CHAPTER II

LITERATURE REVIEWS

1. Definition of cerebral palsy

Cerebral palsy (CP) is a motor disorder appearing in children due to a damage of the brain before it has fully developed. The damage to the brain affects strictly the motor system, producing poor coordination, poor balance control, or abnormal movement patterns. The motor disorder limits the activities of daily living that causes problems of communication, behavior, sensation, cognition and perception (2, 3). Cerebral palsy is classified by the type of motor impairment they produce and further classified by the limbs that they involve such as spastic hemiplegia, spastic diplegia and spastic quadriplegia (14-16).

Spastic hemiplegia refers to the predominant findings of motor involvement of one side of the body. Mostly, the cause may be from cerebral hemorrhage, hydrocephalus, brain infarction, and brain disease. Usually, the arm is somewhat more affected than the leg. Most children with hemiplegia walk, but asymmetries of gait are evident with internal rotation of the leg and toe walking on the affected side. The upper extremity posturing and abnormalities of the gait are especially noticeable during periods of increased physical activity (stressed gait maneuvers or running) or during periods of emotional excitement as shown in Figure 1.

Spastic diplegia is described as spastic findings of all four limbs but the muscle tone in the lower limb is greater than in the upper limb. Mostly, the cause is a lack of oxygen which damages the cerebrum. Those children who have spastic diplegia often develop a tiptoe walking and crossing one leg over the other. Duffy et al (17) conducted a study to find out differences in energy expenditure patterns of ambulant children with CP (n=40), hemiplegia and diplegia), spina bifida (n=21, L3-L4 and L5-S1) and typical development (TD, n=16). The oxygen consumption (VO2) and heart rate (HR) was measured before and after walking at a comfortable speed for a distance of 50 meters. The result showed a significantly higher rate of VO_2 in children with diplegia than others. The author suggested that the children with diplegia consumed more oxygen than other children when walking because of their abnormal equilibrium reactions, impaired balance, and poor walking speed control as shown in Figure 1.

Spastic quadriplegia is another type of CP that affects all limbs; the cause is a lack of oxygen which damages the brain. Spastic quadriplegia mostly finds axial hypotonia which limits postural control of the trunk and head as well as stability for movements, including functional communication, feeding, and ambulation. Children with quadriplegia are often non-ambulatory as a result of severe motor involvement as shown in Figure 1.

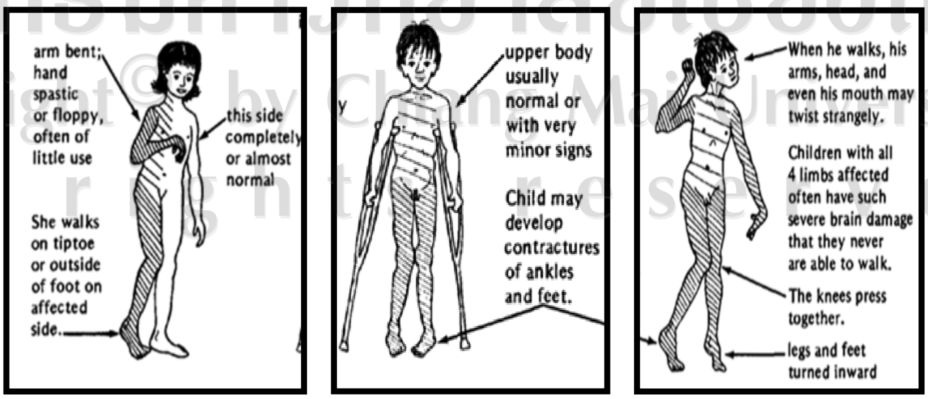

Figure 1 Children with spastic hemiplegia, diplegia, and quadriplegia

2. Gait abnormality in CP

Gait abnormality in CP is caused by abnormal muscle tone or spasticity, uncoordinated agonists and antagonists, poor balance, and poor posture. Gait abnormality in CP includes: 1) Scissoring or crossing gait of the lower legs which occurs secondary to bilateral increase tone of hip adductor and internal rotation muscles 2) toe walking, a most common type of gait abnormality in CP which occurs due to an uncoordination of ankle plantarflexor and dorsiflexor muscles (18) 3) crouch gait which is characterized by persistent hip and knee flexion during walking (11-13) as shown in Figure 2.

Figure 2 Scissoring or crossing gait, Toe walking, and crouch gait

These gait patterns have been shown to be related to energy expenditure during walking in children with CP (19-22). Previous studies found that children with spastic CP increased the use of energy expenditure while walking because of a less efficient walking pattern (19, 21). Kramer and MacPhail (20) also found that knee extensor strength was related to energy expenditure, with the relationship becoming stronger at faster walking speed. Rising energy cost is seen with increasing knee flexion angles in adults without disability (23, 24). Weakness quadriceps have been shown to be related to a crouched gait position (25) and strengthening of these muscles has been shown to lead to a decrease in the knee flexion angle, suggesting the potential for energy cost also be affected (25).

3. Gait training in CP

3.1 Ankle foot orthoses (AFOs)

The use of AFOs is related to the energy expenditure during walking in children with CP. Mossberg et al (26) studied the effect on energy expenditure of gait in 18 children with spastic diplegia during wearing AFOs and not wearing AFOs. Heart rate (HR) and distance (meter) were recorded every minute for 50 minutes in order to calculate for physiological cost index (PCI = HRambulate - HRrest / V (m/min)). The results found a significant difference between walking with AFOs (PCI = 1.34±0.69 beat/meter) and without AFOs (PCI = 1.51±0.75 beat/meter). This study showed that the AFOs can help children with CP walk with similarly normal gait and decrease the use of energy expenditure by supporting or stabilizing the foot and ankle. However, the AFOs are expensive, can be used only as an adjunct intervention, cause some pressure areas and muscle weakness/muscle imbalance, and need several adjustments with growth (27).

3.2 Traditional techniques

Traditional techniques can include the neuro-developmental techniques, proprioceptive neuromuscular facilitation, Brunnstrom, and others. These traditional techniques are based on clinical observation. All techniques involve assistance with the natural developmental process or activate facilitation of responses. These traditional techniques, when aimed at improving gait function, are limited by the biomechanical and neurological deficits of the patients. For example, without sufficient posture and balance, the leg lifted in supine position is used to improve during swing phase, and static weight bearing in standing is used to improve the dynamic of the stance phase. In addition, an individual with poor posture and balance control in sitting usually does not have an opportunity for gait training until he/she passes his/her goal of good posture and balance control during sitting and standing (28).

3.3 Parallel bar

Parallel bar has been used worldwide. Parallel bar and assistive devices such as a walker and crutches are readily used when the upper body strength of the patient is sufficient enough to allow the patient to maintain the upright posture and some balance so that the lower limb can be trained. If the patient lacks upright control, therapists often resort to using of several staff members in order to assist with positioning of the patient because there are limitations in therapists' physical ability to play the role of a multiple-hand support structure, attempting to lift the upper body into position. This type of support for upright control and balance often leads to abnormal biomechanical positioning of the patient, whether the assistance is from parallel bar, an assistive device, or a helper. Therefore, the patients with poor upright control have to wait for further neurological and functional return and hence, improve ability to provide their own upright position before receiving any gait therapy (28).

3.4 Gait training on treadmill with partial body weight support (PBWS)

Gait training on treadmill (mostly forward walking) with PBWS uses a treadmill to control slow rates of walking. Advantages of gait training on a treadmill that walking velocity and intensity on the treadmill can be adjusted (7) and constant speed provides the rhythmic input that reinforces a coordinated reciprocal pattern of movement (28) as shown in Figure 3.

Figure 3 Gait training with PBWS on a treadmill

The PBWS is accomplished through a harness that removes a controllable portion of the weight from the legs and redistributes it to the trunk, hip, and groin. This arrangement permits free movement of the patient's arms and legs. Advantages of the PBWS that reduce weight bearing to provide increase postural control, support the patient rigidly above both shoulders, providing the postural stability required for treating patients with lower level function, allow access to the trunk, hip, and lower extremities so clinicians can manually help patients achieve desired gait components (such as symmetry, heel strike, and step-through gait), promote standing and prevent sitting during therapy though its harness design, and reduce the risk of back injury to the therapist and the risk of fall to the patient (28). Then, the therapists can train the patient to walk as normal as possible using posture training, step walking and correct weight bearing (29).

Several variations of PBWS gait training protocol can be developed based on how fast and what order the parameter (such as speed and weight bearing) is modulated. Seif-naraghi and Herman proposed (28) explains about the PBWS gait training variation as follows;

- Protocol A increase speed from 0.25 mph to 1 mph with stable of weight bearing, and then when participants able walk constant rhythm of movement and good balance at speed 1 mph will moving to the next level is increase weight bearing and then increase speed from 0.25 mph to 1 mph as shown in Figure 4.

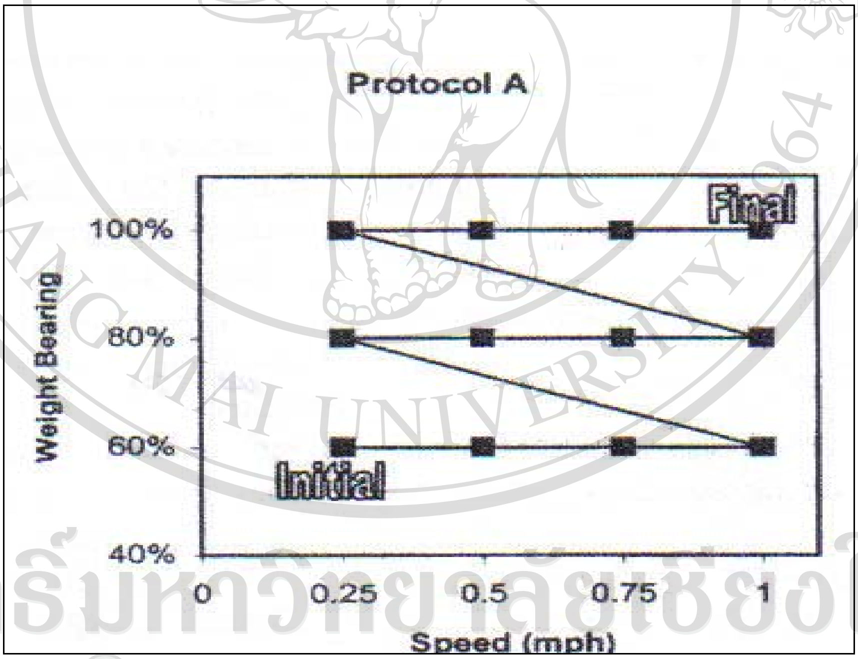

Figure 4 Gait training with PBWS on a treadmill for protocol A

- Protocol B increase weight bearing from 60% to 100% with stable of speed, if participants able walk constant rhythm of movement and good balance moving to next level (increase speed and weight bearing) as shown in Figure 5.

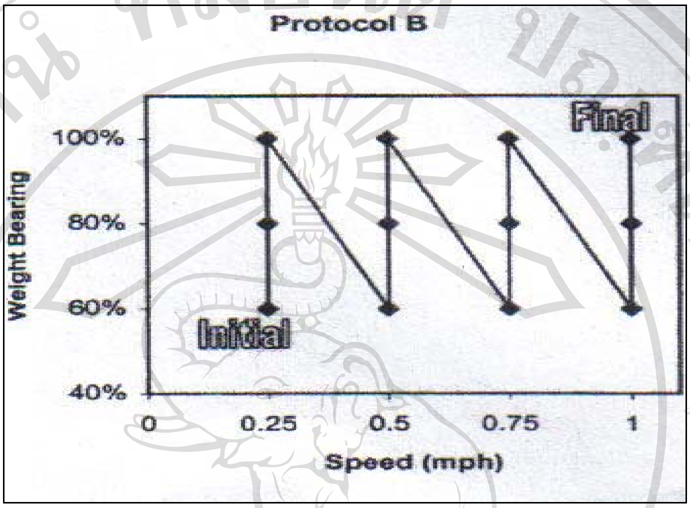

Figure 5 Gait training with PBWS on a treadmill for protocol B

- Protocol C increase speed from 0.25 mph to 1 mph during stable of weight bearing is 60%, when participants able walk constant rhythm of movement and good balance at speed 1 mph increase weight bearing from 60% to 100% as shown in Figure 6.

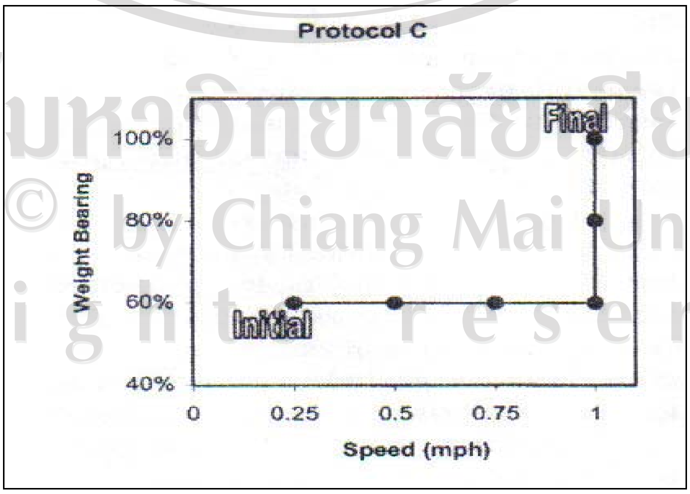

Figure 6 Gait training with PBWS on a treadmill for protocol C

- Protocol D will start at 0.25 mph and 60% for weight bearing until participant can walk constant rhythm of movement and improve balance. Then, training velocity will be set at 0.5 mph and weight bearing increase from 60 to 80%. After that will be set at 0.75 mph for speed and weight bearing increase from 80 to 100% as shown in Figure 7.

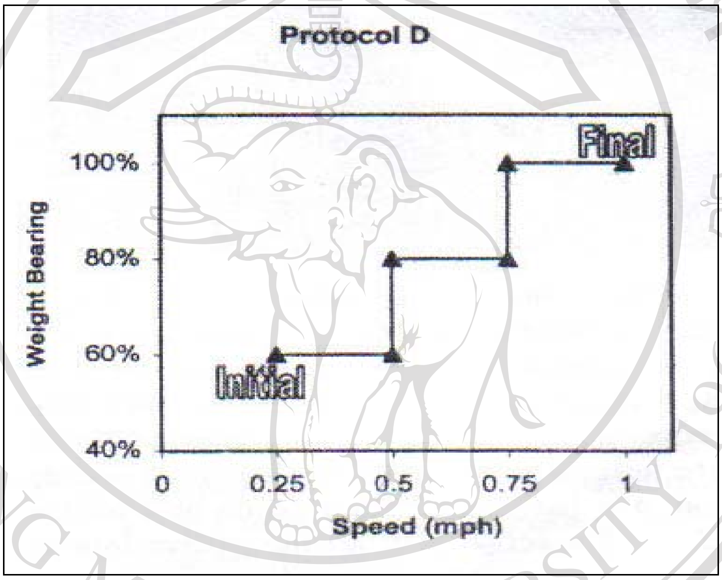

Figure 7 Gait training with PBWS on a treadmill for protocol D

In addition, the therapy session should be half to one full hour long and should occur three to five times a week for inpatient and one to three times a week for outpatient. Each hour of therapy should be divided into two to three session of therapy followed by rest periods. If the therapy session is with partial or full support, patients should not exceed 15 minutes. Improvement or change of gait pattern should be continuing walking training for 4 week (28, 30).

Hesse et al (31) studied treadmill training with PBWS for stroke patients. An A-B-A single-case study design was used to compare treadmill training plus PBWS (A) with physiotherapy based on the Bobath concept (B) in seven nonambulatory hemiparetic patients. The minimum post-stroke interval was 3 months and each treatment phase lasted 3 weeks. The results were found that the treadmill training was more effective with regard to restoration of gait ability ($p<0.05$) and walking velocity ($p<0.05$). Other motor functions improved steadily during the study. Muscle strength did not change, and muscle tone varied in an unsystematic way. The ratio of cadence to stride length did not alter significantly. These results can be implied that treadmill training offers the advantages of task-oriented training with numerous repetitions of a supervised gait pattern.

Not only does treadmill training with PBWS improve energy expenditure, but gait velocity and functional ability are also improved. Maltais et al (32) determined physiological responses including metabolic and cardio respiratory response during treadmill walking in CP patients during repeated walking bouts on different days and different speeds. The patients received 12-15 minutes of treadmill walking practice and had their fastest walking speed (FWS) during the introductory visit and walked for 3 minutes at 60, 75 and 90% FWS for three subsequent visits (day1, day2 and day3). The oxygen consumption (VO_2), net ventilation (VE), respiratory rate (RR), respiratory exchange ratio (RER) and heart rate (HR) values were determined. The result was shown that the VE was found to decrease from day 1 to day 3 at 90% FWS by 3.6 L/min. The HR was also found to decrease from day 1 to day 3 at 90% FWS by 8 beats/min. In addition, the HR in day 3 was less than that in day 2 at 60% FWS and, independent of speed, net VO_2 (per kilogram of body mass and per stride) and net energy expenditure (kJ.min-1). These results suggested that after 12-15 minutes of treadmill walking, the physiological responses would only change at the fastest walking speed (90% FWS).

Morgan et al (4) compared the used energy expenditure during treadmill walking at speed and age differences. At slow speed, children with CP had used excessively oxygen consumption (VO_2), while healthy adults and children had used medium and little VO_2, respectively. When walking speed increased speed, healthy adult and children had used more VO_2 while children with CP had reduced VO_2 which indicated that children with CP had difficulty in transporting O_2 to the muscle.

Dodd et al (5) studied two groups of 14 children with CP (10 boys, 4 girls), mean of age was 8 years 10 month (7 control, 7 intervention). The intervention group received treadmill program two times a week for six weeks. The results showed that the intervention group could improve walking speed and distance when compared with the control group, and some children had increased endurance.

Schndl et al (6) examined the potential role of treadmill training with PWBS in 10 nonambulatory children with CP. For group A, 6 children were nonambulatory and for group B, 2 children required continuous physical help, one child was able to walk short distances with a stand-by and another child was able to walk short distances independently. Treadmill training lasted three months, three times a week, with 25 minutes a session. Main outcome measures, the Functional Ambulation Categories (FAC) and the Gross Motor Function Measure (GMFM standing and walking dimentions), were assessed at 6 and 3 weeks before the study onset (as baseline), the beginning, and end of the training. The results showed no significant difference between the baseline and the beginning of the training. However, during treadmill training, the mean FAC improved significantly from 1.1 to 1.9 ($p<.05$). The sum score of GMFM standing dimention increased by 47% ($p<.05$) and the sum score of GMFM walking dimention increased by 50% ($p<.01$). Of the six nonambulant children in group A, transfer abilities improved in four, one child could walk short distances independently, and two children could walk with continuous physical support after training. Of group B, one child could climb stairs independently, three children only needed verbal support while walking, and all subjects could then stand up arm-free after training. These results suggested that treadmill training with PBW is a promising treatment technique in nonambulatory children with cerebral palsy.

Waagfjord et al (33) investigated the effects of treadmill training on temporospatial parameters in a patient with right hemiplegia who was 3 years post-injury. Training was a maximum of 10 minutes on a motorized treadmill without elevation at a comfortable walking speed. Training was found to affect the base of support and right step length. An increase in symmetry between right and left step length was apparent after treadmill training. There were no effects on right or left stride length, left step length, cadence, or walking velocity. The results indicated an improvement in some aspects of gait with treadmill training in the patient with hemiplegia.

Besides forward gait training on the treadmill with PBWS, backward gait training should be considered. Backward walking is a hard skill and not popular in every day life. However, it can often be seen that backward walking is needed for avoiding the obstacles, or pulling a heavy object, or promoting and preparing before forward walking.

In general the mechanics of the backward walking are different from the forward walking;

1. In particular, stance during walking is characterized by an inverted plantigrade–digitigrades sequence in these two movement directions. The forward walking stance begins with the heel strike and ends at toe off whereas the backward walking stance begins with the toes contacting the ground and ends when the heel is lifted off the ground.
2. The anatomical and functional asymmetries of the foot and leg along the antero-posterior axis also impose different biomechanical constraints on backward walking and forward walking. For anterior parts of the foot and leg, the toes articulate on the metatarsal joints and behave as a deformable support surface whereas for posterior parts of those, the tarsus represents a more rigid segment and articulates with the shank and the leg. Calf and thigh muscles are highly asymmetrical about the frontal plane; the mass and strength of triceps surae on the posterior aspect of the calf and of quadriceps femoris on the anterior aspect of the thigh are much greater than those of the muscles on the respective opposite side. All these asymmetries may well explain the lack of correspondence of many gait parameters between forward walking and backward walking directions, leading to that backward walking have short stride length and increase cadence. The increasing of cadence affect to recruitment activity of Hamstring and Quadriceps muscle.
3. During backward walking has increase knee flexion, leading to more activity of Quadriceps muscle. Quadriceps muscle work at swing phase for control of foot

before touch floor with concentric contraction in stance phase for promote knee extension (34).

4. The main forward walking thrust is normally provided by ankle plantar-flexors whereas the main backward walking thrust is provided by hip and knee extensors (35).

Thorstensson (44) found that the patterns of the muscle activity of backward walking bear a poor relation to those of forward walking. The foot impacted on the ground in early stance is sustained by co activation of several limb muscles (flexors and extensors at the hip, knee, and ankle) for forward walking whereas the same event is accompanied by activity in the knee extensors and ankle plantar-flexors for backward walking.

The advantages of forward and backward walking are improvement of balance and postural control, gait velocity, muscle coordination of legs, and improve of energy expenditure during walking. Beside, backward gait training have specific advantages that stretches hamstring muscle group during stride, a prevention of knee injury by reducing the ground reaction forces at contact which is advantageous during knee injury rehabilitation, decreasing the flexion angles of the trunk, hip, and knee which facilitate the upright posture during walking, and increasing the ankle dorsiflexion (9).

Therefore, most CP has abnormal gait pattern especially crouch gait (persistent hip and knee during standing or walking which occurs muscle spastic of hip and knee flexor) and toe walking (muscle spastic of plantar flexor) leading to uses more energy expenditure and decrease of gait velocity during walking, poor balance and postural control, and poor muscle coordination of lower extremity. Then, if CP performs train of backward gait training may improve energy expenditure, gait velocity, balance and postural control, and muscle coordination of lower extremity.

Weng et al (10) found the effectiveness of backward gait treadmill training to be the restoration of motor function, balance and walking speed in patients with stroke. Twenty-six patients with stroke (17 males and 9 females), aged 36-64 years were divided in to two equal groups (control and training groups). The training was 60 minutes conventional training and then 30 minutes backward walking training 5 times a week for 3 weeks. After training period, it was found that the training group improved their performances significantly as compared to the control group. These results suggested that additional backward walking training helps improve the damaged motor function, balance, and walking speed in patients with stroke.

Yang et al (2) examined the effectiveness of additional backward gait training on gait parameters in 25 patients with stroke. These patients had a lower extremity Brunnstrom motor recovery stage at 3 or 4, were able to walk 11 m with or without a walking aid or orthosis, and were divided into two equal groups, control (n = 12) and training (n = 13) groups. Both groups participated in 40 min of conventional training 3 times a week for 3 weeks. The training group received additional 30 minutes of backward gait training for 3 weeks at a frequency of 3 times per week. Gait parameters including walking speed, cadence, stride length, gait cycle and symmetry index were measured using the Stride Analyzer. It was found that after a 3-week training period, the training group showed significantly an improvement in walking speed ($p = 0.032$), stride length ($p = 0.006$), and symmetry index ($p = 0.018$) as compared to the control group. These results suggested that an asymmetric gait pattern in patients post stroke could be improved from receiving additional backward walking therapy.

In conclusion, the gait training (forward and backward walking) on a treadmill with PBWS can improve energy expenditure, gait pattern, walking speed, muscle coordination of lower extremity, balance and postural control, and upright posture during training in children with CP. Besides backward walking training can decreasing the flexion angles of the trunk, hip, and knee which facilitate the upright posture during walking, increasing the ankle dorsiflexion, stretches hamstring muscle during stride, and prevention of knee injury by reducing the ground reaction forces at contact.

However, there are no evidences about the effects of backward gait training with PBWS on a treadmill in children with CP. Therefore, we are interesting of effect of backward gait training.