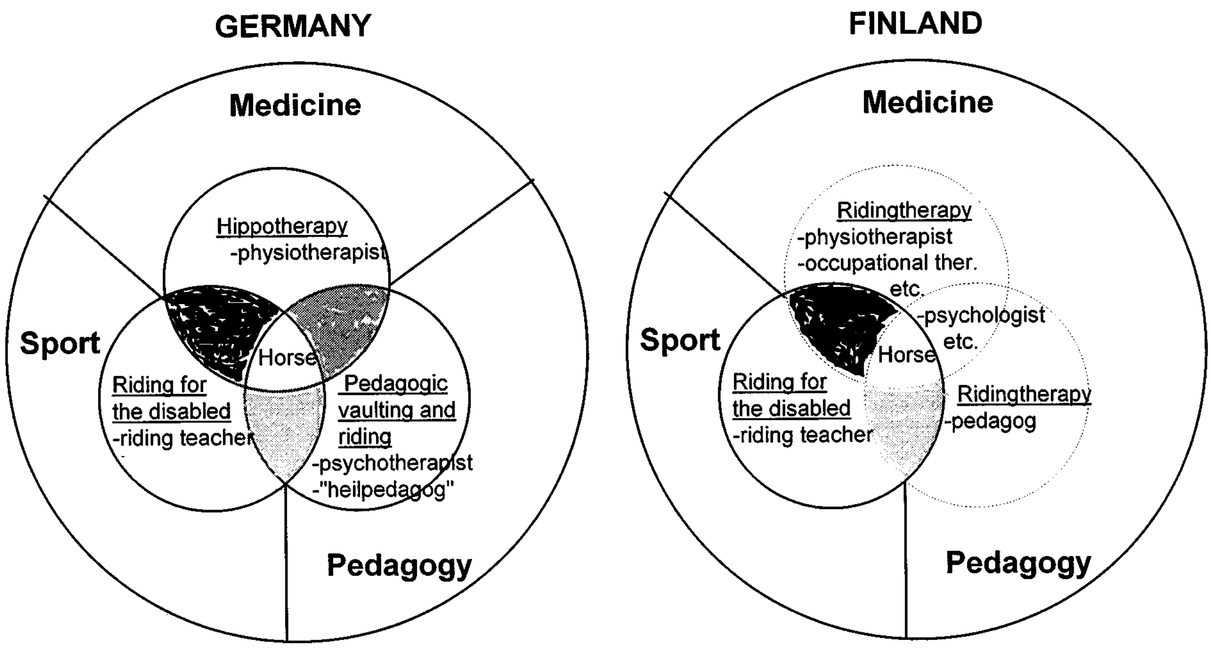

FIGURE 2. Therapeutic riding: Schematic model of the division in Germany and Finland (German model: Strauss 1991, 23-25; applied Finnish model: Rautio-Honkavaara 1996)

The role of the horse is considered essential in therapy. The size, quality of movements, and characteristics of personality are important factors when therapy horse is chosen. Suitable horse must be reliable, tolerant, social by its nature and cooperative. It must have even length of stride, be supple, balanced with good rhythm in a collective frame, and proper basic training in dressage. After basic training, and from six years of age on, the horse can be trained for the riding therapy. If it is possible to choose a therapy horse according to the needs of the patient, it gives additional dimension and value to the therapy. The horse must be in a total control of the therapist (and the assistant) which requires a suitable animal and proper skills in riding and in horsemanship. (Does 1983; Rautio-Honkavaara 1996.) The horsemanship is to know how the horse is reacting in different situations and how to take care of the horse. The horsemanship is acquired not only from books, but by experiences in seeing and taking care of many different horses. (Laurila 1995, 94.)

The role of an assistant is also important. The assistant takes care of the horse in therapy situations. She brings the horse to the patient, and during the therapy leads the horse by the bridle or drives it with the long reins walking behind the horse. An assistant must be experienced and skillful with the horses. In some cases another helper is needed to support or to help a patient on horseback. (Rautio-Honkavaara 1996.)

4.2. Riding therapy as a neurophysiological rehabilitation

Since the central nervous system is responsible for controlling the movements, posture, and balance, it is the main target of the neurophysiological rehabilitation. The treatment programs are based on a theory of optimal motor development. The strategy is to produce sensory stimulation focusing on corrective motor learning processes. The therapy aims to improve motor abilities by altering the incorrect motor patterns and reactions, and reinforcing the correct ones. (Blum 1993; Fetters & Kluzik 1996.) Riding therapy is a holistic treatment approach to the neurological disabilities. Although the emphasis in riding therapy is on the improvement of the motor performance of a patient, it utilizes a multitude of physiological and psychological advantages of the horse and riding.

Horse's gait is the basic component in riding therapy used to produce neurophysiological therapeutic effects on rider. The therapy horse is moving firmly and symmetrically with four extremes producing rhythmic, smooth walk with four beats. There is always three legs in contact of ground and one leg in swing phase at one time. Sequence of the swing phase is: left hind, left front, right hind, and right front leg. The movement occurring along the horse's back is vital in riding therapy, since it produces the forces that are transmitted to the rider through his pelvis. (Brownie & Hodge 1990.)

The rider is exposed to **physical forces** (Table 4). Horse's swinging movements are producing three-dimensional dynamic and rhythmic impulses that are transmitted to the rider. These impulses are exposing the rider to forward and backward movements, shifts sideways, and rotations.

The pattern of the three-dimensional movement transmitted to the rider is resembling the human gait. (Blum 1993; Riede 1983; Strauss 1991, 12; Taufkirchen 1993; Ölsböck 1992.)

TABLE 4. Physical forces (Ölsböck 1992)

PHYSICAL EFFECTS OF HORSES' MOVEMENT ON RIDER
* Three-dimensional impulses transmitted from the swinging horseback to the rider (90 -110 impulses/min)
* Acceleration and deceleration forcesthrough alterations of motion
* Centrifugal forces

The movements of the walking horse facilitate almost identical patterns of movements in the human pelvis and trunk. All the movements are in their peak when the hind leg is underneath the horse. When the hoof hits the ground and the horse puts the weight on leg there is vertical lift and the rider feels his buttock rise. The pelvis is passively moved by the horse, and there is lateral pelvic tilt and weight shift producing stretch on the opposite side of the trunk. Since the horse's pelvis and rider's pelvis are at 90 degree angle to each other the lateral flexion of the horse produces rotation in the pelvis of the rider, and rotation in the horse's pelvis causes lateral flexion in the rider. (Brownie & Hodge 1990.) The simplified analogy of horse's movements transmitted to human pelvis is presented in Table 5.

The riding therapist is taking advantage of different methods of varying the horse's movement to produce the desired physical effects on the patient. The therapist may, for example, change the phase of gait of the horse, make the horse do large or small circles and change direction, advance sideways, go uphill and downhill, trot or gallop when vaulting, or step over low fences. Usually the horse is driven from behind with long reins. It helps to maintain the collective frame of the horse, which again is essential considering the good quality of horse's gait. Whilst on the horse, the patient has to adapt himself to the altering physical forces. Elementary in effective therapy is a good sitting posture. Proper postural alignment of the rider is the basis of the riding therapy as a neurophysiological treatment. (Rautio-Honkavaara 1996; Tauffkirchen 1993.)

TABLE 5. Effect of the horse's movement through rider's pelvis (aplied from: Brownie & Hodge 1990), with some average figures of an adult (Taufkirchen 1993)

HORSE'S MOVEMENT	EFFECT THROUGH RIDER'S PELVIS
Hind leg push off -pelvis drops -pelvis and trunk rotate **Steps with hind legs** -shifting the center of gravity	**Lateral pelvic tilt, weight shift from one side to another** -pelvic drop of 5 cm -lateral twist of 16 degrees, on the vertebral location of L1 -lengthening and shortening of the sides of the trunk **Lateral pelvic displacements** -7-8 cm movement sideways
Hind leg swings forward -lateral flexion of spine	**Pelvic rotation** -8 degrees -rot. in lumbar vertebrae of 19 degrees
Acceleration during the swing phase of the hind leg	**Posterior pelvic tilt** -compensations in the trunk and neck
Deceleration during the stance phase of the hind leg	**Anterior pelvic tilt** -compensations in the trunk and neck

The activation of the sensory system is an essential neurophysiological effect, that is to be emphasized in the context of this study. To maintain the balance the rider has constantly to be active with the spontaneous, symmetric, and rhythmic reactions. The movements of the horse transmitted to the rider stimulate the vestibular system and proprioception, and also activate the tactile and motor sensory systems. The sensory input through riding and integration of sensory stimulation is improving equilibrium reactions for walking and enhancing the spatial and body awareness of the patient. Transmitted dynamic movements, and stretch in muscles and tendons, are normalizing the muscle tone and movement patterns (Rommel 1993; Strauss 1991, 26-35.) The normalized muscle tone, and improved overall function of motor system was verified, for example, in a study organized by Zahrádka (1993).

TABLE 6. Physiological factors (Ölsböck 1992)

PHYSIOLOGICAL EFFECTS ON RIDER		
* Heart rate:	Gait Trot Gallop	120 / min 140 / min 180 / min
* Warmth of the horse (about 1 C higher than human body temp.) transmitted to the muscles of the rider		
* Activation of the sensory system		
* Improvement in respiration		
* Improvement in peristalsis of stomach, intestines, and urethra		

Physiological effects are presented in Table 6. Improvement in respiration is based on opening of the thorax due to the dynamic, balanced muscle work and improved erect posture, along with, abduction of the scapulas, and controlled head position through extension of the neck. The basis for good posture and, hence, releasing the thorax for respiration, is extension of the pelvis through an adequate contraction of the abdominal muscles. (Taufkirchen 1993.) The physical strain showing in increased heart rate can also be concluded to be responsible for improved functioning of the respiratory (and circulatory) systems. The warmth of the horse is transmitted to the muscles of the buttock and hips (Strauss 1991, 34).

Transmission of the physiological effects on rider, is reinforced in riding therapy by riding without a saddle (Strauss 1991, 34). Special safety belt in front of the rider, attached around the horse's trunk, is often used in therapy. There is a grip that the patient can hold on occasionally, if the balance is not sufficient yet on the horseback. (Rautio-Honkavaara 1996.) Often the therapist is riding with a child, and sitting behind him or her. In that position the therapist is able to support the child and facilitate the correct posture and movement patterns. (Taufkirchen 1983.)

Psychological effects of riding therapy are presented in Figure 3. Since they are valuable side products of neurological treatment with the horse, they are not treated very profoundly in this context. Nevertheless, they are important factors of the holistic idea of riding therapy, and often secondary goals in treatment of cerebral palsy (Rautio-Honkavaara 1996). The motivation is vitally important when improving in motor tasks, and the physical educator or therapist has to determine the conditions under which each individual learns best (Sherrill 1993, 220).

In riding therapy motivation usually remains strong from one session to the next one (Strauss 1983) increasing the effectiveness of therapy. A devoted patient is getting more actively involved in therapy. Because of the more active role of the patient due to improved cooperation, the process is resembling normal training. Although the primary therapeutic goals are the prevention of long term decrease in motor abilities and the improvement in the ADL -functions (Activities of Daily Life), especially the children can often be motivated only with the secondary goals as being in interaction with the horse and improving riding skills. (Rautio-Honkavaara 1996; Rommel 1993; Strauss 1991, 42.)

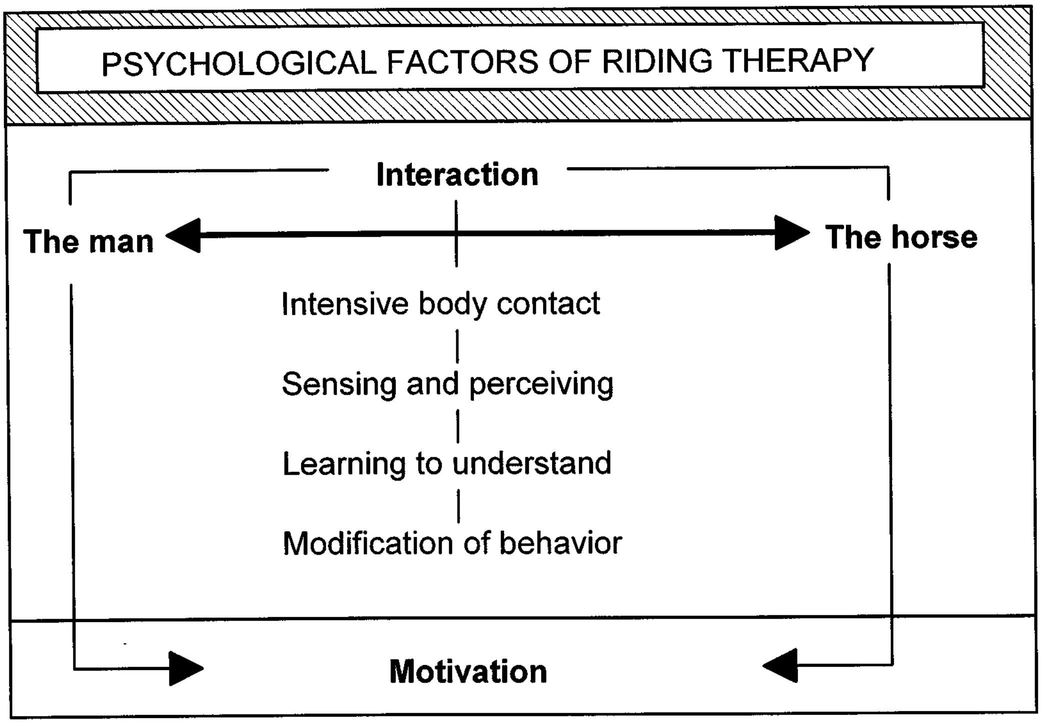

FIGURE 3. Psychological factors (applied from Ölsböck 1992, 'motivation' added)

There is also theoretical basis, e.g. Harter's (1978) developmental model of competence motivation, to state that advancing in motor skills improves perceived competence and motivation. The improved self-esteem gives a better basis for social interaction and, hence for cognitive development (Harter 1978).

Planning the treatment is involving the cooperation of patient (and parents), physician, physiotherapist and the riding therapist (Taufkirchen, Klaushofer & Pirkfelner 1990). In riding therapy for children with spastic cerebral palsy four major goals can be listed:

1. Mobilization of the pelvis, lumbar spine and hip joints
2. Normalization of muscle tone
3. Development of head and trunk postural control
4. Development of equilibrium reactions in the trunk

(Bertoti 1988.)

Examples of the process of determining goals and planning treatment in riding therapy of children with spastic cerebral palsy are presented in Appendix 3.

4.3. Related research

Although there are plenty of studies of the consequences of neurological deficits, there is lack of research on the effects of rehabilitation. Only recently there has been evidence of scientific interest towards some novel treatment programs and therapies. (Rommel 1993.) In this perspective the riding therapy is not any exception. There is need for more studies (Brock 1988; DePauw 1986), even if, several studies have been published during the past twenty years. Especially longitudinal studies are needed (Brock 1988; Weber 1994). In Finland riding therapy has recently become increasingly popular topic for students' Masters thesis (Halonen 1992; Pulkkinen 1993; Törmälehto 1993).

As examples of subjective evaluation of the effects of riding one can present the studies of Rosenthal (1975) and Wingate (1982). Rosenthal collected information with a questionnaire from 102 persons with physical impairment who were participating in a riding program (riding mostly once a week) in different centers. Information was received from time span of over two years. Some 80 percent of the subjects were with impairment of congenital origin, 57,8 percent of them with cerebral palsy. Mean age of all the subjects was 10,9 (range 4 to 67) years. The questionnaires were filled out by, quote, 'professionals' in riding centers. According to the filled out questionnaires, and after statistical analyses, it was concluded that there was significant improvement in mobility ($p=.04$), motivation ($p=.03$), and courage ($p=.01$) after the riding therapy.

Wingate (1982) used a parent group to evaluate their children's response to the therapeutic riding program. The subjects were seven children with cerebral palsy. The parents observed them at home and found improvement in gait, balance when walking, sitting posture and head control, decrease in excessive muscle tone, and improved independence in ADL functions. They also noticed positive change in self esteem.

Fox, Lawlor and Luttges (1984) organized a pilot study of novel test instrumentation to objectively evaluate therapeutic riding. Subjects were 19 children, ages from seven to fourteen years, with cerebral palsy, spina bifida, or mental retardation. The electrical apparatus was to measure balance, coordination, and arm, hand and leg strength. The subjects were tested right before and after a 90 to 120 minute riding lesson. It was reported that all the tests were not appropriate for, nor completed by all subjects. The results were not reported individually according to the impairment. For measures of sitting balance, coordination, and muscle strength in hands, and legs, marked improvement was noted for most children. Usefulness of the apparatus was considered appropriate.

Schmitt (1986) studied the effect of physiotherapy and hippotherapy on the muscle tone of the spastic lower extremities. Subjects of the study were 16 adults with multippelisclerosis (MS). The method was to measure the electrical activity of contracting muscle. Electromyographic (EMG) data was recorded with surface electrodes from vastus medialis, tibialis anterior, and gastrocnemius. The result showed that after physiotherapy and also after hippotherapy the excessive muscle tone was decreased. The riding therapy seemed to be especially effective, and the effects sustained rather well all day long. Conclusion was that hippotherapy, especially, when combined with physiotherapy, is markedly reducing spasticity, hence hippotherapy is good support for physiotherapy.

Bertoti (1988) measured postural changes in children with spastic cerebral palsy after participation in a therapeutic riding program. The subjects were eleven children from two years four moths to nine years to six months. Their medical diagnosis was spastic diplegia (eight subjects) or quadriplegia (three) with normal intelligence and without other medical complications. The experimental repeated measures design consisted of pretest 1 about ten weeks before, and pretest 2 just before riding therapy program, followed by ten weeks of therapeutic riding (twice a week, one hour per session), and a posttest. The subject thereby acted as their own controls. The qualitative change in posture was assessed visually by three pediatric physical therapists with a scale designed by the researcher for this study. Friedman test was used to determine whether a significant change existed between the intervals (assuming an alpha level of .05). Interrater reliability was found to be good (r=.82) when determined by Spearman rank order correlation. A statistically significant improvement in posture after riding therapy program was found (df=2, $p \leq .05$) when data of all the subjects were analyzed. Subjective clinical improvements were observed in muscle tone, weight bearing, and functional balance skills. Subject by subject there was improvement in functional ability in eight children, small change in two, and decrease of abilities in one subject.

Brock (1988) measured the effects of eight weeks (two sessions per week) therapeutic riding program on the self-concept, coordination, and strength of participants with different type of impairments. Among the subjects there were some individuals with cerebral palsy. He used two research designs. A pretest-posttest design involved 15 subjects. In a posttest-only design there were 24 subjects randomly assigned as experimental and control subjects. Strength and coordination were recorded with the Strength and Coordination Instrument (SCI Model # 1), and self concept was measured by the Tennessee Self Concept Scale. Statistical analyses were used analyses of variance (ANOVA with alpha level of .05). Pre-posttest design depicted significance at $p<.01$ level for both arm and leg coordination and posttest-only design yielded significance at $p<.01$ level for arm coordination. For the self-concept no statistically significant differences (despite somewhat higher scores) were found as a result of therapeutic riding program.

Biery and Kaufman (1989) studied the effects of riding therapy on balance of eight individuals with mental retardation. Criteria for selection to participate were that the subjects were able to understand and follow verbal instructions and not having participated in riding programs in the past three years. The subjects were tested on four standing balance items and six quadruped (hands and knees on the ground) balance items. There were two pretests: the first pretest six months before, and the second one just before the six-month therapeutic riding program. Posttest took place after the riding phase. The riding program of 24 weeks consisted of 20 minutes sessions once a week. In overall standing balance tests a paired t-test revealed no significant difference between the pretests, but a significant change when compared the pretest 2 with the posttest ($p=.013$). Also it was found significant change in quadruped balance tests after therapeutic riding program ($p=.001$).

The research organized by Zahrádka (1993) aimed to give objectivity to the results of hippotherapy in treatment of children with spastic cerebral palsy. In the first half of the study the purpose was to inspect the change in spasticity due to hippotherapy. The change was determined by measuring the maximal distance between the knees when the subject was in laying position. Assessments took place in each therapy session before and after riding. Twelwe subjects were divided into two groups: one group were riding once a week, ten times, and 15 minutes in each session; another group rode the same amount in a saddle of a riding machine. The improvement in the latter group was not statistically significant, but the group that attended to hippotherapy showed significant change in scores ($p<.02$). The second half of the research was concentrating on the motor abilities of children. The assessment procedures were ten different motor tasks developed by dr. Christine Heidelpez-Hengst. Twelwe children were asssessed before and after every eight riding sessions. Eleven children improved their scores after riding. One had lower scores. Another group of ten children was divided into two groups. The first group received physiotherapy three times per week, and the second group, in addition to physiotherapy, were participating in hippotherapy program. All the subjects attended in physiotherapy 72 times and the second group also in hippotherapy 52 times. The first group showed no statistically significant improvement in motor skills, but the group receiving also hippotherapy demonstrated statistically significant ($p<.05$) improvement in their scores.

Weber (1994) studied the effect of hippotherapy on gait of MS patients combining two different methods: EMG measurements with surface electrodes to give data about muscle tone and coordination, and analysis of accelerations in the human center of gravity to present further information about the quality of gait. Additional quantitative data was gathered of some gait parameters. The EMG results were compared with normative data. The accelerations of center of gravity were compared with three-dimensional graphic displays of persons without an impairment. There were three measurements for each subject: the first before hippotherapy, the second right after, and the last about one hour later. The cases were analyzed individually. Improvement was shown in six subjects out of the nine.

5. RESEARCH PROBLEMS

5.1. Purpose of the study

The walking skill is very important for a child's functional independence, and it is one of the main targets in physical therapy of cerebral palsy. The elements of riding are presumed to have therapeutic value on motor performance, but there are no scientific studies about the effects of riding therapy on gait of children with cerebral palsy. Therefore, the primary purpose of this study is to find out, if the riding therapy affects the gait. The primary interest is to study the functional quantitative change in gait of children with different types of cerebral palsy.

The secondary purpose is to describe the possible qualitative changes in gait. The subjective evaluation is not supposed to have scientific value in itself, but it is important to present information of the most evident qualitative changes in gait. That gives an opportunity for those working in this field to compare their observations with similar cases. The qualitative perception also gives perspective for forming hypothesis of the future studies.

Another secondary purpose of this study is to present a practical tool for the therapists to assess the outcome of riding therapy when the goal is the improvement of gait. The study is presumed to give sufficient evidence of the validity of the gait assessment procedures used in this research.

5.2. Setting the problems

The primary problem is the effect of intensive riding therapy program on the gait of children with cerebral palsy. The quantitative functional outcome is measured with temporal and stride parameters: velocity, and its components stride length and cadence. No hypothesis was set, since there is no previous research of the effects of riding therapy that could be related to the problems of this study. The primary problems in a form of question are:

1. What is the effect of the riding therapy on gait velocity?
2. What is the effect of the riding therapy on stride length?
3. What is the effect of the riding therapy on cadence?

6. METHODS

6.1. Single-subject design

6.1.1. Justification of the design

Research in adapted physical activity or in measuring treatment outcome in special populations, has a number of particular problems. Most frequently mentioned are the heterogeneity of subjects and small sample size available for research (Broadhead 1986; Watkinson & Wasson 1984). With these kind of populations the traditional group designs (with random assignments to experimental and control groups) are not only impractical, but in many cases ineffective for assessing all the variables of intervention (Barlow & Hersen 1984, 14; Watkinson & Wasson 1984).

Single-subject design, a paradigm with variety of labels such as "time series experimentation" (Hayes 1981) and "within subjects comparisons" (Greenwald 1976), is used to overcome some of the methodological problems. A conclusion sometimes drawn, that single-subject design is selected on pragmatic grounds and not for substantive reasons, is based on a misconception (Bouffard 1993; Test, Spooner & Cooke 1987). It is misleading to compare group designs with single-subject designs, since both have their pros and cons, for example, in regards of generalizability.

Often the critical point in research is, whether the theory can be generalized to a person. Assuming that treatment effects are random rather than fixed, that is, the number of subject characteristics that may interact with the treatment are so broad that one cannot assume that the treatment effect is the same for everybody. Hence it is important to use and develop theories that have a person as the basic unit of analysis. (See especially Bouffard 1993; Bryk & Raudenbush 1988.)

Kratochwill and Williams (1988) name five characteristics of single-subject designs that improve the ability of researchers to draw valid inferences from the data.

1) The researcher repeatedly assess the dependent variable across various phases of the experiment.

2) The researcher is able to measure variability on single or multiple dependent measures.

3) The researcher can usually specify in great detail the nature of independent and dependent variables, as well as the characteristics of the setting, therapist, and client.

4) Single case research designs can rule out major threats to internal validity through replication of the experimental effects.

5) In these applications of design structures, researchers have some degree of flexibility to change the nature of the design as the data are evaluated across time; or to combine design elements to better rule out various threats to internal validity.

Single-subject design was selected as the research method. Kearns (1986) names four different evaluation strategies for single-subject experimental designs that are employed to address different types of intervention questions:

1) Treatment--no treatment comparison

2) Component assessment

3) Treatment--treatment comparison

4) Successive level analysis

6.1.2. Treatment--no treatment comparison

The treatment--no treatment comparison that is applied in this study, requires a minimum of two series of measurements: before and during the intervention. The simplest form is called AB design or simple baseline design (Figure 4). Phase A is the "no treatment" period and it forms the baseline to be compared with the phase B, which is the intervention phase when the treatment is added. This design is to a great extent incapable of constituting sufficient experimental control or internal validity. AB design should be used only if circumstances do not allow for more extensive experimentation. (Barlow & Hersen 1984, 142-3; Birnbauer, Peterson & Solnick 1974; Martin & Epstein 1976; McReynolds & Thompson 1986.)

The greatest single threat to internal validity is history which refers to events other than treatment occurring in time (Barlow & Hersen 1984, 143; Kazdin & Kopel, 1975). In order to minimize the risk of involvement of confounding variables due to extraneous conditions, AB design requires an accurate follow up and report of the procedures and all the relevant factors that might affect the results. Cautious, but valid interpretations may be made, if the differences between phases A and B are abrupt and large. However, usually a replication of an experiment is necessary to increase the reliability. (Gonnella 1989.)

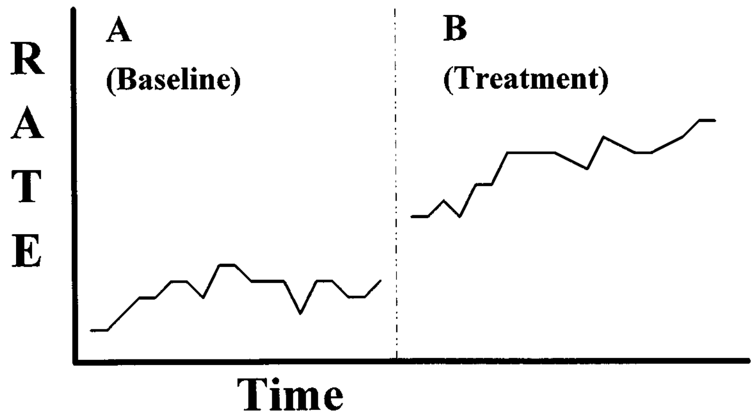

FIGURE 4. AB (simple baseline) design.

There are several approaches to increase internal validity. Experimental control is often demonstrated by incorporating several A and B phases in the design. ABA design (Figure 5) is adding another baseline after the intervention supposing that there is reversal of the effect after the treatment is withdrawn. Sequencing more AB components and comparing performance across phases is giving additional evidence, that it is just the treatment which is causing the effect. The basic consideration is, if the therapeutic effect is likely to reverse following the withdrawal of the treatment. In some cases the effects may be permanent (Figure 6). (Kearns 1986; McReynolds & Thompson 1986.)

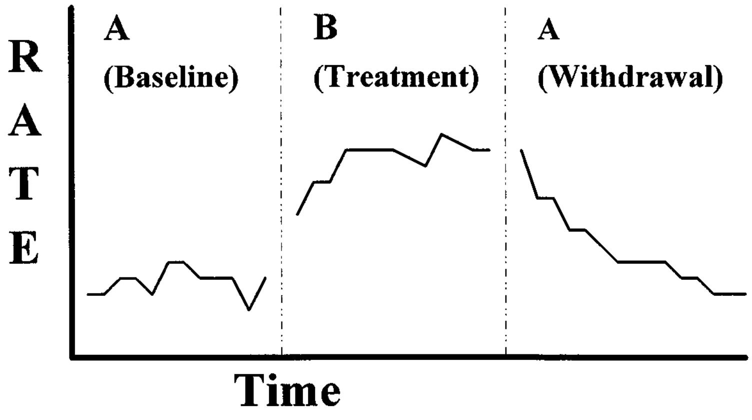

FIGURE 5. ABA withdrawal design.

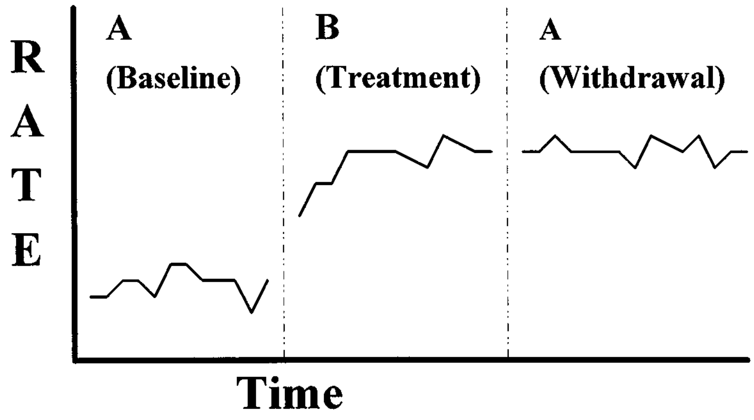

FIGURE 6. ABA withdrawal design with retention.

6.1.3. Analysis of the data

Kazdin (1984, 285) names two approaches to evaluate data in order to draw conclusions about behavior chance: experimental criterion and therapeutic criterion. The experimental criterion is based on a comparison of behavior under different conditions (baseline phases). It refers to the way in which data are evaluated to determine, if an intervention has had a reliable or veridical effect on behavior.

The therapeutic criterion is evaluating the importance of the effects comparing between the behavior change accomplished and the level of change required for the adequate functioning in society. To meet the requirements of the therapeutic criterion, the intervention needs to make an important change in the client's everyday functioning. (Kazdin 1984, 285.) It may be important to compare visually the pre- and post-performances in order to decide if the change in gait parameters have therapeutic value. This subjective evaluation method provides a professional opinion from the therapists responsible for the subjects "everyday life" rehabilitation programs. This may give further dimension for the interpretations of clinical significance of the change. (Kazdin 1982, 255.)

Experimental criterion in single-subject designs can be evaluated using visual and statistical analysis of data. The traditional and most used approach in analyzing single-subject data is **visual inspection of the graphic displays** (Kazdin 1982, 241). According to Kazdin (1982, 232) visual analysis "refers to reaching a judgment about the reliability or consistency of intervention effects by visually examining graphed data."

Test et al. (1987) and Kazdin (1982, 232) promote the use of graphic displays, but they note that with visual analysis the change in behavior must be large enough to be interpreted as reliable effects of intervention. This method is supported by Ottenbacher (1990), but his study indicates that there is some inconsistency in decisions in visual analysis, if the variables do not produce powerful clinically important effects. Test et al. (1987) and Ottenbacher (1990) also pay attention to the fact that statistical comparison may yield a significant difference that is not visually apparent. Kazdin (1982, 232) states that, "statistical evaluation often is more sensitive than visual inspection in detecting intervention effects."

6.2. Subjects

The subjects of this study were four school children with three different types of cerebral palsy. Everyone had their individual type of walking: ataxic gait, athetoid gait, diplegic gait with a walker, and diplegic four-point gait with two canes. They were pre-selected by the researcher with the help of a physiotherapist who knew the children well and was professionally familiar with their medical backgrounds relevant to this study.

The basis was that the child with cerebral palsy should walk independently (with or without assistive devices), and the style of walking would be close to normal reciprocating manner. It was considered important that the child's physiotherapy and walking skill was at a stage that he or she could presumably benefit from riding therapy (as it would be normally when riding therapy is prescribed). Since the subjects formed a group that was "working" together, they were selected from about the same age group (12-15 years) in order to increase the motivation. Previous riding experience did not affect the selection, but it was more than six months from the last riding session. There were no medical operations, from which the subject was not, in regards of walking, totally recovered. One boy (Jim) had gone through an orthopaedic operation five months before, but he was considered qualified for this study by his physiotherapist.

The parents were informed about the relevant details and asked for the permission, but the children themselves made the final decision for participation. All were willing to take part, and agreed to go through the whole study. Naturally the children had to be able to understand in what kind of program they were to participate in. Detailed information about the subjects is presented in following chapters. The names are changed.

6.2.1. Donny

Donny (Table 7) is a talkative and humorous boy, and he is active in physical education lessons. Mentally he has progressed according to his age. Donny is very reliable in performing tasks, follows orders and gives his best; mentally he is stable and acts like grown up when doing things. Donny tells straight how he feels. When he feels unconfident he blabbers and makes sarcastic jokes.

TABLE 7. Donny: Subject data

Sex	boy
Age (years)	13 (in puberty)
Height (cm)	160 (6-11 cm /year during last four years)
Weight (kg)	48
Birth	preterm (32. week; 1820 g)
Diagnosis	CP, diplegia spastica (detected at seven months)

Posture, joints and motor performance: Donny sits asymmetrically with center of gravity on the right side, but he is able to correct the posture by himself. When he is standing on his knees the pelvis is about to collapse to the right side. Donny can not maintain balance standing without help or assistive devices. His knees can be passively fully extended, ankles move to 90 degrees, and there is hip abduction 50 degrees on both sides. He has stable hips with normal rotations. Donny's upper extremities, for example finger oppositions, are slightly clumsy. He has problems in perception and in visuo-motoric tasks, and poor eye-hand coordination.

ADL: Donny is independent in most activities: in toileting, dressing (except the shoes), eating, drinking etc. He wants to do things by himself without help.

Ambulation, assistive devices, orthotics: Donny moves crawling, leaning on furniture, with small canes, or with wheelchair. In school Donny uses mainly canes and sometimes wheelchair: using canes requires flat surface. He needs assistance with wheelchair when uphill, rough ground or long distances. He will get electric scooter in order to be able to move easier nearby his home. Donny is using dynamic ankle foot orthosis (DAFO) .

Orhopaedics: 10/87 adductor tenotomy and ileopsoas tenotomy; obturatorius resection and achilles tendon lenghtenings (both). The postoperative control indicated that everything was all right.

Medication: There is no medication given to Donny at present.

Physiotherapy: When cerebral palsy was diagnosed at the age of 7 months the physiotherapy begun immediately. It has continued ever since about two times per week (at present two times/week) aiming to improve gait and secure the joint mobility. The training of reciprocal movement patterns and balance is also in program. Because of stiffness in the hips, knees and ankles Donny needs regular stretching. He has been training with DAFOs, and using them is hoped to help in ambulation and proper weight distribution to both feet.

Gait: Donny's training of walking includes walking with two or one cane, and without assistive devices only facilitated on pelvis: the facilitated gait has the best quality. At present he walks with two canes in school. The key points for Donny that are to be improved: controlling the upper body and the pelvic area, maintaining the balance, and avoiding of leaning forwards. Donny is performing his four point walk without differentiated movements in the trunk and pelvis (moving as a block). The right hip is internally rotated and foot in a 'toe in' position. His knees are in flexion and stiff, and he has great difficulties in getting his foot totally off the ground during the swing phase. His steps are short, asymmetrical, since the left-right step length is more restricted than the right-left. The walking base is narrow. His walking is stiff and evidently consuming much energy, so he gets tired very soon. Donny is a typical example of crouch knee gait where problems are often due to hamstring contractures or/and quadriceps weakness.

Riding experience: Donny had no previous experience in riding. Attitude towards riding was hesitating (slightly afraid beforehand), but he was willing to try anyhow.

6.2.2. Jim

Jim (Table 8) is shy, emotional, cries easily but he has guts too. He is enthusiastic and persistent doing tasks in physical education lessons and physical therapy situations. He is playful and likes ball games a lot. Due to young age he is sometimes playful when one should be serious. Jim has a good sarcastic sense of humor: associates verbally very fast and "in absurd manner" when he is relaxed and in good humor. Mentally Jim has progressed according to his age. He is good at school, especially in English language but has some difficulties (dislike) in mathematics. Jim seems to be thinking a lot and pondering about what is happening and why.

TABLE 8. Jim: Subject data

Sex	boy
Age (years)	12.5 (in early puberty)
Height (cm)	128 (5-6 cm /year during last two years)
Weight (kg)	28
Birth	preterm (31. +2 week; 1740 g)
Diagnosis	CP, diplegia spastica (detected at eight months)

Posture, joints and motor performance: Jim is sitting in relatively good posture sometimes slightly leaning to the right side. When Jim is standing on his knees, the pelvis is about to collapse to the right side. His knees can almost be fully extended, ankles move to over 90 degrees, the hip abductions are good, and there is passive flexion 60 degrees on both sides. His finger oppositions with all fingers are rather fast in right hand, but in the left side they are slightly slow.

ADL: Jim needs help in many daily activities, for example in toileting and dressing, but he can eat and drink by himself.

Ambulation, assistive devices, orthotics: Jim moves crawling (at home), with Kaye walker or with wheelchair. In school he uses mainly walker, and wheelchair only for longer distances. Jim needs assistance with wheelchair when uphill, rough ground or long distances. Jim uses DAFOs.

Orhopaedics: 1/93 adductor tenotomy (both sides) and ileopsoas resection; 11/94 Grise-Green extra articular arthrodesis (right side), to correct the functioning of ankle. The cast was removed 24.1.1995.

Medication: There is no medication given to Jim at present.

Physiotherapy: CP was diagnosed at the age of 8 months and Jim's physiotherapy was started immediately. His physiotherapy has continued about two times per week, but during the periods after the operations even more often. Practicing walking and improving independent functioning when moving in daily activities are the main goals for Jim. Training the erect posture and weight shifting are in Jim's program; the strength of arm muscles and the being able to lean on his arms are considered important for him too.

Gait: Jim's erect posture, and overall posture when using Kaye walker, has improved after the latest operation, but the trunk is still bent forwards. He still leans on arms quite heavily which may increase tonus in his legs. There is weakness in his leg muscles. The weight is too much on his arms when it should be on legs. Jim has difficulties in getting his foot off the ground during the swing phase, and his right step is very asymmetrical compared to the left step. Jim's walking base is very narrow and his legs are sometimes scissoring. Jim is able to walk only short distances at a time before he gets tired. In therapy situations walking has been trained with crutches, but then Jim needs to be facilitated.

Riding experience: Jim has tried riding once some years ago. The riding was badly organized with little expertise. This caused Jim to stop. Despite the experience he was easily persuaded to take part in this riding program.

6.2.3. Helen

Helen (Table 9) is a clever girl. She is good and ambitious at school. She is very reliable and persistent completing tasks whatsoever. She seems to be enthusiastic when she is in physical education lessons, especially when ball games are played. Helen is active on leisure time: go to see ice hockey, movies, theater. In summertime she rides a horse and goes to summer camps.

TABLE 9. Helen: Subject data

Sex	girl
Age (years)	14 (in late puberty)
Height (cm)	150 (has not grown height in one year)
Weight (kg)	41
Birth	preterm (41.+3 week; 3630 g)
Diagnosis	CP, athetosis, cum hypotonia (followed intensively from early infancy because of motor delay and other symptoms; diagnosis at 17 months)

Posture, joints and motor performance: There is high tonus in Helen's left arm: it is in pronation with elbow in extension, and the wrist is in flexion. The tonus rises easily also in her right arm and there is athetotic movement in it. Her ankles are extended but the tonus can be broken. Her hips are with normal rotations.

ADL: Helen eats by herself from special plate, but she needs help with soups and when tired. She dresses herself if there is time enough, but she needs assistance with shoes, buttons, and zippers. In toilet Helen is independent.

Ambulation, assistive devices, orthotics: Helen walks without assistive devices, but uses DAFOs and takes wheelchair along only for longer trips. At home she uses tricycle or electric moped.

Orhopaedics: There have been no medical operations.

Medication: There is no medication given to Helen at present.

Physiotherapy: Helen's physiotherapy began at the age of one year and five months and it is given at present 2 times per week. The main goal has been improving her gait to become more symmetrical. That can be achieved with proper weight distribution in both feet. Summer 1994 her physiotherapy was given as therapeutic horseback riding by a riding therapist (7 times).

Gait: Helen is walking independently. Tonus in her upper extremities is high when she is walking: her left arm is extended down- and backwards; right elbow is more in flexion, the arm is directed more upwards and swinging on wide range. Her steps are ataxic, high, she is toeing strongly, and the walking base is wide.

Riding experience: Helen has been riding, mainly on summertimes, for eight years now. Before this riding therapy program she had ridden last time nine months ago. Helen enjoys riding and she is quite experienced in it. Her riding lessons and therapy have included various practices while walking and trotting. She has tried last summer, once and only shortly, galloping. According to her riding therapist, Helen is "surprisingly good on horse back, adapts herself to horse's movement very fast and especially likes trotting" (Pulli 1994).

6.2.4. Anne

Anne (Table 10) was born abroad and immigrated to Finland two years ago from Estonia, and because of that she has some problems with Finnish language. Anne is going to school following adapted education plan, since mild mental retardation is presumed without closer examinations made yet. Anne is very emotional: her moods are changing quickly (from hilarious to apathetic or dejected), and she cries easily especially when doing something exiting. Anne likes physical activities, but she must be encouraged regularly. Her motivation and concentration may change abruptly.

TABLE 10. Anne: Subject data

Sex	girl
Age (years)	15.5 (in late puberty)
Height (cm)	154 (2 cm /last year)
Weight (kg)	44
Birth	fullterm (asphyxia; 3500 g)
Diagnosis	CP, ataxia, strabismus convergens alternas (diagnosed at seven months)

Posture, joints and motor performance: Anne's posture is symmetric: there is only a slight lumbar lordosis. Her posture seems sometimes slightly collapsed or kyphotic, depending more on her mood than organic structure or muscle imbalance. She has from time to time complained aching lower back, origin of which has not medically been verified. A physiotherapist has examined her and there are no limits in range of movements even when the pain is in acute phase. Her basic motor skills are relatively good when she is concentrating on task. Anne has problems in balance especially when moving fast or changing directions, and she sometimes stumbles when walking. When Anne tries jumping upwards it seems to be inflexible. There is tremor in her both hands, but the left side is more ataxic.

ADL: Anne is independent in ADL functions.

Ambulation, assistive devices, orthotics: Anne walks independently, but is using foot orthosis (FO).

Orhopaedics: There are no medical operations.

Medication: Anne has no medication at present.

Physiotherapy: There is no clear record of the treatment given to her before immigrating to Finland. Only information is that she has been given massage, mud and paraffin treatment and some medication in early childhood. At present physiotherapy is given to her once a week. Improvement of her gait is one goal, and because of the back pain complaints there has been stretching and muscle training in her program.

Gait: Anne has been walking independently since the age of seven years. Although Anne is walking with rather good quality, she is staggering on occasion. Resiprocality in her arms is missing if she is not concentrating. Both of her arms may swing simultaneously back and forth in sagittal plane, crossing in the coronal plane or not swing at all. There is not an adequate heel strike ending the gait cycle, but her heels contact the ground before foot flat. She walks in a slightly leaping manner. Anne's walking base seems to be close to normal.

Riding experience: Anne had no riding experience before. She was willing to take part in the program, although she was complaining the back pain and pondering if it would get worse.

6.3. Pilot-testing of the assessment procedures

The pilot-testing of the setting and the procedures took place in September and October 1994. The subjects were three children (age among 8 and 10 years) with diplegia spastica type cerebral palsy. Two of them were walking with two canes, and one without any assistive devices. There were from three to five assessments per child: one time per week since they had the riding therapy prescribed for once a week. The gait was measured in every assessment two times just before and two times just after the riding therapy. The assessment was arranged in the stable for practical reasons.

The walking took place in a 10 meter walkway and was videotaped from front and right side. The time was taken with a stopwatch, steps were counted, and the exact distance was measured with a tape line from the footprints. Also the width of walking base and the right/left and left/right ratio was measured from the footprints in the middle of the walkway. Relevant details of each riding therapy session and assessment were filled in a form (Appendix 4) as were the other relevant variables possibly affecting the performance of the child.

Analyzing the experiences of the pilot assessment it was concluded that:

-the children were usually too tired for an adequate walking performance after an effective riding therapy occasion.

-the therapy was intruded too much with the measurements before and after it.

-the gait assessment should take place in an environment, where it was easier to arrange and free from disturbing factors.

-measuring the width of walking base and the right/left and left/right ratio took too much time, was difficult to arrange, and was evidently too unreliable when measured from the footprints manually in a tight schedule

-the data showed no visible consistency.

Even though the children were often very tired after the therapy, and hardly managed to walk twice the ten meter distance, they usually had the feeling that walking after riding felt easier anyhow. They were asked this after every assessment. Interviewing the children also confirmed my previous notion that especially in the beginning of riding therapy sequence there may be fatigue, stiffness and some pain in muscles next day or days after riding. This was a sign of training effect in the muscles. Would it remain, have cumulating effect, and especially lead to improved gait? These experiences gave enough insight revising some key questions and the original design.

6.4. Description of the empirical phase

The empirical phase of the study took place in the Ruskeasuo school and in a riding stable in Sipoo during the school days. The Ruskeasuo school is a special school for children with neurological impairment, in which the experimenter of this study is working as a physical education teacher. All the subjects attended to this school.

Due to the nature of the Ruskeasuo school as a special institution, the medical, therapeutical and educational professions are working in close interaction. Also the parents are naturally more involved than usual. The pupils are closely followed and taken care of throughout their school years in collaboration. In this kind of setting it is easier to receive and give information of the subjects, and agree on all the details related to the study and avoid misunderstandings turning to confounding variables. These circumstances made it easier to record the possible changes in their health and alterations in other situations related to this research.

6.4.1. Research design

The independent variable of this study is the riding therapy program. The dependent variables are: gait velocity, stride length and cadence.

In the design (Figure 6) there were first three rehearsal measurement sessions. One of them was with videotape recordings (v). After the rehearsals there were six baseline gait assessments (A1) before the riding therapy program (B), and six assessments (A2) after the phase B. Each occasion consisted of three separate trials; if there was an exception to this rule it had to be argumented. Two asessments before, and two after the phase B was videotaped.

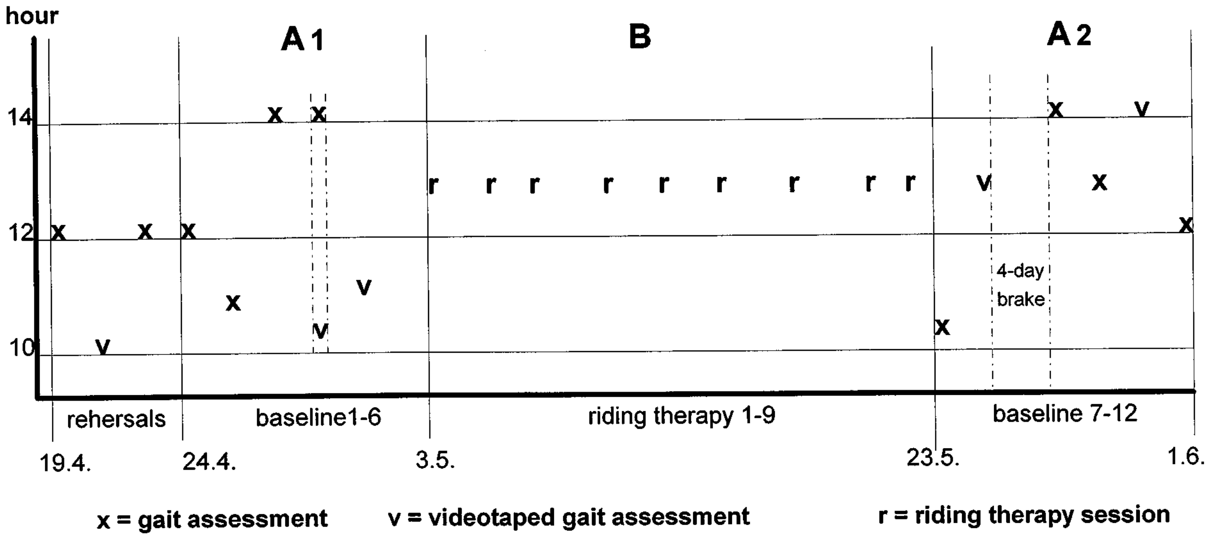

FIGURE 6. Progression of the empirical phase

There are some methodological questions with this design why one cannot name it as traditional ABA design in a same sence as it is described in the literature. One basic criterion required of a single subject research design is that there are repeated measures in each phase of the study (e.g., Harris 1996). In this study it was considered reasonable to refrain from arranging assessments during the phase B. There are three reasons behind that decision:

1) The very intensive riding therapy program will most probably cause a physical fatigue and, hence, affect (momentarily) negatively on walking in spastic CP (not necessarily in athetoid and ataxic type). The pilot testing gave reason for this conclusion.
2) The multitude of gait assessments would decrease gradually the children's motivation to attend.
3) The ethical reason was that the intensive riding and the gait assessments together would take too much time of their school work.

Another deviation, when compared to the traditional ABA design, is that there is not supposed to be withdrawal after intervention. On the contrary, the effects are presumed to show only after the intervention phase. If there is a withdrawal, the tendency is presumed to show after some unknown time span. This dilemma is further discussed in chapter 8.

The empirical phase was arranged in a tight schedule during 19.4.-1.6.1995. There were three rehearsals of the gait assessment with the children and assisting persons before the first baseline (A1) measurement. The six baseline assessments (A1) were arranged in five days, during the week just before beginning the riding therapy. One day, as an exception, there was assessment in two separate occasions, one before the noon and one in the afternoon.

The very intensive riding therapy program (B) was carried out 3.5-22.5., and consisted of nine sessions of riding. The gait assessments of the second set of baselines (A2) began in the next day after the last riding therapy session in order to record the possible fatigue and recovery effect. This information was considered important especially since there is no data of phase B.

During the empirical phase subjects' routines proceeded as normally as possible considering the physiotherapy and other activities affecting the physical status of the subjects. It was agreed with the professionals involved that there would be no changes in activities and therapy that would probably cause abrupt variation in walking of the children. This meant there were no additional gait training or activities focusing on improved gait during this phase; but if there was for example a regular gait training session weekly that had continued for months, it was not removed from the program without a reason. All the relevant changes in therapies, health, etc., were recorded.

6.4.2. Temporal and stride measurements

The assessments of gait were arranged in the gym of Ruskeasuo school. It was a familiar environment to the subjects, and it was reserved for the assessments only in order to avoid any disturbances. It took about one hour with all the arrangements to measure the walking of four children. The procedures and the measuring equipment remained exactly the same in measurements throughout all the baseline (A1 and A2) measurements.

The gait parameters were measured in a 15,5 meter walkway (Figure 7) with a digital stopwatch and a tape line. The steps were counted, the time was taken, and the exact distance was measured from the footprints left in a thin layer of magnesium powder spread in both ends of the 10 meter section of the walkway. The same part of the same foot started and ended the walk. The whole cycle was measured in order to avoid an error, if there was differences in the length of the right/left ratio compared to the left/right ratio. The purpose was to measure the mean step length.

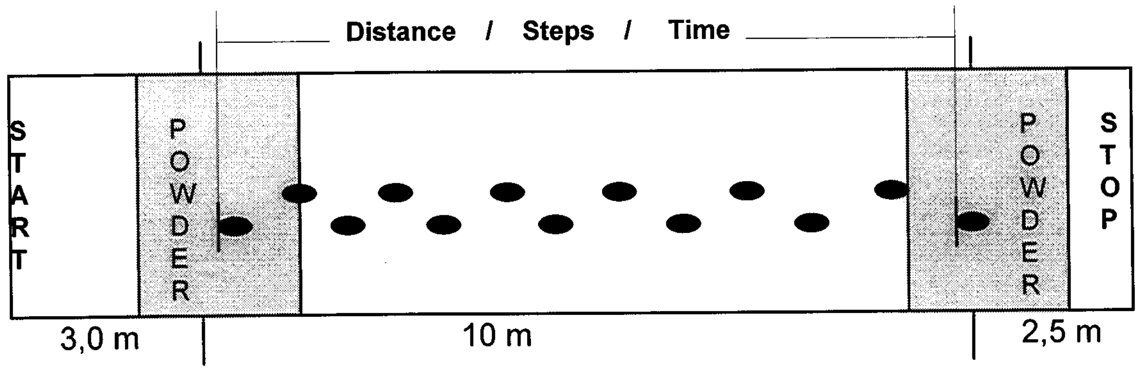

FIGURE 7. Measuring walkway

Different powders were tested and compared; magnesium was chosen and found best in avoiding the walkway and shoes becoming slippery. The powder was the most practical alternative for marking the footprints for the purpose of this study. After each walk the bottoms of the shoes were cleaned with a wet rag, and when necessary also the walkway was cleaned. The proper functioning of the stopwatch was checked before and after the empirical phase, comparing the time taking with another stopwatch.
It was decided that the gait would be assessed with the shoes and orthoses on. That was because the subjects normally walked with the orthosis on: the quality of the walking depends much on the orthosis and walking with them requires having the shoes on. For example Wheelwright, Minns, Law & Elton (1993b) consider this important when the intention is to gain information about the optimum walking ability.

When the child was ready for walking, he or she was helped in the starting position about three meters behind the line where the step was to leave the first footprint. There was enough space after the ten meter line to stop walking without difficulty. The child decided when to start walking and walked with self selected speed. There was enough time to recover between the trials since at least two children were attending in the same occasion of the assessment. After three qualified trials there were additional walks only if there was seemingly radical successive improvement in every walk one after another during that session.

A physiotherapist took part in the gait assessments. The physiotherapist knew the subjects and their medical case histories well, and she originally helped in choosing the children for the study. She was responsible for checking the quality of gait in each assessment. She decided if there were evident deviations in the quality of gait during a trial, which was not due to the physical impairment itself. Unsatisfactory performance was interrupted immediately. She also in her part made sure that there were no confounding variables affecting the gait during the empirical phase and assured that if something appeared, it was recorded. The physiotherapist prepared the children for the walking: checked that they wore every time the same shoes, that the orthoses were in order, that they wore no tight garments, and arranged a warm up for each child. She also asked how they felt and motivated the children to concentrate and do their best.

An assistant prepared the magnesium powder, cleaned the walkway, helped in measurements with the tape line and marked the footprints of the first and last step insuring that they were with the same foot. The only alteration in the whole setting was changes of the assisting person (three persons altogether) according to their work lists. The researcher counted the steps, took the time with the stopwatch, and filled the results in a data form (Appendix 5). The physiotherapist or the researcher wrote in the form about all the possible incidents during and before the assessment that could have affected the results. The form was signed by the adults responsible for the assessment.

There were also videotape recordings of the walk in the fourth, sixth, eight and eleventh baseline gait assessment. The videotape examination was a secondary purpose of this study and hoped to give some additional information of the observable qualitative changes in gait and, hence, add a further dimension for evaluating the therapeutic value of the results (compare "subjective evaluation", e.g., Kazdin 1982, 255).

For the sake of possible more thorough video analysis later on, the recording procedures were done according to more strict protocol than required for the purposes for this study. The children wore swimsuits and the relevant anatomical reference points in major joints were marked with black ink spots. They had their normal shoes and orthoses on as usual. There was one camera in front of the walkway and another moving camera on the right side. The reference lines in the floor and the wall behind the walkway, and the known distance of the cameras, would make it possible to measure for example the accelerations in the joints. For practical reasons, the walking was videotaped from these two angles, from the front and the right side.

6.4.3. Riding therapy program

The intensive therapeutic horseback riding program began five days after the last gait assessment, since there were school holidays in between. It lasted twenty days and consisted of nine different occasions of therapeutic horseback riding for each subject. All the children progressed in riding so that the amount of time on horseback could be increased towards the end from 25 to 40 minutes. In the therapy the horse's gait was the tool to improve the walking of the subjects. Some balance exercises were added gradually to the riding.

The riding therapy program was planned and put into practice by a qualified riding therapist, who is also a physiotherapist by profession and experienced in working with children with neurological impairments. The program was especially designed to improve the walking of children with cerebral palsy and individually modified along the way according to the needs and progression of each child. The therapy was assisted by an experienced person, who was responsible for controlling the horse and leading it from behind with long reins.

Two therapy horses were used. They were specially selected and used only for riding therapy purposes, and both of them were very suitable for working with children. The therapist chose the most suitable one considering the needs of each subject, and unless there was any particular reason they rode the same horse throughout the whole program.

It must be noted that in the latter part of the phase children had their therapy sessions in pairs: two children rode their horses simultaneously in the same occasion. This was an exception to the normal practice. With this arrangement the riding time for each child could be increased. The tight schedule in regards of children's school work and the working hours of the riding therapist required this compromise.

6.5. Analysis of the results

There is great inter-subject variability in motor performance of persons with cerebral palsy even if they had the same type of diagnosis. It is usual that the heterogeneity makes the traditional group comparisons and statistical analysis purposeless or impossible. In this study every subject has his or her individual style of walking. The interpretation of the results is based on the data of each subject separately, since it is not rational to compare the performance of one child with another.

In this study the effects of the independent variable (riding therapy program) on the dependent variables (gait parameters) are presented as percentage changes from the baseline (phase A) before the intervention (phase B) to the baseline (phase A) after it. Interpretation of the results is made using **visual analysis of graphic displays.**

For example, Rintala (1988) has used similar analyzing procedure in his study of the effect of an intensive physical training program on physical fitness and motor ability of children with cerebral palsy. Rintala (1988, 60) stated that using the graphic presentation is in accordance with the tradition of single-subject study.

Important characteristics that are related to the magnitude of changes across phases are mean and level. The characteristics related to rate are trend and latency of the change. Variability of performance within a phase is important factor of reliability and must be taken into consideration in visual inspection. (Kazdin (1982, 233-7.)

6.6. Validity of the research

6.6.1 External validity

External validity refers to whether the results can be generalized beyond the particular experiment in regards of other subjects and situations (Cook & Campbell 1979, 70; Kazdin 1982, 81; Thomas & Nelson 1990, 343). Single subject research designs have traditionally been criticized of results that can not be generalized because of small sample sizes and lack of control group. In fact, external validity is a problem also for group comparisons especially in clinical decision making, since the difficulty is often the variability within and between patients. Since single subject study focuses on one subject, variability from sources other than treatment can be identified and controlled at the level of the individual. The generality of results is determined through systematic replications. With subsequent replication of single-subject design, one can gather data until it is possible to detect variability and produce more reliable general rules of individual results. The specific knowledge may be related to particular client or therapy situation. (Bouffard 1993; Gonella 1989; Ottenbacher 1991.)

It has been argued by some authorities that aggregated single-subject procedures may have more external validity in heterogenic low-incidence patient groups than group comparisons. Still, it is important to regognize the limitations of the single subject findings. (Ottenbacher 1991.) The problem of single-subject research is not that the results lack generality among subjects, but rather, there are difficulties (largely inherent in the methodology) for assessing the dimensions that may dictate generality of the results. Focusing on one subject within a single experiment does not allow for the systematic comparison of different treatments among multiple subjects who differ in various characteristics. (Kazdin 1982, 283-4.)

According to Cook and Campbell (1979, 70-4) external validity can be considered as the search for conditions that may interact with intervention effects. These conditions of interest (in the framework of this study) could be varying dimensions in subjects as type of impairment, severity of impairment, sex, age, the way of ambulating, and assistive devices.

In group comparison designs it is easier to compare the data across these dimensions and determine whether the treatment effects depend on the variable upon which the subject was grouped. This type of comparison is made with factorial designs that combine subject by treatment variables in the same investigation. Factorial analyses give directly and more efficiently the information, which can be obtained using aggregated single-subject methods. Single-subject process is more time-consuming involving the collection of multiple preplanned studies. (Barlow & Hersen 1984, 56-62.)

In this study the results of each subject must be interpreted separately due to their individual basis for motor performance and different styles of ambulation. The generality of the results is limited because: the subjects were pre-selected; in cerebral palsy there is large variability between subjects; the riding therapy program was individually planned and modified according to the needs of each subject; there may be alterations in the effectiveness of riding therapy, if the program, therapist and/or the horses are not the same. The results can be cautiously generalized to include similar individual cases with same age and sex. The results may give valuable information about the possibilities of riding therapy on treatment of cerebral palsy, and be basis for future similar studies or replications to increase the generality of the findings.

6.6.2. Internal validity

Internal validity refers to the degree of causality of results: to what extent the results can be attributed to the experimental variables rather than to extraneous variables. Threats to internal validity in this study could be: history, maturation, testing, and instrumentation. (Cook & Campbell 1979 50-5; Thomas & Nelson 1990 343.) Rintala (1988, 61) has examined internal validity in somewhat similar setting.

1. History means the effect of variable other than the independent variable (riding therapy program) on the dependent variable (result of the gait measurement) during the research. Controlling the history effect may be criticized because the design differed from the traditional ABA design since there were no gait assessments during the intervention phase B. The problems of internal validity resemble to those that are mentioned in the context of AB designs.

Because of these facts, it was of utmost importance during all phases to control or detect the history variables threatening the internal validity. This was constituted firstly, by agreeing with the other professionals not to make any changes in the programs and activities the way that it could affect the results. This was possible due to the nature of the special institution where personnel and families are in close interaction. Secondly, the children were asked regularly about their health and other facts relevant to this study. Thirdly, their level of performance was observed during assessments. All intrusions were recorded.

2. Maturation implies that the behavioral change may be caused due to normal developmental process with time. Although the children were in puberty and maturing fast, it can be doubted, if maturation has any significant influence on the results. That is since the time span between the first and the last gait assessment was about six weeks (44 days). This means growing height mostly one centimeter during the period, which has minor effect on walking speed. On the other hand, growing fast does not usually improve motor performance (more likely just the opposite).

3. Testing threatens the internal validity, if one cannot rely on that the results would be the same without the baseline assessments before of the program. The effect may be due to learning, adaptation, or motivation.

   The walking skill is achieved during a long period of time for all the subjects. Sudden improvement can not be expected to emerge through learning by walking some extra trials. Gait assessment rehearsals beforehand were expected to decrease the effect of adaptation. Motivation may cause a problem if there is as tight schedule of baseline assessments as in this study. The six baseline assessments before the riding therapy program are supposed to be sufficient in order to reveal the possible testing-effect.

4. The instrumentation means the lack of constancy in measurements. It is vital that the repeated assessments are done according to same protocol, and with the same or correctly calibrated measures.

6.6.3. Validity and reliability of measurement

Validity of measurement indicates the degree to which the test, or instrument measures what it is supposed to measure (Thomas & Nelson 1990, 343). It is the main criterion when selecting a test to assess treatment outcome.

Reliability is an integral part of validity. A test cannot be considered valid if it is not reliable. Reliability pertains to the consistency, or repeatability of a measure: one must be able to depend on that the measurement is free of random errors, so the results in using the same test are reproducible. Reliability does not always guarantee validity. (Michels 1982; Ottenbacher & Tomchenk 1993; Thomas & Nelson 1990, 343.) Considering the context of this study, possible sources of measurement error that threatens the reliability are: the testing procedures, the instrumentation, and the subject (Thomas & Nelson 1990, 349).

The objectivity of the study required a valid quantitative assessment tool measuring simply the functional change in walking. Practicality and simplicity were two other criteria for choosing the method. Valid results are more likely achieved in reduced settings than in very complex ones, especially when children are in concern as subjects. Quoting Whittle (1991, 175): "for example, an intrusive measurement system and a cluttered laboratory environment might not worry a fit adult, who was acting as an experimental subject, but could cause a significant changes in the gait of a child with cerebral palsy."

The simple gait assessment procedure used in this study is suggested for example by Rose et al. (1991) and Sutherland et al. (1980b). Holden, Gill, Magliozzi and Piehl-Baker (1984) in their study found this type of analysis highly reliable way to measure temporal and distance parameters in human gait, when interrater and test- retest reliability are concerned. Pearson correlation coefficient varied between .92 - .98 for test- retest reliability, and between .90 - 1.00 for interrater reliability (except stride-time differential, which had low correlations). Holden et al. (1984) state that velocity, cadence, step length, and stride length are excellent tools for assessing physical therapy treatment outcomes because they are highly reliable and relate significantly to functional status. They warn though that testing subjects who require verbal assistance to walk because poor judgment or attention span may be unreliable. Also Brandstater, Bruin, Gowland and Clark (1983) found walking speed to be significantly related to motor recovery when studying hemiplegic stroke patients.

The self selected (i. e., normal, free, comfortable) walking speed, that is adopted in the gait assessments of this study, is widely considered to give the sufficient and most relevant information in gait analysis. Hence, self selected speed is used almost without an exception (e.g., Brandstater et al. 1983; Brown et al. 1991; Himann, Cunningham, Rechnizer & Paterson 1988: Leonard et al. 1991; Mattsson, Ohlsson & Broström 1990a; Mattsson, Broström, Borg & Karlsson 1990b; Richards et al. 1991; Robinson & Smidt 1981; Shores 1980; Sutherland et al. 1980a; Wheelwright, Minns, Law & Elton. 1993a; Wheelwright et al. 1993b; Winters et al. 1987.) Results of Olsson, Goldie and Wykman (1986) showed that free and maximal walking velocity were the best indicators of a subject's walking function. Trials with maximum speed or different speeds are suggested by Andriacchi, Ogle & Galanti (1977), but especially for subjects with neurological impairment this may cause technical difficulties (Brown et al. 1991). Hirokawa and Matsumaram (1987) found that free walking velocity had the lowest coefficient of variation when compared with slow and fast speeds. It was concluded to be possibly due to an optimized efficiency of energy consumption at the velocity of choice.

It is important to note that the whole setting and the equipment remained the same during all the assessments. Also supplementary instructions and motivation in testing are threats to reliability (Thomas & Nelson 1990). The instructions and external motivation were from the beginning focused on the best possible performance of subjects: it was required that they were concentrating and that the quality of walking remained sufficiently high according to individual standards. It was tried though to avoid unnecessary intruding on subjects' walking performance. Every relevant incidence that occurred was recorded.

The possible measurement error associated with the subjects in this study might be: changing of the mood and motivation, fatigue, health, fluctuations in performance, knowledge of the purposes of the study, and previous practice (Thomas & Nelson 1990). The risks were tried to diminish by pre-selecting the subjects so that they would be able to understand correctly their role in this program and be motivated to finish. The main risk was that the subjects would give up after the riding program when getting tired of gait assessments. Fluctuations in motor performance are typical for subjects with cerebral palsy (e.g., Fetters & Kluzik 1996), but inappropriate behavior during assessment was controlled by the physiotherapist and the experimenter. Walking as a motor performance was familiar to the subjects and they walked with their usual style. No new skill was learned, so, the previous practice was promoting the reliability in this study. All the emerging relevant factors concerning the subjects were recorded.

7. RESULTS

The change of velocity, stride length, and cadence are presented subject by subject in the graphic displays. The effects of the riding therapy program on the gait parameters are measured as percentage changes from the baseline measurement sessions (MS) 1-6 before the intervention phase to the baseline MS 7-12 after the intervention. The change of each parameter is presented as the difference from the mean of all scores (total mean), which is marked as 100 %.

Interpretations of the results are made using visual analysis of the graphs. In order to give numerical basis for interpretations the following figures are presented in Tables 11- 22.

- The mean of A phases and the difference of means, representing the change in performance.
- The mean of MS 7-8 and MS 9-12, representing the possible fatigue and recovery effect.
- The difference of the means of MS 1-6 and MS 9-12, representing the change in performance after recovery.
  (Note! The 100 % here is the mean of these two means)
- The mean range of the both baseline phases, representing the variation within individual measurement sessions.

- -The lowest and the highest score of all scores within one phase, representing the maximum variation during one phase
- -The gait parameters in normal measuring units, with reference to the normal ranges (Appendix 6) in free speed walking according to the age and sex.

The range is the simplest measure of variation, but can be used here within the measurement sessions, because of the limited number of scores. The range is calculated deducting the lowest score from the highest score of each session.

The range and the low/high score are giving important information about the trial by trial and day by day variation of motor performance of subjects. It is relevant in analyzing the true effect of independent variable on dependent variables. If the variation is great, the difference between baselines has to be bigger to prove the effect than if the variation is minimal. Constant baseline before intervention requires less separate measurements than a one with great variation.

The means MS 7-8 and 9-12 are presented separately, because it was originally considered important to receive information about the possible fatigue and recovery effect after the intensive riding therapy. The baseline assessments 7 and 8 were immediately the next two days after the last riding session of the phase B. Then there were a gap of four days to recover before the measurement session 9 on the seventh day after the end of therapy program. It was considered most practical and clear to present the separate MS 7-8 and 9-12 values with the mean of all scores. The exact difference of MS 1-6 and 9-12 could not be derived directly from the means of all scores presented before, but had to be recalculated separately.

Additional information is derived from the figures that present the change in velocity explained with its components (e.g., Figures 12 and 13). The scores of velocity can be compared with cadence and stride length. Since velocity is the combined product of these two components, they may have either cumulative or annulling effect on velocity. Also the individual components may have different percentile portion of the change in velocity. For example, if there were no variation at all in cadence, all the changes in velocity would be explained with the changes in stride length.

The original assessment scores and the calculated individual gait parameters are presented in Appendix 7. The details of percentage calculations can be found in Appendix 8.

7.1. Donny: Change in stride length, cadence and velocity, and comparison of components

Stride length:
Change in stride length is presented in the Figure 9 and the Table 11. The mean ranges within sessions (8,4 % and 5,8 %) are rather large. The almost 20 % gap between the highest and lowest score of the trials before intervention (MS 1-6) is evidence of day by day variation of motor performance. The variation is typical in cerebral palsy, but the extent is still somewhat surprising. The restriction in stride length is clear when compared with the normative values, which are twofold or more.

Since the variability of scores is high, the change has to be clear. That is the condition of reliable conclusions. The difference of means of phases before and after riding therapy program is 11,2 %. The mean of MS 7-12 is well above the highest score of MS 1-6. The difference of the best scores in two phases is 18,2 %.

TABLE 11. Donny: Key figures of stride length

Mean 1-6	=	94,4	%	;	mean range	8,4 %	;	l/h 85,2 / 103,3 %
Mean 7-12	=	105,6	%	;	mean range	5,8 %	;	l/h 90,8 / 121,5 %
Difference	=	11,2	%					
Mean 7-8	=	98.0	%					
Mean 9-12	=	110,2	%					

Stride length/Donny:	
Mean 1-6	= 0,54 m
Mean 9-12	= 0,63 m
-normal range 1,06 -1,64 m	

Difference of the means of MS 1-6 (92,3 %) and 9-12 (107,7 %)
= 15,4 %

Note: percentages are relative to 100 % (mean of the means 1-6 and 7-12); range is variation within measurement sessions; l/h = the lowest / the highest score of the phase

The recovery from the strains of riding, visible in MS 7-8, can be seen after the seven days in MS 9-12. The improvement in stride length is clear when the mean of MS 9-12 is compared with the means of MS 1-6 and MS 7-8. Most powerful detail is that all the individual scores of MS 9-12 are above the highest score of MS 1-6. Low scores of MS 7-8 indicate, as presumed, the fatigue after riding, although it seems that Donny has already somewhat adapted himself to the strenuous physical training.

The change of the stride length from the baseline before the intervention phase and after the recovery is 15,4 %, which means nine centimeters average improvement per stride. It can be concluded that the change is clear: the riding therapy program has increased the stride length of Donny noticeably.

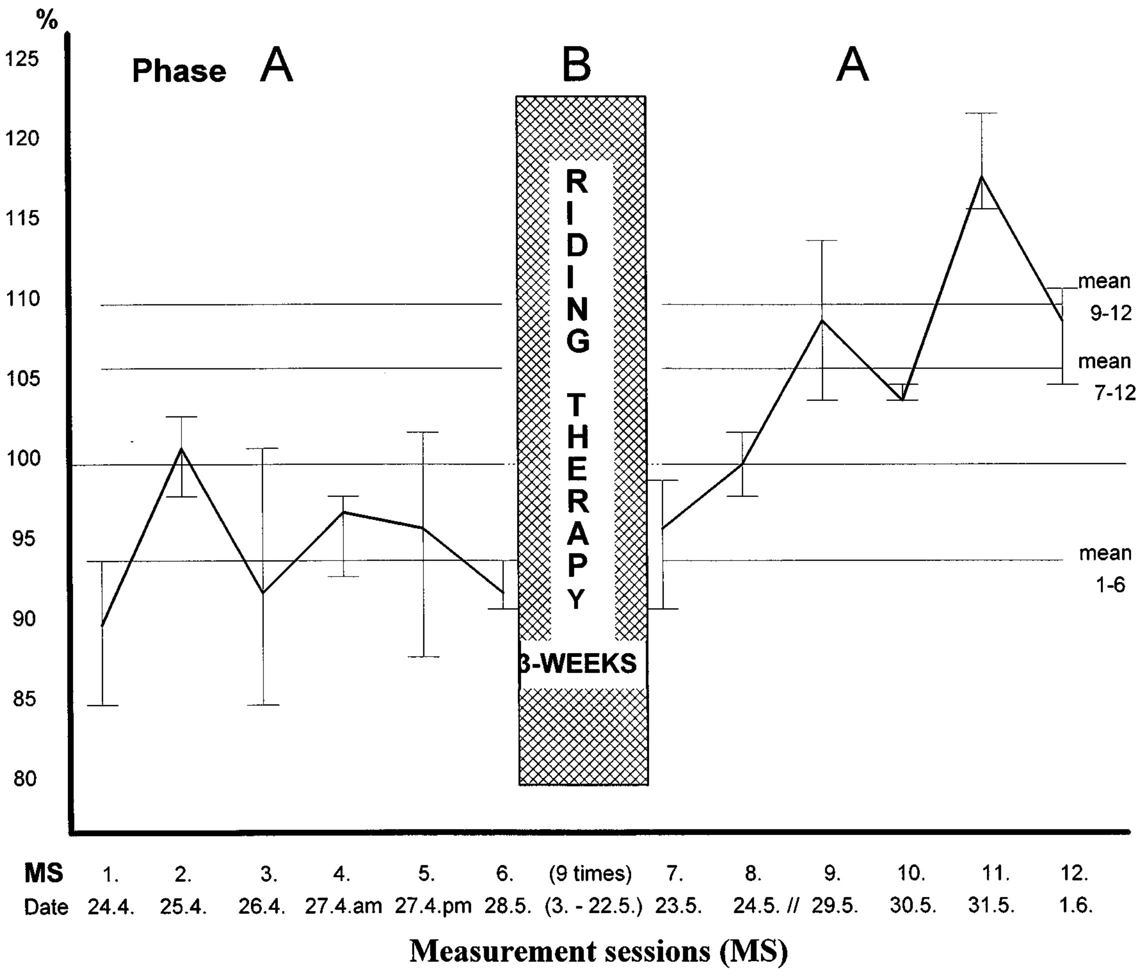

FIGURE 9. Donny: Stride length before and after riding therapy program
- the mean, and the highest/lowest score in each session

Cadence:

Change in cadence is presented in the Figure 10 and the Table 12. The mean ranges of cadence are rather high (6,8 % and 5,8), about the same as in stride length. The largest day by day variation is 12,7 % when measured comparing the highest score with the lowest one in phase before intervention. The normal values of cadence are clearly greater, but not radically.

TABLE 12. Donny: Key figures of cadence

Mean 1-6	=	98,7	% ;	mean range 6,8 % ;	l/h 92,9-105,6 %
Mean 7-12	=	101,3	% ;	mean range 5,8 % ;	l/h 93,8-106,2 %
Difference	=	2,6	%		
Mean 7-8	=	99,9			
Mean 9-12	=	101,9			

Cadence/Donny:
Mean 1-6 = 78.0 steps/min
Mean 9-12 = 80,6 steps/min
-normal range 100-149 steps/min

Difference of the means of MS 1-6 (98,4 %) and 9-12 (101,6 %) = 3,2 %

Note: percentages are relative to 100 % - the mean of all scores; the range is the variation within measurement sessions; l/h = the lowest / the highest score of the phase

Even though five of the means of MS 1-6 are under the 100 % line and five means over it after the intervention phase, the change (difference of MS 1-6 from MS 7-12 = 2,6 % and MS 9-12 = 3,2 %) is small when compared with the extent of variation. It can not be concluded that the riding therapy has changed the cadence of Donny, even though there is slight increase in the means after intervention.

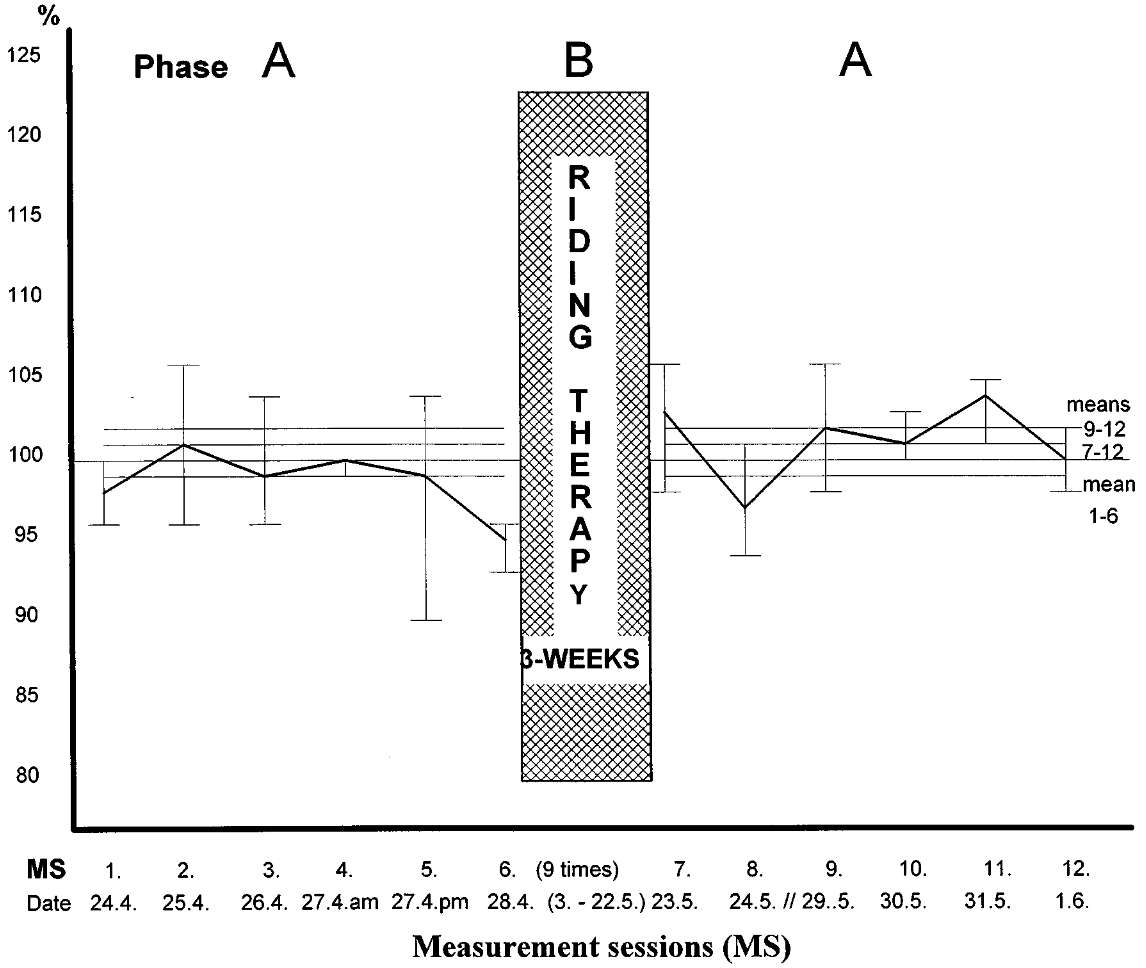

FIGURE 10. Donny: Cadence before and after riding therapy program
- the mean, and the highest/lowest score in each session

Velocity:

Change in gait velocity is presented in the Figure 11 and in the Table 13. Striking fact is the wide range of scores throughout the baseline measurements. The variation in motor performances averaged within measurement sessions over 10 % in both baseline phases. The gap of almost 30 % between the the lowest and the highest score in baseline assessments before intervention shows the extent of day by day variation.

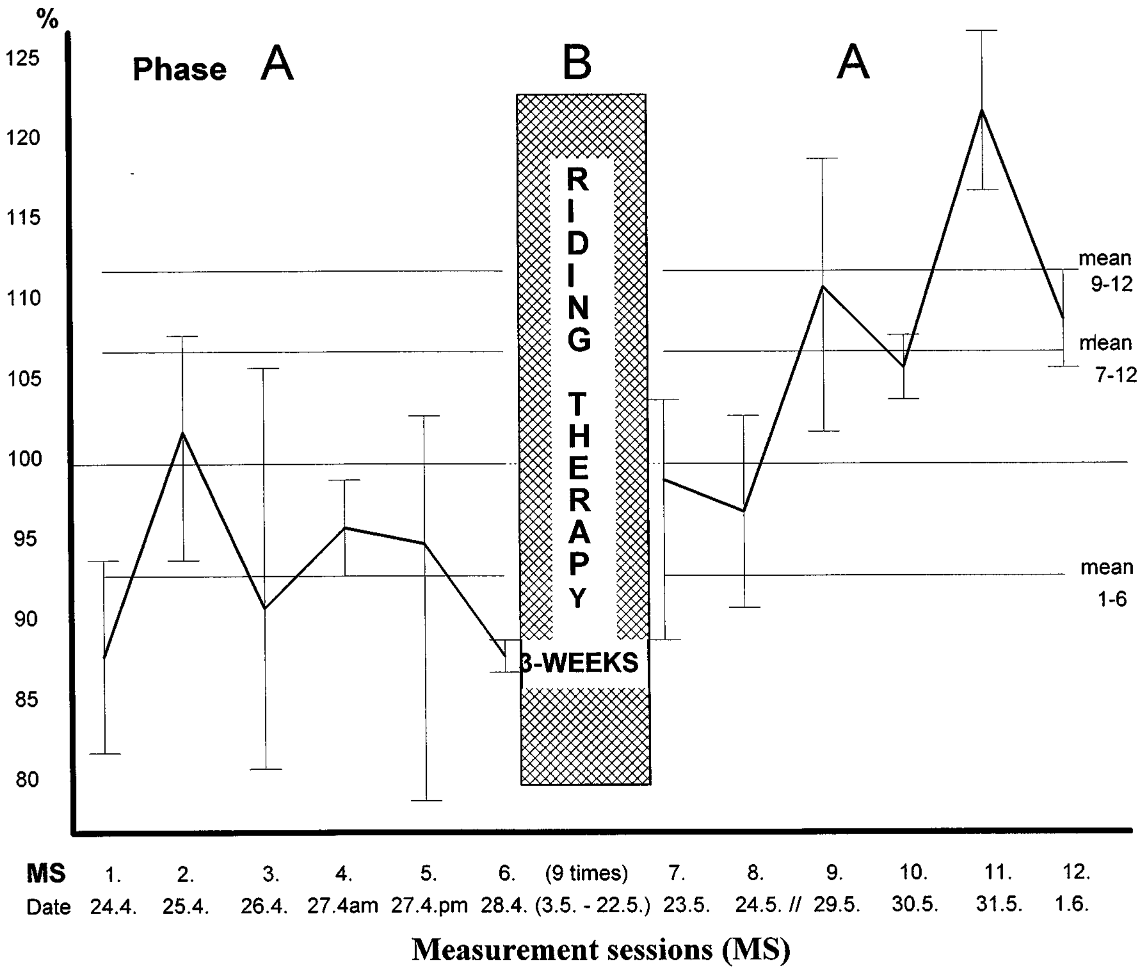

FIGURE 11. Donny: Gait velocity before and after riding therapy program
- the mean, and the highest/lowest score in each session

The change in velocity was still evident. In the baseline phase before intervention there was only one mean (MS 2) slightly over the total mean. Mean improvement after the riding therapy program was 13,6 %. Also it seems very probable that there was fatigue involved in baselines 7 and 8.

Very clear positive effect on the gait velocity of Donny can be seen after the seven days of recovery (MS 9-12). There were not any baseline scores in first phase close to the mean of MS 9-12. The mean increased up to 112,0 %, and all the scores were clearly over the total mean 100 %. The difference between MS 1-6 and MS 9-12 was 18,4 %.

TABLE 13. Donny: Key figures of gait velocity

Mean 1-6	=	93,2	% ;	mean range	15,2 %	;	l/h 79,2-108,4
Mean 7-12	=	106,8	% ;	mean range	11,2 %	;	l/h 88,6-127,3

Difference	=	13.6	%
Mean 7-8	=	97,8	%
Mean 9-12	=	112,0	%

Velocity/Donny:
Mean 1-6 = 0,35 m/s
Mean 9-12 = 0,42 m/s

-normal range 0,95 -1,67 m/s

Difference of the means of MS 1-6 (90,8 %) and 9-12 (109,2)
= 18,4 %

<u>Note</u>: **percentages are relative to 100 % - the mean of all scores; the range is the variation within measurement sessions; l/h = the lowest / the highest score of the phase**

One has to notice that the gait velocity is the combined effect of the two components, stride length and cadence, which explains the greater variability in velocity (although theoretically it might be the same or even less). According to the Figure 12, mostly the increase in stride length was accompanied by increase in cadence, thus, having a cumulative effect. Only in MS 7 there was annulling effect of components, since the stride length was below 100 %, but the cadence was faster than average. The stride length explained in both baseline phases about 77 % of the changes in velocity (Figure 13).

The gait of Donny was slow (at its fastest 0,48 m/s) and it required a great effort. Four-point walk requires additional coordination, because one has to combine the support and movement of the arms with the movement of the legs. This difficult motor task may be one explaining factor in figures of variation: slight problem in one motor component of gait may lead into further difficulties in others and so forth multiply the effect of bad performance. Compared to the normal range one can describe Donny's walking as very slow.

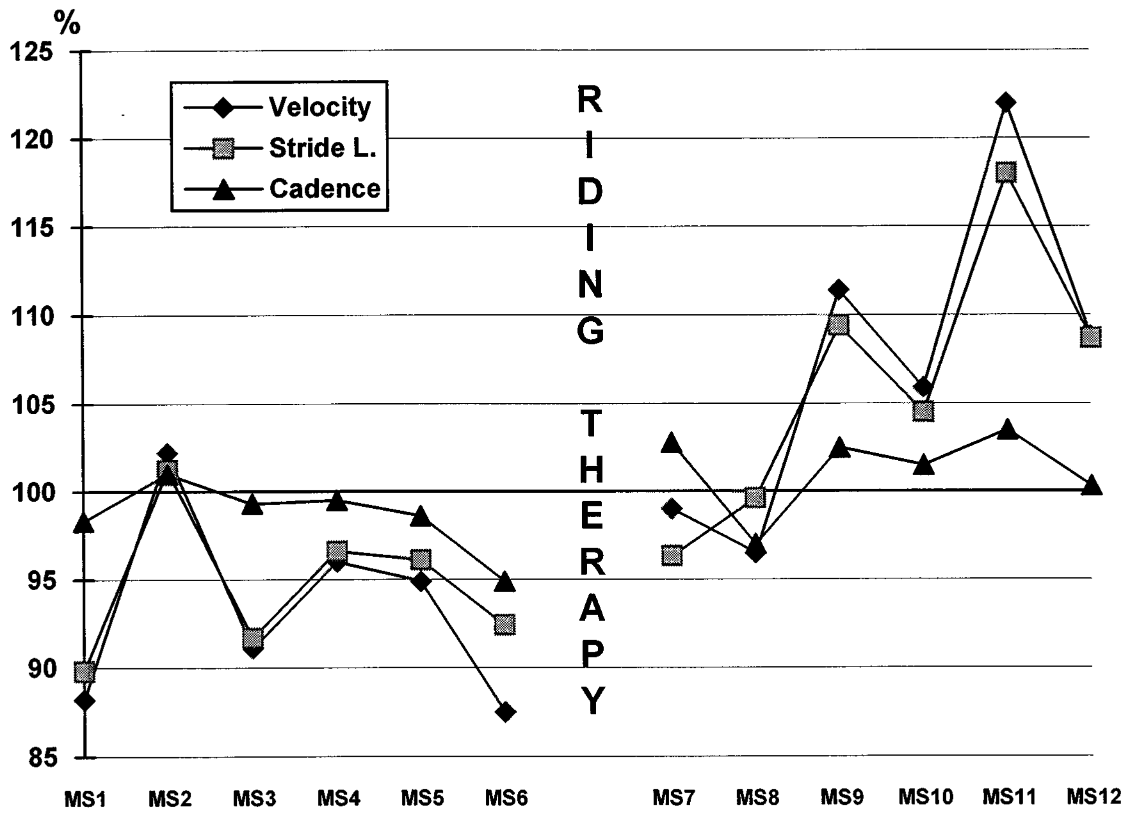

FIGURE 12. Donny: Comparison of change in gait velocity, stride length and cadence

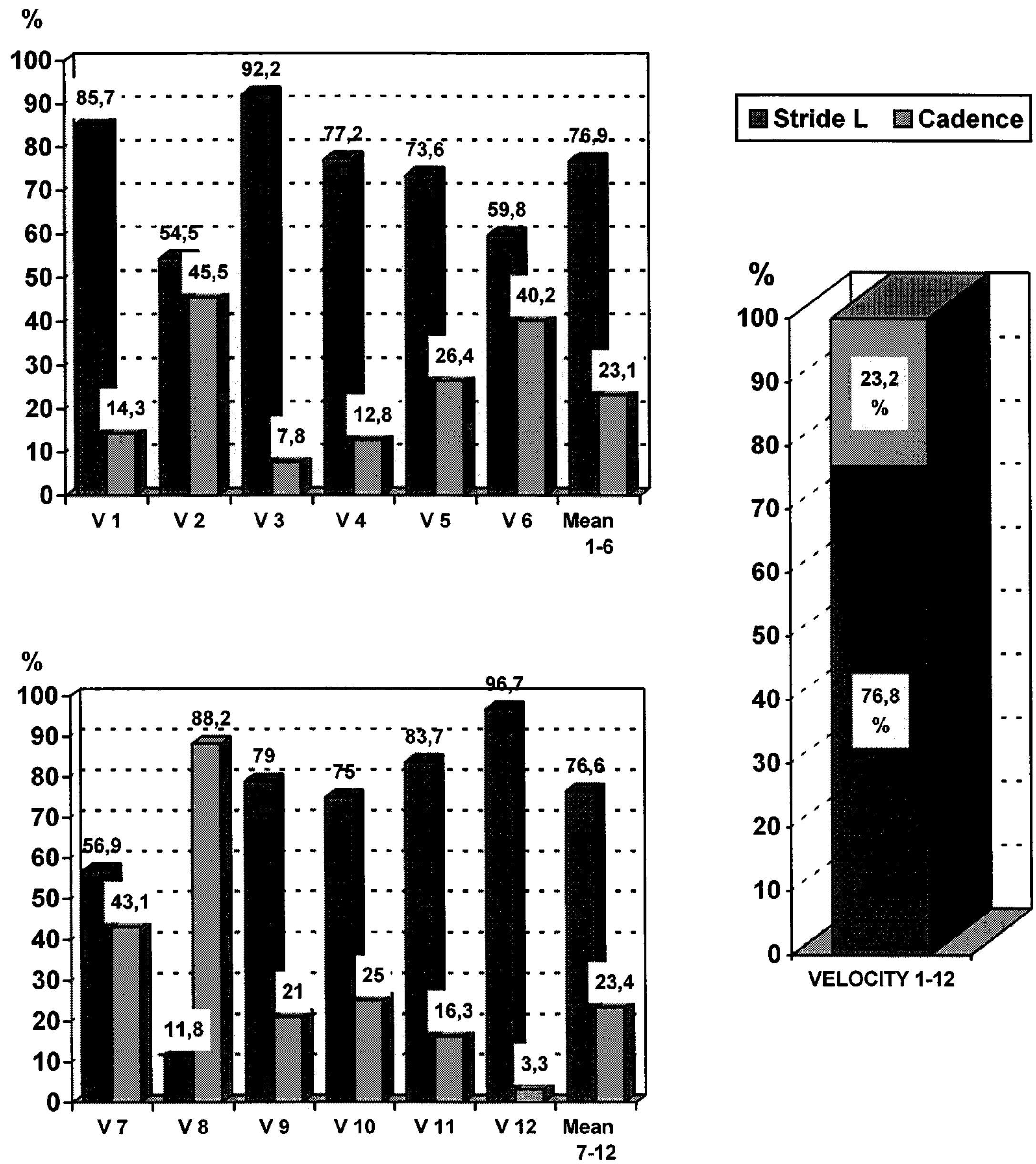

FIGURE 13. Donny: Change in velocity explained by its components: stride length and cadence

7.2. Jim: Change in stride length, cadence and velocity, and comparison of components

Stride length:
Change in stride length is presented in the Figure 14 and the Table 14. The mean ranges within sessions (4,0 % and 7,0 %) are rather large. The almost 15 % gap between the highest and lowest score of the trials before intervention shows the variation of motor performance. The restriction in stride length is clear when compared with the normative values, although it has to be borne in mind that Jim is very short to his age.

TABLE 14. Jim: Key figures of stride length

Mean 1-6	=	97,2	%	; mean range 4,0 %	; l/h	91,3 / 105,8 %
Mean 7-12	=	102,8	%	; mean range 7,0 %	; l/h	93,3 / 112,7 %
Difference	=	5,6	%			
Mean 7-8	=	96,8	%			
Mean 9-12	=	105,4	%			

Stride length/Jim:
Mean 1-6 = 0,71 m
Mean 9-12 = 0,77 m
-normal range 0,96 -1,54 m

Difference of the means of MS 1-6 (96,1 %) and 9-12 (103,9 %) = 7,8 %

Note: percentages are relative to 100 % - the mean of all scores; the range is the variation within measurement sessions; l/h = the lowest / the highest score of the phase

The difference of the means of the phases before and after the riding therapy program is 5,6 %. There is only one peak score of MS 1-6 above the mean of MS 7-12 (also the mean of MS 9-12). The difference of the best scores is 6,9 %. Low scores of MS 7-8 are indicating about the fatigue after riding. The physical recovery can be seen in the slope of MS 9-12. That can be the interpretation despite the rather low mean of MS 9, which still is above the 100 % line.

The change of the stride length from the baseline before the intervention phase and after the recovery is 7,8 %, equal to six centimeters. It can be concluded that the riding therapy program has increased the stride length of Jim.

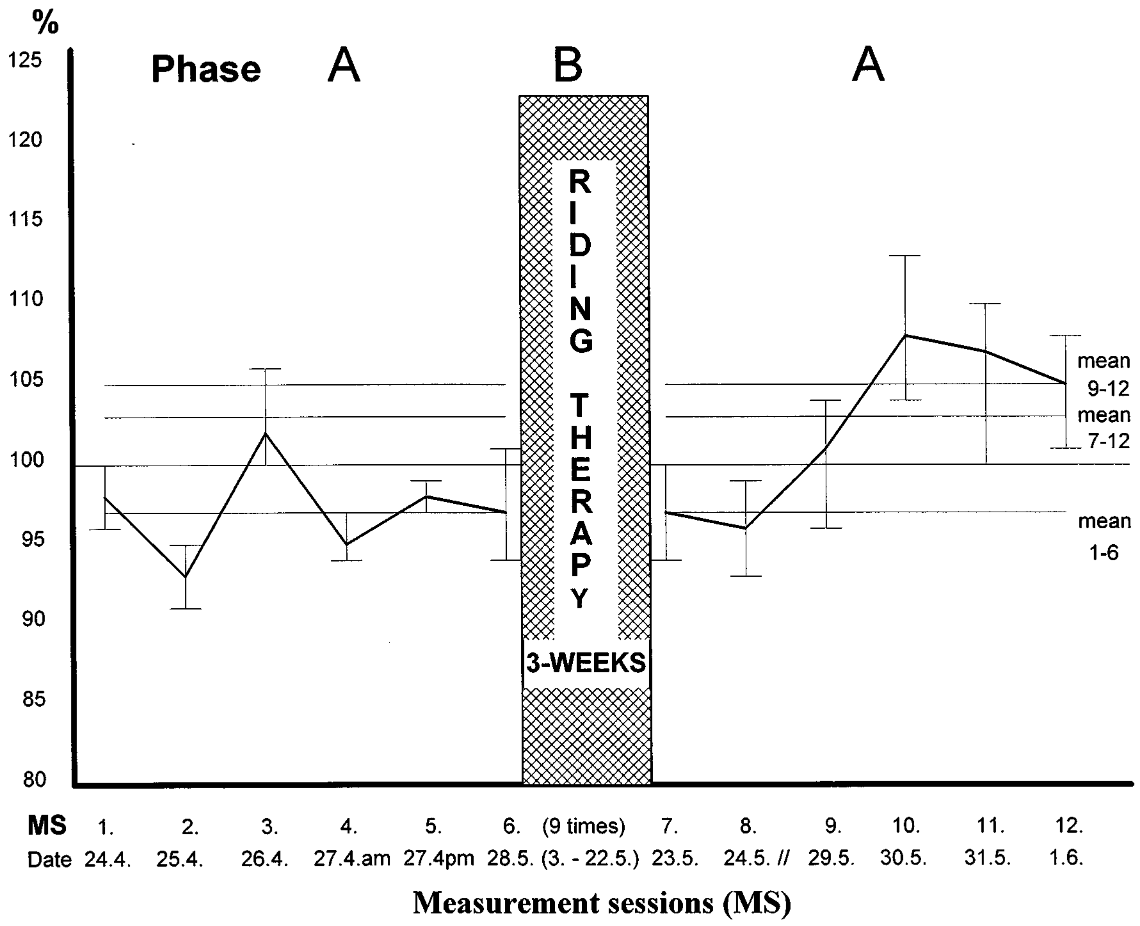

FIGURE 14. Jim: Stride length before and after riding therapy program **- the mean, and the highest/lowest score in each session**

Cadence:
Change in cadence is presented in the Figure 15 and the Table 15. The normal values of cadence are somewhat greater than Jim's. The mean ranges of cadence are rather high, and maximum day by day variation before intervention is 16,4 %. The difference of the best scores is 7,2 %, greater after the intervention.

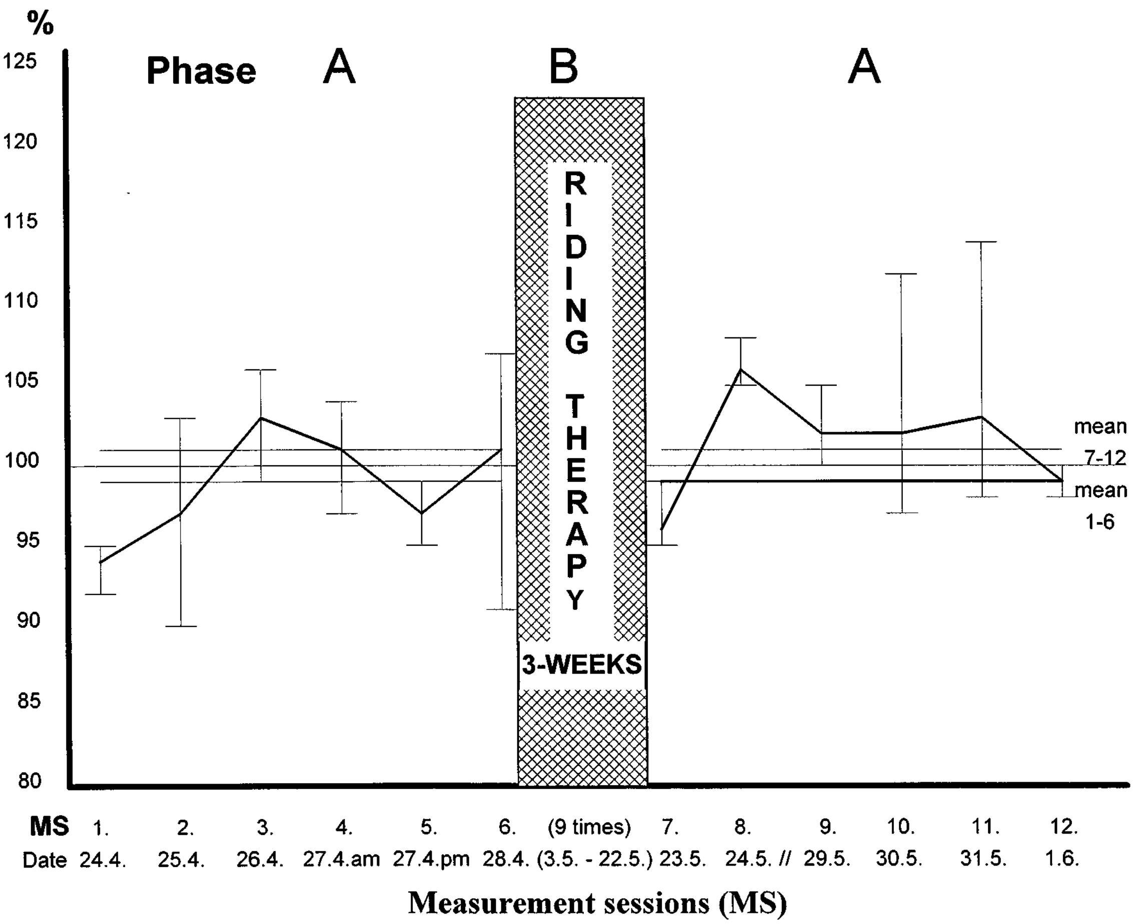

FIGURE 15. Jim: Cadence before and after riding therapy program
- the mean, and the highest/lowest score in each session

TABLE 15. Jim: Key figures of cadence

Mean 1-6	=	98,8	% ;	mean range 8,1 %;	l/h	90,2 / 106,6 %
Mean 7-12	=	101,2	% ;	mean range 7,6 %;	l/h	95,0 / 113,8 %

Difference	=	2,4	%
Mean 7-8	=	101,4	%
Mean 9-12	=	101,6	%

Cadence/Jim:

Mean 1-6 = 86,5 steps/min
Mean 9-12 = 89,1 steps/min

-normal range 105 - 156 steps/min

Difference of the means of MS 1-6 (98,5 %) and 9-12 (101,5 %) = 3,0 %.

Note: percentages are relative to 100 % - the mean of all scores; the range is the variation within measurement sessions; l/h = the lowest / the highest score of the phase

The change between phases is small when compared with the extent of variation. It can not be concluded that the riding therapy has changed the cadence of Jim even though there is slight increase in the mean.

Velocity:
Change in gait velocity is presented in the Figure 16 and the Table 16. There is a wide range of scores throughout the baseline measurements. The variation in velocity averaged within measurement sessions about 10 % in both baseline phases. The gap of almost 25 % between the the lowest and the highest score in the first baseline is an evidence of large day by day variation. There is a 19 % difference between the lowest and highest scores in the two phases.

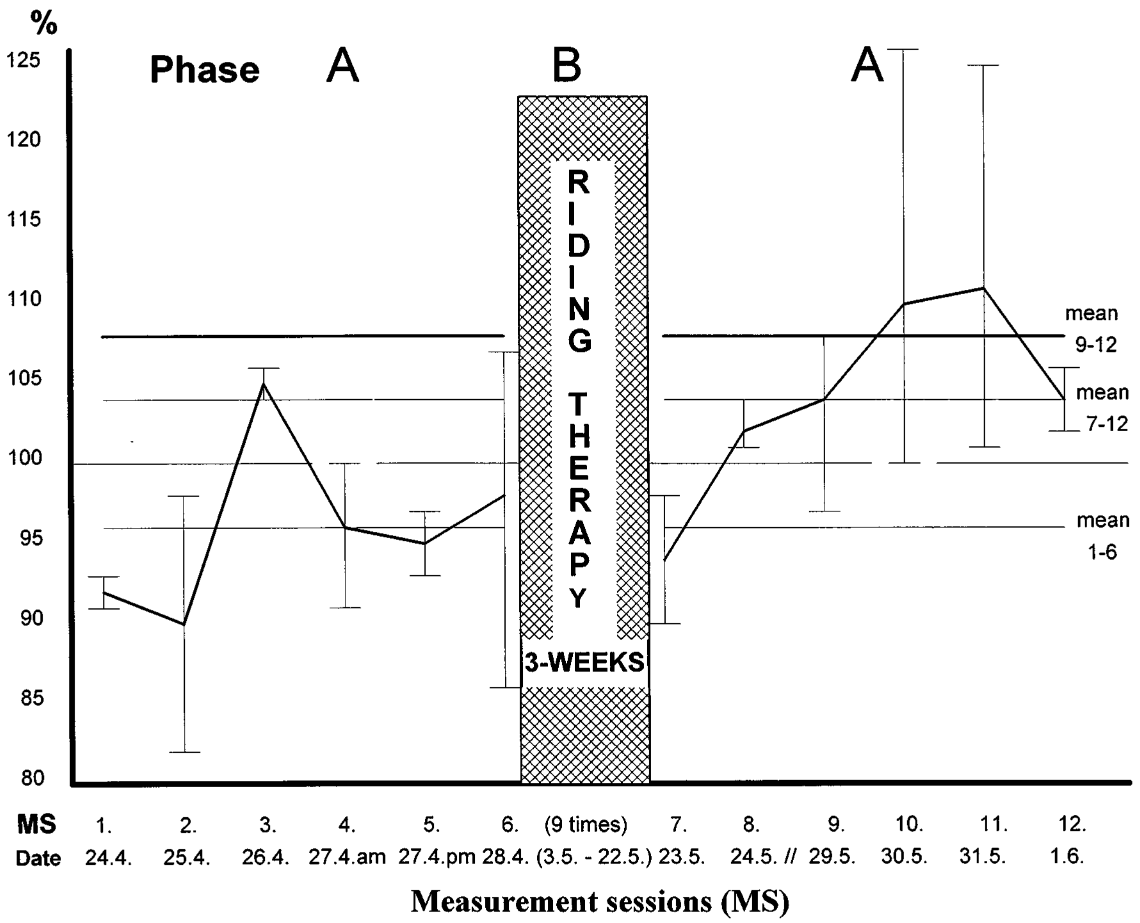

FIGURE 16. Jim: Gait velocity before and after riding therapy program **- the mean, and the highest/lowest score in each session**

The change of velocity is rather clear despite the great variability. In the baseline phase before intervention there was only one mean (MS 3) over the total mean (although clearly over), and some peak scores over the average of the second A phase. Mean improvement after the riding therapy program was 8,0 %.

TABLE 16. Jim: Key figures of velocity

Mean 1-6	=	96,0 %	;	mean range 9,3 %	; l/h 82,3 / 107,2 %
Mean 7-12	=	104,0 %	;	mean range 12,9 %	; l/h 90,1 / 126,2 %

Difference	=	8,0 %
Mean 7-8	=	98,2 %
Mean 9-12	=	107,5 %

Velocity/Jim:	
Mean 1-6	= 0,51 m/s
Mean 9-12	= 0,57 m/s
-normal range	0,88-1,60 m/s

Difference of the means of MS 1-6 (94,5 %) and 9-12 (105,5 %) = 11,0 %

Note: percentages are relative to 100 % - the mean of all scores; the range is the variation within measurement sessions; l/h = the lowest / the highest score of the phase

The improvement in the gait velocity of Jim can be seen after the seven days of recovery in MS 9-12. There was not any baseline scores in first phase over the mean of MS 9-12. The difference between MS 1-6 and MS 9-12 was 11,0 %. The great variation within some sessions (visible in four sessions out of 12) has to be discussed.

According to the Figure 17 the change in stride length is not without exception accompanied by similar change in cadence. The combined effect on Jim's gait velocity is as often cumulating as it is annulling, but the stride length is more responsible for the change in velocity (Figure 18). Of all changes in velocity the stride length is explaining 57,9 %.

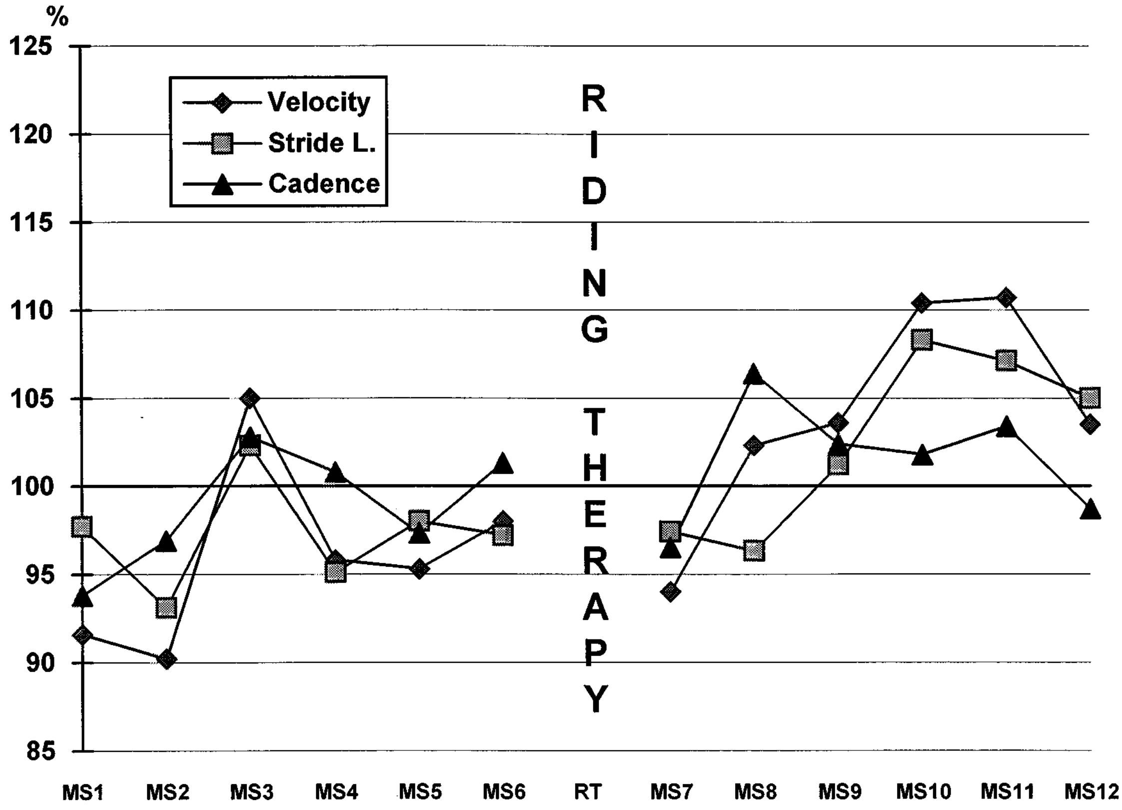

FIGURE 17. Jim: Comparison of change in gait velocity, stride length and cadence

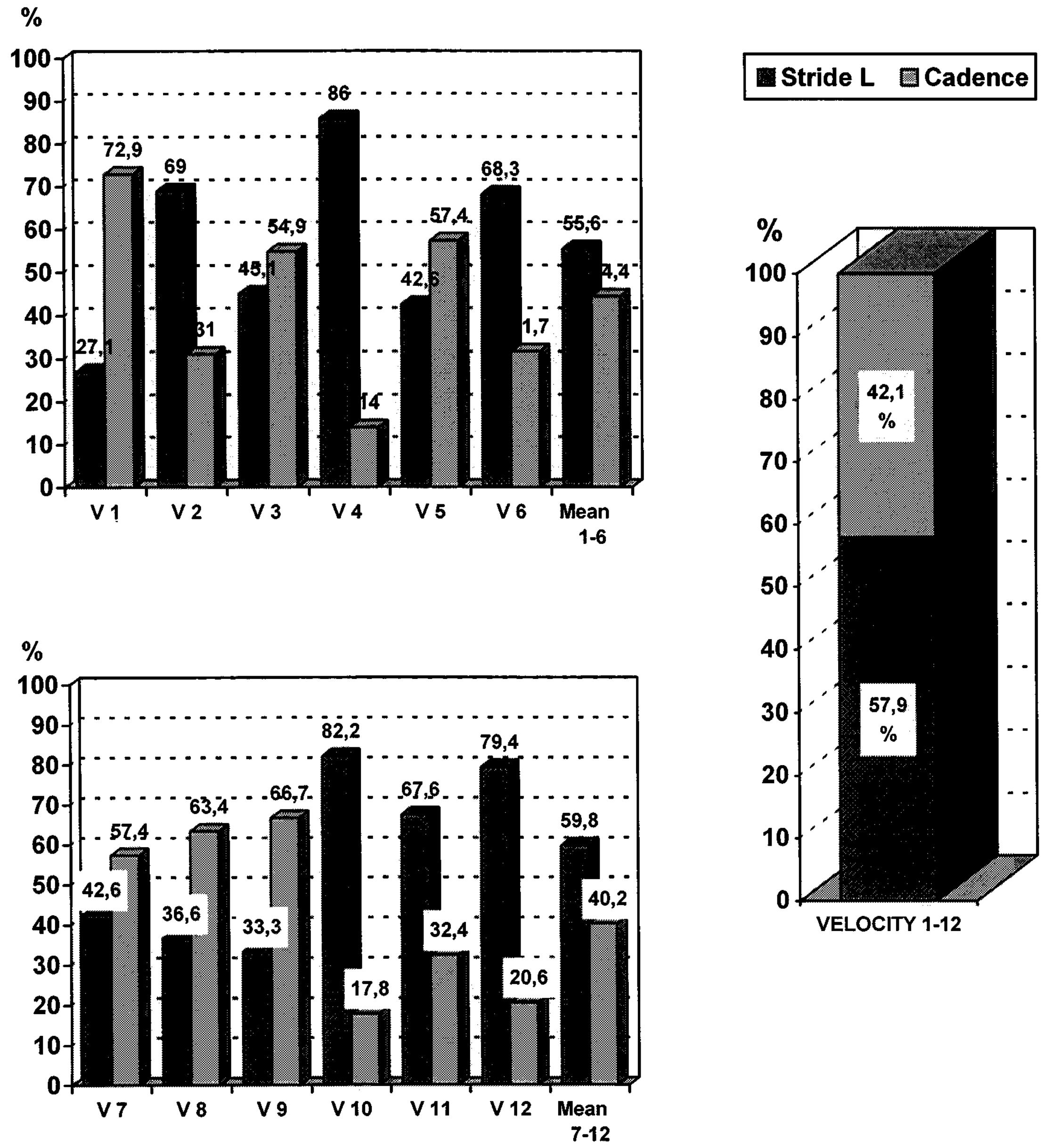

FIGURE 18. Jim: Change in velocity explained by its components: stride length and cadence

7.3. Helen: Change in stride length, cadence and velocity, and comparison of components

Stride length:
Change in stride length is presented in the Figure 19 and the Table 17. The mean ranges within sessions of the two baselines are: in first 4,8 % and in the second 5.6 %. The 10,5 % gap between the highest and lowest score of the trials before intervention shows the variation in the first baseline phase. There is no clear restriction in stride length when compared with the normative values. Since Helen is relatively tall, the steps can be considered slightly short.

TABLE 17. Helen: Key figures of stride length

Mean 1-6	=	97,7 %	; mean range 4,8 %	;	l/h 92,0 / 102,5 %
Mean 7-12	=	102,3 %	; mean range 5,6 %	;	l/h 94,1 / 110,9 %

Difference	=	4,6 %
Mean 7-8	=	100,2 %
Mean 9-12	=	102,7 %

Stride length/Helen:	
Mean 1-6	= 1,16 m
Mean 9-12	= 1,22 m
-normal range	0,99-1,55 m

Difference of the means of MS 1-6 (97,5 %) and 9-12 (102,5 %)
= 5,0 %

Note: percentages are relative to 100 % - the mean of all scores; the range is the variation within measurement sessions; l/h = the lowest / the highest score of the phase

The difference of the means before and after riding therapy program is 4,6 %. There is no peak score of MS 1-6 above the mean of MS 7-12, which is due to the rather steady first baseline. There is more variation in performance with some rather low scores after the intervention. Low score of MS 7 is an indication of the fatigue after riding. The physical recovery can be seen already in the MS 8.

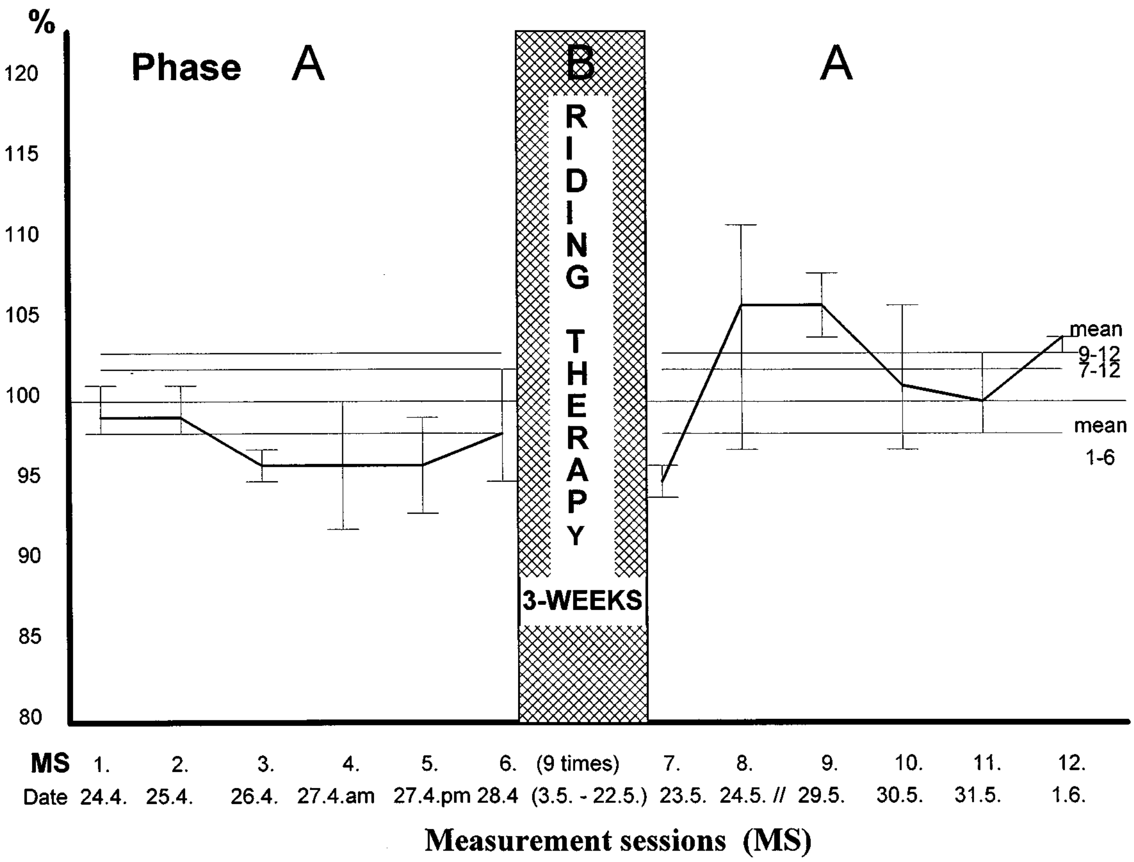

FIGURE 19. Helen: Stride length before and after riding therapy program **- the mean, and the highest/lowest score in each session**

The chance of the stride length from the first baseline and after seven days recovery is 5,0 %, that is equal to six centimeters. It seems that the riding therapy program has improved the stride length of Helen. It has to be noticed, though, that her stride was originally close to appropriate length and no radical change was expected.

Cadence:

Change in cadence is presented in the Figure 20 and the Table 18. The normal values of cadence can be considered somewhat greater than Helen's, even though she is just within the limits. Her baseline performance before intervention was steady except two peak scores. There was one very high and one very low score (gap over 20 %).

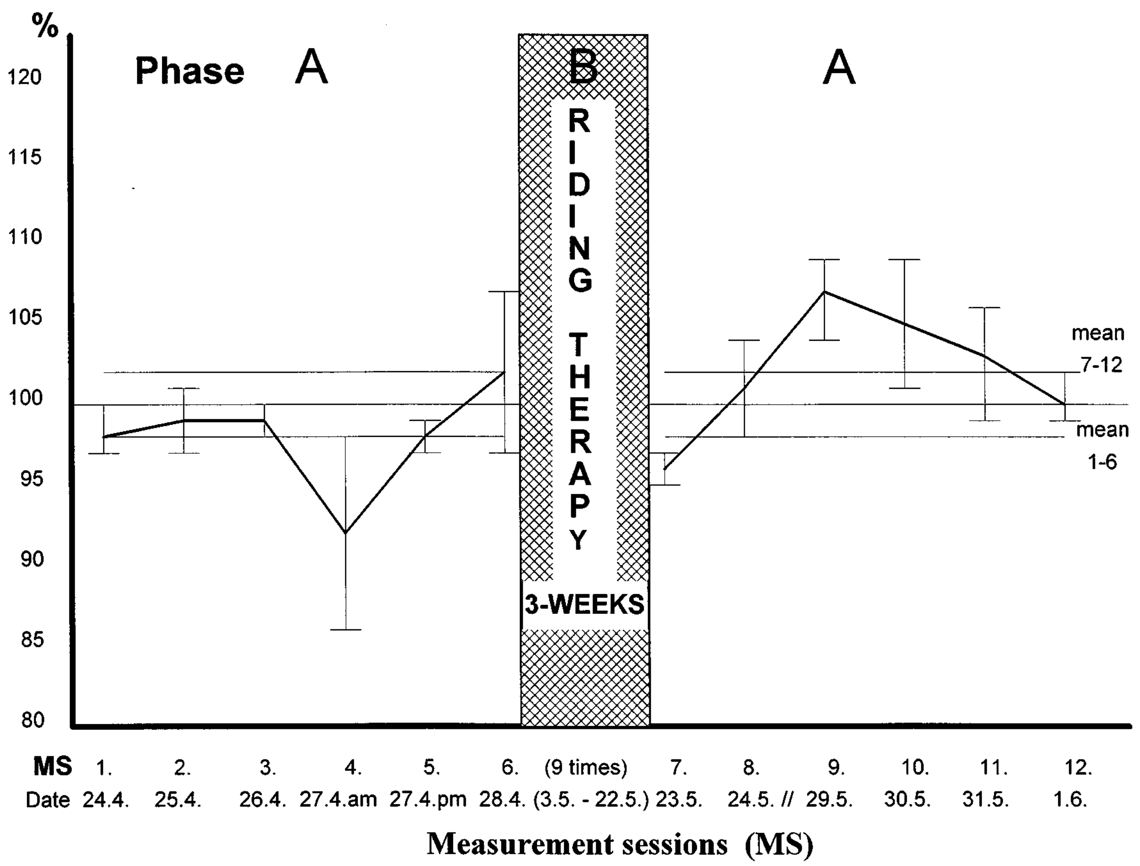

FIGURE 20. Helen: Cadence before and after riding therapy program
- the mean, and the highest/lowest score in each session

The 5,4 % increase after recovery may show that there is a minor effect on cadence. There is still a doubt due to the upward slope in the end of the first baseline and the high scores in the MS 6. Interesting is the shape of the slope after the intervention, which indicates a short effect and then withdrawal, but no conclusions can be drawn because of the short follow up time.

TABLE 18. Helen: Key figures of cadence

Mean 1-6 = 98,1 % ; mean range 5,6 % ; l/h 86,0 / 107,4 %
Mean 7-12 = 101,9 % ; mean range 4,8 % ; l/h 95,6 / 109,4 %

Difference = 3,8 %

Mean 7-8 = 98,8 %

Mean 9-12 = 103,5 %

Cadence/Helen:	
Mean 1-6	= 103 steps/min
Mean 9-12	= 108 steps/min
-normal range	103-150 steps/min

Difference of the means of MS 1-6 (97,3 %) and 9-12 (102,7 %) = 5,4 %

Note: percentages are relative to 100 % - the mean of all scores; the range is the variation within measurement sessions; l/h = the lowest / the highest score of the phase

Velocity:

Change in gait velocity is presented in the Figure 21 and the Table 19. The variation in velocity averaged within measurement sessions about seven percent in both baseline phases. There is a gap of over 20 % between the lowest and the highest score in the first baseline due to the extreme scores in cadence.

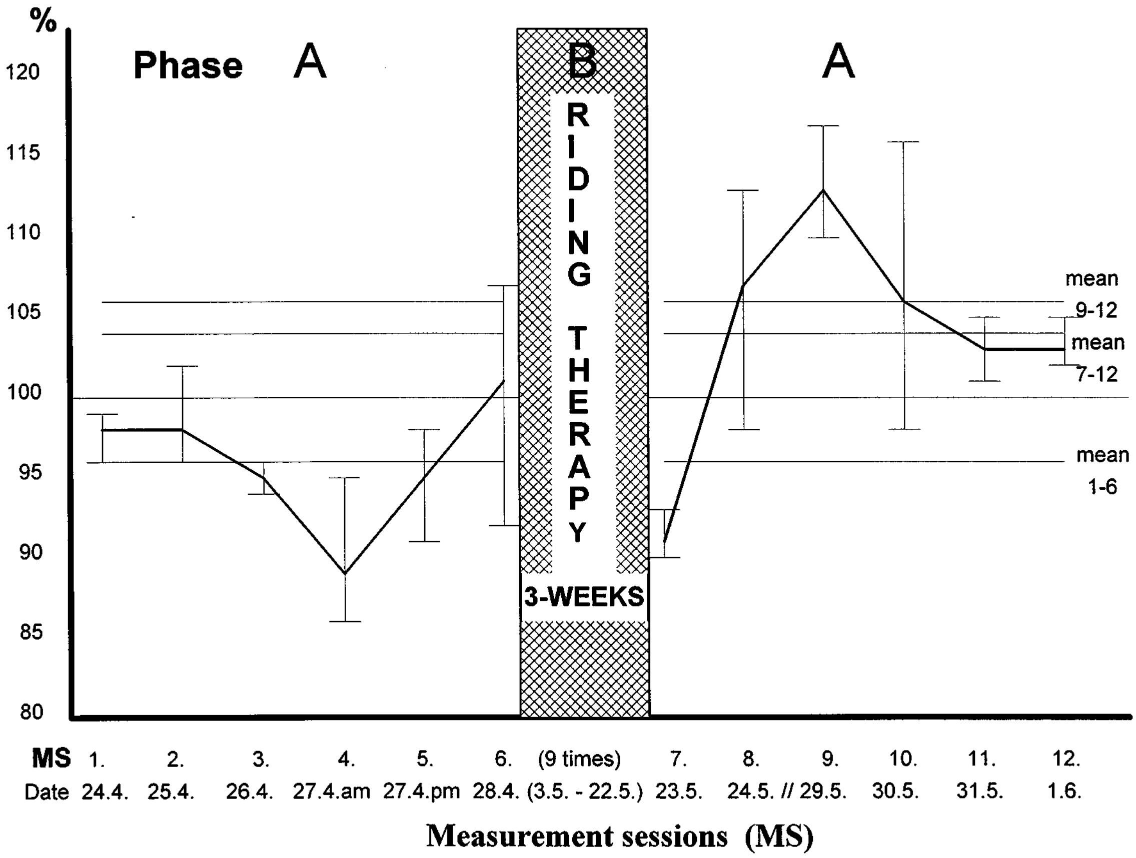

FIGURE 21. Helen: Gait velocity before and after riding therapy program **- the mean, and the highest/lowest score in each session**

In the baseline phase before intervention there was only one mean (MS 6) slightly over the total mean, and one peak score over the mean of the MS 7-12. On the second baseline there were only two individual scores under the 100 % line.

TABLE 19. Helen: Key figures of velocity

Mean 1-6	=	95,9 %	; mean range 7,1 %	; l/h	85,6 / 107,4 %
Mean 7-12	=	104,1 %	; mean range 6,6 %	; l/h	90,2 / 117,0 %

Difference	=	8,2 %
Mean 7-8	=	99,1 %
Mean 9-12	=	106,2 %

Velocity/Helen:
Mean 1-6 = 0,99 m/s
Mean 9-12 = 1,10 m/s
-normal range 0,90-1,62 m/s

Difference of the means of MS 1-6 (94,9 %) and 9-12 (105,1 %)
= 10,2 %

Note: percentages are relative to 100 % - the mean of all scores; the range is the variation within measurement sessions; l/h = the lowest / the highest score of the phase

There is a 8,2 % difference between the two baseline phases and over 10 % change after recovery, which is already seen in MS 8. The change of Helen's gait velocity seems rather clear in spite of the variation. A small question mark is the upwards slope in the end of the first baseline. It is explained by the peak scores of cadence.

The Figure 22 indicates that the changes in stride length seem to be relative to the changes in cadence, and there is a cumulative effect on velocity. Figure 23 shows that both of the components are equally responsible for the changes in velocity.

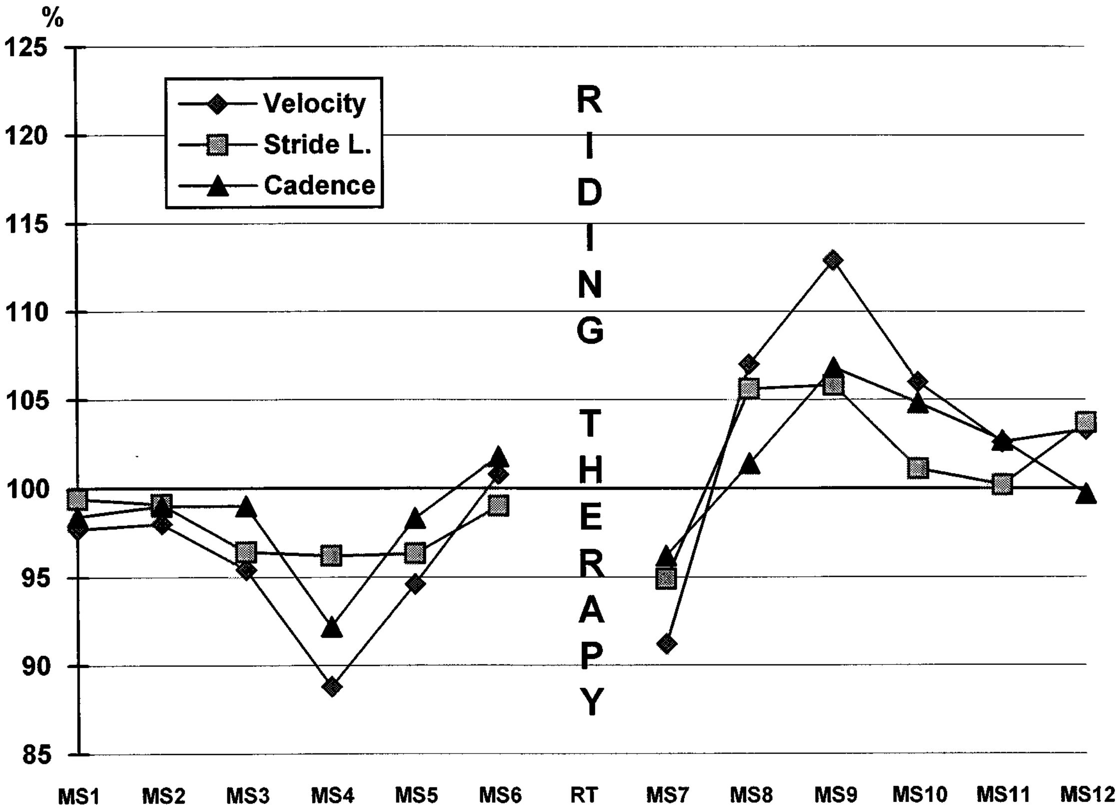

FIGURE 22. Helen: Comparison of change in gait velocity, stride length and cadence

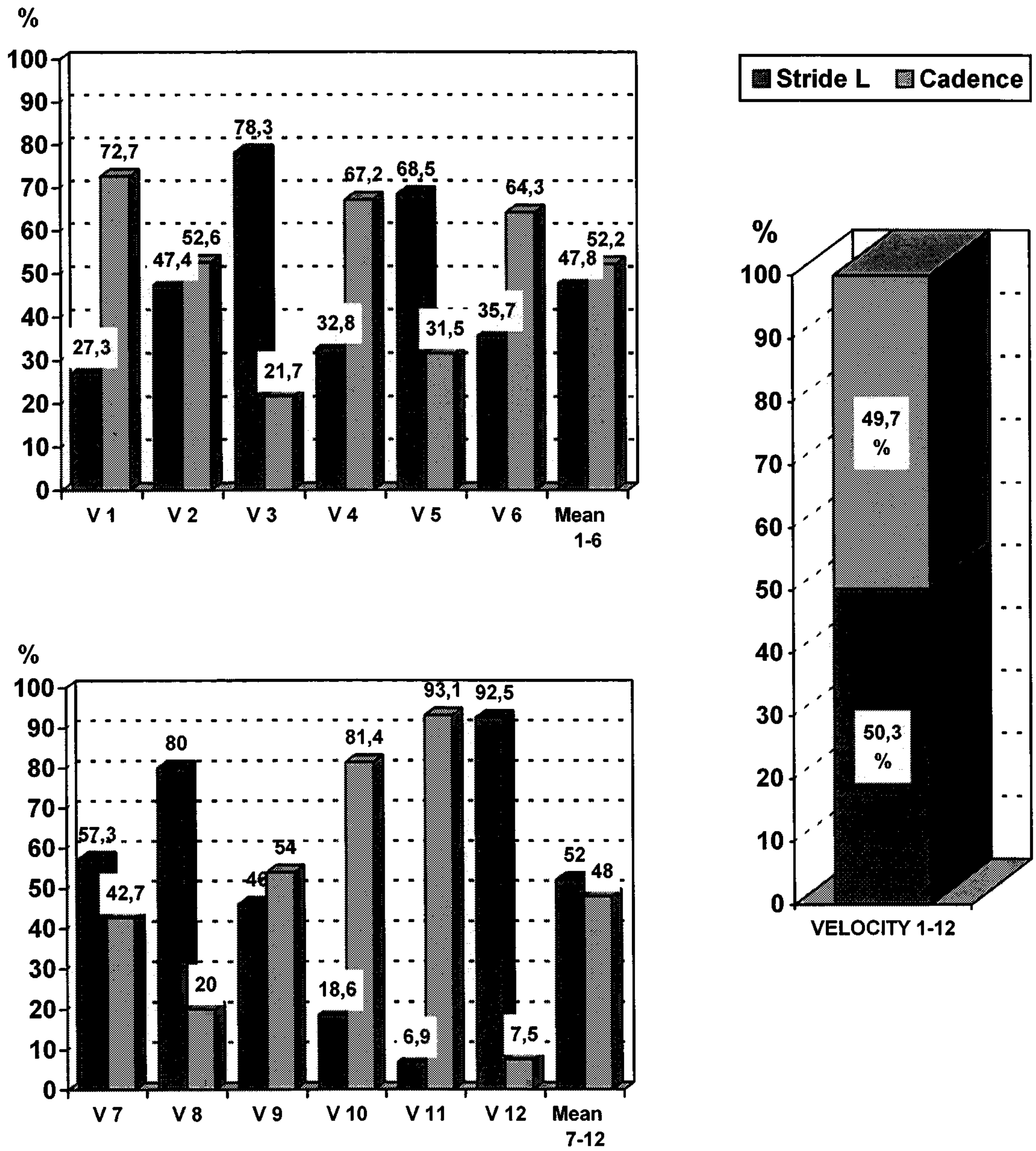

FIGURE 23. Helen: Change in velocity explained by its components: stride length and cadence

7.4. Anne: Change in stride length, cadence and velocity, and comparison of components

Stride length:

Change in stride length is presented in the Figure 24 and the Table 20. Anne's stride length is adequate when compared with the normal values. There is no clear change visible in the means despite the small increase. The variation in first baseline makes it difficult to interpret the change.

TABLE 20. Anne: Key figures of stride length

Mean 1-6	=	98,8 %	; mean range 5,8 %	; l/h	92,1 / 105,5 %
Mean 7-12	=	101,2 %	; mean range 3,9 %	; l/h	90,6 / 106,7 %

Difference	=	2,4 %
Mean 7-8	=	104,5 %
Mean 9-11	=	99,0 %

Stride length/Anne:	
Mean 1-6	= 1,32 m
Mean 9-11	= 1.40 m
Mean 7-8	= 1,44 m
-normal range	1,03-1,57 m

Difference of the means of MS 1-6 (97,4 %) and 7-8 (102,6 %)
= 5,2 %

<u>Note</u>: percentages are relative to 100 % - the mean of all scores; the range is the variation within measurement sessions; l/h = the lowest / the highest score of the phase

The slope after the intervention is downwards with higher scores in MS 7-8. The average stride in these sessions is 12 cm longer than in baseline. The effect shows specifically shortly after the riding. After the four days brake in testing the effect cannot be seen.

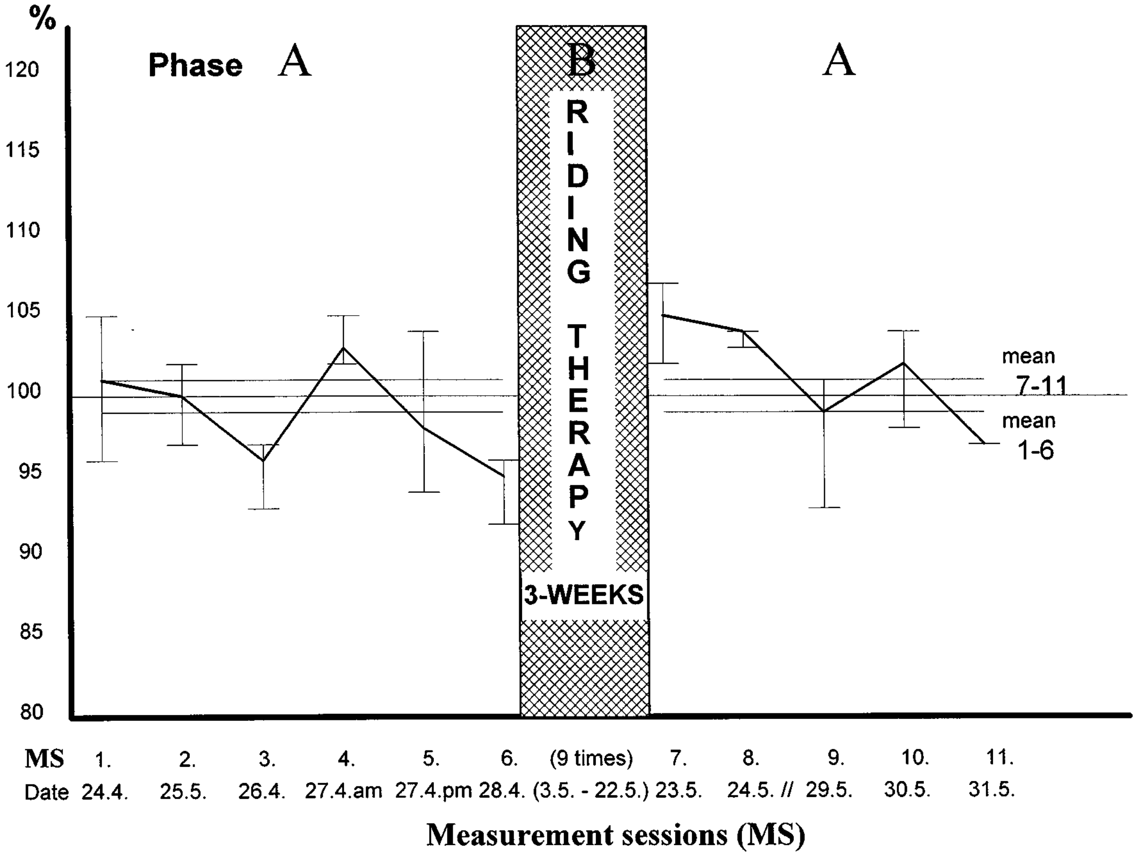

FIGURE 24. Anne: Stride length before and after riding therapy program **- the mean, and the highest/lowest score in each session**

Cadence:
Change in cadence is presented in the Figure 25 and the Table 21. Anne's cadence is within the normal values. There is no clear change visible in the means despite the small increase. The variation in the first baseline makes it difficult to interpret the change. The slope after the intervention is slightly upwards, thus, the opposite direction than the slope of stride length.

TABLE 21. Anne: Key figures of cadence

Mean 1-6	=	99,0 %	; mean range 4,4 %	; l/h	91,8 / 104,6 %
Mean 7-12	=	101,0 %	; mean range 4,9 %	; l/h	96,0 / 104,0 %

Difference = 2,0 %

Mean 7-8 = 100,2 %

Mean 9-11 = 101,6 %

Cadence/Anne:	
Mean 1-6	= 120,7 steps/min
Mean 9-11	= 123,1 steps/min
-normal range 100-144 steps/min	

Difference of the means of MS 1-6 (98,7 %) and 9-11 (101,3 %) = 2,6 %

<u>Note</u>: percentages are relative to 100 % - the mean of all scores; the range is the variation within measurement sessions; l/h = the lowest / the highest score of the phase

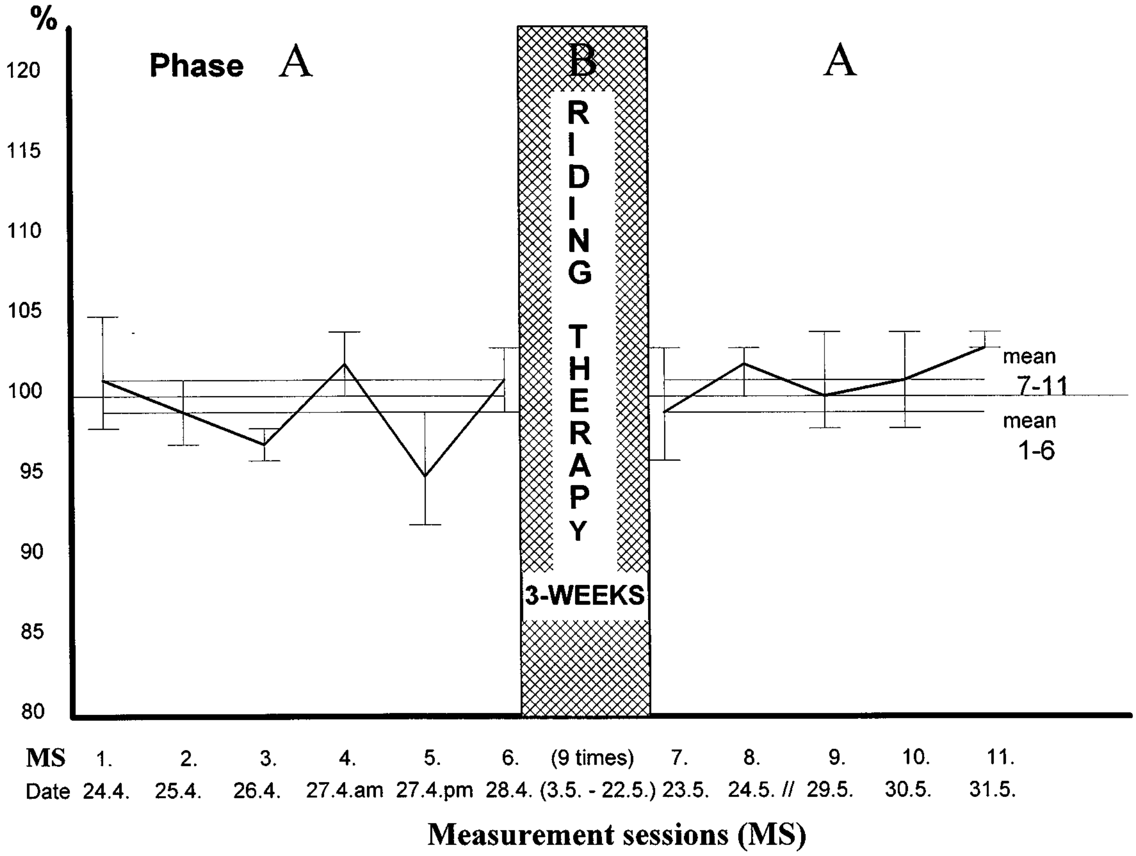

FIGURE 25. Anne: Cadence before and after riding therapy program
- the mean, and the highest/lowest score in each session

Velocity:

Change in gait velocity is presented in the Figure 26 and the Table 22. Anne's velocity is adequate when compared with the normal values. There is a small increase in the means, but no clear change visible in the graphic display. The large variation in the first baseline makes it unreliable to interpret the possible change.

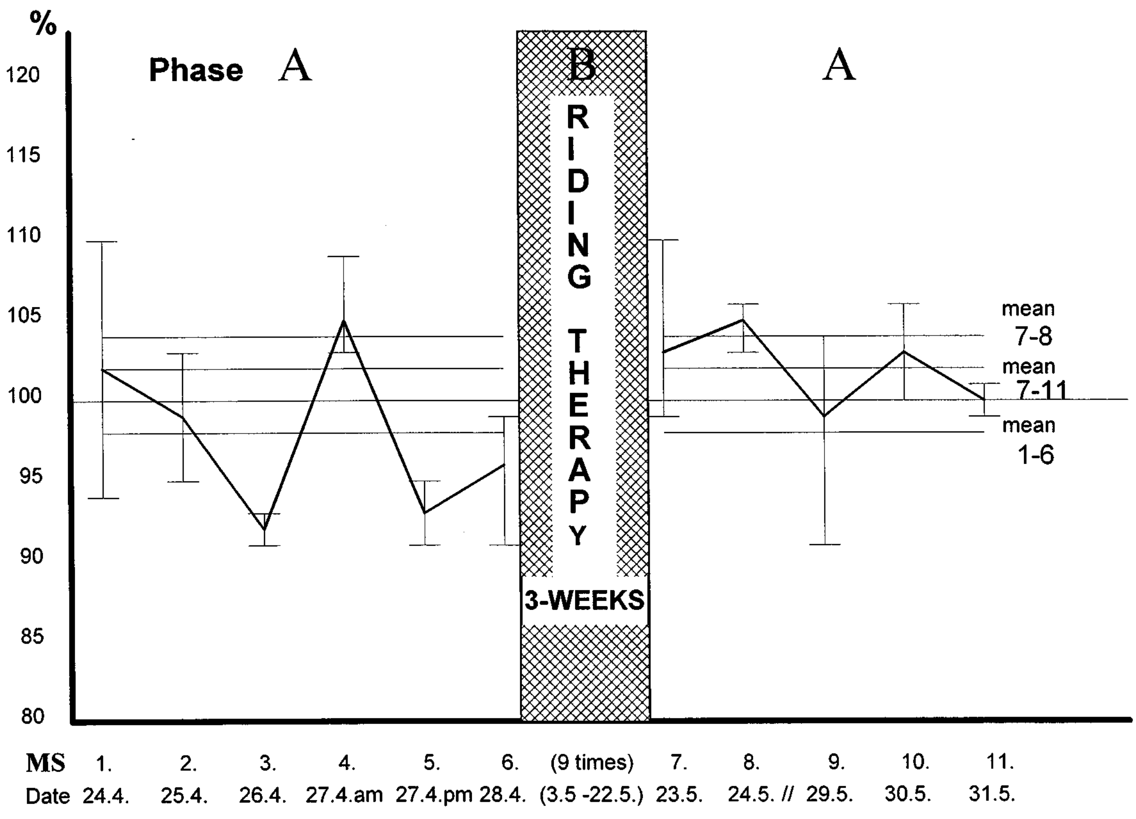

FIGURE 26. Anne: Gait velocity before and after riding therapy program
- the mean, and the highest/lowest score in each session

TABLE 22. Anne: Key figures of velocity

Mean 1-6	=	97,8 %	;	mean range	7,4 %	;	l/h 90,7 / 109,6 %
Mean 7-11	=	102,2 %	;	mean range	7,6 %	;	l/h 90,6 / 109,6 %

Difference = 4,4 %

Mean 7-8 = 104,2 %

Mean 9-11 = 100,5 %

Velocity/Anne:	
Mean 1-6	= 1,37 m/s
Mean 7-11	= 1,43 m/s
Mean 7-8	= 1,46 m/s
-normal range	0,92-1,64 m/s

Difference of the means of MS 1-6 (96,8 %) and 7-8 (103,2 %)
= 6,4 %

Note: percentages are relative to 100 % - the mean of all scores; the range is the variation within measurement sessions; l/h = the lowest / the highest score of the phase

The slope after the intervention is downwards, with higher scores in MS 7-8. It may indicate (as in stride length) that there is an effect that is showing specifically shortly after the riding. Since there are two means (MS 1 and 4) in the first baseline on the same level, it is not reasonable to state any effects of intervention.

The Figure 27 indicates that the changes in stride length are somewhat relative to the changes in cadence, and there is a cumulative effect on velocity. The Figure 28 shows that both of the components are responsible for the changes in velocity. The combined effect on Anne's gait velocity is slightly more often cumulating than annulling, but the stride length is more responsible for the change in velocity. Of all changes in velocity the stride length is explaining about 60 %. Especially in MS 7-11 the small changes in cadence are responsible for the difference.

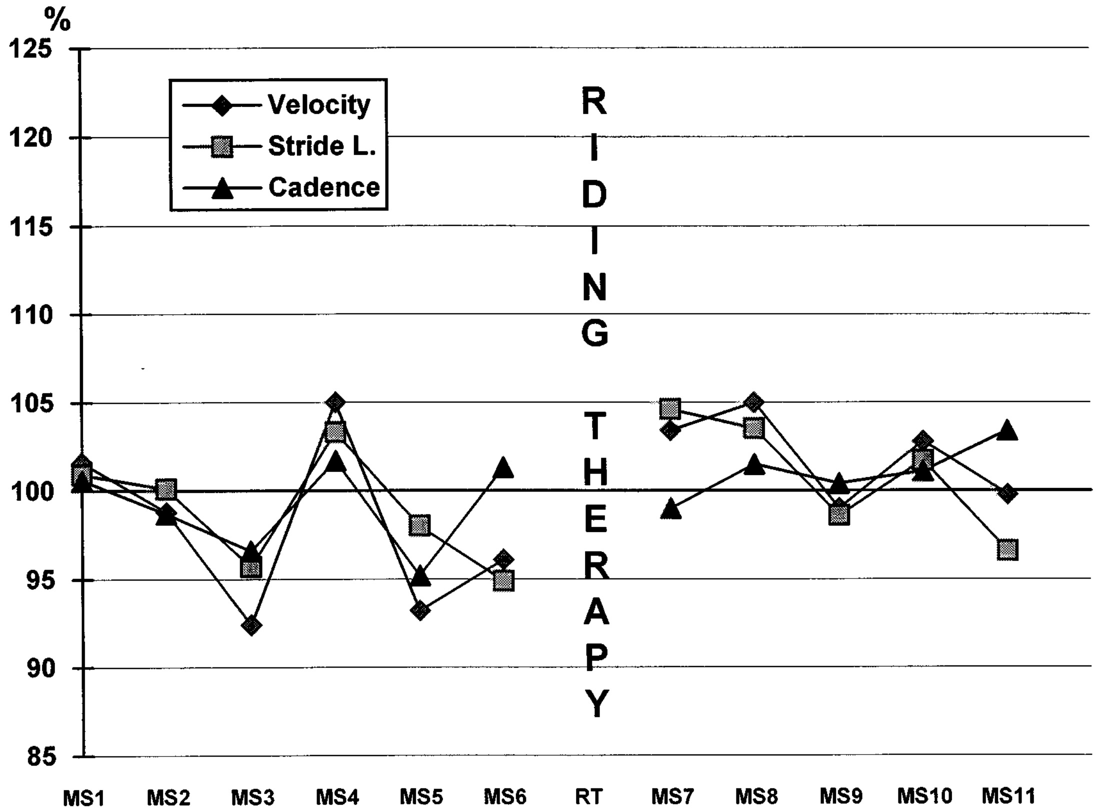

FIGURE 27. Anne: Comparison of change in gait velocity, stride length and cadence

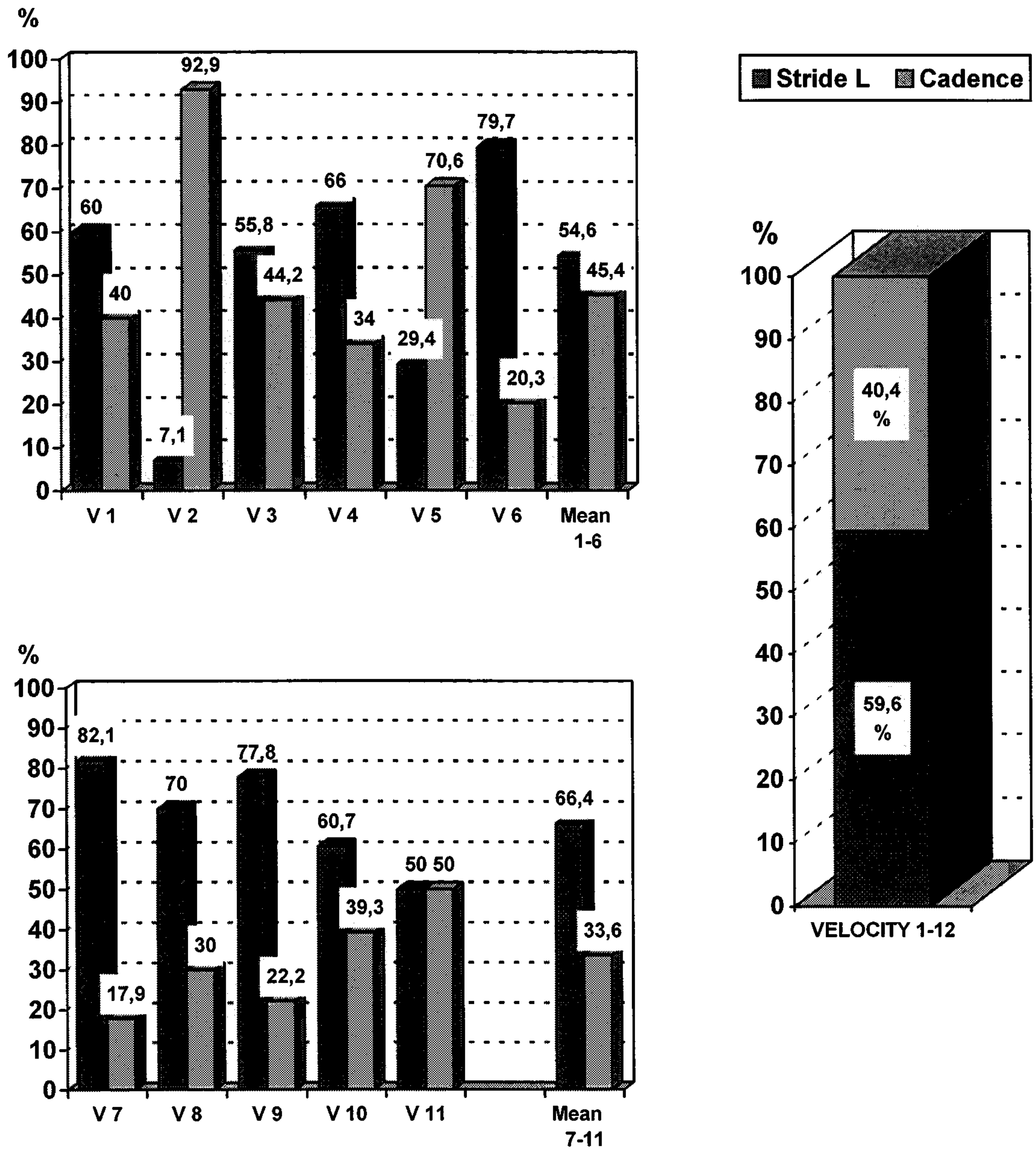

FIGURE 28. Anne: Change in velocity explained by its components: stride length and cadence

8. DISCUSSION

The great variability in performance was a striking and common feature in the results of all subjects. Another characteristic of the three children with more severe physical impairment (Donny, Jim, and Helen) was that there seemed to be a clear fatigue effect on gait. This can be seen in the two measurement sessions (7 and 8) just after the riding therapy phase. Also there was an evident recovery from the strenuous exercise and improvement in gait parameters when compared to the baseline before the intervention. These features are visible in the similar slopes of stride length and velocity of Donny, Jim, and Helen. Only exception was Anne's least restricted gait, results of whom showed reversal slope. Also her second baseline means of the gait parameters were higher than in the first baseline.

All the children improved their gait with increased stride length: at least 50 % of improvement was explained by this named factor. The improvement in stride length is clearly visible in graphic displays of Donny, Jim, and Helen. Also cadence was increased in all children after the therapy, but the improvement was more difficult to detect from the graphs. The change was not as logical as in stride length.

8.1. Subjective analysis of videotapes

Subjective analyses were the secondary purpose of the study. The quality of gait was evaluated from the videotapes by three physiotherapists. Two of them were NDT (Neuro Developmental Treatment) trained physiotherapists. All three were experienced in cerebral palsy. They evaluated the children's gait without any formal observation protocol. The observers were aware of which gait assessment was before and which after the riding therapy phase. They were to present the details of quality that was clearly visible. This additional subjective information is useful in discussing the possible causes of improvement in function that was measured quantitatively, and relating this study more into the practice. This information should not be taken as scientific facts. That is because of the informal protocol and because the evaluation was based only on four videotaped measurement sessions (MS 4, 6, 8, and 10).

The results are discussed individually. It is hazardous to make generalizations to other individuals and across different types of cerebral palsy. This is typical feature of single subject study. Generalizations may be possible only after replications. Important is to remember that the results show only the short term effect on gait.

According to the written notes and the videotapes, it seems that **Donny's** walking before the riding therapy program was more unconfident than after it. Before the intervention there were some falling and stumbling but none after it. On the contrary the walking seemed easier and more relaxed in the second baseline phase. This is in accordance to the quantitative analysis.

The conclusion can be drawn that the riding therapy improved Donny's walking markedly. The short time effect was shown. The change in velocity is an evidence of functional improvement of gait. The change was explained mostly with the improvement in stride length, and less with the slightly increased cadence. This is an expected improvement in spastic gait, since a major functional problem is restriction in the ability to take adequately long steps. The clear increase in stride length is indicating the qualitative improvement of Donny's gait.

Observing the videotapes it can be concluded that after the intervention Donny has his center of gravity more over the base of support. This can be detected especially as decreased leaning forward with weight on the canes, and the canes are closer to the body. This has been the goal of Donny's gait training in physiotherapy. It was also noticed that there were differentiated movements in the pelvis and the trunk after the intervention. These were not visible before the riding therapy phase. There is decreased internal rotation of the right hip and, thus, improvement in the whole leg function that is seen best as decreased 'toe in' positioning in stance. This allows a longer step length with his right leg. Also it was reported less flexion in the lower extremities and decreased protraction in shoulders.

Most interesting fact was that these named improvements could be observed also in the MS 8, which had low scores in gait parameters. This gives a reason to hypothesize that there was improvement in coordinated function, but the physical fatigue affected on the muscles and restricted the walking.

The improved gait can be observed very clearly in the MS 11, which represents Donny's best performance. Even the gait symmetry is visibly of better quality in this session. The stride length is improved and the step length ratio is more even. The right foot is advancing more adequately and passing clearly the left foot. The left-right step length seems to have increased more when compared to the right-left step length.

The physiotherapist of Donny (not involved in the assessments) reported that she had to give up the weekly gait training with Donny when the riding therapy program had begun. This was because the aching and strained muscles made the gait training impossible or useless. It began again after the riding period was over. Donny's physiotherapist also reported that after the riding therapy program, for the first time ever, Donny was able to maintain balance when standing unassissted. There was, quote, "surprising improvement in standing balance." She also reported that her personal impression was that the walking skill had improved and that Donny clearly benefits of the combined treatment approach of physiotherapeutic exercises and riding therapy.

There was rather evident improvement in **Jim's** gait due to the increased stride length. The stride length did not show very great variation and there was a clear upward slope after the seven day's recovery from the strains of riding. The slightly increased cadence reinforced the effect that is visible in scores of velocity.

According to the video observations and written notes during assessments Jim's walking was easier and more relaxed after the riding therapy program. Before the intervention he leaned more on his walker, and the weight was on his arms. After the riding phase the weight was less on arms, and clearly more on the legs than before. There seemed to be less crossing of the feet and better rhythm in walking. Jim has been very motivated in training his walking and has progressed fine after the assessments, and now (after more than a year later) is walking with canes.

Although **Helen's** gait was close to normal values, there was an improvement in stride length and velocity. Also the cadence was increased after the intervention, and it explained about 50 % of the changes in velocity. The change took place after one day's recovery from riding, which is visible in MS 8. MS 7 showed the fatigue effect also on Helen's gait.

Helen's athetotic gait was more difficult to evaluate than the spastic gait of the boys. There are many small varying details occurring during the walking, which are difficult to differentiate. The few walks observed from video screen did not give a sufficient basis to locate the change when compared the quality before and after intervention. There was a clear difference between the best and the worst trials, but of the best two walks one occurred before and the other after the riding phase. The worst walk took place before the intervention, but the rest of the trials could not be ranked.

There was no clear restriction in the motor function of **Anne's** gait. The quality and the changes in walking seemed to be more due to her moods making the measurements and interpretations unreliable. For example, her posture and the absence or presence of reciprocal arm movements were depending on her mental stage. No change could be detected when the quality of walking was observed from the videotapes. The quality of the trials seemed to be equally changing during the two baselines. The conclusion to be drawn from Anne's results is that the riding therapy may have had an immediate or a very short term effect on her gait. The riding therapy for Anne should be more in accordance with educational and psychosocial approach. She would benefit of riding lessons in a group with nondisabled youngsters.

It is important to compare from videotape the pre- and post-performances to decide, if the changes in gait parameters have therapeutic value. This subjective evaluation method provides a professional opinion from the therapists responsible for the children's "everyday life" rehabilitation programs. This gives further dimension for the interpretations of clinical significance of the change. (Kazdin 1982, 255.) In this study, though, the changes were supposed not necessarily to be visible and possibly show only in quantitative analysis. This was the basic assumption when choosing the primary method (quantitative analysis). Complexity of arranging controlled video analysis and controversy concerning the reliability of observation was the basis of giving a minor emphasis on videotape evaluations.

It is very difficult to make reliable observations of such complicated motor performance as human gait. Especially unreliable is to analyze the quality of gait in cerebral palsy with multitude of deviations. Some years ago I was participating as one observer of many in a project, the purpose of which was to constitute a tool to analyze segment by segment individual gait deviations of children with cerebral palsy. The analyzing process was very time consuming and obviously the complexity decreased reliability.

Even if an expert can record the deviations in gait, it is almost impossible to observe reliably the detailed changes in the quality of walking, if they are not very large and visible. Overall image can be evaluated, but the segmental and joint by joint analyses may be purposeless, at least, without professional laboratory conditions and complicated analyses.

It is not very reliable in cerebral palsy to compare just a few walks before and after intervention because the intrasubject variability is so great. Even during a single walk there may be several incidents causing additional deviations in gait pattern: scissoring, occasional poor clearance of swing leg and stumbling, abnormal reflexes, poor positioning of a cane, correcting the direction of a walker, etc. If any conclusions are to be made, then first one has to find out the 'true gait' at one moment, and furthermore the true gait in another moment (for example, after an intervention). The hypothetical true gait would be the mean quality of performance excluding all accidental deviations. The degree of functional improvement could be the decrease of accidental variables of gait -- complicated and time consuming process indeed.

A quantitative approach to gain information, for example, of the improvement in symmetry of walking, is to measure the step length ratio and other quantitative temporal and stride parameters. In the context of this study it was considered too time consuming and unreliable, but in a gait laboratory that information is received simultaneously with other parameters. It has to be noted that the gait laboratory assessments may cause other reliability problems, especially in children with neurological deficits.

8.2. Design and the subjects of the study

Organizing the empirical phase of this study was depending on voluntary cooperation of several key persons. The multitude of gait assessments was one effort. The total number was over 180 measured trials plus pre testing. Also economically organizing the riding therapy over 20 hours with transportations would have been impossible without voluntary work and supporters. Seven different persons were involved in the procedures of this study, and Ruskesuo school contributed its valuable support.

The riding therapy program was realized for all the subjects as planned. All the children became more confident and skillful on horseback towards the end of the phase. The individual notes of the riding sessions are presented in Appendix 9. Although the children were not too enthusiastic over the gait assessments, there were no signs of serious lack of motivation towards the end. The orientation remained adequate and the atmosphere was filled with good sarcastic humor. This was to the credit of all those who were involved in organizing or participating in this research project, and showing an excellent attitude. Children were always on time in the gymnasium. Only Anne had to be absent one time from the gait assessments (MS 12). Considering the tight schedule we were very fortunate in organizing the program.

Donny was very solid in his participation in the riding program and assessments: not very enthusiastic, but seriously involved and doing his job well. He liked being with the group -- obviously more than the riding itself. Especially in the beginning he was slightly afraid of riding and nervous, but more confident towards the end and seemingly enjoying it more.

On the fifth gait measurement session (MS 5, second trial) he fell and the next trial after falling was possibly cautious, as it was written in the notes. This incidence can also be seen in the results as his worst score in gait velocity. The trial should have been excluded immediately during the assessment, but since the style was not visually very much out of line, it was not really detected before the calculations and the quantification gait parameters. At that point it was naturally unethical to manipulate the data. On the MS 10 Donny complained that he was tired because of flu. The flu may have affected his performance, even though the scores were not visibly out of line. In the gait assessments Donny had to give his best in every trial because of the great difficulty in walking.

Jim is very clever boy, a professor type, pondering everything carefully. Also he is an occasional joker. He liked participating in the program for the same reasons as Donny. One reason was, as the boys joked, that it was a perfect excuse to skip the afternoon of the schooldays. Jim said afterwards that he would like to continue the riding, but "only because it is good for his walking" -- the walking is difficult enough for him to be taken seriously.

It was considered essential to supervise closely the quality of performances in the assessments. On some occasions Jim was told by the physiotherapist to pay more attention to the quality of walking, and not to walk hastily. This took place in the MS 6, and MS 8, 9, 10 and 11. Although the faster pace may have been the effect of the intervention, it was originally decided that the performance has to be within the limits of their personal normal quality of proper walking. Even if this may cause some reliability problems, the problems are less than in uncontrolled trials. It can be stated that the control had to be used more after the riding therapy phase. Hence it was at least not increasing the change in gait parameters. It would have been more controversial for interpreting the results, if the emphasis of the needed verbal intrusions had been before the therapy phase.

The third trial of MS 8 was strikingly hasty and out of line, and was immediately decided to disqualify. Jim was tired, and there was only two successful trials recorded in that session. Jim's second trial in MS 9 was very slow when compared with the trials before and after. The reason was most probably that the physiotherapist asked him very strictly 'not to hurry'. On the MS 2, which was his worst performance, Jim did not wear his DAFOs, since he had forgotten them home. According to the physiotherapist that may have affected to some degree on the scores, but not radically in his case.

Helen was the most experienced in riding of the four subjects. She enjoyed very much the riding program and became emotionally very involved with the horse she rode. She was also very fond of the riding therapist. She is a very clever girl, reliable and devoted to all projects that she begins. Motivating Helen to go through all the assessments was not a problem.

It has to be taken into consideration that Helen wore different DAFOs on the second baseline phase. She began to use them in May 19, which was four days before the gait assessments. Helen's own impression was that there was no difference when compared walking with the old ones. She had not grown height during the last year, and the old orthosis had not become too small. The physiotherapist's opinion was that wearing the new orthosis would not affect on Helen's gait parameters, since the new DAFOs were similar to old ones and Helen was already used to wearing them before the second baseline begun. Still, this uncontrolled variable is a hypothetical threat to the reliability. Ethically it was thought to be wrong to ask her to wear the old DAFOs until the end of assessments. Wearing them only in the assessments instead of the new orthosis would have been worse solution considering the reliability.

Anne enjoyed being with the group and riding. Even though her mental potential is not in the same level as the others in this group, she was accepted well by the others. Her capability to understand the reason for this project and realize her part in it was limited. This could have caused motivational problems in gait assessments towards the end, if the rest of the group would not have given a fine example to her. At that time her moods were changing quickly and she was constantly complaining back pain. Her motivation towards all tasks was changing irrationally. When Anne was leaving for riding she sometimes complained that she had to go, but on the days with no riding she was frequently asking about the next time.

Because of the above named reasons and her minimal physical impairment, she was not originally selected in the group of this study. She was replacing another girl who was chosen to participate, but had to cancel at the last moment. Anne's gait was close to normal. The major deviations and variability in walking were mostly depending on the fluctuations in her mood. She had to be constantly reminded to concentrate on her performance. She was not attending the MS 12, since she was not at school due to personal reason, which was not illness.

8.3. Considerations of validity and reliability

The design had its limitations, but it satisfied the experimental requirements at this stage. The purpose was to find out, if it is reasonable to believe that there is a functional outcome of riding therapy on gait. It has to be remembered that there are no previous studies of the effect on gait in children with cerebral palsy.

Rintala (1988) studied the effect of intensive physical training program on children with cerebral palsy. According to the experiences of his study, Rintala (1988, 108-9) has two important suggestions for this type of setting: including a reduced number of dependent variables that are to be measured, and constituting the basic level of performance in the first baseline with 5-6 separate measurement sessions. This study fulfilled those recommendations. The baselines were long enough to reveal the basic level without any intervention, and the measurements focused only on three variables describing one important function. Shorter baselines would have caused serious problems for interpreting the results.

The visual analysis of graphic displays proved to be valid method for interpreting the results in this study. According to Kazdin (1982, 242-4) "the use of statistical analyses for single-case data has been suggested primarily to supplement rather than to replace visual inspection." Statistical analysis for single-subject data is considered important when the changes in performance are subtle and minor, baselines are unstable, or intrasubject variability is increased. Statistical test may identify as significant the effects of variables that ordinarily would be rejected through visual inspection. (Kazdin 1982, 241.)

In this study it was unnecessary to use statistical analyses, since the graphs were informative enough for interpretations. There is also some controversy over the use of statistical analyses, which pertains to the appropriateness of various traditional tests for single-subject research. There are some assumptions that these tests depend on, and may be violated by the single-subject data. (Kazdin 1982, 242.) For example, if t-test is used, **autocorrelation** must be computed in order to find out, if there is serial dependency involved in the data. (Kazdin 1982, 248; Kazdin 1984, 287-8.)

There is statistical analysis that may be sometimes used for single-subject data. **Time series analysis** compares data over time for separate phases. Time series analysis depends on a relatively large number of data points, which sets a limitation to its use in most applied studies. (Kazdin 1984, 296-301.) There is also method that is simpler to calculate and often used in addition to analyses of the graphs. **Split-middle technique** describes the rate of behavior change over time revealing the linear trend in the data. It characterizes the performance in one phase and predicts the performance in the next phase. (Kazdin 1984, 312-313.)

In split middle technique the effect is supposed to show a change of trend when intervention is begun. That was not relevant in this study. The phases to be compared in time series analysis and split-middle technique should be in successive order. In this study there was an intervention phase without assessments in-between. The use of statistical analysis was too controversial with the setting of this study.

Organizing gait assessments during the intervention phase was one difficult question when planning the methods. The decision not to assess gait was based on the experiences of the pilot testing of procedures. That conclusion was supported somewhat by the results of MS 7 and 8 in the next two days after the riding therapy phase. The fatigue did show in these scores. It seems evident that during the intensive riding therapy the quantitative scores of walking were decreased in the three children with more severe impairment. Along with this, for example, Donny's muscles were too strained and he was too tired to train his walking in physiotherapy. The short intervention phase minimizes the possibility that the maturation would affect the results. Although the decision was a necessity in this design, an ABA design should include, if possible, assessments in all phases. In this study the reliability of the results is increased by this fact that the three children showed similar recovery in their scores.

The assessment tool was found very useful and valid in its relative simplicity to measure the effect of intervention on gait parameters. The reliability of the assessment procedures was derived from literature, which has found this type of measurements and analysis highly reliable. Organizing reliability testing specifically for this study was considered artificial and unnecessary. It has to be stated that the test- retest reliability, which is drawn from healthy subjects, is an evidence of the usefulness of the assessment, but cannot be relevantly tested from children with cerebral palsy with large variation in motor performance. One has to note that a mental impairment may influence on test- retest reliability. Interrater reliability would be possible to determine also with this kind of subjects. Since there are no technical differences when measuring impaired or healthy, the further reliability testing was considered to be in vain.

In cerebral palsy it is important to determine beforehand in what part of the foot to measure the footprints, if the heel does not frequently meet the ground during the stance phase. If this is unclear, it will cause a threat to reliability, especially, if individual step lengths are to be measured. In this study we were very careful with this detail, in spite of the fact that in ten meters distance this would have a minor effect on results. From videotapes it was checked afterwards (observing about 30 trials) that there was not a single mistake in calculating the strides.

Walking is a skill acquired during a long period of time, and based on long term training and maturation. One cannot expect abrupt and great improvements in gait. Sudden changes can be expected to have some explainable external reason. This might be an illness or an operation and recovery from it. The healt status for all the subjects was controlled and found to have been good for past months before the assessments. Jim had well recovered from the surgery, and his gait was considered to have been stable for some time before the first measurement session. It is reasonable enough to be confident that the visible change in quantitative gait parameters is caused because of the intervention, if no further confounding variables exist. Literature review did verify the validity of the temporal and stride parameters that can be related to improvement of motor performance in human gait.

The question of reliability has to be discussed. In this study it was possible to record the disturbances in the process and most probably the major confounding variables. Minimizing the undesired extra variables was the purpose, but as described in the following, it seems almost impossible to control all the variables. This is often also an ethical question. At least in a well organized single subject study the confounding variables are possible to record for discussion.

8.4. Importance of this experiment and suggestions for future study

The results were analyzed visually from the graphs, which is the primary method used in single subject study. The comparison of the components proved to provide valuable additional information of the changes in velocity. Since this analyzing method was developed by the experimenter for this study, the validity of the method and possible development may be a topic of further discussion.

This study presented the short term effect on gait in the subjects. Even though it showed the positive effect on gait of three children, replications are needed before it is possible to generalize the results. The importance of this study was also in giving basis for planning more comprehensive method. Long term effect is a topic to be studied in the future, since the change of motor performance may be or not be permanent.

Suggestions for a single subject design for future study:

-systematic replications of the design

-selecting subjects from a more homogenous group of children with same type of cerebral palsy -- probably it would be spastic diplegia

-using the same assessment procedures possibly along with some assessments in gait laboratory

-a longer period of first baseline A to measure more reliably the level of performance (i.e., six or more measurement sessions, during six weeks or more)

-intensive riding therapy phase of about six weeks with about 15 riding sessions, and measurements during the intervention, if possible

-flexible using of a single-subject research design including longer follow up in baseline A2 -- the length could be determined during the follow up according to the requirements to show relevant change

To this ABA design it could be added also another riding therapy phase (B). The new treatment could be introduced after the effect has clearly decreased. If the effect would remain its level, the second intervention phase would try to change the level again. It is though possible that reaching the next stage relatively soon may be difficult, because it is very probable that the treatment is most effective when introduced the first time. This longitudinal study might include two interventions with a time interval of one year. This ABABA design would be very informative and meet well the requirements of reliability.

Forming the baseline could be revised slightly considering the scoring system. Instead of calculating the mean of scores of measurement session, the best score of many trials in one session (daily optimal score) would represent the baseline score. In this way the warming up and fatigue effects would be eliminated, and supposedly the "most true" and comparable score (or close to it) would be attained. In this study it was shown the great variability in performances (important to verify) which is interesting and valuable information when considering the future planning of research. Using the best score would be a 'lawful,' reasoned, way to eliminate the confusing within assessment variation from the results. The variability in the performance of the subject would be seen in day to day variation (and maybe in separately reported figure of mean daily variation for discussion).

The reliability is often increased also by using multiple baseline designs. The multiple baseline across relatively homogenous subjects would introduce the riding therapy phase for each subject in sequential order and after different lengths of baselines. The effects should show on each subject after the intervention has begun. The design was not suitable in this study because of the heterogeneity of the subjects. The effects of intensive riding therapy probably will appear only after the therapy phase -- how this fact affects the design has to be considered carefully. Furthermore, the effects may be permanent, which also sets requirements for selecting the method.

Another secondary purpose of this study was to present a practical tool for the therapists to assess the outcome of riding therapy. The study gave sufficient evidence of the validity of the gait assessment procedures used in this research. It showed the usefulness and relative practicality of this method to measure treatment outcome on gait. It was also valuable to experience the cooperation between the different professions with combined interests. It is important when working in the field of adapted physical activity (APA) to understand the different approaches profoundly: aspects of medical, therapeutic, educational, care taking, etc., are combining interest to benefit the development of the children with cerebral palsy.

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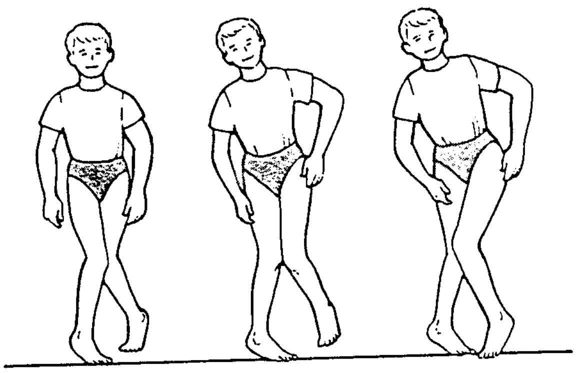
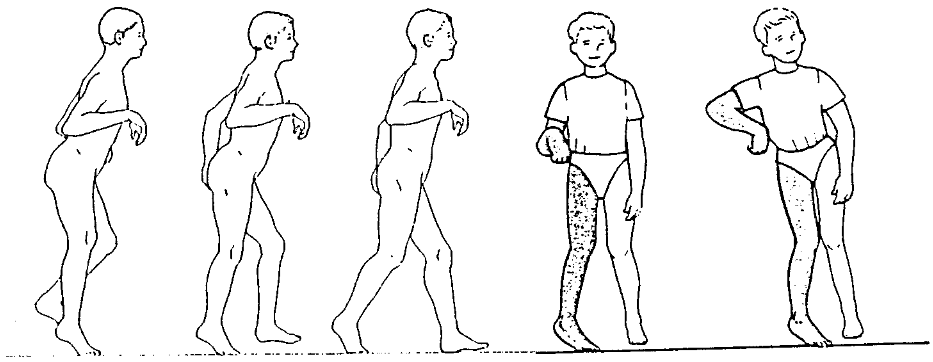
LIST OF APPENDIXES

Appendix 1. Characteristcs of gait in cerebral palsy

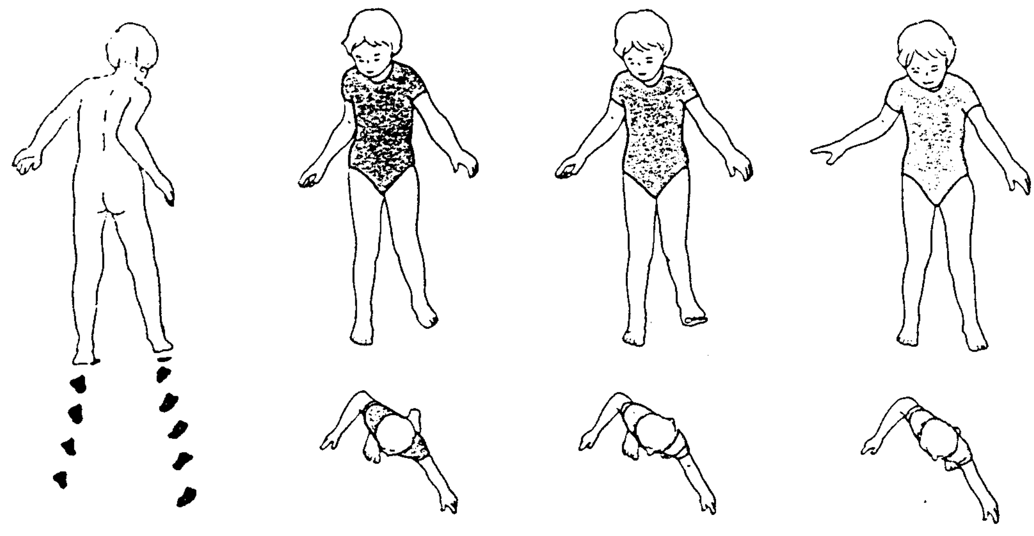
1.



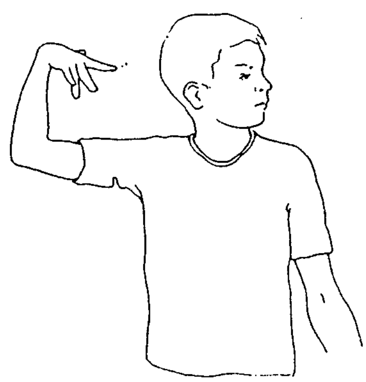
2.



3.



4.

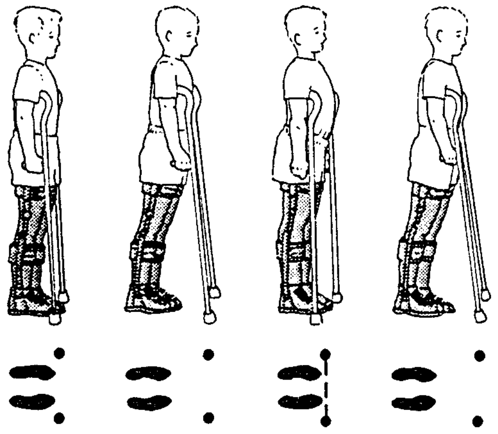


1. Diplegia spastica (mild quadriplegia)
2. Hemiplegia
3. Ataxic gait
4. Athetosis, dystonic type: posturing of upper limb

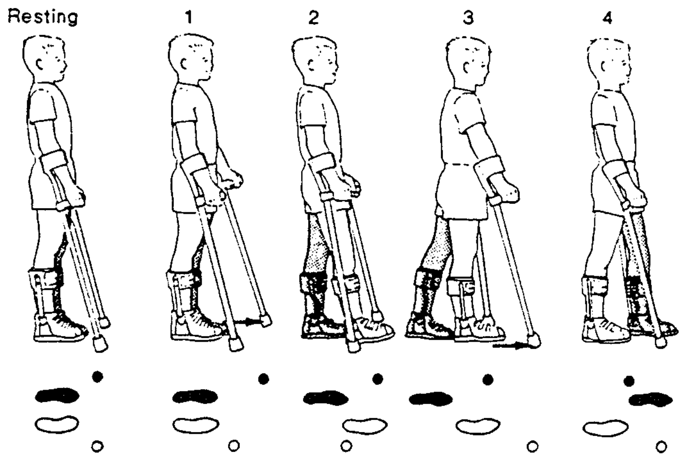
(Bleck 1982; Sherrill 1993)

Appendix 2. Examples of gait with two crutches

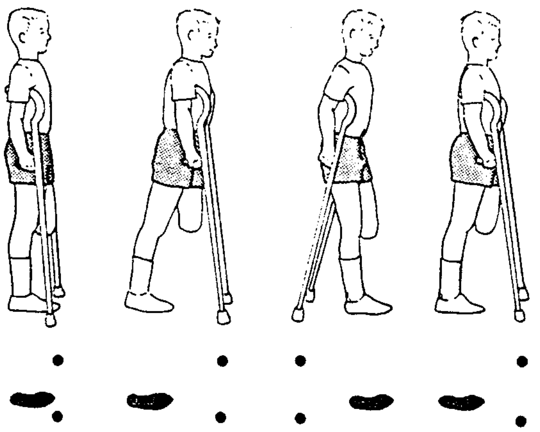
1. Swing-to gait



2. Four-point gait



3. Swing-through gait



DO NOT CONFUSE SWING-THROUGH WITH SWING-TO.

(Sherrill 1993, 280)

Appendix 3. Planning treatment in riding therapy

Examples of the process of planning goals and treatment in riding therapy of children with spastic cerebral palsy (CP). (Applied from: case examples, treatment goals, and treatment plans from Taufkirchen et al. 1990; details of riding therapy plan from Rautio-Honkavaara 1996)

RIDING THERAPY IN TREATMENT OF CHILDREN WITH SPASTIC CP			
CASE	TREATMENT GOAL →	TREATMENT PLAN →	RIDING THERAPY PLAN
DIPLEGIA	Cooperative behavior in physiotherapy Erect sitting	-improvement in motivation -Inhibition of abnormal flexor pattern -activation of spine extension	-child's involvement in riding and realising the demands of achievement -horse's gait -riding downhill
HEMIPLEGIA left side	Improvement of gait Symmetrical posture Dynamic stabilisation of the spine	-weight shifting to the left side -increasing pelvic mobility: *mobilisation of lumbar spine and left hip -observing associated reactions	-vaulting /arching -advancing sideways -riding downhill -gait in collective frame
QUADRIPLEGIA non ambulatory	Stable upright posture Equilibrium reactions for walking Integration of sensory stimulation	-tone stabilisation -weight shifting -body awareness training	-straight forward and rhythmic gait -no stopping -riding hands free -acceleration/deceleration -reversing -complete turns -riding in various positions e.g., lieing on horseback sitting backwards or sideways etc. -verbalizing the position and directions

Appendix 4. Pilot-testing form

Nimi [redacted] Päivä 15/9 Kerta 15/18

I mittaus

A) MÄÄRÄLLISET MITTAUKSET

Mittaus	Matka	Aika	Askel	V/O-pit.	V/O-lev.	O/V-pit.	O/V-lev.
E 1.	9,80	13,81	14 paria	35,0 m	11,7	39,5	5,5
E 2.	8,68	13,02	13	30,2	18,9	30,7	9.4
E 3.		~~11,02~~	~~12~~				
J 1.	8,38	11,02	12	33,7	5.4	33,6	5,0
J 2.	8,61	11,20	13	35,5	16,0	33,2	7,8

B) RATSASTUS:

1) Miten toteutettiin: [illegible] tasaisesti

2) Kokonaisaika: [illegible] min 1h

3) Akt. ratsastus: 30 min

C) HUOMIOITA KÄVELYSTÄ JA KÄVELYYN MAHDOLLISESTI VAIKUTTANEISTA SEIKOISTA:

- [illegible]; [illegible] [illegible] kävelyn [illegible]
- [illegible] [illegible] [illegible]

D) MUUTA HUOMIOITAVAA:

⊗ [illegible] E_1 - E_2 mittausten välillä [illegible] [illegible] että kävely [illegible]

Appendix 5. Gait assessment form

Nimi: [redacted] Päivä: 23.5. (10-15 Kerta: Ret/ 1

MÄÄRÄLLISET MITTAUKSET

Mittaus	Aika	Askel	Matka	V/O-p.	V/O-l.	O/V-p.	O/V-l.
J 1.	31.02	40	10.31				
J 2.	26.65	36	10.10				
J 3.	25.85	36	10.10				
	25.55	36	9.54				

HUOMIOITA KÄVELYSTÄ JA KÄVELYYN MAHDOLLISESTI VAIKUTTANEISTA SEIKOISTA:

1) REHKON TUNTUISTA
RAUHALLISTA RENTOA KÄVELYÄ /AK

Allekirjoitukset: [signature] JUSSI METSÄRANTA, [signature]

Appendix 6. Normal ranges of gait parameters

Approximate range (95% limits) for general gait parameters in free-speed walking by normal *children*

Age (years)	*Cadence (steps/min)*	*Stride length (m)*	*Velocity (m/s)*
1	127–223	0.29–0.58	0.32–0.96
1.5	126–212	0.33–0.66	0.39–1.03
2	125–201	0.37–0.73	0.45–1.09
2.5	124–190	0.42–0.81	0.52–1.16
3	123–188	0.46–0.89	0.58–1.22
3.5	122–186	0.50–0.96	0.65–1.29
4	121–184	0.54–1.04	0.67–1.32
5	119–180	0.59–1.10	0.71–1.37
6	117–176	0.64–1.16	0.75–1.43
7	115–172	0.69–1.22	0.80–1.48
8	113–169	0.75–1.30	0.82–1.50
9	111–166	0.82–1.37	0.83–1.53
10	109–162	0.88–1.45	0.85–1.55
11	107–159	0.92–1.49	0.86–1.57
12	105–156	0.96–1.54	0.88–1.60

Approximate range (95% limits) for general gait parameters in free-speed walking by normal *female* subjects of different ages

Age (years)	*Cadence (steps/min)*	*Stride length (m)*	*Velocity (m/s)*
13–14	103–150	0.99–1.55	0.90–1.62
15–17	100–144	1.03–1.57	0.92–1.64
18–49	98–138	1.06–1.58	0.94–1.66
50–64	97–137	1.04–1.56	0.91–1.63
65–80	96–136	0.94–1.46	0.80–1.52

Approximate range (95% limits) for general gait parameters in free-speed walking by normal *male* subjects of different ages

Age (years)	*Cadence (steps/min)*	*Stride length (m)*	*Velocity (m/s)*
13–14	100–149	1.06–1.64	0.95–1.67
15–17	96–142	1.15–1.75	1.03–1.75
18–49	91–135	1.25–1.85	1.10–1.82
50–64	82–126	1.22–1.82	0.96–1.68
65–80	81–125	1.11–1.71	0.81–1.61

(Whittle 1991, 202-3)

Appendix 7/1. Original scores of Donny

MS 1-6

CodeMS	Time	Steps	Distance	Velocity	Cadence	StrideL	CycleT
UE1/1	33,25s	42	1016cm	30,56	75,79	48,38	1,58
UE1/2	28,74s	38	1010cm	35,14	79,33	53,16	1,51
UE1/3	29,20s	38	980cm	33,56	78,08	51,58	1,54
UE2/1	28,50s	36	999cm	35,05	75,79	55,5	1,58
UE2/2	26,91s	36	1056cm	39,24	80,27	58,68	1,5
UE2/3	24,41s	34	992cm	40,64	83,57	58,35	1,44
UE3/1	33,27s	42	1016cm	30,54	75,72	48,38	1,58
UE3/2	33,09s	42	1031cm	31,16	76,16	49,1	1,58
UE3/3	30,99s	40	1013cm	32,69	77,44	50,65	1,54
UE3/4	26,70s	36	992cm	37,15	80,9	55,11	1,48
UE3/5	26,27s	36	1030cm	39,21	82,22	57,22	1,46
UE4/1	28,77s	38	1007cm	35	79,25	53	1,51
UE4/2	27,42s	36	1006cm	36,69	78,77	55,89	1,52
UE4/3	27,67s	36	1005cm	36,32	78,06	55,83	1,54
UE5/1	26,36s	36	1005cm	38,12	81,94	55,83	1,46
UE5/2 *	33,71s	40	1002cm	29,72	71,2	50,1	1,68
UE5/3	28,93s	38	1040cm	35,95	78,81	54,74	1,52
UE5/4	27,01s	36	1040cm	38,5	79,97	57,78	1,5
UE6/1	31,02s	38	1010cm	32,56	73,5	53,16	1,63
UE6/2	29,89s	38	987cm	33,02	76,28	51,95	1,57
UE6/3	30,24s	38	995cm	32,9	75,4	52,37	1,59
				M 34,94	M 78,02	M 53,66	M 1,54

MS 7-12

CodeMS	Time	Steps	Distance	Velocity	Cadence	StrideL	CycleT
UJ1/1	31,02s	40	1031cm	33,24	77,37	51,55	1,55
UJ1/2	26,65s	36	1010cm	37,9	81,05	56,11	1,48
UJ1/3	25,85s	36	1010cm	39,07	83,56	56,11	1,44
UJ1/4	25,95s	36	994cm	38,3	83,24	55,22	1,44
UJ2/1	29,12s	36	998cm	34,27	74,18	55,44	1,62
UJ2/2	28,54s	36	1016cm	35,6	75,68	56,44	1,58
UJ2/3	26,95s	36	1043cm	38,7	80,15	57,94	1,5
UJ3/1	23,54s	32	995cm	42,27	81,56	62,19	1,47
UJ3/2	26,30s	34	1009cm	38,36	77,57	59,35	1,55
UJ3/3	21,43s	30	975cm	44,66	83,99	65	1,43
UJ4/1	25,83s	34	1004cm	38,87	78,98	59,06	1,52
UJ4/2	25,40s	34	1007cm	39,64	80,31	59,24	1,49
UJ4/3	25,07s	34	1018cm	40,61	81,37	59,88	1,47
UJ5/1	22,49s	30	988cm	43,93	80,04	65,87	1,5
UJ5/2	23,31s	32	1062cm	45,56	82,37	66,38	1,46
UJ5/3	21,68s	30	1035cm	47,73	83,03	69	1,44
UJ6/1	24,75s	32	1006cm	40,65	77,58	62,88	1,55
UJ6/2	23,73s	32	1001cm	42,18	80,91	62,56	1,48
UJ6/3	25,70s	34	1017cm	39,57	79,38	59,82	1,51
				M 40,06	M 80,12	M 60,00	M 1,50
				M3 42,00	M3 80,59	M3 62,60	M3 1,49

Appendix 7/2. Original scores of Jim

MS 1-6

CodeMS	Time	Steps	Distance	Velocity	Cadence	StrideL	CycleT
JE1/1	20.16s	28	989cm	49,06	83,33	70,64	1,44
JE1/2	20.46s	28	990cm	48,39	82,11	70,71	1,46
JE1/3	20.79s	28	1027cm	49,4	80,81	73,36	1,48
JE2/1 *	19.91s	30	1046cm	52,54	90,41	69,73	1,33
JE2/2 *	24.34s	32	1070cm	43,96	78,89	66,88	1,52
JE2/3 *	21.15s	30	1019cm	48,18	85,11	67,93	1,41
JE3/1	18.52s	28	1032cm	55,72	90,71	73,71	1,32
JE3/2	18.01s	26	1007cm	55,91	86,62	77,46	1,38
JE3/3	18.15s	28	1030cm	56,75	92,56	73,57	1,3
JE4/1	20.25s	30	1041cm	51,41	88,89	69,4	1,35
JE4/2	21.20s	30	1029cm	48,54	84,9	68,6	1,41
JE4/3	18.49s	28	992cm	53,65	90,86	70,86	1,32
JE5/1	19.60s	28	1005cm	51,28	85,71	71,78	1,4
JE5/2	19.43s	28	1015cm	52,24	86,46	72,5	1,39
JE5/3	20.16s	28	994cm	49,3	83,33	71	1,44
JE6/1	21.13s	28	991cm	46,09	79,51	70,78	1,51
JE6/2 *	18.01s	28	1032cm	57,3	93,28	73,71	1,29
JE6/3	19.30s	30	1037cm	53,73	93,26	69,13	1,29
				M 51.30	M 86,49	M 71,21	M 1,39

MS 7-12

CodeMS	Time	Steps	Distance	Velocity	Cadence	StrideL	CycleT
JJ1/1	21.43s	30	1032cm	48,16	83,9	68,8	1,43
JJ1/2	20.20s	28	1021cm	50,54	83,17	72,93	1,44
JJ1/3	19.93s	28	991cm	49,72	84,3	70,78	1,42
JJ1/4	19.43s	28	1020cm	52,5	86,46	72,86	1,39
JJ2/1	19.05s	30	1025cm	53,8	94,49	68,33	1,27
JJ2/2	18.31s	28	1018cm	55,6	91,75	72,71	1,31
JJ3/1 *	16.91s	26	977cm	57,78	92,25	75,15	1,3
JJ3/2 *	20.30s	30	1049cm	51,67	88,67	69,93	1,35
JJ3/3	17.84s	26	994cm	55,72	87,44	76,46	1,37
JJ3/4	17.28s	26	973cm	56,31	90,28	74,85	1,33
JJ4/1 *	14.68s	24	990cm	67,44	98,09	82,5	1,22
JJ4/2 *	18.49s	26	992cm	53,65	84,37	76,31	1,42
JJ4/3	18.36s	26	1027cm	55,94	84,97	79	1,41
JJ5/1	18.86s	28	1022cm	54,19	89,08	73	1,35
JJ5/2 *	15.67s	26	1047cm	66,82	99,55	80,54	1,2
JJ5/3	18.24s	26	1048cm	57,46	85,53	80,62	1,4
JJ5/4	17.78s	26	1034cm	58,16	87,74	79,54	1,37
JJ6/1	17.98s	26	1014cm	56,4	86,76	78	1,38
JJ6/2	19.29s	28	1033cm	53,55	87,09	73,78	1,38
JJ6/3	18.31s	26	1024cm	55,92	85,2	78,77	1,41
				M 55,57	M 88,55	M 75,24	M 1,36
				M3 57,22	M3 89,07	M3 77,03	M3 1,35

Appendix 7/3. Original scores of Helen

MS 1-6

CodeMS	Time	Steps	Distance	Velocity	Cadence	StrideL	CycleT
HE1/1	10,24s	18	1048cm	102,34	105,47	116,44	1,14
HE1/2	9,37s	16	956cm	102,03	102,45	119,5	1,17
HE1/3	10,56s	18	1052cm	99,62	102,27	116,89	1,17
HE2/1	10,60s	18	1056cm	99,62	101,89	117,33	1,18
HE2/2	10,41s	18	1039cm	99,81	103,75	115,44	1,16
HE2/3	10,14s	18	1070cm	105,52	106,51	118,89	1,13
HE3/1	10,30s	18	1027cm	99,71	104,85	114,11	1,14
HE3/2	10,38s	18	1016cm	97,88	104,05	112,89	1,15
HE3/3	10,47s	18	1038cm	99,14	103,15	115,33	1,16
HE4/1	11,06s	18	979cm	88,52	97,65	108,78	1,23
HE4/2	11,95s	18	1061cm	88,79	90,38	117,89	1,33
HE4/3	10,52s	18	1033cm	98,19	102,67	114,78	1,17
HE5/1	10,41s	18	1027cm	98,65	103,75	114,11	1,16
HE5/2	10,59s	18	994cm	93,86	101,98	110,44	1,18
HE5/3	10,38s	18	1056cm	101,73	104,05	117,33	1,15
HE6/1	9,57s	18	1063cm	111,08	112,85	118,11	1,06
HE6/2	10,62s	18	1009cm	95,01	101,69	112,11	1,18
HE6/3	10,13s	18	1091cm	107,7	106,61	121,22	1,12
				M 99,4	M 103,11	M 115,64	M 1,16
MS 7-12							
CodeMS	Time	Steps	Distance	Velocity	Cadence	StrideL	CycleT
HJ1/1	10,55s	18	1020cm	96,68	102,37	113,33	1,17
HJ1/2	10,75s	18	1010cm	93,95	100,46	112,22	1,19
HJ1/3	10,74s	18	1002cm	93,3	100,56	111,33	1,19
HJ2/1	10,22s	18	1032cm	100,98	105,68	114,67	1,14
HJ2/2	10,52s	18	1108cm	105,32	102,66	123,11	1,17
HJ2/3	9,88s	18	1137cm	115,08	109,31	126,33	1,1
HJ2/4	8,83s	16	1033cm	116,99	108,72	129,12	1,1
HJ2/5	9,01s	16	1050cm	116,54	106,55	131,25	1,13
HJ3/1	8,41s	16	1018cm	121,05	114,15	127,25	1,05
HJ3/2	8,49s	16	989cm	116,49	113,07	123,62	1,06
HJ3/3	8,75s	16	996cm	113,83	109,71	124,5	1,09
HJ4/1	8,35s	16	1004cm	120,24	114,97	125,5	1,04
HJ4/2	8,77s	16	945cm	107,75	109,46	118,12	1,1
HJ4/3	10,19s	18	1037cm	101,77	105,99	115,22	1,13
HJ5/1	9,72s	18	1040cm	106,1	111,11	115,56	1,08
HJ5/2	10,16s	18	1100cm	108,27	106,3	122,22	1,13
HJ5/3	10,14s	18	1062cm	104,73	106,51	118	1,13
HJ6/1	10,11s	18	1100cm	108,8	106,82	122,22	1,2
HJ6/2	9,26s	16	980cm	105,83	103,67	122,5	1,16
HJ6/3	9,24s	16	987cm	106,82	103,9	123,37	1,16
				M 108,03	M 107,10	M 120,97	M 1,13
SL	2 122,50	V	2 110,39	M3 110,14	3 108,80	3 121,51	M3 1,11

Appendix 7/4. Original scores of Anne

MS 1-6

CodeMS	Time	Steps	Distance	Velocity	Cadence	StrideL	CycleT
AE1/1	6,59s	14	1017cm	154,32	127,46	145,29	0,94
AE1/2	8,04s	16	1062cm	131,92	119,4	132,75	1
AE1/3	6,94s	14	978cm	140,92	121,04	139,71	0,99
AE2/1	7,02s	14	962cm	137,04	119,66	137,43	1
AE2/2	6,83s	14	987cm	144,51	122,99	141	0,98
AE2/3	8,13s	16	1088cm	133,83	118,08	136,00	1,02
AE3/1	8,16s	16	1066cm	130,64	117,65	133,25	1,02
AE3/2	8,24s	16	1075cm	130,46	116,5	134,38	1,01
AE3/3	8,06s	16	1029cm	127,67	119,11	128,62	1,01
AE4/1	6,82s	14	990cm	145,16	123,17	141,43	0,97
AE4/2	6,65s	14	1019cm	153,23	126,32	145,57	0,95
AE4/3	6,86s	14	983cm	143,29	122,45	140,43	0,98
AE5/1	8,29s	16	1059cm	127,74	115,8	132,38	1,04
AE5/2	7,51s	14	1006cm	133,95	111,85	143,71	1,07
AE5/3	7,97s	16	1037cm	130,11	120,45	129,62	1
AE6/1	7,92s	16	1017cm	128,41	121,21	127,12	0,99
AE6/2	7,66s	16	1064cm	138,9	125,33	133	0,96
AE6/3	7,74s	16	1060cm	136,95	124,03	132,5	0,97
				M 137,17	M 120,69	M 136.34	M 0,99

MS 7-12

CodeMS	Time	Steps	Distance	Velocity	Cadence	StrideL	CycleT
AJ1/1	7,06s	14	988cm	139,94	118,98	141,14	1,01
AJ1/2	7,18s	14	1017cm	141,64	116,99	145,28	1,02
AJ1/3	6,68s	14	1031cm	154,34	125,75	147,28	0,95
AJ1/4	6,94s	14	1007cm	145,1	121,04	143,86	0,99
AJ2/1	6,70s	14	995cm	148,51	125,37	142,14	0,96
AJ2/2	6,76s	14	1006cm	148,82	124,26	143,71	0,96
AJ2/3	6,91s	14	997cm	144,28	121,56	142,43	0,99
AJ3/1	6,66s	14	980cm	147,15	126,13	140	0,95
AJ3/2	8,07s	16	1030cm	127,63	118,96	128,75	1,01
AJ3/3	6,88s	14	974cm	141,57	122,09	139,14	0,98
AJ4/1	6,80s	14	1008cm	148,24	123,53	144	0,97
AJ4/2	7,03s	14	989cm	140,68	119,49	141,28	1
AJ4/3	7,57s	16	1086cm	143,46	126,82	135,75	0,95
AJ5/1	7,62s	16	1065cm	139,76	125,98	133,25	0,95
AJ5/2	7,66s	16	1065cm	139,03	125,32	133,25	0,96
AJ5/3	7,57s	16	1068cm	141,08	126,82	133,5	0,95
				M 143,2	M 123,07	M 139,67	M 0,98

Appendix 8. Calculations of the data - percentage figures 8./1

STRIDE LENGTH: MEANS OF MS 1-12, HIGH/LOW VALUES AND RANGE (R)

BASELINE	MEAN SL-%	HI / LO SL-%	G	BASELINE	MEAN SL-%	HI / LO SL-%
		100,2	A			99,6
1	97,7	R 3,7	I	7	97,4	R 8,0
		96,5	T			94
		95,2				99,3
2	93,1	R 3,9	S	8	96,3	R 4,4
		91,3	T			93,3
		105,8	R			104,4
3	102,3	R 5,3	I	9	101,2	R 9,9
		100,5	D			95,5
		96,8	E			112,7
4	95,1	R 3,1		10	108,3	R 8,5
		93,7	L.			104,2
		99				110,1
5	98	R 2,0	J	11	107,1	R 5,5
		97	I			99,7
		100,7	M			107,6
6	97,2	R 6,3		12	105	R 5,4
		94,4				100,8
	1-6 M 97,2	RM 4,0	TM 100%		7-12 M 102,8	RM 7,0

BASELINE	MEAN SL-%	HI / LO SL-%	G	BASELINE	MEAN SL-%	HI / LO SL-%
		93,6	A			98,8
1	89,8	R 8,4	I	7	96,3	R 8,0
		85,2	T			90,8
		103,3				102
2	101,2	R 5,6	S	8	99,6	R 4,4
		97,7	T			97,6
		100,7	R			114,4
3	91,7	R 15,5	I	9	109,4	R 9,9
		85,2	D			104,5
		98,4	E			105,4
4	96,6	R 5,1		10	104,5	R 1,4
		93,3	L.			104
		101,7				121,5
5	96,1	R 13,5	D	11	118	R 5,5
		88,2	O			116
		93,6	N			110,7
6	92,4	R 2,1	N	12	108,7	R 5,4
		91,5	Y			105,3
	1-6 M 94,4	RM 8,4	TM 100%		7-12 M 105,6	RM 5,8

Appendix 8./2

BASELINE	MEAN SL-%	HI / LO SL-%	G	BASELINE	MEAN SL-%	HI / LO SL-%
		105,3	A			106,7
1	100,9	R 9,1	I	7	104,6	R 4,4
		96,2	T			102,3
		102,2				104,1
2	100,1	R 3,6	S	8	103,5	R 1,1
		98,6	T			103
		97,4	R			101,4
3	95,7	R 4,2	I	9	98,6	R 8,1
		93,2	D			93,3
		105,5	E			104,3
4	103,3	R 3,7		10	101,7	R 5,9
		101,8	L.			98,4
		104,1				96,7
5	98	R 10,2	A	11	96,6	R 0,1
		93,9	N			96,6
		96,4	N			
6	94,9	R 4,3	E	12		
		92,1				
	1-6 M 98,8	R M 5,8	TM 100%		7-12 M 101,2	R M 3,9

BASELINE	MEAN SL-%	HI / LO SL-%	G	BASELINE	MEAN SL-%	HI / LO SL-%
		101	A			95,8
1	99,4	R 2,6	I	7	94,9	R 1,7
		98,4	T			94,1
		100,5				110,9
2	99,1	R 2,9	S	8	105,6	R 14,0
		97,6	T			96,9
		97,5	R			107,6
3	96,4	R 2,1	I	9	105,8	R 3,1
		95,4	D			104,5
		99,6	E			106,1
4	96,2	R 7,6		10	101,1	R 8,7
		92	L.			97,4
		99,2				103,3
5	96,3	R 5,8	H	11	100,2	R 5,6
		93,4	E			97,7
		102,5	L			104,3
6	99	R 7,7	E	12	103,7	R 1,0
		94,8	N			103,3
	1-6 M 97,7	R M 4,8	TM 100%		7-12 M 102,3	R M 5,6

Notice! Calculations are done according to the original data. Due to that there may be inaccuracy if recalculated according to the data presented in these tables.

Appendix 8./3

CADENCE: MEANS OF MS 1-12, HIGH/LOW VALUES AND RANGE (R)

BASELINE	MEAN C-%	HI / LO C-%	G	BASELINE	MEAN C-%	HI / LO C-%
		95,2	A			98,8
1	93,8	R 2,8	I	7	96,5	R 3,8
		92,4	T			95
		103,3				108
2	96,9	R 13,1	C	8	106,4	R 3,2
		90,2	A			104,8
		105,8	D			105,4
3	102,8	R 6,8	E	9	102,4	R 5,5
		99	N			99,9
		103,8	C			112,1
4	100,8	R 6,8	E	10	101,8	R 15,0
		97				97,1
		98,8				113,8
5	97,3	R 3,6	J	11	103,4	R 16,1
		95,2	I			97,7
		106,6	M			99,5
6	101,3	R 15,7		12	98,7	R 2,1
		90,9				97,4
	1-6 M 98,8	R M 8,1	TM 100%		7-12 M 101,2	R M 7,6

BASELINE	MEAN C-%	HI / LO C-%	G	BASELINE	MEAN C-%	HI / LO C-%
		100,3	A			105,6
1	98,3	R 4,5	I	7	102,8	R 7,8
		95,8	T			97,8
		105,6				101,3
2	101	R 9,8	C	8	97	R 7,5
		95,8	A			93,8
		103,9	D			106,2
3	99,3	R 8,2	E	9	102,5	R 8,1
		95,7	N			98,1
		100,2	C			102,9
4	99,5	R 1,5	E	10	101,5	R 3,1
		98,7				99,8
		103,6				105
5	98,6	R 13,6	D	11	103,5	R 3,8
		90	O			101,2
		96,4	N			102,3
6	94,9	R 3,5	N	12	100,3	R 4,2
		92,9	Y			98,1
	1-6 M 98,7	R M 6,8	TM 100%		7-12 M 101,3	R M 5,8

Appendix 8./4

BASELINE	MEAN C-%	HI / LO C-%	G	BASELINE	MEAN C-%	HI / LO C-%
		104,6	A			103,2
1	100,6	R 6,7	I	7	99	R 7,2
		97,9	T			96
		100,9				102,8
2	98,7	R 4,0	C	8	101,5	R 3,1
		96,9	A			99,7
		97,7	D			103,5
3	96,6	R 2,1	E	9	100,4	R 6,9
		95,6	N			97,6
		103,6	C			104
4	101,7	R 3,2	E	10	101,1	R 6,0
		100,4				98
		98,8	A			104
5	95,2	R 7,0	N	11	103,4	R 1,2
		91,8	N			102,8
		102,8	E			
6	101,3	R 3,4		12		
		99,4				
	1-6 M 99,0	R M 4,4	TM 100%		7-12 M 101,0	R M 4,9

BASELINE	MEAN C-%	HI / LO C-%	G	BASELINE	MEAN C-%	HI / LO C-%
		100,4	A			97,4
1	98,4	R 3,1	I	7	96,2	R 1,8
		97,3	T			95,6
		101,3				104
2	99	R 4,4	C	8	101,4	R 6,3
		96,9	A			97,7
		99,8	D			108,6
3	99	R 1,7	E	9	106,8	R 4,2
		98,1	N			104,4
		97,7	C			109,4
4	92,2	R 11,7	E	10	104,8	R 8,6
		86				100,8
		99	H			105,7
5	98,3	R 2,0	E	11	102,7	R 4,6
		97	L			101,1
		107,4	E			101,6
6	101,8	R 10,6	N	12	99,7	R 3,0
		96,8				98,6
	1-6 M 98,1	R M 5,6	TM 100%		7-12 M 101,9	R M 4,8

Notice! Calculations are done according to the original data. Due to that there may be inaccuracy if recalculated according to the data presented in these tables.

Appendix 8./5

VELOCITY: MEANS OF MS 1-12, HIGH/LOW VALUES AND RANGE (R)

BASELINE	MEAN V-%	HI / LO V-%	G	BASELINE	MEAN V-%	HI / LO V-%
		92.4	A			98.2
1	91.6	R 1,8	I	7	94.0	R 8,1
		90.6	T			90.1
		98.3				104.0
2	90.2	R 16,0	V	8	102.3	R 3,3
		82.3	E			100.7
		106.2	L			108.1
3	105.0	R 1,9	O	9	103.6	R 11,4
		104.3	C			96.7
		100.4	I			126.2
4	95.8	R 9,6	T	10	110.4	R 25,8
		90.8	Y			100.4
		97.8				125.0
5	95.3	R 5,6	J	11	110.7	R 23,6
		92.2	I			101.4
		107.2	M			105.5
6	98.0	R 21,0		12	103.5	R 5,3
		86.2				100.2
	1.6 M 96.0	R M 9.3	TM 100%		7-12 M 104.0	R M 12,9

BASELINE	MEAN V-%	HI / LO V-%	G	BASELINE	MEAN V-%	HI / LO V-%
		93.7	A			104.2
1	88.2	R 22,2	I	7	99.0	R 15,6
		81.5	T			88.6
		108.4				103.2
2	102.1	R 14,9	V	8	96.5	R 11,8
		93.5	E			91.4
		106.4	L			119.1
3	91.1	R 25,0	O	9	111.4	R 16,8
		81.4	C			102.3
		97.8	I			108.3
4	96.0	R 4,5	T	10	105.9	R 4,7
		93.3	Y			103.6
		102.7				127.3
5	94.9	R 23,5	D	11	122.0	R 10,2
		79.2	O			117.1
		88.0	N			112.5
6	87.5	R 1,2	N	12	108.8	R 7,0
		86.8	Y			105.5
	1-6 M 93.2	R M 15.2	T M 100%		7-12 M 106.8	R M 11,0

Appendix 8./6

BASELINE	MEAN V-%	HI / LO V-%	G	BASELINE	MEAN V-%	HI / LO V-%
		109.6	A			109.6
1	101.6	R 15,9	I	7	103.4	R 10,3
		93.7	T			99.3
		102.6				105.7
2	98.8	R 7,6	V	8	105.0	R 7,2
		95.0	E			102.5
		92.8	L			104.5
3	92.4	R 2,1	O	9	99.0	R 13,9
		90.7	C			90.6
		108.8	I			105.7
4	105.0	R 7,0	T	10	102.8	R 5,3
		101.8	Y			100.4
		95.1				100.6
5	93.2	R 4,4	A	11	99.8	R 1,4
		90.7	N			99.2
		98.6	N			
6	96.1	R 7,4	E	12		
		91.2				
	1-6 M 97.8	RM 7.4	TM 100%		7-11 M 102.2	RM 7,6

BASELINE	MEAN V-%	HI / LO V-%	G	BASELINE	MEAN V-%	HI / LO V-%
		99.0	A			93.5
1	97.7	R 2,7	I	7	91.2	R 3.3
		96.3	T			90.2
		102.0				112.7
2	98.0	R 5,7	V	8	107.0	R 15,1
		96.3	E			97.6
		96.4	L			117.0
3	95.4	R 1,8	O	9	113.0	R 6,9
		94.6	C			110.1
		94.9	I			116.3
4	88.8	R 9,3	T	10	106.0	R 7,9
		85.6	Y			98.4
		98.1				104.7
5	94.6	R 7,6	H	11	102.6	R 3,4
		90.5	E			101.3
		107.4	L			105.2
6	100.8	R 15,5	E	12	103.3	R 2,9
		91.9	N			102.3
	1-6 M 95.9	RM 7,1	TM 100%		7-12 M 104.1	RM 6.6
Notice!	Calculations	are done acc	ording to the	original data.	Due to that	there may be
	inaccuracy if	recalculated	according to	the data	presented in	these tables.

Appendix 8./7

DONNY: CADENCE (steps/min) / MEASUREMENT SESSIONS (MS) 1-6 AND 7-12 -- PERCENTAGE FIGURES

MS 1-6	Mean	%
75,79		
79,33	77,7	98,3
78,08		
75,79		
80,27	79,9	101,0
83,57		
75,72		
76,16		
77,44	78,5	99,3
80,90		
82,22		
79,25		
78,77	78,7	99,5
78,06		
81,94		
71,20	78,0	98,6
78,81		
79,97		
73,50		
76,28	75,1	94,9
75,40		
	78,0	98,7

MS 7-12	Mean	%
77,37		
81,05		
83,56	81,3	102,8
83,24		
74,18		
75,68	76.7	97,0
80,15		
81,56		
77,57	81,0	102,5
83,99		
78,98		
80,31	80,2	101,5
81,37		
80,04		
82,37	81,8	103,5
83,03		
77,58		
80,91	79,3	100,3
79,38		
	80.1	101,3

TOTAL MEAN: 79,1 steps/min = 100 %

Appendix 8./8

DONNY: STRIDE LENGTH (cm) / MEASUREMENT SESSIONS (MS) 1-6 AND 7-12 -- PERCENTAGE FIGURES

MS 1-6	Mean	%
48,38		
53,16	51,0	89,8
51,58		
55,50		
58,68	57,5	101,2
58,35		
48,38		
49,10		
50,65	52,1	91,7
55,11		
57,22		
53,00		
55,89	54,9	96,6
55,83		
55,83		
50,10	54,6	96,1
54,74		
57,78		
53,16		
51,95	52,5	92,4
52,37		
	53,7	94,4

MS 7-12	Mean	%
51,55		
56,11	54,7	96,3
56,11		
55,22		
55,44		
56,44	56,6	99,6
57,94		
62,19		
59,35	62,2	109,4
65,00		
59,06		
59,24	59,4	104,5
59,88		
65,87		
66,38	67,1	118,0
69,00		
62,88		
62,56	61,8	108,7
59,82		
	60,0	105,6

TOTAL MEAN: 56,8 cm = 100 %

Appendix 8./9

DONNY: VELOCITY AND ITS COMPONENTS

DONNY COMPARISON OF %: **VELOCITY**
STRIDE LENGTH
CADENCE

MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
					Velocity						
88,2	**102,2**	**91,1**	**96,0**	**94,9**	**87,5**	**99,0**	**96,5**	**111,4**	**105,9**	**122,0**	**108,8**
					Sride Length						
89,8	101,2	91,7	96,6	96,1	92,4	96,3	99,6	109,4	104,5	118,0	108,7
					Cadence						
98,3	101,0	99,3	99,5	98,6	94,9	102,8	97,0	102,5	101,5	103,5	100,3

Notice! Difference of SL and C from 100 added together (SLd +Cd) should be equal to the difference of V from 100. The possible error is due to the fact that the calculations are done according to the original data.

Appendix 8./10

DONNY: THE DIFFERENCES FROM 100 % OF THE COMPONENTS OF VELOCITY: CADENCE AND STRIDE LENGTH (MS 1-12)

MS	**Sride Length**
10,2	
1,2	Mean 1-6
8,3	5,77*100/7,5
3,4	= 76,9 %
3,9	
7,6	
3,7	
0,4	Mean 7-12
9,4	7,45*100/9,72
4,5	= 76,6 %
18,0	
8,7	
79,3/12=6,61	
	Mean 1-12
	6,61*100/8,61
	= **76,8 %**

MS	**SL + C**
:	
11,9	
2,2	Mean 1-6
9,0	7,5
3,9	
5,3	
12,7	
6,5	
3,4	Mean 7-12
11,9	9,72
6,0	
21,5	
9,0	
103,3/12=8,61	
	= **100 %**

MS	**Cadence**
1,7	
1,0	Mean 1-6
0,7	1,73*100/7,5
0,5	= 23,1 %
1,4	
5,1	
2,8	
3,0	Mean 7-12
2,5	2,27*100/9,72
1,5	= 23,4 %
3,5	
0,3	
24,0/12=2,0	
	Mean 1-12
	2,0*100/8,61
=	**23,2 %**

DONNY **% of VELOCITY:** STRIDE LENGTH Mean 76,8 %
CADENCE Mean 23,2 %

MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
85,7	54,5	92,2	77,2	73,6	59,8	56,9	11,8	79,0	75,0	83,7	96,7
14,3	45,5	7,8	12,8	26,4	40,2	43,1	88,2	21,0	25,0	16,3	3,3

The difference of SL and C from 100 % explaining together (SLd + Cd) 100 % of Velocity (for example: SLd x 100 : SLd + Cd = SL %)

Appendix 8./11

JIM: CADENCE (steps/min) / MEASUREMENT SESSIONS (MS) 1-6 AND 7-12 -- PERCENTAGE FIGURES

MS 1-6	Mean	%
83,33		
82,11	82,08	93,8
80,81		
90,41		
78,89	84,8	96,9
85,11		
90,71		
86,62	89,96	102,8
92,56		
88,89		
84,90	88,22	100,8
90,86		
85,71		
86,46	85,17	97,3
83,33		
79,51		
93,28	88,68	101,3
93,26		
	86,5	98,8 %

MS 7-12	Mean	%
83,90		
83,17	84,46	96,5
84,3		
86,46		
94,49	93,12	106,4
91,75		
92,25		
88,67	89,66	102,4
87,44		
90,28		
98,09		
84,37	89,14	101,8
84,97		
89,08		
99,55	90,48	103,4
85,53		
87,74		
86,76		
87,09	86,35	98,7
85,20		
	88,6	101,2

TOTAL MEAN: 87,5 cm = 100 %

Appendix 8./12

JIM: STRIDE LENGTH (cm) / MEASUREMENT SESSIONS (MS) 1-6 AND 7-12 -- PERCENTAGE FIGURES

MS 1-6	Mean	%
70,64		
70,71	71,57	97,7
73,36		
69,73		
66,88	68,18	93,1
67,93		
73,71		
77,46	74,91	102,3
73,57		
69,40		
68,60	69,62	95,1
70,86		
71,78		
72,50	71,76	98,0
71,00		
70,78		
73,71	71,21	97,2
69,13		
	71,2	97,2 %

MS 7-12	Mean	%
68,80		
72,93	71,34	97,4
70,78		
72,86		
68,33	70,52	96,3
72,71		
75,15		
69,93	74,10	101,2
76,46		
74,85		
82,50		
76,31	79,27	108,3
79,00		
73,00		
80,54	78,43	107,1
80,62		
79,54		
78,00		
73,78	76,85	105,0
78,77		
	75,2	102,8 %

TOTAL MEAN: 73,22 cm = 100 %

Appendix 8./13

JIM: VELOCITY AND ITS COMPONENTS

JIM COMPARISON OF %: **VELOCITY**
STRIDE LENGTH
CADENCE

MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
					Velocity						
91,6	**90,2**	**105,0**	**95,8**	**95,3**	**98,0**	**94,0**	**102,3**	**103,6**	**110,4**	**110,7**	**103,5**
					Stride Length						
97,7	93,1	102,3	95,1	98,0	97,2	97,4	96,3	101,2	108,3	107,1	105,0
					Cadence						
93,8	96,9	102,8	100,8	97,3	101,3	96,5	106,4	102,4	101,8	103,4	98,7

Notice! Difference of SL and C from 100 added together (SLd +Cd) should be equal to the difference of V from 100. The possible error is due to the fact that the calculations are done according to the original data.

Appendix 8./14

JIM: THE DIFFERENCES FROM 100 % OF THE COMPONENTS OF VELOCITY: CADENCE AND STRIDE LENGTH (MS 1-12)

MS	**Sride Length**
2,3	
6,9	Mean 1-6
2,3	3,53*100/6,35
4,9	= 55,6 %
2,0	
2,8	
2,6	
3,7	Mean 7-12
1,2	4,65*100/7,78
8,3	= 59,8 %
7,1	
5,0	
49,1/12=4,09	
	Mean 1-12
	4,09*100/7,07
	= 57,9 %

MS	**SL + C**
:	
8,5	
10,0	Mean 1-6
5,1	6,35
5,7	
4,7	
4,1	
6,1	
10,1	Mean 7-12
3,6	7,78
10,1	
10,5	
6,3	
84,8/12=7,07	
= **100 %**	

MS	**Cadence**
6,2	
3,1	Mean 1-6
2,8	2,82*100/6,35
0,8	= 44,4 %
2,7	
1,3	
3,5	
6,4	Mean 7-12
2,4	3,13*100/7,78
1,8	= 40,2 %
3,4	
1,3	
35,7/12=2,98	
	Mean 1-12
	2,98*100/7,07
	= 42,1 %

JIM **% of VELOCITY:** STRIDE LENGTH Mean 57,9 %
CADENCE Mean 42,1 %

MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
27,1	69,0	45,1	86,0	42,6	68,3	42,6	36,6	33,3	82,2	67,6	79,4
72,9	31,0	54,9	14,0	57,4	31,7	57,4	63,4	66,7	17,8	32,4	20,6

The difference of SL and C from 100 % explaining together (SLd + Cd) 100 % of Velocity (for example: SLd x 100 : SLd + Cd = SL %)

Appendix 8./15

HELEN: CADENCE (steps/min) / MEASUREMENT SESSIONS (MS) 1-6 AND 7-12 -- PERCENTAGE FIGURES

MS 1-6	Mean	%
105,47		
102,45	103,4	98,4
102,27		
101,89		
103,75	104,0	99,0
106,51		
104,85		
104,05	104,0	99,0
103,15		
97,65		
90,38	96,9	92,2
102,67		
103,75		
101,98	103,3	98,3
104,05		
112,85		
101,69	107,0	101,8
106,61		
	103,1	98,1

MS 7-12	Mean	%
102,37		
100,46	101,1	96,2
100,56		
105,68		
102,66		
109,31	106,6	101,4
108,72		
106,55		
114,15		
113,07	112,3	106,8
109,71		
114,97		
109,46	110,1	104,8
105,99		
111,11		
106,30	108,0	102,7
106,51		
106,82		
103,67	104,8	99,7
103,90		
	107,1	101,9

TOTAL MEAN: 105,1 steps/min = 100 %

Appendix 8./16

HELEN: STRIDE LENGTH (cm) / MEASUREMENT SESSIONS (MS) 1-6 AND 7-12 -- PERCENTAGE FIGURES

MS 1-6	Mean	%
116,44		
119,50	117,6	99,4
116,89		
117,33		
115,44	117,2	99,1
118,89		
114,11		
112,89	114,1	96,4
115,33		
108,78		
117,89	113,8	96,2
114,78		
114,11		
110,44	114,0	96,3
117,33		
118,11		
112,11	117,1	99,0
121,22		
	115,6	97,7

MS 7-12	Mean	%
113,33		
112,22	112,3	94,9
111,33		
114,67		
123,11		
126,33	124,9	105,6
129,12		
131,25		
127,25		
123,62	125,1	105,8
124,50		
125,50		
118,12	119,6	101,1
115,22		
115,56		
122,22	118,6	100,2
118,00		
122,22		
122,50	122,7	103,7
123,37		
	121,0	102,3

TOTAL MEAN: 118,3 cm = 100 %

Appendix 8./17

HELEN: VELOCITY AND ITS COMPONENTS

HELEN COMPARISON OF %: **VELOCITY**
STRIDE LENGTH
CADENCE

MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
					Velocity						
97,7	**98,0**	**95,4**	**88,8**	**94,6**	**100,8**	**91,2**	**107,0**	**112,9**	**106,0**	**102,6**	**103,3**
					Sride Length						
99,4	99,1	96,4	96,2	96,3	99,0	94,9	105,6	105,8	101,1	100,2	103,7
					Cadence						
98,4	99,0	99,0	92,2	98,3	101,8	96,2	101,4	106,8	104,8	102,7	99,7

Notice! Difference of SL and C from 100 added together (SLd +Cd) should be equal to the difference of V from 100. The possible error is due to the fact that the calculations are done according to the original data.

Appendix 8./18

HELEN: THE DIFFERENCES FROM 100 % OF THE COMPONENTS OF VELOCITY: CADENCE AND STRIDE LENGTH (MS1-12)

MS	**Sride Length**	MS	**SL + C**	MS	**Cadence**
0,6		:		1,6	
0,9	Mean 1-6	2,2		1,0	Mean 1-6
3,6	2,27*100/4,75	1,9	Mean 1-6	1,0	2,48*100/4,75
3,8	= 47,8 %	4,6	4,75	7,8	= 52,2 %
3,7		11,6		1,7	
1,0		5,4		1,8	
5,1		2,8		3,8	
5,6	Mean 7-12	8,9		1,4	Mean 7-12
5,8	3,58*100/6,88	7,0	Mean 7-12	6,8	3,3*100/6,88
1,1	= 52,0 %	12,6	6,88	4,8	= 48,0
0,2		5,9		2,7	
3,7		2,9		0,3	
35,1/12=2,93		4,0		34,7/12=2,89	
	Mean 1-12	69,8/12=5,82			Mean
	2,93*100/5,82				2,89*100/5,82
	= **50,3 %**		= **100 %**		= **49,7 %**

HELEN		**% of VELOCITY:**		STRIDE LENGTH CADENCE			Mean 50,3 % Mean 49,7 %				
MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
27,3	47,4	78,3	32,8	68,5	35,7	57,3	80,0	46,0	18,6	6,9	92,5
72,7	52,6	21,7	67,2	31,5	64,3	42,7	20,0	54,0	81,4	93,1	7,5

The difference of SL and C from 100 % explaining together (SLd + Cd) 100 % of Velocity (for example: SLd x 100 : SLd + Cd = SL %)

Appendix 8./19

ANNE: CADENCE (steps/min) / MEASUREMENT SESSIONS (MS) 1-6 AND 7-11 -- PERCENTAGE FIGURES

MS 1-6	Mean	%
127,46		
119,40	122,6	100,6
121,04		
119,66		
122,99	120,2	98,7
118,08		
117,65		
116,50	117,7	96,6
119,11		
123,17		
126,32	123,9	101,7
122,45		
115,80		
111,85	116,0	95,2
120,45		
121,21		
125,33	123,5	101,3
124,03		
	120,7	99,0 %

MS 7-11	Mean	%
118,98		
116,99	120,7	99,0
125,75		
121,04		
125,37		
124,26	123,7	101,5
121,56		
126,13		
118,96	122,4	100,4
122,09		
123,53		
119,49	123,3	101,1
126,82		
125,98		
125,32	126,0	103,4
126,82		
	123,1	101,0 %

TOTAL MEAN: 121,9 steps/min 100 %

Appendix 8./20

ANNE: STRIDE LENGTH (cm) / MEASUREMENT SESSIONS (MS) 1-6 AND 7-11 -- PERCENTAGE FIGURES

MS 1-6	Mean	%
145,29		
132,75	139,2	100,9
139,71		
137,43		
141,00	138,1	100,1
136,00		
133,25		
134,38	132,1	95,7
128,62		
141,43		
145,57	142,5	103,3
140,43		
132,38		
143,71	135,2	98,0
129,62		
127,12		
133,00	130,9	94,9
132,50		
	136,3	98,8 %

MS 7-11	Mean	%
141,14		
145,28	144,4	104,6
147,28		
143,86		
142,14		
143,71	142,8	103,5
142,43		
140,00		
128,75	136,0	98,6
139,14		
144,00		
141,28	140,3	101,7
135,75		
133,25		
133,25	133,3	96,6
133,50		
	139,7	101,2 %

TOTAL MEAN: 138,0 cm = 100 %

Appendix 8./21

ANNE: VELOCITY AND ITS COMPONENTS

ANNE COMPARISON OF %: **VELOCITY** STRIDE LENGTH CADENCE

MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
					Velocity						
101,6	**98,8**	**92,4**	**105,0**	**93,2**	**96,1**	**103,4**	**105,0**	**99,0**	**102,8**	**99,8**	**------**
					Sride Length						
100,9	100,1	95,7	103,3	98,0	94,9	104,6	103,5	98,6	101,7	96,6	------
					Cadence						
100,6	98,7	96,6	101,7	95,2	101,3	99,0	101,5	100,4	101,1	103,4	------

Notice! Difference of SL and C from 100 added together (SLd +Cd) should be equal to the difference of V from 100. The possible error is due to the fact that the calculations are done according to the original data.

Appendix 8./22

ANNE: THE DIFFERENCES FROM 100 % OF THE COMPONENTS OF VELOCITY: CADENCE AND STRIDE LENGTH (MS 1-11)

MS	**Sride Length**
0,9	
0,1	Mean 1-6
4,3	2,62*100/4,8
3,3	= 54,6 %
2,0	
5,1	
4,6	
3,5	Mean 7-11
1,4	2,92*100/4,4
1,7	=66,4 %
3,4	
30,3/11=2,75	
	Mean 1-12
	2,75*100/4,62
	= **59,6 %**

MS	**SL + C**
:	
1,5	
1,4	Mean 1-6
7,7	4,8
5,0	
6,8	
6,4	
5,6	
5,0	Mean 7-11
1,8	4,4
2,8	
6,8	
50,8/11=4,62	
	= **100 %**

MS	**Cadence**
0,6	
1,3	
3,4	2,18*100/4,8
1,7	= 45,4
4,8	
1,3	
1,0	
1,5	Mean 7-11
0,4	1,48*100/4,4
1,1	= 33,6 %
3,4	
20,5/11=1,86	
	Mean
	1,86*100/4,62
	= **40,4 %**

ANNE **% of VELOCITY:** STRIDE LENGTH Mean 59,6 %
CADENCE Mean 40,4 %

MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
60,0	7,1	55,8	66,0	29,4	79,7	82,1	70,0	77,8	60,7	50,0	------
40,0	92,9	44,2	34,0	70,6	20,3	17,9	30,0	22,2	39,3	50,0	------

The difference of SL and C from 100 % explaining together (SLd + Cd) 100 % of Velocity (for example: SLd x 100 : SLd + Cd = SL %

Appendix 9. Riding therapy notes

Session Time	Length	Donny	Jim	Helen	Anne
1.	25 min	-flexion pattern in lower extremities -poor extension in trunk -afraid	-flexion pattern in lower extremities -poor extension in trunk	-clear difference in left and right hands -weight more in front of body (occasionally)	-poor sitting balance -poor concentration -react with flex. patt. -poor s & b awareness
2.		-stiffness in muscles -good grip with hands -good extension in trunk for a moment -tense	-legs rather well in abduction -improved extension	-muscles relaxed -weight more in front -adapting to movement	-sitting relaxed -riding hands free
3.		-adapts to movement somewhat but reacts too strongly to horses movements	-riding hands free -block in trunk and pelvis	-less associated movements -relaxed -adapting to movement	-problems in telling the directions -slides to right side
4.		-very stiff leg muscles -complains stiffness -relaxation is slow -poor body control -after riding hypotonic	-gradually relaxing -improved body control	-symmetrical posture head in midline -relaxed arms with symmetry	-spasticity and flexion in left hip -slides to right side -balance problems
5.		-stiffness in left hip -poor sitting posture -leans properly	-relaxed (after physio-therapy!) -riding hands free -unstable sideways (backw./forward ok)	-symmetrical arms -symmetrical posture head in midline	-stiffness in pelvis in weight shifting
6.		-nervous -leans too much on hands	-slides to right and left sides when riding with hands free -leans well in downhills good body control	-weight more in front of body (occasionally) -relaxed arms -good body control	-trunk is stiff/kyphotic -pelvis is not adapting to horses movements -improvement in sitting when hands free
7.		-good sitting posture leans properly and releases hands even when uphills -relaxed	-riding hands free -good body control in various movements	-relaxed -less relaxed arms	-relaxed -good sitting posture
8.		-slides to right side -relaxed	-good sitting posture	-relaxed	-relaxed
9.	40 min	-relaxed	-riding hands free -good body control in various movements -overall image during all sessions was slightly hesitating	-relaxed but pathology in arms lasted long	-relaxed -good posture