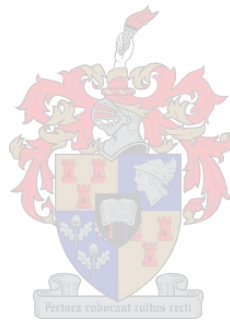# An investigation into the immediate effect of patellar taping on knee control in patients with adult acquired hemiplegia due to stroke

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Thesis presented in partial fulfillment of the requirements for the degree of Master of Physiotherapy at the University of Stellenbosch.

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# Declaration

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# Acknowledgements

# Abstract

The ability to walk has been rated by stroke patients as one of the most important goals of their rehabilitation. Knee control is a key element in normal gait. Currently, treatment options aimed at improving poor knee control in stroke patients are often costly, need specialised equipment and have poor patient compliance.

The purpose of the current study was to assess whether medial patellar taping could improve knee control in stroke patients. Gait speed, dynamic standing balance, knee alignment and whether the subjects experienced any subjective stabilising effect on the knee after taping were tested. Twenty subjects diagnosed with hemiplegia after a stroke served as their own controls in a repeated measures experimental study. Results indicated that dynamic standing balance as tested by the Step Test ($p=0.063$) and the Timed-up-and-go test ($p=0.099$) (Wilcoxon test) showed marginal improvement after taping. This improvement in dynamic standing balance may indicate that neuro-motor control and/or eccentric knee control had improved. There was no change in walking speed and knee alignment as tested by change in the Q-angle (Wilcoxon test). However, a decrease in the Q-angle correlated with an improvement in dynamic standing balance as tested by the Step Test ($p=0.029$) (Spearman's test). Participants with decreased Q-angles after taping possibly had better knee alignment and were more willing to accept weight on their affected leg indicating a change in quadriceps activation. No change in walking speed ($p=0.351$) (Wilcoxon test) before and after taping may indicate that there was no change in the magnitude of contraction and/or concentric activity in the quadriceps muscle. Thirty percent of the participants reported a subjective change in knee stability after taping. Subjective change did not, however, significantly correlate with either of the balance tests, walking speed or Q-angle measurements.

The possibility that medial patellar taping may be useful in treating poor knee control in stroke patients during dynamic balance activities should be investigated further.

# Opsomming

Beroerte-pasiënte het die vermoë om te kan loop geïdentifiseer as een van die belangrikste doelwitte van hul rehabilitasie. Goeie kniebeheer is ´n sleutelelement van normale loopgang. Huidige behandelingsopsies vir swak kniebeheeer in beroerte-pasiënte is duur, het gespesialiseerde toerusting nodig en pasiënte se samewerking is dikwels onvoldoende.

´n Mediale patellêre verbindingstegniek is in die huidige studie ondersoek om te bepaal of dit kniebeheer in beroerte-pasiënte kan verbeter. Die volgende uitkomsgebaseerde toetse is voor en na toepassing van die verbindingstegniek getoets: loopspoed, dinamiese staanbalans, kniegewrig-belyning en of die toetspersoon enige subjektiewe stabiliseringseffek van die knie ervaar het. Twintig persone, gediagnoseer met hemiplegie na ´n beroerte, het as hul eie kontroles in ´n herhaalde metings navorsingsprojek opgetree. Resultate het aangedui dat dinamiese balans, getoets deur middel van die "Step Test" (p=0.063) en die "Timed-up-and-go test" (p=0.099) (Wilcoxon toets), minimale verbetering getoon het na toepassing van die verbindingstegniek. Die verbetering in dinamiese staanbalans kan moontlik daarop dui dat motoriese kniebeheer en/of eksentriese kniefleksie-beheer verbeter het. Loopspoed en die Q-hoek het nie beduidend na toepassing van die tegniek verander nie (Wilcoxon toets), maar daar was wel 'n beduidende korrelasie tussen ´n verminderde Q-hoek en ´n verbetering in dinamiese staanbalans soos getoets deur die "Step Test" (p=0.029) (Spearman's test) Laasgenoemde bevinding mag daarop dui dat diegene wie se Q-hoeke verklein het na toepassing van die verbindingstegniek, beter kniebelyning gehad het, meer gewig op die aangetasde been kon plaas en dus ´n verandering in die sametrekking van die quadriceps-spier ondervind het. Die onveranderde loopspoed (p=0.351) (Wilcoxon toets) dui daarop dat die intensiteit van spiersametrekking en/of konsentriese spieraktiwiteit van die quadriceps-spier nie verander het nie. Dertig persent van die toetspersone het, nadat die knie verbind is, ´n subjektiewe verbetering in kniestabiliteit ervaar, maar hierdie subjektiewe verandering het geen korrelasie getoon met enige van die ander toetse nie.

Verdere studie is nodig om die gebruik van mediale patellêre verbinding vir die behandeling van swak kniebeheer in beroerte-pasiënte te ondersoek.

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# Chapter 1

# Introduction

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In the developed world, stroke is the third leading cause of death and the primary cause of disability (Turnbull *et al,* 1995). Data relating to the rehabilitation of stroke patients in South Africa, Finland and Australia found that pathology in the three countries is similar, but that patients in South Africa are generally younger (Green *et al,* 2005). Almost half of the stroke patients treated in rehabilitation facilities in South Africa are younger than 64-years-old (Green *et al,* 2005). The economic implications may thus be significant as these patients are hampered from contributing their time and skills to the workforce of the country.

The ability to walk has been rated by stroke patients as one of the most important goals of rehabilitation (Goldie *et al,* 1999; Bohannon *et al,* 1991). Knee control is one of the key elements in normal gait, and loss of knee control influences function and movement at other key points, such as the ankle and hip. Lack or even loss of knee control due to abnormal tone, muscle weakness and poor sensation and proprioception as seen in hemiplegia is just one of the many problems associated with gait function in this population. Currently there are treatment options aimed at improving poor knee control like orthotics, functional electric stimulation and biofeedback (Cozean *et al,* 1988) but these are often costly, need specialised equipment and have poor patient compliance.

## 1.1 Prevalence

Turnbull *et al* (1995) state that in North America, stroke is the third leading cause of death, the primary cause of disability in the elderly, and presents an ongoing international health care problem. They further state that the incidence of stroke increases with age and, as the projected number of elderly increases in developed countries due to improved medical care, disability as a result of stroke will impact

greatly on the health care system. Published statistics regarding stroke prevalence in the USA confirm these findings (strokerecovery-info.com, Feb. 2008):

In the United States, stroke was found to be the third leading cause of death, and the leading cause of disability.

Approximately 600 000 to 700 000 strokes occur or re-occur in the United States annually, and of these, approximately 150 000 (25%) are fatal.

Stroke occurs at an equal rate in men and women, but women are more likely to die as a result. Seventy-two percent of cases were over 65 years of age, with ischemic stroke occurring more frequently in this category. Haemorrhagic stroke is more common in younger people.

More than 30% of stroke patients required assistance with daily living and approximately 15% required care in an assisted-living facility (e.g., nursing home, rehabilitation centre).

Approximately 20% of stroke patients required help with walking (e.g. cane, walker) and as many as 33% suffer from depression.

Comprehensive stroke rehabilitation was considered to improve functional abilities of stroke survivors and decrease long-term patient care costs.

Approximately 80% of stroke patients benefited from inpatient or outpatient stroke rehabilitation programmes.

The estimated cost of care and earnings lost in 2003 in the USA was about $51 billion.

Recent statistics for the prevalence of stroke in South Africa was not found in the literature. It can be argued that the above mentioned statistics cannot be appropriated in the South African contexts due to differences in the socio-economic environment but these statistics indicate that the prevention of strokes and the treatment of stroke victims are an ongoing challenge for healthcare workers.

## 1.2 Medical Treatment

Early medical treatment can help minimize damage to brain tissue and improve the prognosis. Treatment depends on whether the stroke is ischemic or haemorrhagic and on the underlying cause of the condition. Initial treatment for ischemic stroke involves removing the blockage and restoring blood flow. Haemorrhagic stroke usually requires surgery to relieve intracranial pressure caused by bleeding. The long-term goals of treatment include rehabilitation and prevention of additional strokes (Neurologychannel, Nov. 2007). It is during this rehabilitation phase that the physiotherapist would assess a patient and recommend appropriate exercises and compensatory strategies to address functional difficulties like abnormal gait.

## 1.3 Prognosis

Prognosis depends on the type of stroke, the degree and duration of obstruction or haemorrhage, and the extent of brain tissue death. Most stroke patients experience some permanent disability that may interfere with walking, speech, vision, understanding, reasoning or memory. Approximately 70% of ischemic stroke patients are able to regain their independence, and 10% recover almost completely. Approximately 25% of patients die as a result of the stroke. The location and extent of a haemorrhagic stroke determines the outcome (Neurologychannel, Nov. 2007).

## 1.4 Rehabilitation and Outcome

Rehabilitation is an important aspect of stroke treatment and could help facilitate undamaged areas of the brain to take over the functions that were lost when the stroke occurred. Physical rehabilitation is multidisciplinary and includes physiotherapy, speech therapy, and occupational therapy.

Green *et al* (2005) compared data relating to the rehabilitation of stroke patients in South Africa, Finland and Australia. The data used was drawn from studies conducted between 1998 and 2004 – 995 cases from 23 private hospitals in South

Africa; 4,691 cases from 30 public hospitals in Finland; and 10,687 cases from 43 public hospitals in Australia. Their results indicated that the pathology in all three countries was similar, but that the South African patients were generally younger In Australia and Finland, 26% and 38% respectively of the stroke population were under 64-years-old, while in South Africa, 48% of patients were younger than 64. Reasons for the above differences were not discussed, but the current researcher hypothesised that possible reasons for this could be as follows: Firstly, South Africa is a developing country while the other two countries are first world and most likely have access to better aftercare. Secondly, pathology may differ; for example, the effect of HIV/Aids and its complications in the South African context should be considered.

In the cited study, rehabilitation outcome was measured by length of stay and functional improvement as measured by the 18-item FIM™[1] (Green *et al*, 2005) in which higher scores indicated a higher level of functional independence. These were similar for all three countries, with a gain of 16 to 22 points during hospitalisation. The average length of stay was 30 to 34 days. However, the following difference was noted. It showed that South African patients were admitted and discharged with much lower functional status, and were often discharged with poorer functional status than Finnish and Australian patients displayed on admission.

Stroke patients have rated the ability to walk as one of the most important goals of rehabilitation (Goldie *et al*, 1999; Bohanned *et al*, 1991). Hill *et al* (1994) confirm this point by stating that gait outcome is a significant factor influencing the patients' chances of returning to their premorbid environments and participation in community-based activities. Shinkai *et al* (2000) found, after testing 736 individuals older than 65, that walking speed was the best physical performance measure for predicting the onset of functional dependence in an older, rural Japanese population. In the light of these findings, it is understandable that gait analysis and the impairments that cause gait disturbances have been comprehensively described. In the following chapter, hemiplegic gait, the impairments that influence gait and the treatment thereof will be discussed.

## 1.5 Knee control in hemiplegic patients

Poor knee control in hemiplegic patients causes high energy expenditure and plays a significant role in normal ankle and hip function during gait (Olney *et al,* 1991). Impairments that impact on knee control are muscle weakness, spasticity, and sensory deficits (Hsu *et al,* 2003). Current treatment thus focuses on addressing these impairments through neuro-developmental treatment, strengthening exercises or more specific techniques like electromyographic biofeedback, functional electrical stimulation or orthotics (Cozean *et al,* 1988). Biofeedback and FES needs specialised equipment which may not be available in all clinical settings and can only be used in the therapeutic environment whereas orthotics are very costly and compliance are often poor due to difficulty putting it on and discomfort while wearing it. The current researcher proposes patellar taping as an alternative technique to possibly alter neuro-motor control and/or enhance force generation in the quadriceps muscle as well as proprioceptive feedback to improve knee control. Patellar taping has shown to be effective to reduce pain in a population with patella-femoral pain syndrome (Cowan and Bennell *et al*, 2002; Gilleard *et al*, 1998; Ernst *et al,* 1999)) and osteo-arthritis of the knee (Hinman and Bennell *et al,* 2003 and Hinman and Crossley *et al,* 2003). These studies indicated changes in the force generation or neuro-motor control of the knee and enhanced proprioception of the knee joint. The technique is cost effective and the therapeutic benefits may be experienced in- and outside of the therapeutic environment.

## 1.6 Conclusion

Gait rehabilitation has been identified as one of the primary goals in therapy by stroke patients. Regaining knee control is an integral part of the rehabilitation process. The objective of this study is to investigate if patellar taping could be beneficial during the rehabilitation process in regaining knee control after a stroke.

# Chapter 2

# Literature Review

From the statement of the problem as described in Chapter 1, an understanding of the hemiplegic gait is imperative if effective treatment is to be given. In this chapter a CVA and the diagnosis thereof will be defined, also, hemiplegic gait and balance and the mechanism of knee control will be described in more detail. Current approach to rehabilitation is explained, current use of patellar taping is discussed and the use of patellar taping in stroke patients is motivated. The following databases were used in the literature search: Pubmed, EBSCO Host and Google.

## 2.1 Cerebrovascular Accident (CVA): Definition

A Cerebrovascular Accident (CVA) occurs when blood flow to a region of the brain is obstructed, resulting in brain tissue damage. There are two main types of stroke: ischemic and haemorrhagic (Neurologychannel, Nov 2007).

## 2.2 Diagnosis

If a stroke is suspected, accurate diagnosis and treatment is necessary to minimise brain tissue damage. A diagnosis is confirmed by neurological examination to evaluate level of consciousness, sensation and functional status and to determine the cause, location and extent of the stroke. Other tests that are used to confirm diagnosis are:

- Computed tomography (CT) scan.
- Blood chemistry analysis
- Ultrasound imaging
- Magnetic resonance imaging (MRI) scan
- Single photon emission computed tomography (SPECT) and positron emission tomography (PET)

## 2.3 Hemiplegic gait

Various researchers have described hemiplegic gait. While some focussed on the quality of gait patterns, others looked at the temporal assessment of gait.

### 2.3.1 Quality of gait

Gait deviation in adult-acquired hemiplegia follows a consistent pattern, varying proportionately with the severity of central nervous system involvement (Pinzur *et al*, 1987). In their study, these researchers recruited 50 adults with acquired hemiplegia, and 60 healthy, age-matched adults for the control. Multiple factor gait analysis was based on the percentage of the walking cycle devoted to stance, swing and double-limb support, as well as qualitative assessment of the gait pattern, positions of the hip, knee and ankle at four selected times during the gait cycle, and phasic muscle activity of selected muscle groups. The hemiplegic patients were divided into three groups that reflected the severity of their neural involvement. Type 1 represented an almost normal gait pattern. Asymmetry was, however, observed due to decreased knee flexion with weight acceptance on the affected limb. Type 2 had a typical spastic equinovarus gait characterised by dynamic equinus deformity coupled with knee hyperextension and increased hip flexion. Time spent in weight bearing on the affected leg was reduced to half of that of normal gait, and the period of double limb support was prolonged. Type 3 patients had the most severely abnormal gait patterns. Hyperextension of the knee of the affected limb was so severe that the uninvolved limb did not advance past the affected stationary limb during the swing phase of the unaffected leg. Pinzur *et al* (1987) concluded that: 1) An increased proportion of the gait cycle was spent in limb-support phases (stance of the unaffected leg and double support) 2) Consistent abnormalities in the phasic activity of muscle groups (tibialis anterior, gastrocnemius-soleus and rectus femoris) were present in the affected lower limb and 3) Consistent patterns of deviation from normal position of the affected hip, knee and ankle through the gait cycle. They argued that this consistent pattern of deviation from normal gait would implicate that the underlying

impairments for these gait abnormalities would be the same for all the described gait patterns.

Olney *et al* (1991) describes the muscle work and power characteristics of both limbs of stroke patients during gait, and relate these characteristics to self-selected speeds of walking. Thirty ambulatory hemiplegic patients who had recently suffered strokes were used for the study. Olney *et al* further explain that mechanical law states that the body can change its speed only when work is done on, or energy applied to, it. During gait, the energy level of the body returns to approximately the same level at the same point in the gait cycle for each succeeding stride, and successive bursts of positive work and negative work occur in known patterns. Positive work is performed by concentric contractions and negative work is done against gravity or other external forces, and is performed by eccentric contractions. Both forms of work require metabolic energy. They calculated the work performed by a muscle group that crosses a particular joint during one stride by using mathematic integration of the power curve with time. At a given point in time, the power of a muscle group can be calculated if the next moment of force at the joint and the joint angular velocity is known. Joint angle disturbances as shown in the results of Pinzur *et al* (1987) could thus influence the ability to produce power in a muscle group. For the knee, maximum flexion during the swing and stance phases respectively was calculated. Although the authors did not include healthy adults in their study, they claim that joint angle profiles demonstrated most of the phases found in able-bodied walking. Profiles were similar in shape for both the affected and unaffected sides, but the amplitudes were generally smaller. These findings confirm those of Pinzur *et al* (1987) that gait disturbances follow a consistent pattern and have the same underlying impairments. The current researcher hypothesises that if impairments are similar regardless of the severity of the stroke, treatment approach to rehabilitate gait disturbances would be similar for all stroke patients.

Joint angle disturbances of the affected side include reduction or loss of the knee flexion phase in stance, reduction of knee flexion range during the swing phase, occasional loss of dorsiflexion of the ankle in swing phase and at initial contact, and generally reduced active range of movement (Olney *et al*, 1991). Regardless

of these disturbances, Olney *et al* (1991) found that about 40% of the positive (concentric) work during gait is performed by the affected side and this does not change substantially with the level of gait competence. This would mean that 60% of the positive work is done by the unaffected side. The discrepancy was mostly the result of differences between work done at the ankle and to a lesser extent at the hip. There was no difference between positive work contributions of the knee muscles. A correlation was found between the peak power and positive work parameters for the hip and ankle muscles with walking speed. Eccentric or negative work of the affected knee muscles was positively related to walking speed. These results indicate that, for the knee, eccentric control is essential for the gait cycle and will be discussed later in more detail (section 2.6).

Olney *et al* (1994) studied the temporal, kinematic and kinetic variables related to gait speed in patients with hemiplegia. The gait of 32 subjects was analysed through stepwise regression and they identified the variables most useful in predicting stride speed. For the affected side, these variables were the hip flexion, knee and ankle moment range, and the proportion for double support. The studies by Olney *et al* (1994) and Olney *et al* (1991) suggest that treatment to improve knee dynamics should be directed at eccentric knee control and greater knee flexion range during the stance and swing phases of the affected leg – this will improve gait speed. For the purpose of this study, the mechanism of knee control was investigated further and is discussed below.

Kramers De Quervain *et al* (1996) assessed movement patterns of the affected limb in eighteen stroke patients. Gait was analysed using motion analysis, force-plate recordings and dynamic surface electromyographic studies of the muscles of the lower extremities. The description of the gait patterns were very similar to those of Pinzer *et al* (1987) as discussed above and additional information was acquired through the EMG recordings. EMG recordings of the rectus femoris muscle showed abnormal contractions of this muscle in terms of when it contracted and for how long the contraction lasted. No association could, however, be made between the electromyographic recordings and the different motion patterns that were recorded. The authors concluded that motion patterns

stayed the same regardless of the abnormal timing and length of quadriceps contraction.

Kramers De Quervain *et al* (1996) further found that movement patterns were primarily associated with external joint moments. They noted that movement patterns of the lower limbs on the hemiplegic side had a stronger association with the clinical severity of muscle weakness than with the degree of spasticity, balance control or phasic muscle activity. Targeting muscle weakness is thus more likely to produce a favourable outcome regarding gait improvement than any of the other impairments.

It could be argued that the change in muscle strength of the quadriceps muscle could be the cause of the change in external joint moments of the knee, thereby attributing to the change in gait patterns and speed. The EMG recordings did, however, also indicate a disturbance in the neuro-motor control of the rectus femoris muscle in terms of timing of contraction and the length of the contraction during gai (Kramers De Quervain *et al*, 1996). As discussed in the section on muscle strength and neuro-motor control (section 2.2.1), a neuro-motor control problem has been indicated as a factor in dynamic standing balance. Since dynamic standing balance and walking speed correlate with each other (Ringsberg *et al,* 1999), it is possible that neuro-motor control could possibly play a direct albeit a minor role in walking speed.

Olney *et al* (1991) took a more specific look at hemiplegic gait and focused on the role of the knee. In normal gait, there are three phases which are attributed to knee extensor activity, 1) Eccentric work at weight acceptance, 2). A very small concentric period during mid-stance and 3) A large eccentric phase at "push-off". At the end of the swing phase, the knee flexors act eccentrically. In hemiplegic gait (during swing-phase) they found a tendency for knee flexion and hip extension to decrease with declining walking speed. This was more pronounced on the affected side than the unaffected side. Eccentric work of the knee extensors of the affected side was positively related to both walking speed and maximum flexion of the knee during swing phase. The researchers argue that this indicates that more capable walkers flex their knees at the end of stance while weight is still on the

foot. Furthermore, the action of the concentric knee extensor during mid-stance, followed by eccentric work at the end of stance, may be intimately linked to the opportunity for power generation of the ankle. If knee flexion does not occur, the limb must clear the supporting surface using only the hip musculature, causing high energy expenditure on the part of the patient. Knee control, therefore, plays a significant role in normal ankle and hip function during gait.

The findings of the above studies indicate that gait deviation in adult-acquired hemiplegia follows a consistent pattern, varying proportionately with the severity of central nervous system involvement. Underlying impairments for these gait abnormalities would therefore be the same for all gait patterns described (Pinzur *et al,* 1987).  Joint angle profiles in hemiplegic gait demonstrate most of the phases found in able-bodied walking, and profiles are similar in shape for both the affected and unaffected sides, but amplitudes are generally smaller (Olney *et al,* 1991). Reduction in joint angle amplitudes can influence the muscle's ability to produce power, and thus the ability of patients to change their walking speed.

Eccentric or negative work of the affected knee is positively related to walking speed (Olney *et al,* 1991). A reduction in the knee flexion amplitude during weight bearing phase can be the cause or the result of poor strength and/or motor-control of the knee extensors. The finding supports the argument that movement patterns of the lower limbs on the hemiplegic side have a stronger association with the clinical severity of muscle weakness than with the degree of spasticity, balance control or phasic muscle activity (Kramers De Quervain *et al*, 1996). For the knee, treatment should thus be directed at improving eccentric control of the quadriceps muscle and range of movement during walking.

### 2.3.2 Temporal Gait Measurements

While the previous studies focussed on description and quality of gait, the following studies looked at temporal measurements in normal and hemiplegic gait. These include gait velocity or speed and temporal asymmetry.

Hsu *et al* (2003) analysed the impairments influencing gait velocity and asymmetry of hemiplegic patients after a mild to moderate stroke. They studied a convenience sample of 26 subjects measuring their gait velocity as well as temporal and spatial asymmetry as subjects walked at their comfortable and fast speeds. They found gait velocity of stroke patients to be 0,62m/s ±0,21m/s. This is considerably slower that the gait velocity of healthy 75-year-old men and women as tested by Rantanen *et al* (1994). The latter tested 101 men and 186 women and found that the maximal walking speed of the healthy individuals was on average 1,8m/s for men and 1,5m/s for women. This discrepancy was also evident in a study by Brandstater *et al* (1984) where 23 stroke patients and 5 healthy participants were assessed. They found that the gait velocity of healthy elderly is 1,14 ±0,1m/s while that of subjects with stroke were markedly slower at 0,31 ±0,21m/s.

The results of Hsu *et al* (2003) on temporal and spatial asymmetry indicated that patients with hemiplegia avoid spending time in weight bearing on the affected side. This was also the conclusion reached by Wall and Turnbull (1986), who tested 25 subjects with residual stroke and found that all patients favour their affected side by spending longer in support on the non-affected leg.

Hsu *et al* (2003) further identified the most important impairments causing a slower gait velocity and asymmetry in stroke patients. Their results revealed that impairment of muscle strength of the affected hip flexors and knee extensors primarily determined the comfortable and fast gait velocities of these patients whereas spasticity of the affected ankle plantar flexors was the primary determinant of temporal and spatial asymmetry of hemiplegic gait. The third significant independent determinant of comfortable gait velocity was sensation of the affected lower extremity. Patients with visuo-perceptive, tactile or proprioceptive impairments tended to walk slower than healthy adults.

The current researcher concluded that muscle weakness and specifically eccentric muscle control of the quadriceps muscle require attention if gait is to be improved after a stroke.

A consistent weakness in all the studies conducted in the stroke population is that the study samples are small. A possible reason, experienced by the current researcher, is that it may be that logistically difficult to test bigger samples. Also, the experimental studies are often non-controlled, non-randomised or non-blinded which weakens its level of evidence.

## 2.4 Knee control in the hemiplegic patient

Hsu *et al* (2003) identified muscle weakness, spasticity and sensory deficit as impairments causing gait disturbances. Bennell *et al* (2003) added that physical function depends upon many physiological parameters including sensory input from proprioception, visual and vestibular systems, intact balance mechanisms, range of motion and higher cortical function. These impairments, and how they impact on knee control during gait, are discussed below.

### 2.4.1 Muscle strength and motor-control

Muscle strength deficit and altered motor-control has been identified as impairments after a stroke (Kramer De Quervain *et al*, 1996). However, muscle strength, or the lack thereof, in adult acquired hemiplegia has been a controversial issue (Newham and Hsiao, 2001). The view that apparent weakness is a consequence of excessive antagonistic hypertone or spasticity and that inherent muscle strength is unaffected (Davies PM, 1991) has been challenged by others (Bohannon and Walsh, 1992). The latter found a significant correlation between gait speed and knee extension torque on the affected side. Additionally, the current author hypothesised that muscle strength and motor-control are closely linked and should simultaneously be considered when assessing and/or treating these patients and that it may also be difficult to distinguish between the two in functional activities.

Newham and Hsiao (2001) stated: "Muscle weakness may contribute to functional problems after stroke, but is rarely addressed during rehabilitation" (p. 379). In the past, weakness has been considered a consequence of excessive antagonistic

restraint and it was assumed that inherent muscle strength was unaffected. This view was reflected in the training curriculum as experienced by the current author However, since then these views have changed and research indicates that muscle weakness may be a major cause of functional problems (Bohannon and Walsh, 1992). Newham and Hsiao (2001) investigated muscle strength bilaterally in twelve stroke patients, and 20 healthy controls on their preferred side only. Subjects performed maximal voluntary isometric contractions of the quadriceps and hamstring muscles. Simultaneous measurements were made of agonist force and surface EMG readings from agonist and antagonist muscles. They explained the possible mechanisms for a reduction in muscle strength after a stroke are neurological damage as well as possible disuse. Mechanisms for reduced muscle strength were classified as primary or secondary causes. Primary causes resulted from neurological damage, would be apparent earlier after stroke than secondary disuse and involved decreased input from the corticospinal pathways. They added that stroke patients also demonstrate an inability to recruit the whole motor unit population of the paretic limbs. The activation failure might be due to either a failure of motor unit recruitment or reduced firing rates in active units and could also explain reduced muscle strength in the non-paretic limbs. Their results further indicated that both limbs of the stroke patients showed greater activation failure than the control subjects during an isometric maximal voluntary contraction of the quadriceps. The authors explained that the upper neuron lesion itself might therefore be a more important cause of weakness, and possibly also activation failure, than secondary causes e.g. antagonistic co-contraction or disuse atrophy. They suggest that bilateral strength measurements should be incorporated in the assessment of stroke patients and the non-paretic limb should not be used as an indication of an individual's normal strength.  Shortcomings of this study were the small size of the group (only twelve patients), and the fact that EMG recordings were made with surface electrodes.  Interference from adjacent muscles could thus not be excluded and results should be interpreted with caution.

The presence of muscle weakness and its functional implications (i.e. walking speed and dynamic standing balance) in stroke patients were investigated in the studies discussed below. Bohannon (1986) studied the strength of the lower limb and how it relates to gait velocity and cadence in stroke patients. He found that

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the static knee extension torque produced by the paretic and non-paretic lower limbs of 27 stroke patients was decreased on both sides and that static knee extensor strength was significantly correlated with cadence (steps per minute) but not with gait speed. Isometric strength tests may have strengthened the results of this study since that would be more representative of muscle function during walking. Also, the reliability of this study is questionable since a single gait speed trial was recorded where an average of, or best out of, three trials would be a better representation of the patients' walking speed. In a subsequent study, Bohannon (1989) established a correlation between isometric (dynamic) knee extension force and gait speed. Twelve stroke patients were asked to perform isometric knee extension and measurements were taken with a handheld dynamometer while the subjects were seated on a high mat table and their knees were at 90°. Gait speed was tested over 8m at their "most comfortable speed". He concluded that muscle strength on the non-affected side and affected side contributed 29,7% and 49,3% respectively to gait speed. It should be noted that the isometric test was done in a non-weight bearing position and this may have influenced the results. In 1992, Bohannon and colleagues investigated the reliability of various velocity, torque and time measures obtained during maximum knee extension efforts and the correlation of various muscle performance measures of the paretic and non-paretic sides with walking speed. Fourteen stroke patients from a convenience sample were recruited. Results showed that the knee extension velocity on average was 23,9% less on the paretic than on the non-paretic side. In addition, the mean time to peak torque was 13,1% less on the non-paretic side than on the paretic side, and the mean time to 90% peak torque was 24% less on the non-paretic side than on the paretic side. This confirmed the previous results and indicates that the highest correlation is between peak knee extension torque of the paretic side and gait speed. This correlation was also found to be stronger in fast gait speed than in comfortable gait speed.

The association between muscle weakness on the affected side and walking speed was supported by the findings of Kramers de Quervain *et al* (1996), who investigated the gait pattern in the early, post-stroke recovery period in 18 patients. Gait was analysed with the use of motion analysis, force-plate recordings and dynamic surface electromyographic studies of the muscles of the lower limbs.

Firstly, they found that the patterns of motion of the lower extremity on the hemiplegic side had a stronger association with the clinical severity of muscle weakness than with the degree of spasticity, balance control or phasic muscle activity. These researchers recommended that, in order to improve gait velocity, one should improve muscle strength and coordination on the affected side. Secondly, Kramers de Quervain *et al* (1996) found little evidence of weight bearing on the affected side; specifically, the weight of the body transferred from the hemiplegic side to the unaffected side long before the foot on the hemiplegic side cleared the ground. They hypothesised that this decreased ability to take weight on the affected leg are related to abnormalities in standing balance and asymmetry during single-limb stance. The study only included patients who had had an infarct due to obstruction of the middle cerebral artery suggesting that balance may have been affected by loss of proprioception and /or motor-control on the affected side and generalised application of the results to a wider population may thus be limited. For example, the mechanism for balance and coordination disturbances following a stroke in the cerebellum is very different and these patients would have to be included in future studies.

Although there is evidence that gait speed and muscle strength are correlated, this association is curvi/non-linear. In other words, the association was more significant in weak patients. Buchner *et al* (1996) investigated the relationship between strength and physical performance in 434 healthy, older adults, aged 60 to 69 years. The sample was randomly selected, and age and sex-stratified, and tests were done in random order to exclude learning effects. Subjects were familiarised with the procedure before testing started. Gait speed was measured with a single trial. An average of three trials may have been more accurate, but the large sample study may have compensated for that. Using an isokinetic dynamometer, leg strength in both legs was measured in four muscle groups: the knee extensor, knee flexor, ankle plantar flexor and ankle dorsiflexor. The authors chose one score, the sum of absolute strength in the right leg, for analysis of relationship between gait speed and strength. This was done because they found a high correlation between strength in the left and right legs. In stronger subjects there was no association between strength and gait speed, while in weaker subjects there was a positive association. The authors suggest that this finding

represents a mechanism by which small changes in physiological capacity may produce relatively large effects on performance in frail adults, while large changes in capacity have little or no effect on daily function, like gait speed, in healthy adults. When working with the stroke population, relatively small physiological gains could thus translate into meaningful functional gains.

The studies by Kramers de Quervain *et al* (1996) and Buchner *et al* (1996) established that muscle weakness is present in stroke patients and that it impacts on their function. Engardt *et al* (1995) investigated the effect of strength training on knee extension torque, electromyographic activity and motor function. They tested 2 groups of 10 hemiplegic patients each. One group (age 64.6 ± 6.2) did concentric exercises, and the other (age 62.2 ± 7.6), eccentric exercises with the paretic leg. Both eccentric and concentric training were done in a sitting position and a dynamic dynamometer controlled the movements. Their results showed that eccentric as well as concentric training rendered a considerable increase of knee extensor strength after 6 weeks of training, but that eccentric training had better results. They found that after eccentric training, there was a significant improvement in symmetrical body weight distribution when moving from sitting to standing. This was not true for the group that did concentric training. With regard to gait parameters, the concentric exercises significantly improved the walking speed of this group. In the group that did eccentric exercises, the gait speed did not improve significantly. The authors explained that the latter group walked on average with 0.81m/s at self-selected and 1,0m/s at fastest speeds before training. They compared these results with those of Murrey *et al* (1969) who found that the mean gait velocity in healthy older men is 1,18m/s (67-73 years) and 1,45m/s (60-67 years). Thus, there may not have been much scope for improvement in this group. Alternatively, it may be hypothesised that the eccentric exercises could have improved the motor-control leading to improved balance and symmetry. The concentric training, which improves strength, had a bigger impact on gait velocity. The type of strength training nevertheless seems to be of importance for affecting motor performance.

Hamrin *et al* (1982) found evidence of a correlation between dynamic standing balance and gait velocity. A correlation between maximum walking speed,

standing balance and muscle strength of both knees was also investigated by Suzuki *et al* (1999). Thirty-four male hemiparetic stroke patients received 8 weeks of computer-assisted gait training, which was initiated within 3 months after stroke onset. Gait speed was measured over 3 meters. Three trials were performed successively and the fastest time was used for calculations. Muscle strength was measured in sitting position with a dynamometer and static standing balance was measured using a force platform. It may have been more appropriate to use a functional dynamic balance test as was shown in the study by Ringsberg *et al* (1999) where a relationship was established between clinical balance tests and gait but not between laboratory balance tests and gait. This study is further discussed in section 2.5. Suzuki *et al* (1999) however found that the maximum walking speed at four and eight weeks could be predicted by the initial maximum walking speed, the initial muscle strength during knee extension on the affected side and the time since stroke onset. They further reported that, with time, the biomechanical determinant of maximum walking speed changed from the postural control of weight shifting from left to right to the muscle strength during knee extension of the affected side in patients with mild to moderate stroke.

The current researcher hypothesises that initially the subjects' balance was poor and this impacted negatively on the gait speed. As balance improved, its influence was less significant and knee extensor strength became the more important determining factor of gait speed. Where neuro-muscular control initially plays a more significant role in walking speed, muscle strength becomes more important as time goes by.

In a study by Ringsberg *et al* (1999) on healthy 75-year-old women, similar results were found. These authors found a correlation between muscle strength of the knee flexors and extensors and walking speed but not between strength and standing balance. It could be argued that in a healthy population dynamic standing balance should be good and will thus not negatively influence gait speed. Further, the current researcher expects that the results may indicate that motor control, and consequently balance, was good in this healthy population, but weakness, leading to slower gait speed, may have been present for reasons such as inactivity.

Comparison of studies in the stroke population and a healthy population suggest that standing balance is more dependent on neuro-muscular control rather than muscle strength where-as gait speed on the other hand is more dependent on muscle strength.

## 2.4.2 Spasticity

Spasticity has been defined as: "A velocity-sensitive increase in the resistance of muscles to passive stretch associated with exaggerated tendon jerks resulting from upper motor neurone damage" (p.158) (Sloan *et al*, 1992). Spasticity interferes with voluntary movements and can influence posture. The level of spasticity is influenced by a variety of factors like anxiety, depression, fatigue, temperature, infection, medication and positioning (Sloan *et al*, 1992).

Following central nervous system damage, neural and mechanical components to spasticity can be observed. In both cerebral and spinal spasticity there is a slow increase in tone following the initial injury, except in cases of high brain stem lesion in which there is an immediate increase in muscle tone. This slow development suggests that plastic changes in the synaptic connections may contribute to the development of spasticity. The mechanical changes may be due to secondary changes in muscle and other soft tissue. The viscoelastic properties of the tissue in spastic, paretic muscle may contribute to passive restraint that can be limiting in terms of the opposing muscle's ability to produce torque (Sharp and Brouwer, 1997; Carr *et al*, 1995).

The contribution of spasticity to the gait problems seen in this population has been widely investigated. Traditionally it has been believed that spasticity has a major influence on function, and that treatment aimed at reducing spasticity would lead to improved function. In more recent studies, this belief has been challenged. Research in this field is complicated by the fact that no reliable measures for spasticity exist (Haas and Crow, 1995). Hinderer and Gupta (1996) state in their review, investigating the effect of spasticity reducing intervention on function, that no conclusive evidence exists linking a reduction in spasticity with an improved functional outcome. Carr *et al* (1995) state that even though the medical and

therapy professions consider spasticity as a major obstacle in improving function, there is no clinical or experimental evidence to support this view. The complexity of the mechanism of spasticity has made it very difficult to measure the extent and the influence it has on movement and function. Haas and Crow (1995) list the following methods most commonly used to measure the degree of spasticity: EMG, the pendulum test, tendon jerks and rating scales like the Ashworth scale. The authors go on to state that the usefulness of EMG recordings in spasticity is unconfirmed, and surface electrodes have low repeat reliability. Indwelling electrodes are more accurate but have ethical implications in the clinical setting. They further argue that another shortcoming of EMG recordings lies in its inability to distinguish between voluntary muscle activity and the spontaneous firing of a spastic muscle.

Yelnik *et al* (1999) investigated lower limb extensor overactivity in hemiplegic gait disorders. They tested 135 patients who had experienced a stroke in the previous 3 to 24 months. Spasticity in the quadriceps femoris muscle was assessed in a sitting position with a pendulum test and compared with the unaffected side. They concluded that extensor muscle overactivity is one, but rarely the main, component underlying gait disorders in stroke hemiplegics. Another conclusion was that sitting spasticity of the lower limb was not predictive of disabling overactivity during walking. This indicates that spasticity changes with altered positioning, thus complicating the investigation of the extent, mechanism and role of spasticity in gait. A third conclusion was that patients were principally disabled by muscle weakness. Lastly, the speed of gait did not seem to be affected by spasticity. Spasticity does, however, cause an unsightly or sometimes painful gait. Bohannan *et al* (1990) and Nakamura *et al* (1988) had similar results. The purpose of these studies was to investigate the correlation between knee extensor muscle torque, and knee extensor muscle spasticity on the paretic side with gait speed. In both studies, correlations between knee extensor torque and gait speed were significant, while that of spasticity and gait speed were not. In contrast, studies investigation the relationship between spasticity and upper limb function found a positive correlation to exist (Katz *et al,* 1992).

In 1997 Sharp and Brouwer investigated whether persons with chronic hemiparesis can improve function and muscle strength in an isolated joint of the affected lower extremity via a training programme. They also assessed whether gains are associated with alterations in muscle spasticity. Spasticity of the knee extensor muscles was measured in 15 community-dwelling stroke patients using a pendulum test. After a 6-week training program of the hemiparetic knee muscles (flexors and extensors) there was a significant increase in muscle strength and gait speed, without any detectable change in extensor spasticity.

In the discussion on muscle strength and motor control (section 2.4.1), a study by Engardt *et al* (1995) was cited. The researchers argue that concentric training might increase antagonistic co-contraction through a stretch reflex. This argument is contested by Carr *et al* (1995), who state that the antagonist response is not elicited in a way that would resist the agonist. They suggest, therefore, that the antagonistic stretch reflex was not a major contributor to the disability.

The findings of Davies *et al* (1996) agree with the statement of Carr *et al* (1995). Davies *et al* (1996) recorded surface EMG and torque from knee flexors and extensors in 12 control subjects and 12 stroke subjects bilaterally. They performed isometric and isokinetic maximal voluntary contractions and also isokinetic passive movements. These authors found that during isokinetic movement, the antagonistic co-contraction in the paretic leg was generally minimal or absent, and did not differ from that in the non-paretic leg and control subjects. The decreased agonist strength appeared to be largely due to a reduction in force generation of the agonist, rather than excessive antagonistic activity. Spasticity was tested according to the Ashworth scale. The authors also found that the increased resistance to passive movement appeared to be of non-electrical origin, as tested with EMG. They presumed that it must be a mechanical stiffness of the musculo-tendinous unit. These findings suggest that reduction in voluntary force generation of the agonists could be the result of the neurological deficit and/or muscle atrophy.

The mechanism and influence of spasticity is still under investigation. Other contributing factors are that the measurement of the degree of spasticity is

unrefined, and variables like emotional state, fatigue and positioning may change spasticity from one moment to the next (Sloan *et al,* 1992). It would appear, however, that its effect on functional gait is less pronounced than previously believed. In addition, strength training does not appear to increase spasticity, but may rather decrease effects of muscle weakness and thus improve function.

## 2.4.3 Sensation and Proprioception

Loss of sensation and proprioception after a stroke is a common complaint (Cozean *et al,* 1988). Hsu *et al* (2003) tested 26 stroke patients to determine the most important impairments influencing gait speed and asymmetry in people with mild to moderate stroke. These authors found that loss of sensation (light touch and proprioception) is the third significant independent determinant of comfortable gait speed in their subjects.

### 2.4.3.1 The role of proprioception in muscle control

Bennell *et al* (2003) argue that knee joint proprioception is essential to neuromotor control. Neuromotor control of the knee involves the co-ordinated activity of surrounding muscles, in particular the quadriceps muscle. This coordinated activity provides active stability to the knee joint, thus assisting in the absorption of much of the load placed on the knee joint during weight-bearing activities. The proprioceptive afferent information comes from mechanoreceptors in the muscles, ligaments, capsule, menisci and skin. This information contributes on a spinal level to arthrokinetic and muscular reflexes, which in turn play a major part in dynamic joint stability. The information is also conveyed to supraspinal centres where it is integral to motor learning and the ongoing programming of complex movements (Bennell *et al*, 2003). The contributions of the different mechanoreceptors are discussed below and a distinction is made between static and dynamic position sense.

### 2.4.3.2 An anatomical investigation of proprioception

Clark *et al* (1979) investigated the contributions of cutaneous and joint receptors to static knee-position sense in a normal population. Using ten subjects, the authors found that their subjects could correctly detect a 5° change in knee angle

about 85% of the time. Secondly, they found that there were no significant changes in performance due to experience. Tests for learning effects were made prior to anaesthesia experiments to see if a deficit due to anaesthetising the skin or joint might be masked by improved performance due to practice. Five subjects were given two blocks of tests on different days using four extension, four flexion and two control trials in pseudorandom order. Subjects were told that movement sequences were chosen at random, and after each trial were informed whether their judgement was correct or not. All movements were made with the right leg while the left leg remained in a fixed position. There was no significant difference between the two blocks of tests or the control trial in the subject's ability to correctly sense the 5⁰ change in angle of their right knee. This led the researchers to conclude that it would be unlikely that any decrements in performance in subsequent tests would be masked by improvements due to learning. In the study by Clark *et al* (1979), healthy, young adults were used and the current researcher expects that they had normal proprioception and that learning, therefore, most likely did not play a significant role. In an older population or group with pathology where proprioception may be impaired, the results may have been different.

Clark *et al* (1979) then continued to investigate the effect of joint anesthesia, skin anaesthesia and a combination of the two on the position sense of the knee, and concluded that awareness of static knee position does not depend on sensory input from receptors in either the joint or the skin around the joint. The authors argue that muscle receptors could be more important in the perception of static limb position.

While the mechanoreceptors may not have a major role to play in static knee position sense, there is evidence that they may have an effect on neuromuscular function during movement, for example gait. In a review article, Hogervorst and Brand (1998) looked at anatomical studies, physiological studies and clinical studies concerning mechanoreceptors in joint function. For the purpose of this discussion, only the findings of the clinical studies will be discussed. In these studies, the subjects had a tear in, or no anterior cruciate ligament. This was associated with neuromuscular changes, such as loss of proprioception, alterations in muscle reflexes, alterations in muscle stiffness, quadriceps-force

deficit and changes in gait and electromyographic measurements. It is not clear whether these changes were caused by direct loss of mechanoreceptors or by altered stimulation of the remaining receptors. Hogervorst and Brand (1998) conclude that joint and skin mechanoreceptors can signal movement, but are unlikely to play a role in static position sense.

Neuromuscular changes may also be present after a stroke (Carr *et al,* 1995) and it may be that alterations in muscle reflexes, muscle stiffness and quadriceps-force could be due to an alteration in the afferent messages from the joints, muscles and skin. Also, for normal movement, correct sensory feedback and integration of information is needed, but in the stroke population, integration of information received could be affected (Huxham *et al,* 2001). In time, physiological changes in the joints, muscles and other soft tissue may also play a role in the altered sensory feedback (Carr *et al,* 1995).

### 2.4.3.3 Proprioception and quadriceps function

Loss of proprioception affects the quadriceps function, and thus knee control during gait (Hogervorst and Brand, 1998). Gait analysis of patients with a chronic tear of the anterior cruciate ligament showed a decrease in the flexion moment of the knee in the range of 0° to 40° of flexion. During normal gait, the gravity and inertia generate a moment that causes the knee to flex. This external flexion moment is balanced by the action of the quadriceps muscles. A decrease in the flexion moment indicates a decrease in the quadriceps muscle moment. In these patients, both legs showed a quadriceps avoidance gait, even when only one side had a cruciate ligament injury. The authors propose that muscle stiffness is influenced by a complex system, and several receptor populations are involved. An alteration in the afferent signals can lead to a decrease in the activation of the quadriceps muscle at a spinal or higher level. This would explain loss of quadriceps moment on both sides. The authors hypothesised that loss of one group of receptors may, however, be compensated for by other groups.

A similar pattern of quadriceps avoidance as described above is seen in stroke patients (Olney *et al,* 1991). Hogervorst and Brand (1998) argue that in patients with anterior cruciate ligament injury there is an increased sensitivity of

proprioception when the knee is in almost full extension. They further propose that this argument is consistent with findings that mechanoreceptors of the capsule and the anterior cruciate ligament respond primarily to terminal extension, rather than to movement towards flexion, in an almost extended knee. The current researcher hypothesises that it could arguably be the reason why stroke patients often change their gait to a stiff knee pattern or hyperextension of the knee on the affected side. Near full knee extension or hyperextension could be an attempt to enhance the proprioceptive feedback from the mechanoreceptors in the ligaments. If sensory feedback could be enhance by bandaging or taping, hyperextension may be unnecessary.

2.4.3.4 Treatment of loss of proprioception

Proprioceptive ability sometimes improves with the use of an elastic bandage or taping (Perlau *et al*, 1995). The authors observed that many patients and physicians believed elastic bandages wrapped around a previously injured or weak joint give the bandage wearer an increased sense of security during physical activity. They argued that since these bandages were mechanically weak other mechanisms must be responsible for the increased sense of stability and hypothesised that the main beneficial effect of elastic bandages was related to enhancement of joint proprioception. Perlau *et al* (1995) tested 54 healthy individuals using an elastic bandage to brace the knee. Subjects were asked to identify a knee position after a passive movement. The results showed a significant improvement of knee joint proprioception in an uninjured knee and that the benefit was lost after the bandage was removed. The magnitude of the improvement was inversely related to the participant's inherent knee proprioception. The authors argue that the bandage stimulates the skin during joint motion and also increased the pressure on the underlying musculature and joint capsule. They therefore concluded that the most plausible receptors to be involved are the rapidly adapting superficial receptors in the skin such as free nerve endings, hair end organs and Merkel's discs. These receptors react strongly to new stimuli such as the movement of a bandage on the skin and adapt quickly once the motion becomes monotonous. The receptors in deeper skin layers and joint capsule, like the flowerspray organ of Ruffini, could also receive input from the pressure of the bandage. These receptors are tonic, slowly adapting receptors

and can provide dynamic and static phase proprioceptive input that would be enhanced by the elastic bandage, but to a lesser degree than the more superficial receptors. Enhanced afferent stimuli could theoretically be helpful to the proprioceptive system.

The results were supported by a study by Callaghan *et al* (2002). They investigated the effects of patellar taping on knee proprioception in 52 healthy subjects. One strip of tape was applied without tension across the centre of the patella. Proprioception was tested by active angle reproduction, passive angle reproduction and threshold to detection of passive movement on an isokinetic dynamometer. They concluded that subjects with good proprioception did not benefit from patellar taping. However, those subjects with inherent poor proprioception did benefit from the taping. If one extrapolated this principle to a stroke patient, one may expect a significant improvement with taping as a greater proprioception deficit occurs in this population.

2.4.3.5 Possible effect of taping on proprioception and function

The role of cutaneous afferents in knee joint movement was investigated by Edin (2001). The researcher reported that there is neurophysiological evidence that afferent information from skin receptors is important for proprioception of the human hand and finger joints. Edin (2001) investigated whether proprioceptive information is also provided by skin mechanoreceptor afferents from skin areas related to large joints of postural importance, such as the knee. Microneurography recordings were obtained from skin afferents in the lateral cutaneous femoral nerve of humans. This was done in order to study the response to knee joint movements by inserting an electrode transcutaneously. The author's recordings showed that the skin of the human thigh contains an abundance of stretch-sensitive mechanoreceptors that may convey information about knee joint positions and movements. With the exception of hair follicle receptors, all mechanoreceptors are capable of conveying proprioceptive information, but to differing degrees. Also, the most important group was that of the slowly adapting receptors. The author acknowledged that although the study provided strong evidence that cutaneous mechanoreceptors provide high-fidelity information about knee joint movements, it did not address the crucial question of whether or not the

human central nervous system also takes advantage of this information. The author argued that physiotherapists claim that taping improves joint stability. These findings are however not supported by standardised outcome measures. The author suggested that taping can hardly make any mechanical contribution to the stability of large joints, such as the knee, and that another explanation should be found.

Joint stability is not only a result of biomechanical constraints, but also of the ability of a person to appropriately control the muscles acting on the joint. The stabilising effect of tapes and braces may thus be due to altered somatosensory inflow from the skin. Joint movement are necessarily associated with skin movement. When the tape immobilises certain skin areas, movements always cause larger strain in other areas of the skin. This could then provide additional proprioceptive information.

Sensory activity has to be interpreted in a context of actual motor behaviour since proprioception requires integration not only of signals originating in various types of mechanoreceptors, but also of centrally generated efferent activity (Edin, 2001). An investigated of proprioception in a functional context, such as gait was done in the following two studies:

The effect of therapeutic patellar taping on proprioception of the knee was investigated in both subjects with osteo-arthritis of the knee, and in a healthy population (Hinman *et al,* 2004 and Callaghan *et al,* 2002). Hinman and colleagues tested joint position sense, isometric quadriceps strength and electromyographic quadriceps activation onset in subjects with osteo-arthritis. Testings were carried out on patients during stair descent. Their results showed that although pain decreased, the taping worsened the joint position sense at a knee angle of 40° and did not immediately alter any other sensorimotor parameter. Even after three weeks of wearing the tape continuously, sensorimotor function was not altered. Furthermore, no differential effect of tape was noted when participants were stratified into those with poor and good baseline sensorimotor scores. The authors argued that quadriceps weakness in knee osteo-arthritis is multifactorial and this is unlikely to be influenced by taping. A worsening of the

joint position sense was explained as follows: An increased input from cutaneous afferents triggered by contact and movement of rigid tape on the skin may 'confuse' rather than enhance the nervous system (Hinman *et al,* 2004). It could be hypothesised that osteo-arthritis develops over time and that the body would already have made adjustments to compensate for altered afferent information. Worsening of the position sense would thus indicate that taping had an effect on position sense, albeit a negative one. In addition, the current researcher argues that all of the participants had painful knees, and pain inhibition could mask changes in the sensorimotor system.

Bennell *et al* (2003) also investigated the relationship between proprioception and disability in patients with osteo-arthritis of the knees. They recruited 220 participants (aged 50+years) with symptomatic osteo-arthritis of the knees. Tests were performed on the affected leg or the most symptomatic leg in cases of bilateral symptoms. Five, non weight-bearing active tests with ipsilateral limb matching responses were performed at $20^{\circ}$ and $40^{\circ}$ flexion to measure knee joint position sense. Pain and disability were assessed through self-reported questionnaires and objective measures of balance and gait. Objective tests included the Step Test, the Timed-up-and-go Test and walking speed. Results showed poor association between knee joint position sense and measures of pain and disability. The authors hypothesised that a certain threshold of proprioceptive deficit may be required before physical function is affected.

Callaghan *et al* (2002) tested the effects of patellar taping on knee joint proprioception in a healthy population. Fifty-two volunteers (age 23,2 ±4.6 years) were asked to perform active angle reproduction, passive angle reproduction and to identify threshold to detection of passive movement on an isokinetic dynamometer. Results showed no significant difference between the taped and un-taped conditions in any of the three proprioceptive tests; however, when the subjects' results for active angle reproduction and passive angle reproduction were graded as good and poor, taping was found to significantly improve the results in those with poor proprioceptive ability. The question arises whether in a stroke population, taping may enhance/improve proprioception by stimulating the mechanoreceptors in the skin, thereby leading to improved quadriceps function.

## 2.5 Balance control in the hemiplegic patient

Huxham *et al* (2001) explain that balance is an integral component of function. They describe it as a product of the task undertaken and the environment in which it is performed. The task and environment affect the motor performance in two ways: Firstly, they alter the biomechanical features of the activity, and secondly, they affect the amount of information that must be processed in order to achieve both balance and the motor goal. During any given task, the body needs to make anticipatory postural adjustments to prepare for the task. When these adjustments fail or an unexpected destabilisation occurs, the emergency back-up system of reactive balance response is used. Both the anticipatory and reactive systems are dependent on adequate sensory input, efficient central processing and a strong effector system of muscles and joints (Huxham *et al*, 2001).

Bohannon (1995) investigates whether muscle strength of the right and left legs and/or standing balance had an influence on gait performance. Of the thirty patients tested, 14 were diagnosed with stroke, 10 had other neurological diagnoses, and 6 had a non-neurological diagnosis. The subjects were hospitalised patients with a mean age of 63,3 years. Gait was tested with the Functional Independence Measure locomotion score; muscle strength was tested with a hand-held dynamometer; and balance was measured by an ordinal scale. His findings imply that while both balance and lower extremity muscle strength of knee extensors, hip flexors, abductors and ankle dorsi-flexors may be appropriate targets for measurement and treatment, balance was probably more important.

Kramers de Quervain *et al* (1996) have investigated the gait pattern of 18 patients (average age of 59) who had a single infarct due to obstruction of the middle cerebral artery. Data was collected using motion analysis, force-plate recordings and dynamic surface electromyographic studies of the muscles of the lower extremities. This includes tibialis anterior, gastrocnemius (medial head), quadriceps (rectus femoris), medial hamstrings, and gluteus medius and maximus. Results indicated a stronger association between muscle strength and gait than between gait and balance. The current researcher argues that one possible reason for the discrepancy in results between the studies of Bohannon (1995) and

Kramers de Quervain *et al* (1996) is the differing target population. Another possible reason is set forth in the studies conducted by Bohannon (1995) where balance was tested through a functional test whereas, in the studies of Kramers de Quervain *et al* (1996) force plate recordings were utilised and therefore different aspects of balance assessed.

Bohannon (1989) conducted a study investigating the relationship between gait variables (speed, cadence and distance), static standing balance, and isometric muscle strength in the lower limbs of 33 stroke patients (mean age 67,7 ±11.1 years). Muscle strength of the dorsi-flexors and plantar flexors of the ankle, flexors and extensors of the knee, and flexors, extensors and abductors of the hip were tested with a hand-held dynamometer in both affected and unaffected legs. Results showed that static standing balance, as well as muscle strength of both paretic and non-paretic legs, correlates with gait variables. He suggests that the results of the measure of balance and lower extremity strength appear to be indicative of gait performance. This is helpful in determining the appropriate therapeutic intervention targets.

Winstein *et al* (1989) investigated the effects of a balance retraining programme on both standing balance and gait variables (speed, stride length, gait cycle duration, cadence, single and double limb support periods) in post acute hemiparetic adults. Sixty-one patients participated in the study (40 control subjects and 21 experimental group subjects). Twenty-one of the control group were matched as closely as possible to the experimental group. Both the control and experimental groups received therapeutic exercises, including sitting balance activities, coordination training, motor control facilitation and strengthening activities. In addition, the experimental group were trained on a standing feedback trainer consisting of two force plates that measure vertical forces, a microcomputer with custom software, and a visual display system for feedback of information. Subjects trained 30-40 minutes a day, 5 days a week for 3 to 4 weeks. The results indicate that a specialised balance retraining programme leads to a more symmetrical standing posture in hemiplegic adults.  However, although standing balance and gait variables may be highly correlated, a reduction in static standing asymmetry does not necessarily lead to a concomitant reduction in the

asymmetrical gait patterns associated with the hemiplegia. It may however be that static standing balance training was carried out and the effect therefore limited as balance is very task-specific. If dynamic balance-training was used it may have resulted in a bigger effect size. This argument is supported by the findings of Ringsberg *et al* (1999) who investigated the relationship between clinical and laboratory tests on balance, muscular strength and gait in healthy, 75-year-old women. The clinical balance test was a simple, one- leg stance test, while the laboratory test measured both static and dynamic standing balance using a computerised balance system consisting of footplates. There was no relation between the computerised balance test and any of the other tests. The non-computerised balance test and isometric knee extension strength tests both correlated with gait speed (Ringsberg *et al*, 1999).

Balance is an integral part of function and, as discussed in the aforementioned studies, there is a correlation between gait measurements and standing balance. Functional balance testing and training seem to have a greater impact on various gait variables when compared with computerised testing and training. A possible reason is that balance is task and environment dependent (Huxham *et al*, 2001). It can thus be concluded that balance testing and training will have greater functional significance if done, using functional activities, and performing tasks that are appropriate to the specific population and/or patient.

## 2.6 The role of the quadriceps muscle in normal gait and knee stability and the influence it has on the Q-angle

In the stroke population there are various factors contributing to loss of knee control, including decreased trunk stability; insufficient hip, knee and ankle control due to loss of muscle strength; abnormal muscle tone and loss of sensation. Treatment of these impairments should all be incorporated into a rehabilitation programme. However, Morris *et al* (1992) argue that in the light of growing evidence that motor learning is task specific, treatment to improve knee control should be directed specifically at the knee. The quadriceps muscle plays an important role in the dynamic stability of the knee during weight-bearing activities (Bennell *et al*, 2003) and warrants further discussion. The role of specific parts of

the quadriceps in the normal population is discussed below. In a two-subject study, Brandell (1986) showed that in normal gait the vastus medialis muscle was contracting at the early to mid-stance phase, but was inactive during the rest of the gait cycle. This would indicate that the vastus medialis muscle's main function is an eccentric contraction in the early to mid-stance phase (loading response). Differences between the EMG activity levels of the two parts of vastus medialis suggest that this muscle may have varied roles with respect to patellofemoral joint mechanics. EMG activity of the vastus medialis obliquus (VMO) becomes more pronounced at the end-range of extension where the vastus lateralis (VL) and vastus medialis longus (VML) ratio stays constant throughout extension. VML would thus act primarily as a knee extensor, and VMO as a medial patellar stabiliser (Powers, 2000). No study has been found that investigates vastus lateralis and VMO function in the stroke population. In this discussion on hemiplegic gait (section 2.3), it was explained that joint angle profiles in hemiplegic gait demonstrate most of the phases found in able-bodied walking, and that profiles are similar in shape but amplitudes are generally smaller (Olney *et al*, 1991). A reduction in knee flexion amplitudes can influence the quadriceps muscle's ability to produce power (Olney *et al*, 1991). In hemiplegic gait it would thus be a reasonable expectation to have reduced activation of vastus lateralis and vastus medialis influencing the patients' ability to extend the knee. Moreover, reduced activation of vastus medialis obliquus could influence patellar stability in the stroke population.

The above literature does not refer to the effect of patellar instability on the tibio-femoral joint stability. However, it could be argued that instability of the patella-femoral joint may also lead to or indicate instability of the tibio-femoral joint, since they are moved and stabilised by the same muscle groups. Further, if the VMO is involved in patellar stability, this muscle could also be involved in tibio-femoral stability. The discussion below attempts to explain the role of the quadriceps muscle in the biomechanics of both the patellar-femoral joint and the tibio-femoral joint.

The Q-angle describes the orientation of the quadriceps muscle force (Mizuno *et al*, 2001). These authors explain that it is the result of the four muscles of the quadriceps acting on the patella. It is defined as the angle between a line

connecting the centre of the patella and the patellar tendon attachment site on the tibial tubercle, and a second line connecting the centre of the patella and the anterior superior iliac spine on the pelvis when the knee is fully extended (figure 2.1). Normal values vary between 6° and 27° with a mean value of 15° (Mizuno *et al*, 2001). Mean Q-angle values for female subjects are higher than those of male subjects (Sanfridsson *et al*, 2001). In a study done by Horton and Hall (1989) it was found that the mean Q-angle was 15,8° in women and 11,2° in men. A Q-angle exceeding 15° in men, and 20° in women, is considered abnormal for adults (Bayraktar *et al*, 2004).
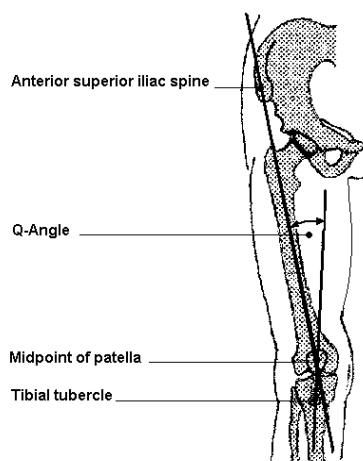


Figure 2.1: The Q-angle

The link between the Q-angle and the biomechanics of the tibio-femoral joint and quadriceps activity was investigated by the Hsu *et al* (1990), Bayraktar *et al* (2004) and Mizuno *et al* (2001). Hsu *et al* (1990) studied 120 normal subjects in a simulation of one-legged, weight-bearing stance. Their results indicated that 75% of the knee joint load passed through the medial tibial plateau. The researchers also found that the knee joint-line obliquity was more varus in male than female subjects. Female subjects, however, had a higher peak joint pressure and a greater patello-femoral Q-angle. Bayraktar *et al* (2004) supported these findings and added that there was a significant association between Q-angle and quadriceps strength. These researchers tested 474 soccer players and 765 sedentary boys (age 9 to19). Q-angles were measured in a non weight-bearing supine position, with the quadriceps muscle relaxed. An increase in muscle tone

and strength caused by both activity and growth were associated with a decrease in the Q-angle. The population studied by Bayraktar *et al* (2004) was young and healthy and thus differs from the population of the current study. It could be argued, though, that regardless of age, the function of the quadriceps muscle stays the same.

During a weight-bearing activity in a normal knee, the tibia rotates outwardly in relation to the femur as the knee is extended ("screw-home mechanism") (Sanfridsson *et al*, 2001). The authors also found that the lateral tibial plateau moves posterior in relation to the femur, indicating that the centre for rotation in the knee is located more towards the medial compartment. One can thus argue that a decrease in the Q-angle will shift the line of weight-bearing to the medial plateau and free the lateral tibial plateau to rotate outwardly and glide posterior. This argument is supported by the following study.

An invitro study was done by Mizuno *et al* (2001) on six cadaver knees (deceased aged 64 to 94 years), which were free of deformities or surgeries. The purpose of the study was to examine the link between the Q-angle and the tibiofemoral and patellofemoral kinematics. Their results include the following:

Influence of the Q-angle on the patella
1. Increasing the Q-angle shifted the patella laterally, while decreasing the Q-angle did not significantly influence the patellar shift.
2. Increasing the Q-angle tilted the patella medially, while decreasing the Q-angle tilted the patella laterally.
3. Increasing the Q-angle rotated the patella medially, particularly at low flexion angles, while decreasing the Q-angle did not significantly influence the patellar rotation.

Influence of the Q-angle on the tibio-femoral joint
1. The tibia tended to translate more laterally after the Q-angle was increased and translate more medially after the Q-angle was decreased. These changes were, however, not significant.

2. Decreasing the Q-angle tended to rotate the tibia externally with the change between 30° to 60° flexion being statistically significant. Increasing the Q-angle did not significantly influence the tibial rotation.

3. Decreasing the Q-angle decreased the tibiofemoral valgus orientation throughout knee flexion. Increasing the Q-angle did not significantly influence the tibiofemoral varus-valgus orientation.

The researchers explain that the results of their study indicate that patellar kinematics can vary dramatically within the range of normal Q-angles. They also found that a large Q-angle could increase the lateral patellofemoral contact pressure. A Q-angle decrease may also increase the medial tibiofemoral contact pressure. Therefore, decreasing the Q-angle from 20° to 11° could be justified in symptomatic patients (Mizuno *et al*, 2001). As mentioned above, an increase in the tone and strength of the quadriceps muscle can decrease the Q-angle and thus lead to more medial tibiofemoral contact pressure. This would allow for a normalising of the tibio-femoral joint biomechanics.

Another factor that influences the Q-angle in standing, is positioning of the foot (Olerud and Berg, 1984). These researchers tested 34 healthy individuals to investigate the variation of the Q-angle with different foot positions. Measurements were taken with the patient in supine position, with the subjects' legs relaxed and knee extended – foot position was not considered. These values were compared with measurements taken while standing in three positions of rotation (15⁰ of lateral rotation, as well as 0⁰ and 15⁰ of medial rotation). Results showed that the Q-angle increases when the foot is moved from lateral to medial rotation. The limbs are internally rotated around an axis that is centred in the hip joint. The patella and the tibial tuberosity followed this rotation, but the pelvis remained excluded. The origin of the rectus femoris muscle and its line of pull were lateralised, leading to an increase in the Q-angle (Olerud and Berg, 1984). In stroke patients, the affected leg is often inwardly rotated due to abnormal muscle tone in the internal rotators and adductors and/or poor motor control and strength of the gluteus medius muscle. This may in turn lead to an increase in the Q-angle on this side.

It could be hypothesised that facilitation of the vastus medialis obliquus muscle may prevent the patella from moving laterally, and lead to a decrease of the Q-angle. This, in turn, could normalise the line of weight bearing and the proprioceptive feedback from the knee. Normal afferent information from the knee could then lead to more effective muscle contraction and thus improved balance and faster gait.

## 2.7 Current physiotherapy intervention for poor knee control in stroke patients

Current physiotherapy interventions to target poor knee control during treatment in stroke patients include orthotics, biofeedback and functional electrical stimulation, and are discussed below. While these specifically address poor knee control, it is used in conjunction with strengthening exercises and gait training.

Orthotics, for example ankle-foot orthoses and knee-ankle-foot orthoses, can compensate for the loss of ankle and knee control in the stroke population. The current researcher found that despite improvement in gait and balance, patients commonly complained that the orthoses are heavy, difficult to put on or take off and were aesthetically unacceptable. Patients also needed to wear appropriate shoes that could accommodate the orthotics. This often leads to resistance and poor compliance on the part of the patient. Carr *et al* (1995) argue that the major barriers to improved function in stroke patients are weakness and loss of skill. It can thus be argued that an orthosis provides external support, thereby limiting active and passive range of movement, resulting in loss of motor control and strength. It may act, in fact, as a barrier to improved function although this still needs to be proven empirically. Moreover, substantial costs can be involved: an ankle-foot-orthosis currently costs from R800 to R2000 and the cost of a knee-ankle-foot-orthosis from R10 000 to R12000.

Biofeedback has been used successfully in the treatment of hyperextension of the knee (Morris *et al*, 1992; Basaglia *et al*, 1989). Morris *et al* (1992) investigated the effect of combining electrogoniometric feedback with contemporary physiotherapy for treatment of genu recurvatum following stroke. A randomised controlled study

was conducted in 26 patients with hemiplegia who presented with hyperextension of the knee. Random allocation was used for the first 20 participants and stratification was used for the remaining six to ensure that groups were matched with respect to age, side of lesion, severity of genu recurvatum and stage of gait recovery. The study comprised of two treatment phases. During the first phase, the control group received standard physiotherapy, and the experimental group received standard physiotherapy plus electrogoniometric feedback. During the second phase, both groups received standard physiotherapy. Each treatment phase lasted four weeks. Gait recovery (dependency on equipment or persons), gait speed and gait symmetry were evaluated. Their results indicated that the addition of electrogoniometric feedback to standard physiotherapy enhances the effectiveness of treatment for genu recurvatum in stroke patients. The researchers did not specify what the standard treatment was, and it is thus difficult to assess what influence it may have had on the results. However, the study of Basaglia *et al* (1989) showed similar results. These researchers recruited 18 subjects with central nervous system lesions caused by either stroke or head injury. The aim of the study was to evaluate the effect of a biofeedback electrogoniometer during gait in the control of genu recurvatum. Parameters calculated for each patient were: self-selected walking speed, maximum walking speed, and an error score calculating the percentage of mistakes (occurrence of genu recurvatum during the trials). Following treatment, evaluation took place at intervals of up to twelve months. Results showed that these patients achieved a significant reduction in recurvation of the knee, and that such control was maintained up to one year following treatment.

Cozean *et al* (1988) examined the efficacy of biofeedback and functional electric stimulation, both separately and in combination, in treatment of gait dysfunction in 32 stroke patients. The researchers investigated the control of ankle movement, but their findings could still be relevant to this discussion. The subjects were randomly assigned to one of 4 groups, 8 per group. These groups were divided as follows: (1) control therapy (passive and active range of motion, strengthening exercises with special attention given to ankle and foot control on the affected side, and gait retraining), (2) electromyographic biofeedback, (3) functional electrical stimulation (FES) and (4) combined therapy of biofeedback and FES.

Both the biofeedback and FES modalities were associated with improved gait parameters, including gait cycle time, leading to improved gait speed, but these improvements were not significant. Statistically significant improvement in 3 of the parameters suggested that the combination of biofeedback and FES was more beneficial than either one of them alone. These parameters were knee flexion, stride length, and gait cycle time. By using these two modalities the researchers were addressing two impairments, i.e. poor sensory feedback and poor force generation. As with the use of orthoses, biofeedback and functional electrical stimulation may be effective, but requires specialised equipment. Moreover, they are costly and may not be available to all therapists in the clinical setting.

An alternative, inexpensive intervention with minimal side effects is thus desirable. The techniques to improve knee control should also be clinically feasible.

## 2.8 Patellar taping

Patellar taping is a technique developed by Jenny McConnell, an Australian physiotherapist, to treat patellar-femoral pain syndrome and described in studies by Crossley *et al* (2000) and Larson *et al* (1995). She proposed that appropriate taping procedures could reduce pain, correct abnormal patellofemoral joint alignment and facilitate vastus medialis obliquus thus allowing normal pain-free movements of the knee. This has been supported by studies conducted by YF Ng and Cheng (2002) and Larsen *et al* (1995). The etiology of patellar pain syndrome is not well understood and the most commonly accepted hypothesis is abnormal lateral tracking of the patella. The effect of this possible abnormal tracking on the tibio-femoral joint has however, to the knowledge of the current author, not been investigated.

While patellar taping was developed for patients with patello-femoral pain syndrome, it is clinically used for a much wider population. In a study that investigated the use of patellar taping on subjects with osteoarthritis of the knees, a significant improvement in pain and disability was found (Hinman and Bennell *et al,* 2003 and Hinman and Crossley *et al,* 2003). Even the subjects with only

tibiofemoral joint disease benefited from the treatment. In the study by Hinman and Bennell *et al* (2003), the researchers investigated the effects of therapeutic taping in 18 participants with knee osteoarthritis. A within-subject study design was used and outcome measures included pain assessment during four functional activities (walking, ascending and descending stairs, the Step Test and the Timed-up-and-go Test). Results showed a significant decrease in pain on three of the four activities. Only one of the functional activities, the Step Test, showed significant change with taping, enabling participants to take more steps indicating improved balance. In a subsequent study, Hinman and Crossley *et al,* (2003) tested the hypothesis that therapeutic taping of the knee improves pain and disability in patients with osteoarthritis of the knee, and that those benefits remain after treatment is discontinued. Eighty-seven participants with osteo-arthritis of the knees were recruited for a randomised single blind controlled study. Three interventions, therapeutic taping, control taping and no tape were used in the study and outcome measures were reduction of pain and perceived disability, as measured by the Western Ontario and MacMaster Universities osteoarthritis index. The therapeutic tape reapplied weekly and worn continuously for three weeks, significantly improved pain and disability in these patients. Some of the participants had only tibio-femoral joint involvement, highlighting that taping could be used in the wider osteo-arthritis population. This may also indicate that the tibio-femoral joint was influenced by the taping.

Researchers agree that the taping is effective in relieving pain, but the mechanism for this is not clear. The argument that taping might only have a psychosomatic effect was refuted by the outcome of studies using placebo taping (Hinman and Crossley *et al*, 2003 and Cowan *et al*, 2002). Cowan *et al (*2002) proposed that taping might influence the tracking by any one or combination of the following ways: 1) improving the neuromotor control of the patellofemoral joint, 2) affecting the osseoligamentous structures via altered patella alignment, and 3) improving proprioceptive feedback. Studies that investigated these three theories are discussed below as well as a study that investigated the effect of patellar taping on knee extensor moment.

## 2.8.1 Altered quadriceps activation

Ernst *et al* (1999) studied the effect of patellar taping on knee extensor moment during a vertical jump and lateral step-up. Fourteen women with patella-femoral pain performed the two tasks under three conditions: patellar tape, placebo tape and no tape on the affected knee. Knee extensor moment was calculated by the inverse-dynamics approach. This is a method of determining joint forces and internal moments from the known motion that is produce by the external forces and moments. The patellar tape condition resulted in a greater knee extensor moment than did the no-tape and placebo tape. The current author suggested that EMG recordings might have strengthened this study as this may give a reading of force generation in the knee extensors pre- and post- taping. Participants may have been inclined to increase use of hip and ankle muscles to improve their performance after taping. Also, the study sample was small and subjects that agreed to participate in a research study may be inclined to bias after the tape was applied. Using the placebo tape strengthened the study provided that the participants were truly unaware of which tape was therapeutic and which was placebo. The following studies investigated the effect of taping on vastus lateralis and vastus medialis obliquus.

## 2.8.2 Improving neuromotor control

Researchers have focussed on either the magnitude of the contraction of the vastus medialis obliquus and vastus lateralis or the relative timing of the contraction of these muscles in subjects with patello-femoral pain syndrome.

Studies that investigated the magnitude of VL and VMO concluded that taping does not increase the relative activity or magnitude of contraction of VMO to VL (YF Ng and Cheng, 2002; Cerny, 1995). In the study by YF Ng and Cheng (2002), fifteen subjects with patellofemoral joint pain were tested before and after taping. Pain and surface EMG activity ratio of vastus medialis obliquus to vastus lateralis during single-legged semi-squat were documented. They concluded that after taping, there was a significant decrease in pain and in the relative activity of vastus medialis obliquus (VMO) to vastus lateralis. The authors argue that a

possible reason for this result was that taping caused mechanical realignment and stabilisation of the patella. Since the VMO is primarily a patellar stabiliser during knee extension, VMO activity did not need to increase. Limitations of this study were the use of surface EMG studies and the possible influence of overlap from adjacent muscles. Also, a small study sample and no control group were tested which may suggest too much variability in the outcome and generalisability is thus limited. However, the study by Cerny (1995) displayed similar results. In this study, indwelling wire electrodes were used to reduce possible overlapping of other muscle contraction activity. Although the ten test subjects reported that patellar taping decreased their pain by 94% during a step-down test, the VMO/VL ratio did not change. In both these studies, a functional weight bearing activity was used during testing. It is thus reasonable to expect these findings to be consistent with muscle function during activities of daily living. Research thus suggests that taping may not significantly change the relative magnitude of activity in VMO and VL contraction.

Studies that investigated the timing of vastus medialis obliquus relative to that of vastus lateralis supported the use of patellar taping to facilitate VMO. Researchers found that taping alters the temporal characteristics of VMO and VL activation during a functional weight bearing activity like stair climbing (Cowan and Bennell *et al*, 2002; Gilleard *et al*, 1998). Cowan and Bennell *et al* (2002) tested ten symptomatic subjects with patella-femoral joint pain syndrome, and twelve healthy subjects. Electromyographic data was collected using surface electrodes to test the onset of VMO and VL during the concentric and eccentric phases of a stair stepping task. The results indicated that the application of therapeutic tape altered the temporal characteristics of VMO and VL in subjects with patellofemoral pain syndrome whereas placebo tape had no effect. Before taping, the vastus lateralis of symptomatic subjects contracted before the VMO in both the concentric and eccentric phases of stair climbing. However, after therapeutic taping, the EMG onset of VMO occurred before valstus lateralis in the concentric phase, and simultaneously in the eccentric phase of stair climbing. In contrast, they found no change in the EMG onset of VMO and VL with the application of placebo or therapeutic tape to the knee in asymptomatic subjects. Gilleard *et al* (1998) had similar results after investigating the temporal relationship of VMO and VL in

subjects with patello-femoral pain syndrome in a stair stepping task. When the patellar was taped, the onset of VMO EMG activity was found to occur earlier in the movement on both ascent and descent of the stairs. In a review article by Crossley *et al* (2000), it was proposed that taping the patella could enhance the activation or timing of VMO relative to VL, or alternatively decrease the activation or timing of VL relative to VMO.

Powers *et al* (1997) assessed the influence of patellar taping on gait characteristics and pain of fifteen female subjects with patella-femoral pain syndrome. Data was collected under the following conditions: self-selected, free walking speed, walking at a self-selected fast speed, ascending and descending stairs, and ascending and descending a ramp. They found that the taping decreased pain, and had a small but significant increase in loading response knee flexion when walking at two different speeds, up and down ramps, and up and down stairs. This indicated an ability to load the knee joint with confidence during all gait conditions. As described in section 2.6, the loading response of the knee depends on the quadriceps function. An improvement of the loading response could thus indicate an improvement of the neuro-motor control of the quadriceps muscle. The authors acknowledged that it was not clear whether the taping decreased pain and thus improved loading, or whether the taping improved neuromotor control and loading, leading to decreased pain.

If taping, however, does have an influence on the motor-control of the knee, it could be beneficial to stroke patients who have motor-control impairment.

### 2.8.3 Altered patella alignment

Brockrath *et al* (1993) investigated the effects of patella taping on patella position and perceived pain. Twelve subjects with anterior knee pain syndrome were asked to perform isometric knee extension in a non-weight bearing position. The knee was held at a 45° angle and X-rays were taken pre and post taping. No significant change was found in patellofemoral congruency angle, patella rotation or sulcus angles. They did not, however, investigate patellar tracking during a functional weight-bearing activity, like gait or stair climbing. Such a study was undertaken by

Cowan and Bennell *et al* (2002) and Gilleard *et al* (1998). It is possible that patellar tracking could change under these circumstances. Somes *et al* (1997) investigated the effects of patellar taping on patellar position in open (non-weight-bearing) and closed (weight-bearing) kinetic chains, as well as the effect it has on pain. Nine subjects with patella-femoral pain were x-rayed in the open and closed kinetic chains at a 45° angle of knee flexion, both with and without taping. Subjects also had to complete a visual analogue pain scale, both before and after taping, once they had completed a step-down test. The researcher concluded that patellar taping decreases pain, and improves patellar medial tilt, as defined by the lateral patella-femoral angle in the closed kinetic chain. No change occurred in patellar position with patellar taping in the open kinetic chain, which is in agreement with the study by Brockrath *et al* (1993). These studies indicate that taping may change patellar tracking in a weight-bearing activity and lead to a decrease in pain in a population with patella-femoral pain. Bigger study samples and the use of placebo tape might have strengthened both of these studies.

### 2.8.4 Improving proprioceptive and sensory feedback

Callaghan *et al* (2002) evaluated the effects of patellar taping on knee joint proprioception in healthy subjects. Three proprioceptive tests were performed: 1)- passive angle reproduction, 2)- active angle reproduction, and 3)- threshold to detection of passive movement. Fifty-two subjects participated, each serving as their own control, with the no-tape condition serving as the internal control. It was concluded that in those subjects with poor proprioceptive ability, as measured by active and passive angle reproductions, patellar taping provided proprioceptive enhancement. The researchers argued that subjects with poor proprioception might have received improved afferent feedback via cutaneous receptor stimulation from the patellar tape, thereby improving joint reposition accuracy. This was not the case for subjects that were classified as having good proprioception. Alternatively, they hypothesised that those with good proprioception were capable enough not to need any influence from external aids, such as taping, whereas those with poor proprioception needed the additional information provided by the tape.

Hinman *et al* (2004) studied the influence of tape on the sensorimotor function in patients with knee osteoarthritis. The immediate and short-term (3 weeks) continuous application of knee tape in individuals with symptomatic knee osteoarthritis was investigated. A within subject study (n=18) and a randomised controlled trial (n=87) were performed. Outcomes used were assessment of knee joint position sense, quadriceps strength and quadriceps contraction onset. None of these outcomes showed any change, except for a worsening of joint position sense at a knee angle of 40°. The authors argue that the additional information may have "confused" the nervous system, and conclude that neither immediate application nor continuous use of tape appears to improve sensorimotor function in people with osteoarthritis of the knee. Alterations in sensorimotor function thus cannot explain the pain-relieving effects of therapeutic tape observed in this population. The authors further explain that the multifactorial nature of quadriceps weakness in knee osteo-arthritis is a possible explanation for no change in quadriceps strength and contraction onset. Muscle weakness may be attributed to arthrogenous inhibition, muscle fibre atrophy or myopathic change. It is thus not physiologically possible for tape to reverse all these factors. Alternatively, they explained that muscle weakness may set in over a period of months or years, and that taping may not be able to reverse these.

## 2.9 The use of patellar taping in stroke patients

The use of therapeutic patellar taping has not been investigated in a stroke population. From the findings of the above literature one can argue that patellar taping may influence the following impairments: quadriceps activation (Ernst *et al,* 1999), neuromotor control of the knee (Cowan and Bennell *et al*, 2002; Gilleard *et al*, 1998) and proprioceptive feedback (Callaghan *et al,* 2002). The current author also argues, after considering the results of studies by Mizuno *et al* (2001), that the effect of taping on the biomechanical alignment of the tibio-femoral joint warrants investigation. Taping may arguably have the following effect in a stroke population:

### 2.9.1 Quadriceps activation

Quadriceps strength has been associated with gait speed (Hsu *et al,* 2003). An increase in quadriceps activation could possibly be measured by increase in gait velocity. Even a small change may have clinical/functional benefits in the stroke population (Buchner *et al,* 1996).

### 2.9.2 Neuro-motor control

Medial patellar taping could facilitate the timely eccentric contraction of the vastus medialis obliquus. This could lead to better-aligned and more stable patello-femoral and tibio-femoral joints, and an increase in the ability to take weight on the affected leg. Effective weight bearing is an important component of dynamic standing balance, and an improvement in balance is associated with better gait parameters (Ringsberg *et al*, 1999).

### 2.9.3 Proprioceptive feedback

Afferent feedback during movement comes from the mechanoreceptors in the skin, ligaments and joint capsule and is relayed to the higher centres (Bennell *et al,* 2003). After a stroke, this information is often altered. Application of patellar taping could facilitate the operation of mechanoreceptors in the skin and thus provide additional information to the higher centres. The body can then respond more appropriately with its effector system of muscles and joints, maintaining good joint alignment and improving both dynamic standing balance and gait.

### 2.9.4 Biomechanical alignment

Joint alignment ensures effective balance during activities and is maintained by effective contraction of postural muscles and good feedback from the sensory system (Huxham *et al,* 2001). If taping could facilitate the contraction of vastus medialis obliquus, it could realign the patello-femoral and/or the tibio-femoral joints, ensuring that the line of weight-bearing moves to the medial tibial plateau.

This realignment could be measured by a change in the Q-angle (Mizuno *et al,* 2001).

## 2.10 Conclusion

Knee control is one of the key elements in normal gait (Olney *et al,* 1991). Engardt *et al* (1995) found that good quadriceps muscle function is imperative to knee control and that eccentric quadriceps exercises leads to better standing balance and body symmetry while concentric exercises improves gait speed. One can thus argue that by improving quadriceps control in stroke patients, balance and gait speed may improve.

Studies in the stroke and healthy populations suggest that standing balance is more dependent on neuro-motor control rather than muscle strength where-as gait speed on the other hand is more dependent on muscle strength (Kramers de Quervain e*t al,* 1996). It can thus be argued that by improving eccentric muscle control and/or neuro-motor control of the quadriceps, standing balance should improve. Also, by increasing concentric contraction of the quadriceps one might increase walking speed. By testing both balance and gait speed in the stroke population, one can assess whether neuro-motor control/eccentric control or concentric control is affected.

The different parts of the quadriceps muscle have specific functions during gait and balance. EMG activity of the vastus medialis obliquus (VMO) becomes more pronounced at the end-range of extension where the vastus lateralis (VL) and vastus medialis longus (VML) ratio stays constant throughout extension. VML would thus act primarily as a knee extensor, and VMO as a knee stabiliser (Powers, 2000). Brandell (1986) found that vastus medialis mainly works eccentrically in the early to mid-stance phase (loading response). In the stroke population, one may expect that addressing timing of contraction (neuro-motor control) of the VMO may improve knee control especially when patients have difficulty accepting weight on the affected side.

Proprioception is essential to neuro-motor control of the knee and involves the co-ordinated activity of, in particular, the quadriceps muscle (Bennell *et al,* 2003). An increased Q-angle may indicate poor quadriceps control (Mizuno e*t al,* 2001). It could be hypothesised that facilitation of the vastus medialis obliquus muscle may normalise patellar and knee alignment. This, in turn, could normalise the line of weight bearing and the proprioceptive feedback from the knee. Normal afferent information from the knee could then lead to more effective muscle contraction and lead to better standing balance and gait.

The current researcher argues that interventions to address poor knee control in stroke patients are expensive and compliance is often poor. The use of patellar taping was discussed. Studies that investigated the timing of vastus medialis obliquus relative to that of vastus lateralis supported the use of patellar taping to facilitate VMO contraction before VL contraction. Researchers found that taping alters the temporal characteristics of VMO and VL activation (neuro-motor control) during a functional weight bearing activity like stair climbing with a significant increase in loading response knee flexion (Cowan and Bennell *et al*, 2002; Gilleard *et al*, 1998). It has also been suggested that patellar taping may enhance knee proprioception (Hinman and Bennell *et al,* 2003 and Hinman and Crossley e*t al,* 2003).

In the current study, the author investigates whether medial patellar taping could influence gait speed and dynamic standing balance, knee alignment and whether the subjects experienced any subjective stabilising effect of the knee after taping.

# Chapter 3

# Methodology

A thorough literature review suggests that an investigation into alternative, cheaper and clinically feasible techniques for the improvement of knee control in patients with hemiplegia is needed. Due to the potential effects of patellar taping as investigated in the musculo-skeletal field on knee control, the effect of patellar taping in this population is warranted.

## 3.1 Research question

Could medial patellar taping on the affected side influence knee alignment, gait speed and dynamic standing balance in stroke patients?

## 3.2 Main Aim

To determine whether medial patellar taping on the affected side in stroke patients can influence knee alignment, gait speed and dynamic standing balance.

## 3.3 Project Aims/Objectives

<u>In a population of patients with hemiplegia due to a cerebro-vascular incident, the following objectives were set:</u>

3.3.1 To determine whether medial patellar taping decreases the Q-angle and thus affects the tibio-femoral alignment of the affected knee in stroke patients.

3.3.2 To determine whether medial patellar taping on the affected side increases walking speed of stroke patients.

3.3.3 To determine whether medial patellar taping on the affected side improves dynamic standing balance in stroke patients.

3.3.4 To determine the perceived effect of patellar taping on knee stability in stroke patients.

3.3.5 To investigate whether any of the above effects are correlated with age, weight, height, side affected by the CVA, length of time since the stroke, gender and subjective change.

## 3.4 Hypothesis

H 0   Medial patellar taping on the affected side had no effect on knee alignment, walking speed or dynamic standing balance of stroke patients. Stroke patients perceived no change in knee stability during gait or dynamic standing balance testing after taping.

H 1 Medial patellar taping on the affected side results in a decrease of the Q-angle of the affected knee in stroke patients.

H 2 Medial patellar taping on the affected side improves gait speed in stroke patients immediately after taping.

H 3 Medial patellar taping on the affected side improves the dynamic standing balance of stroke patients immediately after taping, as measured by the Timed-up-and-go Test.

H 4 Medial patellar taping on the affected side improves the dynamic standing balance in stroke patients immediately after taping, as measured by the Step Test.

H 5 Stroke patients perceive an improvement in knee stability after medial patellar taping.

## 3.5 Study structure

A repeated measures experimental study design was used. This limited the number of test subjects needed to complete the study, since subjects acted as their own control (Altman, 1991) Also, the test group and the control group were

the same, and were thus perfectly matched in terms of age, weight, height, affected side and time elapsed since the stroke. External factors that could possibly influence the outcome were thus limited. Also, the testing procedure, both before and after taping, could thus be completed in one test session. These were important considerations in completing the study within acceptable time constraints.

## 3.6 Population

Adults with hemiplegia following a cerebral vascular accident as diagnosed by a neurologist.

## 3.7 Inclusion criteria

Subjects eligible for inclusion into the study:

- Patients with a history of a single CVA (cerebral vascular accident) affecting the right or left side within the twelve months prior to testing.
- Patients who were able to follow simple commands as assessed by the treating physiotherapist.
- Patients with abnormal gait and poor dynamic standing balance as assessed by a physiotherapist.
- Patients who were able to walk 10 meters over an even surface without assistance or walking aids.  An ankle-foot-orthosis was allowed.

## 3.8 Exclusion criteria

Patients with:

- a history of previous knee pathology or surgery
- a history of allergies to plaster/therapeutic tape
- a history of previous strokes, any other neurological diagnosis or pathology that may influence gait and/or balance

were excluded from the study.

## 3.9 Sampling

A convenience sample of twenty patients who were treated at the Entabeni Rehabilitation Centre or at Headway in Durban was recruited. The first 20 patients that were either admitted to Entabeni or Headway and were eligible for inclusion into the study were recruited. These two rehabilitation centres were chosen to minimise transport costs and to reduce administration procedures in obtaining permission to collect data. This sample size was selected to conduct an investigative study and was chosen in consultation with a statistician. It allowed for enough subjects to assess possible benefits of taping as well as indicate where further research could be indicated but was still feasible within financial, time and manpower constraints. The sample size compared well with the sample sizes used in other studies conducted investigating gait and knee control in the stroke population (Hsu *et al*, 2003; Newham and Hsiao, 2001; Kramers De Quervain *et al*, 1996).

## 3.10 Sampling procedure

A list of the inclusion and exclusion criteria was given to the two physiotherapists working at the Entabeni rehabilitation unit and at Headway respectively. The rehabilitation unit at Entabeni Hospital is an inpatient, 40 bed facility where a multi-disciplinary approach is followed. Stroke patients are admitted in the sub-acute stage for rehabilitation for up to three months. Headway is an outpatient facility where patients receive treatment for 1 to 3 days per week. After discharge from hospital or an inpatient rehabilitation unit, patients can continue their rehabilitation at Headway. Both of these facilities admit patients with a variety of diagnoses like head injuries, spinal cord injuries, MS and other pathologies that requires intensive rehabilitation as well as patients with multiple strokes. All the patients yielded by these two facilities who fulfilled the including criteria were approached by their physiotherapist to participate in the study. An appointment was arranged to explain the procedure, get written consent and to collect the data. These appointments had to be arranged with consideration of availability of the

researcher, the treating therapist and the participant. For outpatients, times were selected which coincided with the patient's treatment time in order to minimise inconvenience and travelling costs for the patient and his\her family.

## 3.11 Instrumentation

Four standardised tests were used to measure the impact of medial patellar taping on knee alignment, gait speed and dynamic balance in stroke patients. Measurements were taken immediately before and after taping (section 3.11). The participants were also asked to make subjective comments on the effect of the therapeutic taping and these were recorded on a data capture sheet (Addendum B).

### 3.11.1 Q-angle

The Q-angle describes the orientation of the quadriceps muscle force and is the result of the four muscles of the quadriceps acting on the patella (Mizuno *et al*, 2001). The Q-angle correlates with tibio-femoral alignment and is defined as the angle between a line connecting the centre of the patella and the patellar tendon attachment site on the tibial tubercle, and a second line connecting the centre of the patella and the anterior superior iliac spine on the pelvis when the knee is fully extended. Measurement of the Q-angle was used to detect possible change in knee alignment and line of weight bearing.

Goniometer measurements of the Q-angle in standing have very good intrarater values (r>0,92) and interrater values (r=0,87) in normal subjects (Horton and Hall, 1989).

### 3.11.2 Gait speed

Gait speed gives an indication of a person's functional status in their environment. A walking speed of 1,4m/s is, for example, necessary to negotiate traffic lights (Leiper and Craik, 1991). The gait speed of stroke patients was found to be 0,62 ± 0.21m/s (Hsu *et al*, 2003), whereas that of healthy, 75-year-old adults averages about 1,8m/s for men and 1,5m/s for women (Rantanen *et al*, 1994).

Walking speed was measured with a stopwatch while the subjects walked across a 10m walkway. Good inter-rater reliability was demonstrated by the results of Wall *et al* (2000).

### 3.11.3 Timed-up-and-go Test

The Timed-up-and-go Test is a standardised test for dynamic standing balance. The subject is required to get up from a straight-back armchair, walk 3m, turn around, walk back and sit down on the same chair. Patients who perform the test in less than 20 seconds tend to be independently mobile, have reasonable balance and functional gait speed. Those whose score is higher than 30 seconds needs assistance in many mobility tasks like getting in and out of a chair, are not able to climb stairs or walk outside unassisted. The group that scores between 20 and 30 seconds varies regarding functional capacity and balance.

Podsiadlo and Richardson (1991) found it to be reliable with intraclass correlation coefficient (ICC) scores of 0.99 between raters. Within the same raters the same high correlation was found with ICC=0.99. This test also correlates well with other standardised outcome measures such as the Berg Balance scale, gait speed and Barthel Index of Activities of Daily Living and appears to predict the patient's ability to go outside safely.

### 3.11.4 Step Test

The Step Test is a dynamic standing balance test that has been developed to evaluate dynamic single limb stance. It was developed using both healthy and stroke populations by Hill *et al* (1996). The retest reliability was high in the stroke population (ICC>0.88). A description of the test follows in section 3.11. They advised, after testing different options, that a 7,5cm step should be used and that the duration of the test should be 15 seconds*.*

The authors found the test to be valid as a dynamic balance test since it highly correlated with scores for the functional reach test, gait velocity and stride length (p=0.001). They also found the Step Test to be reliable across time in both healthy elderly and stroke populations at various stages of rehabilitation.

For the purpose of this study, only stepping up with the unaffected leg was recorded. It can be argued that an improvement of balance as tested in the Step Test may indicated a possible change in ability to shift the weight to the affected leg after taping.

The abovementioned two dynamic balance tests were included in the study because they are functional, did not lead to excessive fatigue, were not time-consuming, and minimal equipment was needed. Since balance is task specific (Hill *et al*, 1996), it has been suggested to use more than one test to get a more holistic impression of balance across various activities hence the inclusion of two tests.

### 3.11.5 Questionnaire

The participants' perception of any change in knee stability after medial patellar taping was recorded. A perceived effect of medial patellar taping has been reported in previous studies (Hinman and Bennell *et al*, 2003) where participants reported a "sense of support" after taping, and the authors hypothesised that the improved confidence in the knee may result in more steps taken with the contralateral limb whilst standing on the symptomatic limb. Exact wording of the question was not reported in the study.

A standard question formulated by the current researcher, "Do you think the taping had any effect?" was thus included and asked after walking speed and balance tests (with taping) were completed. The subjects' comments were recorded by the data collector in the participants' own words.

## 3.12 Intervention

Medial patellar taping was applied with the participant in a sitting position according to the method described by McConnell and documented in studies by Wilson *et al* (2003) and Cushnaghan *et al* (1994). In the current study, subjects were in a sitting position and the affected knee was placed in 20° to 30° of flexion and comfortably supported. A single strap of Fixomull® stretch tape (10 cm) was

anchored on the lateral border of the patella. The patella was pushed medially with the thumb, and after applying tension to the tape, it was pulled across the patella and anchored over the medial collateral ligament. The same procedure was followed when a second piece of Leukotape P® was applied over the Fixomull®.



Fig 3.1: Knee with medial patellar taping

## 3.13 Procedure

Ethics approval from the committee for Human research was obtained from US (ref no N05/07/119) (Addendum C).

Verbal consent was obtained from Entabeni Rehabilitation (Life Health Care group) and Headway to use their facility for collecting of data.

Before testing started, the researcher explained the procedure and purpose of the study to the participant. The possible effect of the taping was not mentioned.

All participants signed a consent form in the language of their choice before they were included in the study. If a patient was unable to sign due to upper limb involvement, a family member signed the consent form and that was so noted. A Zulu-speaking physiotherapy assistant working at the Entabeni Rehabilitation unit was used when necessary (Addendum A).

The researcher collected demographic data from participants.

Only the researcher applied the tape but did not take any of the measurements. This ensured consistency with the taping technique and eliminated possible bias from the researcher in collecting the data. Two physiotherapists agreed to assist in data collection and were trained by the current researcher to perform all the measurements as outlined (section 3.13). During all testing procedures at the two test centres, the same venues, measuring tape, wooden step, chairs and stopwatch were utilised. The researcher measured the distances and marked it with tape on every testing occasion. In addition, the current researcher was present during the data collection to ensure that the correct instructions were given, that all subjects fell within the inclusion criteria, and that the data collectors followed the timing procedures as outlined below. Furthermore, each patient was compared to himself/herself to limit external variables such as reaction time of participants. Blinding of the subjects and testers was not possible due to the nature of the technique and recommendations are made in section 6.5.

All measurements of each participant were taken on a single day by the two physiotherapists who were agreed to help with the data collection. The subjects were allowed a practice run of all the measurements to make sure the procedure was properly understood. They then had a 5-minute rest and the measurements were repeated and recorded without the taping. After another 5-minute rest during which the tape was applied (section 3.11), measurements were taken again with the taping. This order of measurements ensured that possible carry-over effect of the taping would not influence the results. Scores were not discussed with participants between un-taped and taped testing procedures. This was done in order to

prevent subjects from influencing the results by trying to set target times in the post-taping re-test procedure. The testing procedure for each subject took between 40 to 50 minutes.

After the standardised tests had been recorded, the participants were asked to comment on their subjective experience of the taping.

## 3.14 Measurement procedure

In this section the procedure for each of the four tests is described.

### 3.14.1 Measurement of the Q-angle

Measurements were taken with a long arm goniometer according to the procedure as described by Guerra *et al* (1994). The goniometer arm that was placed on the superior iliac spine had a custom made adjustable extension, as requested by the researcher (Fig 3.2), to promote accuracy of measurements. The Q-angle is defined as the angle between the line of pull of the rectus femoris muscle and the patellar ligament. According to the study by Olerud and Berg, (1984) the Q-angle is different when taken in supine vs. standing positions. It was also found that the position of the foot influences the Q-angle when measured in standing. The angle increases with inward rotation and pronation of the foot, and decreases with outward rotation and supination. The spontaneous foot position was thus marked on the floor with masking tape and repeated to ensure accurate measurement before and after patellar taping. Measurements were taken with the subject standing since this position is more functional than the supine position and the measurements more accurate (Guerra *et al*, 1994).

France and Nester (2001) found that the accuracy of measurements is dependent on correct identification of anatomical landmarks. Landmarks were therefore used to enhance accuracy of the Q-angle measurements. The quadriceps angle is highly sensitive to error when determining the centre of the patella and tibial tuberosity. According to France and Nester (2001), these centres need to be defined with an accuracy of less than 2mm if the error in the quadriceps angle is to

remain below 5°. Before taping, a mark was made on the anterior superior iliac spine, the centre of the patella and the tibial tuberosity. After taping, the centre of the patella had to be marked again because the tape covered the previous marking; this also allowed the researcher to account for skin movement.



Fig 3.2: Goniometer with extension

### 3.14.2 Measurement of gait speed

Subjects performed three trials for both conditions. Results were then averaged over three trials for both conditions. An averaged over three trials may represent a more functional gait speed than a best out of three trials. The procedure that was followed is described in a course manual: Assessment of mobility and balance in the elderly (Wall, 1999).

Requirements for the test procedure were: A stopwatch, an unobstructed area of 10 meters in which to walk, and markings at 2 and 8 -meter intervals to enable accurate timing over a 6 meter distance.

Method:

- The timer who determined walking speed had to stand back from, but in line with, the first marker.

- The subject had to walk along the walkway from the designated starting position at his\her fastest self-selected walking speed.

- The stopwatch was started as the subject passed the first floor marker with their toe.

- The timer then moved to get in line with the second marker in order to stop the watch as the subject passed this mark with the first toe to cross the marker.

- The time taken to walk 6 meters was recorded. Speed was calculated as time/distance.

## 3.14.3 Measurement of the Timed-up-and-go Test

The method followed in this study is described by Podsiadlo and Richardson (1991) and in course notes by Wall (1999).

The subject was seated in a straight-back armchair with a seat height of 43 (Fig 3.3) centimetres at both the testing venues. A line was drawn (tape) on the ground 3 meters in front of the chair. Subjects were allowed to use their arms to get up from the chair. The data collector was allowed to demonstrate the task and the subjects could have a trial run before measurements were recorded. The time taken to complete the test was documented.

Instructions given to the subjects:

Sit with your back against the chair and with your arms on the armrest. On the word 'go', stand upright and stand still for a moment then walk at your normal pace to the line on the floor, turn round, return to the chair and sit down.

Fig 3.3: Standard chair

### 3.14.4 Measurement of the Step Test

The method followed in this study is described by Hill *et al* (1996): The subject stands unsupported with feet parallel directly facing the 7,5-centimetre high step, which is placed 5 centimetres in front of him/her (Fig 3.4). The rating therapist stands on one side and may use one foot to steady the step. Subjects are then advised which leg must be used for stepping up and are instructed to place the whole foot onto the block, then return it fully to the floor.

For the purpose of this study, the participants were asked to step up with the unaffected leg. They had to repeat the stepping up and down as fast as possible for the test duration of 15 seconds. Subjects were not allowed to move the opposite (supporting) foot during the test period. A step was counted if the foot

was placed fully on, and then off the step. In addition to verbal instructions, the rater demonstrated the task. Each subject was also allowed several practice steps. The rater commenced the 15-second measurement period with the word "go", while simultaneously starting a stopwatch. The word "stop" indicated the end of the measurement time. Supervision, but no hands-on assistance, was given. If the subject lost his/her balance, hands-on assistance was given, counting was stopped and the score recorded, even if the 15 seconds were not completed.



Fig 3.4: Step of 7.5cm

### 3.14.5 Recording of the subjective comments

At the end of the each testing procedure, participants were asked the same question using the exact same words: "Do you think the taping had any effect? Please explain." The researcher recorded the participant's exact words in writing on the data capture sheet (Addendum B). The number of participants who noticed a subjective change, as well as those who noted no change after taping, was calculated and expressed as a percentage of the total number of participants (n=20). Those who reported a change were asked to qualify their answer and from this data themes were identified.

## 3.15 Statistical Analysis

The services of a statistician were utilised during the development of the protocol. A second statistician analysed the results and both helped with interpretation of the results. Data was collected on the data collection sheet (Addendum B) and then entered into a statistical software program.

SPSS version 13.0 (SPSS Inc., Chicago, Illinois, USA) was used to analyse the data. A p value of <0.05 was considered as statistically significant and a p value of between 0.1 and 0.05 was considered marginally significant since a small sample size in a population with individual differences were used.

Data was examined for normality using the skewness statistic. Non-parametric Wilcoxon signed tests were used to compare the change between the paired measurements (without and with tape).

The change between the measurements with and without tape was computed for each outcome by subtracting the value in the non-taped condition from the value in the taped condition. Predictors for the change were evaluated using Spearman's correlation analysis for continuous factors (age, weight, height and period of time since the stroke) and Mann Whitney tests for binary categorical factors (gender, reported subjective change and left or right side involvement).

### 3.15.1 Demographics

Twenty participants were selected to participate in the study. The mean standard deviation and minimum and maximum value were calculated for age, weight and height. This information could be used to compare the current study data and stroke population with previous studies in this area, as well as with possible future studies using patellar taping in the stroke population.

### 3.15.2 Q-angle measurement

A comparison of outcomes between taped and non-taped conditions was made in the affected leg. The affected leg was measured to determine if there was a decrease in the angle, indicating an increase in weight bearing on that side. The median change, $25^{th}$ and $75^{th}$ percentile, the minimum and maximum values, and

the Wilcoxon p value were calculated. Individual results of Q-angle change were also listed.

### 3.15.3 Timed-up-and-go test / Walking speed / Step Test

A comparison of outcomes between taped and non-taped conditions was made by calculating the median change and 25th and 75th percentile, and recording the maximum and minimum values and the Wilcoxon p value. Individual results for the Timed-up-and-go test, walking speed and the Step Test were also listed.

### 3.15.4 Quantitative factors affecting change in outcomes and correlation of outcome measures

Spearman's correlations were calculated using changes in outcome measurements and quantitative factors such as age, gender and length of time since the stroke, the results of which indicate if these factors impact on the final outcome. Correlation between results of outcome measures indicated how change in one outcome measure explained the change that occurred in another. This information may have clinical value when deciding if taping should be considered as a treatment option, and research value when choosing a population for future studies.


### 3.15.5 Analysis of subject perception

Descriptive statistics were used. The number of "Yes" and "No" answers were recorded and the subjective comments were categorised by the current author and the frequency tabulated. This was done in order to determine if patterns emerged in reported subjective change. The Mann-Whitney test was used to assess if there was an association between the objective measurements taken and reported subjective change. The objective was to determine if those subjects who experienced change also had improved dynamic standing balance or gait speed and visa versa.

## 3.16 Ethical and legal considerations

The following ethical aspects were addressed throughout the study:

- The study protocol was submitted to the Committee of Human Research of Stellenbosch University for approval and was received on 6 October 2005 (NO5/07/119) (Addendum C).
- Verbal permission was obtained from the administration of the Entabeni Rehabilitation Centre and the Life Health Care group to conduct data collection on the premises. The study was discussed with the case manager and the treating physiotherapists at these centres.
- The researcher and the treating therapist explained to each potential participant that the research project was part of the requirements for a masters degree.
- It was made clear that participation was voluntary.
- Every subject was asked to sign an informed consent form after the researcher explained the study (Addendum A).
- Personal information will be kept confidential. Results will be published without disclosure of the participants' identities.
- Results will be made available to the Entabeni Rehabilitation Unit, as well as Headway Durban once the study is completed.
- Results published in this thesis and other manuscripts, will be submitted to peer reviewed journals for possible publication in 2009.

# Chapter 4

# Results

The results of the outcome measures used to investigate the impact of medial patellar taping on stroke patients will be presented in accordance with the objectives set in chapter 3. It will also include a description of the study sample. A summary of the age, weight, height and gender will be given, as well as the length of time passed since the stroke. Results of the outcome measures i.e. the Q-angle, the Timed-up-and-go Test, walking speed, the Step Test and reported subjective change will then be presented. Data collection started on February 2006 and was completed on 23 May 2007.

## 4.1 Sample demographics

All 20 participants eligible for inclusion agreed to participate in the current study and completed their testing without any problems or interruptions. The average age for participants was 61, 3 years. The youngest subject was 29-years-old while the oldest was aged 85. Weight also varied considerably for all participants in this study (Table 4.1).

Table 4.1: Description of subjects

| Characteristics | Research Group (N = 20) |
|---|---|
| Age mean (range) | 61.30 years (29yrs – 85yrs) |
| Weight mean (range) | 79.30kg (50.4kg – 140kg) |
| Height mean (range) | 1.67m (1.54m – 1.82m) |
| Male: Female | 12: 8 |
| Affected side (Left: Right) | 10: 10 |

Nineteen participants were right side dominant and only one was left-handed and this person was affected on the right side.

Time since the stroke varied between 14 and 324 days with an average of 93,7 days.

## 4.2 Effect of patellar taping on the outcome measures

In this section the results of patellar taping on the Q-angle, the Timed-up-and-go Test, the Step Test and walking speed will be given. Results of individual subjects will also be mentioned where appropriate.

### 4.2.1 Change in the Q-angle of the affected leg (tibio-femoral alignment)
The median change, 25 and 75 percentile and minimum and maximum values for taped and un-taped conditions are represented in table 4.2 below. Taping did not affect the Q-angle of the affected leg significantly (table 4.2).

Table 4.2: Comparison of outcomes in Q-angle measurements between un-taped and taped conditions

|  | Median Change | Percentile 25 | Percentile 75 | Minimum | Maximum | Wilcoxon p value |
|---|---|---|---|---|---|---|
| **Change in Q-angle (degrees)** | -1.25 | -3.50 | 0.50 | -11.00 | 10.00 | 0.226 |

In this study, 15 of the subjects had Q-angles within normal limits ($6^{o}$ to $23^{o}$) on the affected side before taping in stroke patients Furthermore, the average Q-angle for women was 9,7°, while that of the men was 10,7°. Four of the participants had Q-angles smaller than 6° and one person had a negative value of -3°. After taping, the participant with the negative value had a Q-angle of 5°. Seven of the subjects had a decrease of the Q-angle of 3° or more, 8 had no change or a change smaller than 3°, and 5 had an increase in the Q-angle of between 1° and 10°. Data of individual subjects is presented in Table 4.3.
Change in the Q-angle did correlate significantly with improvement in the Step Test as shown on section 4.2.6 of this chapter. This will be further explored in section 5.4.

Table 4.3: Individual results of Q-angle change

| Q-Angle change | Q-angle (deg) no tape | Q-angle (deg) taped | Difference in Q-Angle |
|---|---|---|---|
| Neg value (increase in Q-angle) | -3 | 5 | -8.00 |
| | 7 | 15 | -8.00 |
| | 6 | 16 | -10.00 |
| | 23 | 29 | -6.00 |
| | 4 | 5 | -1.00 |
| Pos value (decrease in Q-angle) | 15 | 12 | 3.00 |
| | 14 | 3 | 11.00 |
| | 12 | 8 | 4.00 |
| | 13 | 9 | 4.00 |
| | 5 | 2 | 3.00 |
| | 14 | 10 | 4.00 |
| | 20 | 9 | 11.00 |
| Small pos value (decrease in Q-angle) | 5 | 4 | 1.00 |
| | 12 | 11 | 1.00 |
| | 12 | 12 | 0.00 |
| | 10 | 9 | 1.00 |
| | 4 | 2 | 2.00 |
| | 6 | 4.5 | 1.50 |
| | 12 | 11 | 1.00 |
| | 10 | 8 | 2.00 |

Although there was an improvement in tibio-femoral alignment, the effect size was very small and the change statistically insignificant. However, when looking at individual responses, seven subjects showed an improvement in tibio-femoral alignment that may have clinical relevance.

No significant correlations were found between change in Q-angle and quantitative factors (age, gender, weight, height, affected side and length of time since the stroke).

## 4.2.2 Change in the Timed-up-and-go Test (TUG)

One person lost balance during testing in the un-taped test and a pre-intervention time could thus not be established. This subject was omitted in the analysis. The median change, 25th and 75th percentiles and minimum and maximum values for taped and un-taped conditions were calculated and are presented in Table 4.4. Although there was an improvement in the pre to post measure for the TUG test, the change was not significant (p=0.099). Table 4.5 shows that seven subjects improved by 5 seconds or more after taping. Four subjects were between 1 and 5 seconds faster, two had the same time before and after taping, and six subjects performed from 1 to 18,7 seconds slower. The individual who could not complete the pre-tape test due to loss of balance completed the TUG test in 28,81 seconds after taping.

Table 4.4: Comparison of outcomes in TUG test between un-taped and taped conditions

|  | Median Change | Percentile 25 | Percentile 75 | Minimum | Maximum | Wilcoxon p value |
|---|---|---|---|---|---|---|
| **Change in TUG (seconds)** | -1.83 | -5.98 | 0.76 | -52.43 | 18.65 | 0.099 |

Table 4.5: Individual results of the TUG test

| TUG Test change | TUG with No tape (sec) | TUG with Tape (sec) | Difference in TUG |
|---|---|---|---|
| Improvement of 5+ sec | 106.00 | 53.57 | 52.43 |
| | 39.87 | 33.29 | 6.58 |
| | 53.00 | 38.24 | 14.76 |
| | 33.56 | 27.28 | 6.28 |
| | 35.48 | 30.40 | 5.08 |
| | 52.25 | 39.67 | 12.58 |
| | 31.56 | 25.88 | 5.68 |
| Improvement smaller than 5 | 28.31 | 26.41 | 1.90 |
| | 17.01 | 13.16 | 3.85 |
| | 9.08 | 7.32 | 1.76 |
| | 14.65 | 12.72 | 1.93 |
| No change | 13.82 | 13.54 | 0.28 |
| | 39.18 | 38.74 | 0.44 |
| Poorer performance | 36.86 | 55.51 | -18.65 |
| | 15.19 | 15.48 | -0.29 |
| | 21.33 | 22.55 | -1.22 |
| | 16.36 | 19.18 | -2.82 |
| | 27.61 | 31.38 | -3.77 |
| | 14.25 | 20.20 | -5.95 |
| NOT COMPLETED | NC | 28.81 | NC |

No significant correlations between changes in the TUG test and quantitative factors (age, gender, weight, height, affected side and length of time since the stroke) were found.

## 4.2.3 Change in the walking speed

The average walking speed before taping was 0,51m/s, ranging from 0,13m/s to 1,46m/s. After taping, the average walking speed was 0,50m/s and ranged from 0,16m/s to 1,58m/s (as shown in Table 4.7). Change in walking speeds was thus minimal in taped and un-taped conditions. After taping, twelve subjects walked marginally slower with speeds of between 0,01m/s and 0,14m/s, and eight subjects walked faster with an increase of walking speed of between 0,01m/s and 0,12m/s. Table 4.6 shows the median, 25th and 75th percentiles, and minimum and maximum values for walking speeds before and after taping (p=0,351). Walking speed did correlate with results of the TUG Test and is documented later in this chapter (section 4.2.6), and discussed in section 5.4.

Table 4.6: Comparison of outcomes in walking speed between un-taped and taped conditions

|  | Median Change | Percentile 25 | Percentile 75 | Minimum | Maximum | Wilcoxon p value |
|---|---|---|---|---|---|---|
| **Change in walking speed (m/s)** | -0.015 | -0.051 | 0.036 | -0.14 | 0.12 | 0.351 |

Table 4.7: Individual results for walking speed

| Walk speed change | Walking speed m/s with No Tape | Walking speed m/s with tape | Difference in walking speed |
|---|---|---|---|
| Faster gait | 0.39 | 0.42 | 0.04 |
| | 0.13 | 0.14 | 0.01 |
| | 1.46 | 1.58 | 0.12 |
| | 0.34 | 0.41 | 0.07 |
| | 0.51 | 0.57 | 0.06 |
| | 0.48 | 0.51 | 0.04 |
| | 0.31 | 0.35 | 0.04 |
| | 0.24 | 0.26 | 0.02 |
| Slower gait | 0.29 | 0.16 | -0.14 |
| | 0.81 | 0.80 | -0.01 |
| | 0.40 | 0.37 | -0.04 |
| | 0.20 | 0.19 | -0.01 |
| | 1.03 | 0.97 | -0.06 |
| | 0.75 | 0.73 | -0.02 |
| | 0.32 | 0.24 | -0.07 |
| | 0.72 | 0.71 | -0.02 |
| | 0.48 | 0.43 | -0.05 |
| | 0.41 | 0.36 | -0.05 |
| | 0.40 | 0.38 | -0.02 |
| | 0.60 | 0.46 | -0.14 |
| Ave | 0.51 | 0.50 | |

No correlation was found between changes in walking speed and quantitative factors (age, gender, weight, height, affected side and length of time since the stroke).

## 4.2.4 Effect of patellar taping on number of steps taken in the Step Test

For the Step Test, the median, $25^{th}$ and $75^{th}$ percentiles, and minimum and maximum values for taped and un-taped conditions were calculated. The p-value=0,063, which indicates marginal significance between the taped and non-taped conditions. These results are shown in table 4.8. After taping, ten participants increased the number of steps they could take. Five participants could take 1 more step, two participants took 2 more steps, one person took 3 more steps, and two participants could take up to 4 extra steps. Six of the participants showed no change in the number of steps, and the remaining four had a decrease

in the number of steps they could take in 15 seconds. Of these, three had a decrease of 1 step and the remaining person decreased their number of steps by 2. These results are reflected in Table 4.9.

Table 4.8: Comparison of outcomes in Step Test between un-taped and taped conditions

| | Median Change | Percentile 25 | Percentile 75 | Minimum | Maximum | Wilcoxon p value |
|---|---|---|---|---|---|---|
| **Change in Step Test (no. of steps)** | 0.50 | 0.00 | 1.50 | -2.00 | 4.00 | 0.063 |

Table 4.9: Individual results for the Step Test

| Step Test change | Step Test with No Tape | Step Test with Tape | Difference in Step Test |
|---|---|---|---|
| Increase in number of | 7 | 8 | 1 |
| | 0 | 3 | 3 |
| | 0 | 4 | 4 |
| | 9 | 11 | 2 |
| | 8 | 9 | 1 |
| | 10 | 12 | 2 |
| | 2 | 3 | 1 |
| | 2 | 6 | 4 |
| | 4 | 5 | 1 |
| | 3 | 4 | 1 |
| No change in number | 8 | 8 | 0 |
| | 6 | 6 | 0 |
| | 9 | 9 | 0 |
| | 0 | 0 | 0 |
| | 5 | 5 | 0 |
| | 4 | 4 | 0 |
| Decrease in number of | 1 | 0 | -1 |
| | 3 | 2 | -1 |
| | 6 | 5 | -1 |
| | 6 | 4 | -2 |
| Ave | 4.65 | 5.4 | 0.75 |

Again, no correlation for any of the subject characteristics (age, gender, weight, height, affected side and length of time since the stroke) could be found for this measure.

### 4.2.5 Self reported perception of change following patellar taping

Fourteen (70%) of the participants reported no perception of change in knee control and 6 (30%) experienced a subjective difference after taping. Themes and comments are tabulated below (table 4.10).

Table 4.10: Subjective change as reported by the participants

| Themes | Comments | n = 6 |
|---|---|---|
| Change in ability to swing the affected leg through during the swing phase | Affected leg felt lighter | 2 |
| Change in ability to bear weight and balance on the affected side | Balance better on the weak side | 1 |
| | Felt more secure when standing on the weak side with improvement noted to be about 50% | 1 |
| | Felt like something was holding his/her knee. | 1 |
| Change in quality of gait | Steps were more symmetrical during walking after taping | 1 |

### 4.2.6 Correlation of changes in the Q-angle and walking speed with TUG and Step Test

Change in the Q-angle:

Spearman's correlation (2-tailed) between change in the Q-angle on the affected side, in conjunction with: 1) change in TUG test; 2) change in walking speed and 3) change in Step Test, indicates that with a decrease in the Q-angle, the number of steps taken in the Step Test increased (rho=-0,487, p=0,029). There was no correlation between change in the Q-angle and change in the TUG test or walking speed (Table 4.11).

Table 4.11: Correlation of changes in Q-angle, TUG test, walking speed and Step Test

| | Change in Timed-up-and-go (seconds) | | | Change in walking speed (m/s) | | | Change in Step Test (no. of steps) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Correlation coefficient | Sig. (2-tailed) | N | Correlation coefficient | Sig. (2-tailed) | N | Correlation coefficient | Sig. (2-tailed) | N |
| **Change in Q-angle (degrees)** | -0.196 | 0.422 | 19 | 0.247 | 0.294 | 20 | -0.487* | 0.029 | 20 |

Change in walking speed:

Spearman's correlation (2-tailed) between change in walking speed and 1) change in Q-angle on the affected side; 2) change in timed-up-and-go test and 3) change in the Step Test, showed a positive correlation between the TUG test and walking speed (rho=-0,460; p=0,048). The correlation between walking speed and the Step Test was not significant and there was also no correlation between walking speed and the Q-angle (table 4.12).

Table 4.12: Correlation of changes in walking speed, and Q-angle, TUG test and Step Test

| | Change in Q-angle (degrees) | | | Change in Timed-up-and-go (seconds) | | | Change in Step Test (seconds) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Correlation coefficient | Sig. (2-tailed) | N | Correlation coefficient | Sig. (2-tailed) | N | Correlation coefficient | Sig. (2-tailed) | N |
| **Change in walking speed (m/s)** | 0.247 | 0.294 | 20 | -0.460* | 0.048 | 19 | -0.316 | 0.175 | 20 |

## 4.3 Summary

The Step Test and the Timed-up-and-go Test showed marginal improvement after taping. This may indicate that there was a slight improvement in dynamic standing balance in subjects when the affected knee was taped. Study results showed no change in the Q-angle and walking speed in the taped and un-taped conditions.

A statistically significant although weak negative relationship was shown between change in the Step Test and Q-Angle (a decrease in the Q-angle correlated with an increase in number of steps taken) after taping. In addition, a slight positive relationship was found between change in TUG and walking speed (a decrease in time of the TUG test correlated with a decrease in walking speed). None of the demographic factors was found to significantly affect the change in outcome measurements.

The results and the clinical significance thereof will be discussed in chapter 5.

# Chapter 5

# Discussion

## 5.1 Introduction

The main purpose of this study was to determine the effect of medial patellar taping on the Q-angle, gait speed and dynamic standing balance of stroke patients. It has been argued that if taping could improve knee control in patients with patello-femoral pain (Powers *et al,* 1997) and patients with osteo-arthritis of the knees (Hinman and Crossley *et al,* 2003), it may also help with knee control in stroke patients. The results of this study suggest that medial patellar taping may marginally improve dynamic standing balance.

A detailed discussion of the results of the current study will be presented, including a possible explanation of the biomechanical changes in the knee and the effect on quadriceps contraction in light of the literature discussed (Mizuno *et al,* 2001, Engardt *et al*, 1995, Hill *et al,* 1996).

First a brief discussion on the sample demographic characteristics will follow.

## 5.2 Demographic representation

The subjects in the current study had a mean age of 61,3 years. These values are lower than those of participants in the study of Hill *et al* (1996) (mean age=72,5 years) where reliability and validity of the Step Test were determined. In addition, the values are lower than those in the study by Podsiadlo and Richardson (1991) (mean age=79,5 years) where the TUG test was used to test basic functional mobility in frail elderly persons. Discrepancies in the age groups of these studies may limit their comparability. Participants were affected on either the left (n=10) or

the right (n=10) side. Neither age nor the affected side had a significant effect on the outcome of any of the measurements taken.

Weight showed no correlation with any of the outcome measures. Likewise, height did not correlate statistically with any of the measurements taken. The demographic characteristics did not significantly influence the results of the current study and cautious comparison with similar future studies can thus be made even if demographic characteristics differ.

Gender distribution comprised 60% male and 40% female which may have had some impact on Q-angle measurements (table 4.3). Horton and Hall (1989) found that the Q-angle of women (15,8 ± 4,5°) is greater than those of men (11,2 ± 3,0°). In the current study, the average value for the Q-angle is 9,7 ° in women and 10,7° in men. This discrepancy may be due to the small sample size. Moreover, the values reflected in the Horton and Hall (1989) study, were obtained from analysis of a healthy population, whereas the current study measured a stroke population. In the current study, other postural changes in the hip and the ankle may thus have influenced the Q-angle.

Length of time passed since the stroke varied between 14 and 324 days, and did not correlate with any of the outcome measures. For the purpose of this study, all participants were tested within one year of having their first and only stroke.

All participants had to be able to follow simple instructions, walk 10 meters independently, and give feedback on their subjective experience of the taping. Cognitive function was thus satisfactory. This was done to enable this researcher to compare the data with results of gait speed and dynamic standing balance from Podsiadlo and Richardson (1991), Hill *et al* (1996), An-Lun Hsu *et al* (2003) and Brandstater *et al* (1983), as done in the following sections.

All the participants in the current study were selected from two rehabilitation units, one an inpatient unit and the other an outpatient facility. The inpatient unit is a privately run hospital and patients admitted there might be of a higher socio-economic status than the general population. The outpatient facility is a non-profit

private initiative where patients pay a reduced fee. Transport to and from the centre is the patient's own responsibility. These patients are also from a higher socio-economic status than the general population. Inclusion of patients in the public sector may have strengthened this study and helped with generalisation of the results.

## 5.3 The effect of patellar taping on knee alignment as measured by the Q-angle

In the current study, patellar taping did not reduce the Q-angle significantly (Table 4.2). Fifteen (75%) of the participants had Q-angles within normal limits before taping and the margin for change was thus potentially limited. As discussed in the literature review (section 2.6), normal values for the Q-angle vary between 6° and 27° (Mizuno *et al*, 2001). However, analysis of individual responses showed that 7 participants (35%) showed a decrease of the Q-angle of 3° or more (Table 3). According to Bayraktar *et al* (2004), an increase in quadriceps activity could decrease in the Q-angle of the affected leg with resultant greater ability to accept weight on the affected leg. In the study by Lathinghouse and Trimble (2000), the authors also concluded that the Q-angle decreases with an isometric quadriceps contraction and that this decrease is dependent on the magnitude of the Q-angle at rest. This latter finding supports the theory that 15 of the participants (75%) in the current study have a limited margin for change.

Furthermore, Mizuno *et al* (2001) concluded that a decrease in the Q-angle increased the medial tibio-femoral joint pressure. This effect is significant in a weight bearing activity where a decrease in the Q-angle shifts the line of weight bearing to the medial plateau, increasing the joint pressure and freeing the lateral tibial plateau to complete the "screw-home mechanism" during knee extension (Mizuno *et al,* 2001). Hsu *et al* (1990) found that in a normal population, 75% of the knee joint load passes through the medial tibial plateau in a weight bearing position. To normalise knee biomechanics during weight bearing activities, one should encourage weight bearing through the medial tibio-femoral joint. Considering the findings as explained above, this researcher hypothesised that the seven participants with smaller Q-angles after taping, possibly had more

medial tibio-femoral joint pressure and passed more of the knee joint load through the medial tibial plateau. This could indicate that the taping changed the quadriceps muscle activity. Although this was not verified by EMG in the current study, the improved scores of the Step Test in these participants (Table 11) suggest that the quadriceps muscle contraction was affected by the taping, and that these participants were more willing to accept weight on the affected leg after taping. This theory is also supported by Lathinghouse and Trimble (2000) and Bayraktar *et al* (2004) who linked increased quadriceps activity to a decrease in the Q-angle.

Bennell *et al* (2003) argued that proprioceptive afferent information from mechanoreceptors in the muscles, ligaments, capsule, menisci and skin contribute at the spinal level to arthrokinetic and muscular reflexes – this plays a large part in dynamic joint stability. Edin (2001) found that in normal individuals, the skin around the knee contained an abundance of stretch-sensitive mechanoreceptors that may convey information about knee joint positions and movements. The current researcher concluded that the taping could possibly have activated these mechanoreceptors in the skin, enhancing sensory feedback from the knee, which may have affected quadriceps contraction. This hypothesis could possibly also explain the effect in the participant who had a negative value of -3° before taping. A negative value indicates the presence of *genu varus* (bowlegs), and in this case was associated with hyperextension of the knee. After taping, this participant had a Q-angle of 5° on the affected side. Taping thus appeared to have normalised the Q-angle and this could have led to better knee control.

In the current study, there was a significant correlation between a decrease in the Q-angle and an increase in the number of steps taken in the Step Test (Table 4.11). It would thus appear that those patients with smaller Q-angles after the taping also showed improvement in their dynamic standing balance. In the case of the participant with the negative value of -3° before taping, there was no improvement in standing balance as tested by the step test, but time taken to complete the TUG test decreased by 50% after taping. There was thus an improvement in this participant's dynamic standing balance as tested by the TUG test.

The researcher's hypothesis is that those participants with Q-angles that decreased or normalised after taping were more willing to accept weight on the affected side, and that there was a change in quadriceps activation. Whether this change was due to change in the magnitude of the quadriceps contraction or a change in the firing pattern of different parts of the quadriceps will be discussed in the sections below.

## 5.4 The effect of patellar taping on dynamic standing balance as tested by the "Timed-up-and-go Test" and the "Step Test"

In the current study, the "Timed-up-and-go Test" showed marginal statistical significance (p=0,099), (Table 4.4). This suggests that the participants of the current study showed a slight improvement in dynamic standing balance after taping. The 25% of the sample that improved the most decreased their time by almost 6 seconds after taping, while the 25% who had the poorest outcome had an increase in time of less than 1 second (Table 4.5). It would thus appear that 25% of the participants may have benefited significantly, while 75% experienced marginal or no improvement. A 6 second decrease in time taken to perform the test may have a significant impact on a patient's functional status, including improvement in ability to get in and out of a chair and an increase in walking speed. The latter was confirmed by the walking speed as there was a statistically significant correlation (p=0,048) after taping between improvement in the TUG test and improvement in walking speed (Table 4.12).

Analysis of individual results showed that two of the participants who completed the TUG Test faster after taping, moved from a high dependency to a mixed functional ability group, as classified by Podsiadlo and Richardson (1991). This showed a possible improvement of these patients' ability to function within their environment, including activities like getting into a chair, balance and gait speed. Furthermore, before taping, the two participants who showed the biggest change also took the longest to complete the test. Although after taping they did not fall within a different functional ability group, their improvement could have clinical and

functional benefit. It demonstrates that even though these patients might still have needed supervision, they were faster at activities such as getting in and out of a chair, and on and off a toilet as well as other activities that require dynamic standing balance including stair climbing (Podsiadlo and Richardson, 1991). The current study shows that those participants whose balance was most impaired had the biggest gains.

The correlation between change in the TUG test and change in walking speed indicates that those who walked faster after taping also completed the TUG test faster. Conversely, those who walked slower after taping also took longer to complete the TUG test. These results confirm the relationship between walking speed and dynamic standing balance as established by Hamrin *et al* (1982) and Bohannan *et al* (1993). A possible contributing factor to slower gait and poorer performance in the TUG test after taping could be fatigue, since all the testing was done first without, and then with taping. A rest period of five minutes was given in the current study during which the taping was done. Recommendations regarding this will be made in the next chapter.

In the Step Test, the difference between un-taped and taped conditions also showed marginal significance (p=0,063), (table 4.8), further suggesting that the participants had a slight improvement in their dynamic standing balance. According to Hill *et al* (1996), the Step Test incorporates speed of lateral weight shift. This point is important when it is noted a healthy elderly women completes nearly two steps per second during gait, encompassing weight shift from side to side (Hill *et al,* 1996). Participants of the current study may thus have been faster in moving their weight to the affected side after taping.  Furthermore, Powers *et al* (1997) found that in subjects with patello-femoral pain, taping had a small but significant increase in knee flexion loading response during gait. They explained that patients with knee pain, avoid loading response knee flexion, as it is at this point in the gait cycle where the muscular demands and joint forces are the greatest. Also, the amount of quadriceps force needed to stabilise the knee was directly related to the amount of knee flexion, with a rapid rise in demand when the knee was flexed beyond 15°. The functional implications of these findings, they further explained, were that a small increase in knee flexion beyond 15° produced

relatively large increases in quadriceps contraction (Powers *et al,* 1997). These authors thus argued that this demonstrates more willingness on the part of the subjects to load the knee joint, permitting increased shock absorption and indicating increased eccentric quadriceps activity. The current researcher hypothesises that in this study, participants may also have been more willing to shift their weight onto the affected leg after taping, and that there was a possible increase in eccentric quadriceps activity.

Weight shift to the affected side has been identified as one of the impairments in stroke patients. Both Hsu *et al* (2003) and Pinzur *et al* (1987) found that patients avoid spending time in weight bearing on the affected side. Wall and Turnbull (1986) tested 25 subjects with residual stroke on a walkway that allowed for automatic data collection, processing and storage via a microcomputer, and found that all patients favour their affected side by spending longer in support on the non-affected leg. None of these aforementioned studies investigate the reasons for the asymmetry. However, in a study done by Engardt *et al* (1995), it was found that eccentric training of the quadriceps muscle in stroke patients improved symmetrical body weight distribution when rising from a sitting position. The current researcher thus argues that loss of eccentric quadriceps control could be one of the impairments contributing to the asymmetry. In the current study, the participants had to shift their weight to the affected side while stepping up with the unaffected leg. The results of the Step Test indicate that medial patellar taping can possibly address this impairment in stroke patients. This argument is supported by the findings of Olney *et al* (1991) whose study showed that the loading response or weight acceptance of the knee depends on eccentric quadriceps function. In the current study, willingness to load or accept weight on the knee could thus indicate an improvement in the eccentric control of the quadriceps muscle*.*

According to the literature, there is a relationship between dynamic standing balance and motor control, while increased quadriceps activity correlates with walking speed (Ringsberg *et al*, 1999). Neuro-motor control is complex and includes timing of contraction and adjustment of muscle activity both before and during a movement in order to ensure balance and control of the movement

(Powers, 2000 and Cowan and Hodges *et al,* 2002). Cowan and Bennell *et al* (2002) and Gilleard *et al* (1997) found that in subjects with patello-femoral pain, taping altered the temporal characteristics (timing of contraction) of VMO and VL activation during a functional weight bearing activity, such as stair climbing. These researchers found through EMG studies that VMO activated before VL after patellar taping. The current researcher hypothesises that taping may also have changed the temporal characteristics of VMO and VL activation in these stroke patients, resulting in better balance, although this was not confirmed by EMG recordings. Results of the dynamic standing balance tests in the current study thus indicate that taping may affect motor control of the knee.

There was no correlation between the TUG test and the Step Test in the current study. Patients who displayed an improvement in the Step Test did not necessarily improve in TUG test, although both are dynamic balance tests. A possible explanation for this result is that balance is very task specific, and improvement in one balance activity would thus not automatically lead to improvement in other balance activities (Winstein *et al,* 1989). Huxham *et al* (2001) explains that balance is a product of the task undertaken and the environment in which it is performed. Other factors that play a role are the speed of the movement and the mass of the body part being moved (Huxham *et al,* 2001). The authors further explain that anticipatory postural adjustments, and an intact reactive balance response, are needed to maintain or regain dynamic balance during an activity. It can thus be hypothesised that different forces are involved, and different balance reactions are needed for the TUG Test and the Step Test.

## 5.5 The effect of patellar taping on walking speed

There is no statistical indication that participants walked faster after taping (p=0,351). In the current study the average walking speed was 0,51m/s before taping and 0,50 m/s after taping (Table 4.7). Hsu *et al* (2003) found gait velocity of stroke patients to be 0,62 ±0,21 m/s, while Brandstater *et al* (1983) found it to be 0,31 ± 0,21 m/s. Discrepancies in the findings of the three studies could be due to

differences in age of the participants, the ratio of men to women in the test groups, and severity of the stroke.

There is evidence suggesting that there is a non-linear association between gait speed and the magnitude of quadriceps contraction. Buchner *et al* (1996) found that in stronger subjects, there was no association between quadriceps contraction and gait speed, while in weaker subjects there was an association. The authors suggested that this finding could explain how small changes in physiological capacity may have substantial effects on performance in frail adults, while large changes in capacity have little or no effect in healthy adults. There is also evidence to suggest that stroke patients lose the ability to contract their quadriceps muscle after a stroke and that this has a significant impact on these patients' function (Hsu *et al,* 2003 and Suzuki *et al*, 1999). In the study by Ernst *et al* (1999), taping resulted in a greater knee extensor moment during a vertical jump and lateral step-up activity in patients with patella-femoral pain. This may suggest that taping increased the magnitude of quadriceps contraction in these patients. In the current study, it was thus a reasonable expectation that if taping could increase the magnitude of quadriceps contraction, the patients would be able to walk faster. One can argue that since walking speed did not change statistically or clinically before and after taping, it also had no effect on the magnitude of quadriceps contraction. This is supported by the findings of YF Ng and Cheng (2002) and Cerny (1995), who found that taping could not increase the magnitude of quadriceps contraction in patients with patello-femoral pain.

Engardt *et al* (1995) investigated knee control in hemiplegic patients and found that eccentric and concentric quadriceps activity appears to be of importance for different motor functions of daily life. While eccentric quadriceps activity significantly improves symmetrical body weight distribution, concentric activity was associated with walking speed (Engardt *et al,* 1995). Since there was also no statistical significant increase in walking speed, this researcher further concluded that concentric quadriceps activity most likely did not change.

## 5.6 Participant subjective perception of patellar taping on the affected side

In this study, six (30%) of the participants reported a subjective change in sensory feedback after taping. The subjective change did however not correlate with either of the balance tests, gait speed or change in the Q-angle. The current researcher hypothesises that not all participants who reported change in sensory feedback had the muscle control to use the information and respond to it.

Callaghan *et al* (2002) evaluated the effects of patellar taping on knee joint proprioception in healthy subjects and concluded that in those subjects with poor proprioceptive ability, as measured by active and passive angle reproductions, patellar taping provided proprioceptive enhancement. The authors argued that subjects with poor proprioception might have received improved afferent feedback via cutaneous receptor stimulation from the patellar tape, thereby improving joint reposition accuracy. This was not the case for subjects that were classified as having good proprioception. Alternatively, they hypothesized that those with good proprioception were capable enough not to need any influence from external aids such as taping, whereas those with poor proprioception needed the additional information provided by the tape. It could thus be argued that stroke patients with altered sensory feedback may benefit from taping. The current researcher further hypothesises that a possible reason for having only 6 (30%) of the participants reporting change is that the rest (70%) of the participants could not interpret sensory feedback due to parietal cortex damage and consequently  perceptual or cognitive problems after the stroke (Morris *et al,* 1992 and Cozean *et al,* 1988). Moreover, reported subjective change may not reveal altered sensory feedback. In the 70% of participants who did not report any subjective change, increased sensory feedback may have played a role. In a review article, Hogervorst and Brand (1998) looked at studies where the subjects had a tear or removal of the anterior cruciate ligament, and explained that loss of neurosensory feedback is a possible reason for the reduction in quadriceps force production. Furthermore, these patients developed a quadriceps avoidance gait, indicating a decrease in quadriceps muscle moment. In the current study, it is thus possible that in those participants whose dynamic balance improved with taping, the sensory feedback

did change quadriceps activity on a sub-conscious level. This argument is supported by the findings of Bennell *et al* (2003), who showed that knee joint proprioception is essential to neuromotor control, and that neuromotor control of the knee involves the co-ordinated activity of surrounding muscles; in particular, the quadriceps muscle. The authors explained that this coordinated activity provides active stability to the knee joint, thus assisting in the absorption of much of the load placed on the knee joint during weight-bearing activities. The proprioceptive afferent information comes from mechanoreceptors in the muscles, ligaments, capsule, menisci and skin, and this information contributes on a spinal level to arthrokinetic and muscular reflexes – these in turn play a major part in dynamic joint stability (Bennell *et al,* 2003).

Two participants (10%) reported that their leg felt "lighter" after taping (Table 4.10). Olney *et al* (1991) found that in hemiplegic gait (during swing-phase) there is a tendency for knee flexion and hip extension to decrease with declining walking speed. This was more pronounced on the affected side than the unaffected side. Eccentric work of the knee extensors of the affected side was positively related to maximum flexion of the knee during swing phase (Olney *et al,* 1991). The authors argue that this indicates that more capable walkers flex their knees at the end of the stance phase while weight is still on the foot. In addition, concentric knee extensor during mid-stance, followed by eccentric work at the end of stance, may be intimately linked to the opportunity for power generation of the ankle. If knee flexion, however, does not occur, the limb must clear the supporting surface using only the hip musculature, resulting in high-energy expenditure on the part of the patient (Olney *et al,* 1991). In the current study, these two participants may have described a more energy efficient gait pattern as the leg feeling "lighter". Also, in the light of Callaghan's *et al* (2002) findings that taping could improve joint angle perception, it could be argued that these two participants may have had better sensory feedback on the knee flexion angle, as well as the motor ability to react on the information.

Four of the participants (20%) indicated that their ability to weight bear on the affected leg had improved. As discussed previously, the ability to shift weight onto the affected leg has been identified as an impairment that influences gait and

balance in stroke patients (Hsu *et al,* 2003 and Pinzur *et al,* 1987). Although a subjective improvement did not correlate with any of the balance or walking speed tests, it may be that a change will only be detected over time, and would therefore not immediately be evident in the results of this study.

## 5.7 Summary

The outcome of the current study indicates that taping may lead to better dynamic standing balance in stroke patients due improve knee control. Taping did not decrease the Q-angle of the affected side significantly in stroke patients. However, the participants with smaller Q-angles after taping also appeared to have better dynamic standing balance, indicating a possible change in quadriceps contraction. The dynamic standing balance tests showed marginal significant improvement after taping. Results from the TUG Test indicate that those participants with the poorest balance had the most to gain. The Step Test indicates that participants were more willing to accept weight on their affected side, and that the eccentric contraction of the quadriceps and motor-neural control of the knee may have improved. There was no change in the walking speed before and after taping, indicating no change in the magnitude of the quadriceps contraction.

In the next chapter suggestions regarding future studies in the stroke population, measurement of the Q-angle and sensory feedback will be made. Also suggestions for use of patellar taping in the stroke population are discussed.

# Chapter 6

# Conclusion and recommendations

The results of this repeated measures experimental study to determine whether medial patellar taping could influence knee alignment, dynamic standing balance and gait speed in stroke patients, indicate that taping may improve balance marginally. This improvement may be the result of better neuro-motor control of the affected knee, and improved eccentric activation of the quadriceps muscle.

Decreased balance and mobility are strong predictors of the likelihood for falls (Shumay-Cook *et al,* 1997). These researchers claim that between 25% and 35% of people over the age of 65 experiences one or more falls each year, and that fall-related injuries in this age group are the leading traumatic cause of death. Forty percent of hospital admissions among the 65-plus age group are the result of fall-related injuries, and approximately half of these hospital admissions are discharged to nursing homes. Furthermore, falls that do not lead to injury often begin a downward spiral of fear that leads to inactivity and decreased strength, agility and balance, which in turn results in loss of independence (Shumay-Cook *et al,* 1997).

The current researcher argues that an improvement in dynamic standing balance could possibly lead to more independence and a reduced risk of falling. This could be investigated in future studies.

## 6.1 Recommendations for future studies within the stroke population

The following recommendations follow from the current study:

- All participants in the current study were from a higher socio-economic portion of the population of South Africa. Studies that include a wider sample of the population could indicate if the current results could be appropriated to patients outside of the current sample. This sample could be recruited from public hospitals, clinics or rehabilitation units. It is also suggested that stroke patients with a history of more than one stroke could be included provided that it is so documented so that the data can be separately analysed if needed. Another suggestion is that patient who had their stroke more than one year prior to testing be included to ensure a plausible sample size.

- Fatigue may have influenced results in the current study. In this study, a 5-minute rest period was allowed between test procedures, first without and then with the tape. Testing mainly took place in the mid to late morning when most of the patients had already had some of their therapy sessions. For future studies, it is suggested that testing takes place early in the morning before therapy, and that a longer rest period of 20 minutes is allowed before re-testing.

## 6.2 Recommendations for future studies regarding measurement of the Q-angle

- Lathinghouse and Trimble (2000) found that in healthy elderly women, the Q-angle decreases with isometric quadriceps activation. In a future study, EMG recordings of VMO and VL and/or measurement of the quadriceps by a hand-held dynamometer could indicate muscle activity before and after taping. In the current study, the Q-angle did not reduce significantly after taping, but a possible increase in quadriceps contraction may have been insufficient to reduce the Q-angle. Results of an EMG study could be compared to those of YF Ng and Cheng (2002) and Cerny (1995), who concluded that taping did not increase the activity of quadriceps in patients with patello-femoral pain. The current researcher suggests that quadriceps deficit in stroke patients may be more pronounced, and that possible increase in quadriceps activity may be detected in this population.

- The current researcher also suggests that measurement of the Q-angle should be done after taping has been worn for up to two weeks. This could allow the

taping to enhance quadriceps activation over a period of time and may lead to a smaller Q-angle.

- The correlation between a decrease in Q-angle and improvement in Step Test results suggests that there is a change in the neuro-motor control of quadriceps after taping. In future studies, this could be verified by EMG recordings where altered timing of contraction between VMO and VL are measured. These results can then be compared with those of Cowan and Bennell *et al* (2002), who found that taping altered timing of contraction of VMO and VL in patients with patello-femoral pain.

- Normal values for the Q-angle in a healthy population are available (Horton and Hall, 1989 and Sanfridsson *et al,* 2001). Whether these values are the same for the stroke population is unclear and the lack of this information may have weakened this study since comparative values were not available. This researcher suggests that the Q-angle in the stroke population should be determined through further research before it is used as an outcome measure in a stroke population.

- Alternatively, one could measure knee flexion angle at the end of the stance phase with a video based motion capturing system. Olney *et al* (1991) explained that although joint angle profiles in the stroke population are similar to a healthy population, amplitudes are smaller. These authors further found that in a stroke population, better walkers flex their knees at the end of the stance and that this was associated with eccentric quadriceps activity. In a future study, a change in knee flexion during the stance phase may show whether there is a change in eccentric quadriceps activity.

- Previous studies that investigated the effect of patellar taping were done in populations with patello-femoral pain (Cowan and Hodges *et al,* 2002 and Gilleard *et al,* 1997) or osteo-arthritis of the knee (Hinman and Crossley *et al,* 2003). The current researcher suggests that change in the Q-angle should be investigated in these populations. A smaller Q-angle after taping in these populations could indicate change in the biomechanics of the tibio-femoral joint, increasing medial tibio-femoral joint pressure and shifting the line of weight bearing medially (Mizuno *et al,* 2001). This could possibly explain why pain decreased after taping in the subjects used by Hinman and Crossley *et al*

(2003), even when osteo-arthritis was only present in the tibio-femoral joint and not the patello-femoral joint. The method used in the current study may be repeated in the above mentioned populations. The current study indicates that a decrease of more than $3^{o}$ can be viewed as significant change and this data could be used for a power analysis to determine the sample size.

## 6.3 Recommendations for future studies regarding proprioceptive and sensory feedback in stroke patients

- Callaghan *et al* (2002) investigated the effect of patellar taping on knee joint proprioception in 52 healthy adults and found that in those with poor proprioceptive ability, taping provided enhancement of proprioception. These researchers measured active angle reproduction, passive angle reproduction, and threshold to detection of passive movement on an isokinetic dynamometer. In future studies, Callaghan's study could be repeated in a stroke population to enable comparison of data.

## 6.4 Recommendations regarding clinical use of medial patellar taping in stroke patients

- The current investigative study indicates that medial patellar taping might be useful in improving dynamic standing balance. The efficacy of this technique in the stroke population should be investigated further on a larger sample size. Using the results of the two dynamic balance tests used the current study (Timed-up-and-go Test and Step Test) as well as the sample size of 20, a power-analysis could indicate how big the sample size should be to show possible statistical significance (Altman, 1991). It is suggested that calculations should be based on one additional step in the Step Test and an improvement of five seconds in the Timed-up-and-go Test. Other dynamic balance tests, like the Functional Reach Test and the Berg Balance Test could be included in a follow-up study since a battery of tests is reported to be more accurate in balance testing (Hill *et al*, 1996).

- Current research suggests that clinical use of medial patellar taping should be based on improvement in a dynamic standing balance test on case-by-case bases.

- None of the demographic variables or reporting of subjective change correlated with the balance tests.  It thus appears that taping could be considered as a treatment option regardless of age, gender, weight, height, left or right side involvement, time elapsed since the stroke or subjective experience of change.

## 6.5 Study limitations

In the current study, patients and testers were not blinded due to the nature of the technique used. This may have resulted in bias. A pseudo-taping technique was not used due to the limited number of subjects tested. This may have led to subjects trying to, or expecting improvement on their scores after taping.  Subjects were however not reminded of scores in the un-taped testing session before testing commenced after taping. Testers were asked to give instructions as outlined in chapter 3 to prevent testers from using words that may encourage or discourage subjects. The researcher was present at all testing procedures to ensure that protocol was followed. In future studies using a bigger sample size and including a pseudo-taping technique may limit possible bias.

In a future study a bigger study sample may be useful to confirm or refute current results.

Inter- and intra-tester reliability was not confirmed by a pilot study before commencement of the study. This may have influences results. However, the tests that were used are well documented and instructions and procedures are easy to follow. The current author advises that for a bigger follow-up study, tester inter- and intra-reliability should be guaranteed by a pilot study especially when the researcher will not be present at all testing procedures.

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# Addendum: A

# PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM

**TITLE OF THE RESEARCH PROJECT:**

Patellar taping: A treatment option for stroke patients

**REFERENCE NUMBER:**

N 05/07/119

**PRINICIPAL INVESTIGATOR:**

Sonette Dreyer

**ADDRESS:**

PO Box 1785, Hillcrest, Durban, 3650

**CONTACT NUMBER:**

072 2820735

You are being invited to take part in a research project. Please take some time to read the information presented here, which will explain the details of this project. Please ask the study staff or doctor any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how you could be involved. Also, your participation is entirely voluntary and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

This study has been approved by the Committee for Human Research at Stellenbosch University and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki, South African Guidelines for Good Clinical Practice and the Medical Research Council (MRC) Ethical Guidelines for Research.

**What is this research study all about?**

- The study will be conducted at the Entabeni Rehabilitation Centre, Durban, only. Total number of participants will be 20.
- The aim of the study is to investigate a strapping technique for the knee as a treatment option for stroke patients. The technique will provide an easy, cost effective alternative to existing treatment.
- Measurements consist of four (4) tests and a short questionnaire. Each participant will receive a demonstration and a trial run of the measurements. Measurements will be taken before taping and repeated after taping. Participants will then be asked to answer a question. Answers will be recorded by the therapist. Expected time to finish the procedure is 40-50 minutes. Measurements include: walking speed, two balance tests and measurement of a knee angle.

**Why have you been invited to participate?**

- To conduct a scientific study, a set of criteria has been set. You fall within these criteria and are therefore approached to participate. Criteria are the following:

Inclusion criteria are

A person with a history of a single stroke affecting the right or the left side within the last twelve months.

The participant should be able to follow instructions

The person should be able to walk 10m without a walking aid or assistance over an even surface. An ankle-foot-orthosis is allowed.

The treating therapist and the participant should have identified gait training and improvement of dynamic standing balance as part of the treatment goals.

Exclusion criteria are

Persons with a history of previous knee problems or surgery.

Persons with a history of allergies to plaster/therapeutic tape.

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**What will your responsibilities be?**

- On one of your regular treatment days, your will be asked to stay for an additional hour. Before treatment the testing procedure will be explained and demonstrated to you. You may also have a trial run. Measurements will then be taken without the tape and after a short resting period, measurements will be taken with the tape. Testing will take place only once.

**Will you benefit from taking part in this research?**

- Since there is no risk involved in using this treatment technique, you and your therapist may choose to use it as part of your rehabilitation. It may also be considered as a treatment option for other patients with similar difficulties. Once the study is completed, the results may be published and therapists at other centres may find the information useful in treating their own patients.

**Are there any risks involved in your taking part in this research?**

- No known risks are involved in participating in this study. The tape can be removed after testing if the participant so wishes.

**If you do not agree to take part, what alternatives do you have?**

- If you choose not to participate, your therapy will continue as discussed with your treating therapist. You will not suffer any negative consequences.

**Who will have access to your medical records?**

- The information collected will be treated as confidential and protected. If it is used in a publication or thesis, the identity of all participants will remain anonymous. Access to information will be restricted to the staff at Entabeni Rehabilition Centre, the researcher and research promoters at the University of Stellenbosch.

**What will happen in the unlikely event of some form injury occurring as a direct result of your taking part in this research study?**

- Testing will take place under supervision of your treating therapist and during treatment sessions. Permission was obtained from the Life Health Care group to conduct the study at their facility. In the unlikely event of an injury during testing, the same procedure will be followed as injury during treatment.

**Will you be paid to take part in this study and are there any costs involved?**

- No you will not be paid to take part in the study. There will be no costs involved for you, if you do take part.

**Is there anything else that you should know or do?**

- You can contact the Committee for Human Research at (021) 938 9207 if you have any concerns or complaints that have not been adequately addressed by your study therapist.
- You will receive a copy of this information and consent form for your own records.


**By signing below, I………………………………………….. agree to take part in a research study entitled: Patellar taping: A treatment option for stroke patients**

**I declare that:**

- I have read or had read to me this information and consent form and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is voluntary and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (place)…………………………..on (date) ………………………………….. 2006


…………………………..                                           ………………………

Signature of Participant or family member                    Signature of Witness.


**Declaration by Investigator**

I  (name )  ………………………………………………declare that:-


- I explained the information in this document to …………………………..…..
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above.
- I did/did not use a translator. (If a translator is used then the translator must sign the declaration below.


Signed at (place)…………………………..on (date) ………………………………….. 200..


…………………………..                                           ………………………

Signature of Investigator                                     Signature of Witness.


**Declaration by Translator**

I (name )  ……………………………………………declare that:-

- I assisted the investigator (name)…………………………. to explain the information in this document to (name of participant)…………………………….. using the language medium of Zulu.
- We encouraged him/her to ask questions and took adequate time to answer them.
- I conveyed a factually correct version of what was related to me.
- I am satisfied that the participant fully understands the content of this informed consent document and has had all his/her question satisfactorily answered.

.

Signed at (place)…………………………..on (date) ………………………….. 200…

…………………………..                                                  ………………………

Signature of  Translator.                                          Signature of Witness.

# DEELNEMERINLIGTINGSBLAD EN -TOESTEMMINGSVORM

**TITEL VAN DIE NAVORSINGSPROJEK:**

Patellêre verbinding: 'n Behandelings opsie vir pasiente met beroerte

**VERWYSINGSNOMMER:**

N 05/07/119

**HOOFNAVORSER:**

Sonette Dreyer

**ADRES:**

Posbus 1785, Hillcrest, Durban, 3650

**KONTAKNOMMER:**

072 2820735

U word genooi om deel te neem aan 'n navorsingsprojek. Lees asseblief hierdie inligtingsblad op u tyd deur aangesien die detail van die navorsingsprojek daarin verduidelik word. Indien daar enige deel van die navorsingsprojek is wat u nie ten volle verstaan nie, is u welkom om die navorsingspersoneel of dokter daaroor uit te vra. Dit is baie belangrik dat u ten volle moet verstaan wat die navorsingsprojek behels en hoe u daarby betrokke kan wees. U deelname is ook volkome vrywillig en dit staan u vry om deelname te weier. U sal op geen wyse hoegenaamd negatief beïnvloed word indien u sou weier om deel te neem nie. U mag ook te eniger tyd aan die navorsingsprojek onttrek, selfs al het u ingestem om deel te neem.

Hierdie navorsingsprojek is deur die Komitee vir Mensnavorsing van die Universiteit Stellenbosch goedgekeur en sal uitgevoer word volgens die etiese riglyne en beginsels van die Internasionale Verklaring van Helsinki en die Etiese Riglyne vir Navorsing van die Mediese Navorsingsraad (MNR).

**Wat behels hierdie navorsingsprojek?**

- Die studie sal uitgevoer word by die Entabeni Rehabilitasie sentrum in Durban. 'n totaal van 20 deelnemers sal gewerf word.
- Die doel van die studie is om vas te stel of 'n verbindingstegniek vir die knie doeltreffend sal wees in die behandeling van pasiente wat 'n beroerte gehad het. Hierdie tegniek bied 'n maklike en koste effektiewe alternatief vir bestaande tegnieke.
- Vier (4) toetse en 'n kort vraelys sal in die studie gebruik word. Die toetse sluit die volgende in: loop spoed, twee balans toetse en meting van 'n hoek by die knie. Elke deelnemer sal 'n demonstrasie ontvang en kan daarna deur die prosedure gaan om seker te maak dat hy/sy die proses verstaan. Metings sal voor en na die verbindingstegniek geneem word. Deelnemers sal daarna gevra word om die vraelys te beantwoord. Antwoorde sal deur die terapeut gedokumenteer word. Die prosedure sal na verwagting 40-50 minute duur.

**Waarom is u genooi om deel te neem?**

- Om te verseker dat die studie wetenskaplik uitgevoer word, is sekere kriteria vir deelname vasgestel. U val binne die kriteria en is daarom genader vir deelname in die studie. Die kriteria is die volgende:

<u>Insluitings kriteria</u>

Persone wat in die voorafgaande 12 maande 'n enkele beroerte gehad het. Die linker of regter kant kan aangetas wees.

Deelnemers moet in staat wees om instruksies te volg.

Deelnemers moet in staat wees om 10meter oor 'n gladde oppervlak te loop sonder hulp of 'n loophulpmiddel. 'n Stut vir die enkel en voet is wel toelaatbaar.

Beide die deelnemer en die fisioterapeut wat die pasient se behandeling waarneem, moes heropleiding van loopgang en dinamiese staanbalans as behandelingsdoelwitte geidentifiseer het.


<u>Uitsluitings kriteria</u>

Persone wat reeds voor die beroerte knie probleme of chirurgie gehad het.

Persone met 'n allergie vir pleister.


**Wat sal u verantwoordelikhede wees?**

- U sal gevra word om tydens een van u geskeduleerde behandelingsessies vir een ekstra uur te bly. Voor u behandeling sal die prosedure aan u verduidelik en gedemonstreer word. U mag ook een keer deur die toetsprosedure gaan. Metings sal geneem word voor die knie verbind word en herhaal word na 'n kort rus periode waartydens die knie verbind sal word. Die toetsprosedure sal net een keer gevolg word.


**Sal u voordeel trek deur deel te neem aan hierdie navorsingsprojek?**

- Daar is geen risiko verbonde aan die gebruik van die tegniek nie en u kan saam met u terapeut besluit of dit ingesluit kan word by u rehabilitasie program. Na afloop van die studie kan die resultate gepubliseer word en ander terapeute mag die informasie gebruik in die behandeling van hul pasiente.

**Is daar enige risiko's verbonde aan u deelname aan hierdie navorsingsprojek?**

- Daar is geen risiko verbonde aan deelname aan die studie nie. Die pleister kan dadelik verwyder word na afloop van die toetsing indien u so verkies.

**Watter alternatiewe is daar indien u nie instem om deel te neem nie?**

- Indien u verkies om nie aan die studie deel te neem nie, sal u behandeling voort gaan soos bespreek met u fisioterapeut. Daar is geen negatiewe gevolge indien u verkies om nie deel te neem nie.

**Wie sal toegang hê tot u mediese rekords?**

- Alle informasie sal vertroulik en beskermd hanteer word. Deelnemers sal anomiem bly indien dit gebruik sou word in 'n publikasie of tesis. Toegang tot informasie sal beperk word tot die personeel van Entabeni Rehabilitasie Sentrum, die navorser en die navorsings promotors by die Universiteit van Stellenbosch.

**Wat sal gebeur in die onwaarskynlike geval van 'n besering wat mag voorkom as gevolg van u deelname aan hierdie navorsingsprojek?**

- Toetsing sal plaasvind onder toesig van die fisioterapeut wat u behandeling waarneem. Toestemming is verkry van Entabeni Rehabilitasie Sentrum om die studie daar uit te voer. Besering tydens die toetsing is baie onwaarskynlik maar indien u wel n besering sou opdoen sal dieselfde prosedure gevolg word as besering tydens behandeling.

**Sal u betaal word vir deelname aan die navorsingsprojek en is daar enige koste verbonde aan deelname?**

- U sal nie betaal word vir deelname aan die navorsingsprojek nie. Deelname aan die navorsingsprojek sal u niks kos nie.

x

**Is daar enigiets anders wat u moet weet of doen?**

- U kan die Komitee vir Mensnavorsing kontak by 021-938 9207 indien u enige bekommernis of klagte het wat nie bevredigend deur u studieterapeut hanteer is nie.
- U sal 'n afskrif van hierdie inligtings- en toestemmingsvorm ontvang vir u eie rekords.

**Met die ondertekening van hierdie dokument onderneem ek, …………………………….., om deel te neem aan 'n navorsingsprojek getiteld Patellêre verbinding: 'n Behandelings opsie vir pasiente met beroerte**

**Ek verklaar dat:**

- Ek hierdie inligtings- en toestemmingsvorm gelees het of aan my laat voorlees het en dat dit in 'n taal geskryf is waarin ek vaardig en gemaklik mee is.
- Ek geleentheid gehad het om vrae te stel en dat al my vrae bevredigend beantwoord is.
- Ek verstaan dat deelname aan hierdie navorsingsprojek vrywillig is en dat daar geen druk op my geplaas is om deel te neem nie.
- Ek te eniger tyd aan die navorsingsprojek mag onttrek en dat ek nie op enige wyse daardeur benadeel sal word nie.
- Ek gevra mag word om van die navorsingsprojek te onttrek voordat dit afgehandel is indien die navorser van oordeel is dat dit in my beste belang is, of indien ek nie die ooreengekome navorsingsplan volg nie.

Geteken te (plek)……………………….op (datum) …………………………….. 200,,,

…………………………..                                            ………………………

Handtekening van deelnemer                          Handtekening van getuie.

**Verklaring deur navorser**

- Ek (naam ) ……………………………………………… verklaar dat:
- Ek die inligting in hierdie dokument verduidelik het aan ……………………………..
- Ek hom/haar aangemoedig het om vrae te vra en voldoende tyd gebruik het om dit te beantwoord.
- Ek tevrede is dat hy/sy al die aspekte van die navorsingsprojek soos hierbo bespreek, voldoende verstaan.
- Ek 'n tolk gebruik het/nie 'n tolk gebruik het nie.  (Indien 'n tolk gebruik is, moet die tolk die onderstaande verklaring teken.)

Geteken te (plek)…………………………..op (datum) ………………………………….. 200..

…………………………..                                          ………………………

Handtekening van navorser                          Handtekening van getuie

**Verklaring deur tolk**

- Ek (naam ) ……………………………………………… verklaar dat:
- Ek die navorser (naam)………………………… bygestaan het om die inligting in hierdie dokument in Zulu aan(naamvandeelnemer)………………………….. te verduidelik.
- Ons hom/haar aangemoedig het om vrae te vra en voldoende tyd gebruik het om dit te beantwoord.
- Ek 'n feitelik korrekte weergawe oorgedra het van wat aan my vertel is.
- Ek tevrede is dat die deelnemer die inhoud van hierdie dokument ten volle verstaan en dat al sy/haar vrae bevredigend beantwoord is.

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Geteken te (plek) ………………………….. op (datum) ………………………………….. 2006

…………………………..                                          ………………………

Handtekening van tolk                                Handtekening van getuie

# Addendum: B

## <u>**DATA CAPTURE SHEET**</u>

Subject Nr:

Date of birth:

Diagnosis:

Date of CVA:

Weight:

Height:

Left foot dominant\ Right foot dominance prior to stroke:

Male/Female:

Date of measurements:

Test results without taping

- Q-angle in standing:    Left leg -

                          Right leg -

- Timed-up-and-go:

- Walking speed over 6 m:    1.

                             2.

                             3.

- Step test (number of steps in 15sec with unaffected side):

- Subjective comment: Yes/No/Unsure

Motivation:

Test results with taping

- Q-angle in standing:      Left leg -

                            Right leg -

- Timed-up-and-go:

- Walking speed over 6 m:    1.

                             2.

                             3.

- Step test (number of steps in 15sec with unaffected side):

- Subjective comment: Yes/No/Unsure

  Motivation:

# Addendum C

6 October 2005

Mrs S Dreyer
Dept of Physiotherapy

Dear Mrs Dreyer

**RESEARCH PROJECT:**   **"PATELLAR TAPING: A TREATMENT OPTION FOR STROKE PATIENTS"**
**PROJECT NUMBER :**   N05/07/119

At a meeting of the Committee for Human Research that was held on 3 August 2005 the above project was approved on condition that further information that was required, be submitted.

This information was supplied and the project was finally approved on 6 October 2005 **for a period of one year from this date.** This project is therefore now registered and you can proceed with the work. Please quote the above-mentioned project number in all further correspondence.

**Please note that a progress report (obtainable on the website of our Division) should be submitted to the Committee before the year has expired. The Committee will then consider the continuation of the project for a further year (if necessary).**

Patients participating in a research project in Tygerberg Hospital will not be treated free of charge as the Provincial Government of the Western Cape does not support research financially.

Due to heavy workload the nursing corps of the Tygerberg Hospital cannot offer comprehensive nursing care in research projects. It may therefore be expected of a research worker to arrange for private nursing care.

Yours faithfully

**CJ VAN TONDER**
**RESEARCH DEVELOPMENT AND SUPPORT (TYGERBERG)**
Tel: +27 21 938 9207 / E-mail: cjvt@sun.ac.za

CJVT/ev

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