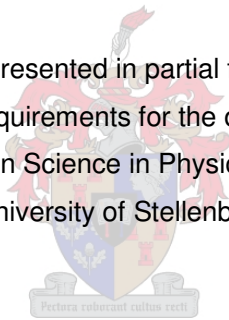


The effect of gluteal taping on gait in ambulant adults with hemiplegia

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my original work and that I have not previously submitted it, in its entirety or in part, at any university for a degree.

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Date:

ABSTRACT

Introduction

Decreased hip extension in the paretic leg is a common impairment after stroke. Gluteal taping was introduced as a technique that helped in increasing hip extension of the paretic leg, and step length in the unaffected leg. The aim of this study was to further investigate the effect of gluteal taping on other temporal spatial and kinematic parameters using a 3D motion analysis system (Moven System).

Methods

The study was conducted in two phases. Phase 1 entailed examining the intra trial reliability of the Moven System, where eight subjects were recruited and tested twice at their normal pace of walking, and twice again at their maximum speed. Phase 2 involved studying the effect of gluteal taping on temporal spatial and kinematic parameters. Thirty subjects participated and were tested under three taping conditions (no tape, therapeutic tape, and placebo tape), while walking at their self selected walking speed. Intra-class correlation coefficient ICC determined around 95% confidence intervals was used to examine the intra trial reliability of the Moven System. Repeated measures-ANOVA was used to study the temporal spatial, and kinematic variables during the three taping conditions.

Results

The Moven showed moderate to excellent reliability in measuring the gait variables including temporal spatial parameters and sagittal kinematic parameters in addition to the lateral pelvic tilt. Taping caused significant increase in hip extension and reduction in knee flexion at terminal stance for the paretic leg. There was a trend toward better hip flexion at terminal stance, and a mild trend toward more planter flexion at terminal stance. Both treatment and placebo tapes caused an increase in the step lengths of either leg, and a significant increase in gait velocity and cadence.

Conclusion

Gluteal taping may be beneficial in producing important clinical effects post stroke, and can be used as an adjunct strategy during gait rehabilitation. Further research is needed to

understand the mechanism of how taping produces effects, and to further explore its effect on kinetic and muscle activation variables.

OPSOMMING

Inleiding

Verminderde heup ekstensie in die verlamde been is 'n algemene aantasting na beroerte. Gluteale verbinding van die aangetaste been is een tegniek om heup ekstensie van die hierdie been sowel as treelengte van die ongeaffekteerde been te vermeerder. Die doel van hierdie studie was dus om die effek van gluteale verbinding op ander tempero-ruimtelike en kinematiese parameters met 'n drie-dimensionele bewegingsanalise sisteem (die Movensisteem) verder te ondersoek.

Metode

Die studie is in 2 fases uitgevoer. Fase 1 het die bepaling van die toets her-toets betroubaarheid van die Movensisteem behels. Agt proefpersone is gewerf en is twee keer getoets tydens selfgeselekteerde normale loopspoed en twee keer tydens maksimale loopspoed. Fase 2 het die ondersoek van die effek van gluteale verbinding op tempero-ruimtelike en kinematiese parameters behels tydens selfgeselekteerde loopspoed. Dertig proefpersone het aan hierdie fase deelgeneem en is getoets met drie verskillende verbindingstrategieë nl. geen -; met terapeutiese -; en met plasebo verbinding. Die 'Intra-class correlation coefficient (ICC)' is gebruik om betroubaarheid tussen meetings van die Movensisteem te bepaal. 'Repeated measures-ANOVA' is gebruik om die tempero-ruimtelike en kinematiese veranderlikes tussen die drie verbindingsmetodes te analiseer.

Resultate

Die Movensisteem het goeie tot uitstekende betroubaarheid getoon in die meet van die gekose loop parameters insluitend die laterale pelviese tilt. Verbinding van die verlamde been het tot 'n beduidende toename in heup ekstensie en 'n afname in knie fleksie tydens terminale staanfase van loop gelei. Daar was 'n matige tendens tot toename in heup fleksie tydens hak kontak van die staanfase asook 'n effense nyging tot meer plantaarflexie tydens terminale staanfase. Terapeutiese en plasebo verbinding het gelei tot 'n toename in die treelengte van beide bene asook 'n beduidende toename in loopspoed en kadens.

Gevolgtrekking

Gluteale verbinding kan voordelig wees vir die verkryging van belangrike kliniese effekte in pasiënte na 'n beroerte aanval. Verbinding kan ook gebruik word as 'n behandeling strategie tydens loop rehabilitasie. Verdere navorsing is noodsaaklik om die meganismes te bepaal wat verantwoordelik is vir die effekte van verbinding. Toekomstige navorsing behoort ook gerig te word op die effek van verbinding op spieraktivering en kinetiese faktore.

TABLE OF CONTENTS

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DECLARATION	ii
ABSTRACT	iii
OPSOMMING	v
LIST OF TABLES	xi
LIST OF FIGURES	xiii
LIST OF APPENDICES	xiv
CHAPTER 1. INTRODUCTION	1
CHAPTER 2. SYSTEMATIC REVIEW	7
2.1 INTRODUCTION	7
2.2 SPECIFIC OBJECTIVES	8
2.3 DEFINITIONS	8
2.4 REVIEW METHODS	9
2.4.1 <i>Inclusion Criteria</i>	9
2.4.1.1 Types of studies	9
2.4.1.2 Types of participants	9
2.4.1.3 Types of interventions	9
2.4.1.4 Types of outcome measures	9
2.4.2 <i>Exclusion criteria</i>	10
2.4.3 <i>Search Strategy</i>	10
2.4.4 <i>Data extraction</i>	11
2.4.5 <i>Level of Evidence appraisal</i>	11
2.4.6 <i>Methodological appraisal</i>	12
2.5 RESULTS	12
2.5.1 <i>Description of studies</i>	12
2.5.2 <i>Methodological Quality</i>	15
2.5.3 <i>Taping over a joint</i>	17
2.5.3.1 Knee Taping	17
2.5.3.2 Ankle Taping	24
2.5.3.3 Scapular Taping	27
2.5.4 <i>Taping over muscles</i>	29
2.6 DISCUSSION	30
2.6.1 <i>Taping over a joint</i>	30
2.6.1.1 Knee taping	30

2.6.1.2	Ankle taping.....	32
2.6.1.3	Scapular taping	32
2.6.2	<i>Taping over muscles</i>	33
2.7	LIMITATIONS	33
2.8	CONCLUSION.....	33
CHAPTER 3. METHODOLOGY.....		35
3.1	RESEARCH QUESTIONS:.....	35
3.2	MAIN AIM OF STUDY.....	35
3.3	OBJECTIVES OF STUDY.....	35
3.4	STUDY DESIGN	36
3.5	RESEARCH SETTING:.....	36
3.6	SAMPLING	36
3.6.1	<i>Population</i>	36
3.6.2	<i>Sample Recruitment</i>	37
3.6.3	<i>Sample Size:</i>	37
3.6.4	<i>Sample Characteristics</i>	38
3.6.4.1	Inclusion criteria	38
3.6.4.2	Exclusion criteria	38
3.7	INSTRUMENTATION.....	39
3.8	SENSORS PLACEMENT	40
3.9	ANTHROPOMETRIC MEASUREMENTS	40
3.10	PILOT STUDY.....	41
3.11	PHASE 1: RELIABILITY OF THE MOVEN SYSTEM.....	41
3.11.1	<i>Aim</i>	41
3.11.2	<i>Study Design</i>	42
3.11.3	<i>Procedure</i>	42
3.12	PHASE 2: EFFECT OF GLUTEAL TAPING	42
3.12.1	<i>Aim</i>	42
3.12.2	<i>Study Design</i>	42
3.12.3	<i>Procedure</i>	42
3.12.4	<i>Taping Procedure:</i>	46
3.13	DATA COLLECTION.....	47
3.13.1	<i>Instrument</i>	47
3.13.2	<i>Outcome Measure</i>	47
3.14	DATA EXTRACTION.....	47

3.15	STATISTICAL ANALYSIS.....	50
3.16	ETHICAL CONSIDERATIONS.....	51
CHAPTER 4. RESULTS		53
4.1	SAMPLE DESCRIPTION:.....	53
4.2	PHASE ONE.....	54
4.2.1	<i>Temporal spatial parameters during normal walking:.....</i>	<i>54</i>
4.2.2	<i>Temporal spatial parameters during fast walking:.....</i>	<i>54</i>
4.2.3	<i>Kinematic parameters during self selected walking speed.....</i>	<i>55</i>
4.2.3.1	At initial contact.....	55
4.2.3.2	Mid stance.....	55
4.2.3.3	Terminal stance.....	56
4.2.3.4	Mid Swing.....	56
4.2.4	<i>Kinematic parameters during fast walk.....</i>	<i>57</i>
4.2.4.1	Initial contact.....	57
4.2.4.2	Mid stance.....	57
4.2.4.3	Terminal stance.....	58
4.2.4.4	Mid Swing.....	58
4.3	PHASE 2.....	59
4.3.1	<i>Kinematic parameters:.....</i>	<i>59</i>
4.3.1.1	At initial contact.....	59
4.3.1.2	At mid stance.....	61
4.3.1.3	At terminal stance.....	63
4.3.1.4	At mid swing.....	66
4.3.2	<i>Temporal spatial parameters.....</i>	<i>68</i>
CHAPTER 5. DISCUSSION.....		71
5.1	PHASE ONE:.....	71
5.2	PHASE 2.....	73
5.2.1	<i>Kinematic parameters:.....</i>	<i>73</i>
5.2.1.1	Effect of taping at initial contact:.....	73
5.2.1.2	Effect of taping at mid stance:.....	73
5.2.1.3	Effect of taping at terminal stance:.....	74
5.2.1.4	Effect of taping at mid swing:.....	74
5.2.2	<i>Temporal-spatial parameters:.....</i>	<i>75</i>
5.2.2.1	Effect of taping on step length, cadence and velocity.....	75
5.2.3	<i>The mechanism by which gluteal taping works.....</i>	<i>75</i>

CHAPTER 6. CONCLUSION, LIMITATIONS, AND RECOMMENDATIONS	77
6.1 CONCLUSION	77
6.1.1 <i>Moven reliability in measuring gait of subjects with stroke</i>	<i>77</i>
6.1.2 <i>The effect of gluteal taping on gait performance.</i>	<i>77</i>
6.2 LIMITATIONS	78
6.2.1 <i>Limitations in the reliability study</i>	<i>78</i>
6.2.2 <i>Limitations in the taping study.....</i>	<i>78</i>
6.3 RECOMMENDATIONS	79
REFERENCES	80

LIST OF TABLES

Table 2.1: JBI level of evidence. (The Joanna Briggs Institute and its collaborating centres and Evidence Translation Groups).....	11
Table 2.2: Search strategy	13
Table 2.3: Search results	14
Table 2.4: Studies description	15
Table 2.5: Results of Critical Appraisal tool for each included study.....	16
Table 2.6: Ratio of VMO:VL (VMO divided by VL) ratio results in subjects without PFPs....	18
Table 2.7: Ratio of VMO:VL (dividing VMO by VL) ratio results for knee taping studies in PFP subjects.....	19
Table 2.8: Muscle activity findings for knee taping in subjects without PFP.....	20
Table 2.9: VMO & VL activity results for knee taping on subjects with PFPs	22
Table 2.10: VMO & VL onset results for knee taping studies of healthy subjects.....	23
Table 2.11: VMO & VL onset results for knee taping studies of PFP subjects	24
Table 2.12: Results for Ankle taping studies	26
Table 2.13: Scapular Taping results.....	28
Table 2.14: Taping over muscles results	30
Table 3.1: Placement of sensors on the body	40
Table 3.2: Anthropometric measurements.....	40
Table 4.1: Characteristics of subjects.....	53
Table 4.2: The reliability of the Moven in measuring the temporal spatial parameters during self selected pace of walking.....	54
Table 4.3: The reliability of the Moven in measuring the temporal spatial parameters during fast walking	55
Table 4.4: The reliability results while the affected leg is at the initial contact phase of selected pace of walking	55
Table 4.5: The reliability results while the affected leg is at the mid stance phase of selected pace of walking	56
Table 4.6: The reliability results while the affected leg is at the terminal stance phase of selected pace of walking	56
Table 4.7: The reliability results while the affected leg is at the mid swing phase of selected pace of walking	57
Table 4.8: The reliability results while the affected leg is at the initial contact phase of maximum pace of walking.....	57

Table 4.9: Reliability results while the affected leg is at the mid stance phase during maximum walking speed.....	58
Table 4.10: Reliability results while the affected leg is at the terminal stance phase during maximum walking speed.....	58
Table 4.11: Reliability results while the affected leg is at the mid swing phase during maximum walking speed.....	59
Table 4.12: Mean differences, SDs, and p values of the hip angles at terminal stance.....	64
Table 4.13: Mean differences, SDs, and p values of the knee angles at terminal stance.....	64
Table 4.14: Effect of taping on cadence	70
Table 4.15: Effect of taping on velocity.....	70

LIST OF FIGURES

Figure 2.1: Grouping of taping techniques.....	11
Figure 3.1: Sample size calculation.....	38
Figure 3.2: Anthropometric measurements	41
Figure 3.3: The procedure steps during the reliability study.....	42
Figure 3.7: The initial contact phase of the left leg occurred in this example at timeframe 0959. The timeframe was then matched on the Excel file of the same trial, and the values were extracted.	48
Figure 3.8: An example of initial contact phase of the left foot.....	49
Figure 3.9: An example of the mid stance phase of the left foot	49
Figure 3.10: An example of the terminal stance phase of the left foot	50
Figure 3.11: An example of the mid swing phase of the left leg.....	50
Figure 4.1: Hemi hip at initial contact	60
Figure 4.2: Hemi knee at initial contact	60
Figure 4.3: Hemi Ankle at initial contact	61
Figure 4.4: Lateral pelvic tilt at initial contact	61
Figure 4.5: Hemi hip at mid stance.....	62
Figure 4.6: Hemi knee at mid stance.....	62
Figure 4.7: Hemi ankle at mid stance	63
Figure 4.8: Lateral pelvic tilt at mid stance	63
Figure 4.9: Hemi hip at terminal stance.....	64
Figure 4.10: Hemi knee at terminal stance	65
Figure 4.11: Hemi ankle at terminal stance	65
Figure 4.12: Lateral pelvic tilt at terminal stance.....	66
Figure 4.13: Hemi hip at mid swing	66
Figure 4.14: Hemi knee at mid swing	67
Figure 4.15: Hemi ankle angle at mid swing.....	67
Figure 4.16: Lateral pelvic tilt at mid swing.....	68
Figure 4.17: Effect of taping on the unaffected leg step length.....	68
Figure 4.18: Effect of taping on the unaffected leg step length.....	69
Figure 4.19: Effect of taping on cadence.....	69
Figure 4.20: Effect of taping on velocity	70

LIST OF APPENDICES

Appendix 1 Approval from the Ethics committee	90
Appendix 2 Permission from community health centers	91
Appendix 3 Permission letter from WCRC.....	91
Appendix 4 Participant information leaflet and consent form	92
Appendix 5 Consent and indemnity for transport of participants.....	96
Appendix 6 Critical Appraisal Tool.....	97
Appendix 7 Results of gluteal taping on the unaffected side	100
Appendix 8 Reliability Results	107

CHAPTER 1. INTRODUCTION

Hemiplegia, paralysis of one side of the body, is a classic sign of neurovascular disease or insult to the brain. It may occur with cerebrovascular accidents (CVA) affecting a cerebral hemisphere or brain stem. Stroke is defined as an acute onset of neurological dysfunction due to an abnormality in cerebral circulation with resultant signs and symptoms that correspond to involvement of focal areas of the brain as a result of either a hemorrhagic or ischemic lesion (O'Sullivan 2001). Strokes result in a sudden specific neurological deficit usually affecting the side of the body contralateral to the lesion. Although hemiplegia is the classical sign of a stroke, other symptoms such as sensory dysfunction, aphasia, dysarthria, visual defects, perceptual, cognitive and mental impairments can contribute to the degree of disability that the stroke survivor experiences (Ryerson 2001). Cerebral infarction, caused by thrombosis or embolism, is the most common form of stroke accounting for 70% of all strokes, while hemorrhage accounts for 20% and the other 10% remain unspecified (Ryerson 2001).

Globally, cerebrovascular disease (stroke) is the second leading cause of death (WHO 2007, Murray & Lopez 1997). It is a disease that predominantly occurs in adults above the age of 55. The World Health Organization (WHO) estimated that in 2005, stroke accounted for 5.7 million deaths world wide, equivalent to 9.9 % of all deaths (WHO, 2007). Over 85% of deaths caused by stroke occurred in people living in low and middle income countries and one third in people aged less than 70 years. It is predicted that stroke will account for 7.8 million deaths world wide in 2030 (WHO, 2007).

The prevalence of stroke in South Africa has been estimated to be around 300/100000 and is lower than in high-income countries such as New Zealand. In this South African study, 66% of stroke survivors were left with disabilities and often needed help with at least one activity of daily living (The SASPI Project Team 2004). Furthermore, it has been estimated that 12% of annual deaths in South Africa for adults aged 35 to 74 years would be due to ischemic heart disease and 14% would be due to stroke (Gaziano , Steyn & Cohen 2005).

Stroke is the leading serious long term cause of disability in the United States of America (McGruder , Greenlund & Croft 2005) leaving 31% of the survivors requiring assistance, 20% needing help for walking, 16% in long term care facilities, and 17% are vocationally impaired after 7 years (Ryerson 2001). Disability following a stroke is believed to have a huge impact on patients, families, and the community (Mayo , Wood-Dauphinee , Ahmed

1999). Disability experienced by stroke survivors as a result of activity limitations and participation restrictions is an important factor for the determination of participation in the community (Mayo, Wood-Dauphinee Ahmed 1999). The resulting functional disability limits the person's abilities to enjoy and be productive in life activities. The sudden onset of hemiplegia makes it different from many other disabling conditions, leaving the patient, and his/her family ill prepared to deal with its circumstances. Rand , Eng , Tang , Hung (2008) measured the amount of physical activity that people with stroke undertake in the community and its relationship with walking capacity. Free living physical activity was very low, and that was highly correlated with low walking capacity. Patients receiving rehabilitation following stroke often place walking as the most important goal of rehabilitation and independent functioning (Katz M & Shochina M 2005).

Many studies have been done to describe the gait pattern in patients with hemiplegia (Otter ARD, Geurts ACH, Mulder Th, & Duysens J 2007; Neckel N, Palliccio M, Nichols D & Hidler J 2006; Chen J, Patten C & Kothari DH 2005; Wooley SM 2001; Onley SJ & Richards C 1996; Von SHP, Coutts RD & Lyden PD 1995; Pinzur MS, Sherman R & Levine PD 1987; Wall JC & Turnbull GL 1986; Knutsson E & Richards C 1979). Some of the typical problems include slow speed, asymmetric patterns of movements, shorter step length, lack of hip extension and ankle dorsiflexion in the affected leg (Chen G, Patten C & Kothari Dh D 2005; Nadeau S, Gravel D, Arsenault AB 1999; Roth EJ, Merbits C & Mroczek K 1997; Olney SJ, Griffin MP & McBride ID 1994).

The degree to which walking is impaired after stroke varies greatly, and it is closely correlated with level of severity of the stroke (Mulroy, Gronley & Weiss 2003; Bohannon & Andrews 1995). It has been found that even among those patients with marked impaired walking, gait deviations may differ greatly (Mulroy *et al* 2003). Identifying those deviations and understanding the mechanism of action and compensations could be used to guide rehabilitation (Milot, Nadeau & Gravel 2006; Chen, Chen & Tang 2003; Lamontagne, Richards, & Malouin 2000; Gaviria, D'Angeli, Chavet 1996).

The movements of the paretic lower limb have been studied extensively in the literature (Higginson, Zajac, Neptune 2007; Milot, Nadeau, & Gravel 2007; Neptune, Zajac & Kautz 2004; Mulroy *et al* 2003; Sadeghi, Sadeghi & Prince 2001). The correlation between different movements and parameters have been studied to explain the particular patterns of movement in the paretic limb, and to compare it to normal pattern of walking (Neptune *et al* 2004). Studying the correlation of movements between all the joints help to explain the different ways the central nervous system adapt to particular impairments. There was a

consistency in the literature correlating the hip flexors and extensors, with knee flexors/extensors, and ankle dorsi/plantar flexors behaviors (Milot *et al* 2007; Higginson *et al* 2006; Tanabe, Kamiya & Muraoka 2006; Tanabe, Muraoka & Kamiya 2004; Lamontagne, Malouin & Richards 2002; Kerrigan, Roth & Riley 1998).

Yamaguchi & Zajac (1999) reported that in normal population, hip flexor torque is important for knee flexion. Piazza & Delp (1996) reported that reducing the hip flexion moment in normal gait inhibits knee flexion in swing in a healthy population. The more the hip extends the longer the hip flexion moment arm becomes. Sadeghi *et al* (2001) reported a high coordination between the hip and the ankle moments during the propulsion phase which was 50-60% of the gait cycle in a healthy population. They also found that maintaining the body supported against gravity was identified as the first task of the hip extensors and planter-flexors. Anderson & Pandy (2003) studied the individual muscle contribution to support in normal walking. They reported that body support was generated primarily by gluteus maximus, vasti, and posterior gluteus medius/minimus. In agreement with that, Neptune *et al* (2004) reported that the hip and knee extensors muscles are critical to body support in the stance phase. Therefore, the hip extensors and flexors are critical for body support and forward progression.

In a population with stroke, Kerrigan *et al* (1998) studied the biomechanics of spastic paretic stiff-legged gait during swing phase. They found that increasing hip flexors torque, which is clinically equivalent to increasing hip flexion action during swing phase, resulted in increased knee flexion which was not improved with subjects who underwent intramuscular block of the quadriceps. Tanaba *et al* (2004 & 2006) investigated the changes of the H-reflex in the soleus muscle during hip movements in people with stroke. They reported a reduction in H-reflex in the soleus with passive hip flexion, and an increase in H-reflex with passive hip extension. Thus improving hip extension in people with hemiplegia, may impact significantly on gait performance and possibly other functional activities.

Reduced hip extension range is one of the consistent characteristics in subjects with hemiplegia. Lehmann *et al* (1987) reported a reduction of 14° of peak hip extension in the paretic leg when compared with able bodied subjects walking at a matched speed. Hip extension at terminal stance is important for propulsion. Forward progression requires the generation of horizontal forces to propel the body forward. The primary mechanisms of propulsion include the plantarflexion torque produced by the calf at terminal stance. To maximise this torque the hip needs to be in some extension so that the body's COM is anterior to the supporting foot/ankle by the end of terminal stance (Shumway-Cook &

Woollacott 2007). Furthermore the hip and knee extensors may show a burst of activity late in stance to also contribute to propulsion, as well as take the hip flexors into a lengthened position so that they can be readied for the forward swing phase Perry (1992).

Gait rehabilitation after stroke is one of the major areas of current research. Different studies have investigated different approaches to gait rehabilitation, and many debates are still going on for selecting the most optimal technique. There is also much discussion regarding the contribution of the varying impairments to the poor motor performance and which of these should be targeted during rehabilitation to ultimately get the most favored outcome. The uses of functional electrical stimulation, treadmill training, and partial body weight support walking training have been the focus of research.

Functional electrical stimulation (FES) has been proven to be very effective during gait rehabilitation, particularly with stimulating to the tibialis anterior during the swing phase of the gait cycle. A multi channel FES has been also used to stimulate different muscle groups to assist walking (Bogotaj U, Gros N, Kljajic M, Acimovic R & Malezic M 1995). Despite the supporting evidence for its use in gait rehabilitation, it is difficult to predict whether this technology will be sufficiently cost effective to merit individual payment. In addition to its high cost, muscles activated by EFS fatigue far faster than muscles activated voluntarily by the central nervous system (Bickle CS & Gregory CM 2005). The effects of other walking aids, such as canes have been reported in the literature. Kuan TS, Tsou JY & Su FC (1999) reported significant increase in stride length, and decreased cadence and step width in subjects with stroke who walk with a cane, compared to those who walked without a cane. There was an increase in hip extension, knee extension and ankle planter flexion in the pre swing phase in those who walked with a cane. The increase in hip extension at the propulsive phase reported in the previous study might not be due to increased activity in the gluteus maximus. Buurke JH, Hermens HJ, Errn-Wolters CV & Nene AV (2005) reported a reduction in the average amplitude of the activity of gluteus maximus and medius after walking with a cane compared to walking without cane as less muscle force is needed because weight is taken on the cane. Despite the improvement in some variables, increased lateral sway was reported when using a cane as a compensatory strategy facilitating foot clearance without activating the tibialis anterior muscle (Buurke JH et al 2005).

Kilbreath, Perkins, Crosbie, & McConnel (2006) introduced gluteal taping in a study of 15 subjects to enhance hip extension during stance phase in people with chronic stroke with the aim of improving their quality of walking. Gluteal taping was applied and subjects were asked to walk at their self selected and fastest walking speeds. These researchers found that hip

extension of the paretic leg increased significantly for both walking speeds at late stance phase. Step length of the unaffected lower limb also increased significantly at both speeds. The clinical conclusion is thus that these stroke subjects seemed to have a more efficient stance phase on the hemiparetic leg and a better and larger swing phase on the unaffected side following gluteal taping. Interestingly, no significant changes were found in the step length of the paretic limb, nor walking velocity. The study didn't explain the effect of gluteal taping on all the temporal, kinematic and kinetic parameters of the paretic leg, and was limited to hip extension at late stance and step length only using a 2D gait analysis system. The study had some limitations in terms of the sample size (15 subjects) and may have overestimated the effect size.

The effect of taping is not well known, but a few theories have been postulated with regards to motorneuron excitability and timing of muscle activation. Alexander, McMullan & Harrison (2007) studied the effect of taping along and across the muscle on motorneuron excitability of the triceps surae and found that taping across the muscle didn't affect the motorneuron excitability, while taping along the muscle reduced the motorneuron excitability. Cowan, Hodges, & Crossley (2006) found that the application of therapeutic knee taping didn't affect the levels of activation of the vastii (medialis, and lateralis); however, it has been found that the application of patellar taping does affect the timing of the muscle activation in patients with patella-femoral pain. The effect of gluteal taping on gluteal muscle activity and running speed was investigated in a pilot study (Cerdenia JT, Ang A, Asuque JD, Bucasas PA, Datinguino L, De Belen JJ, Eugenio EC & Maralit SM 2006). Thirty university student subjects were asked to run a distance of 100m. The EMG activity of the gluteus maximus was measured at the baseline before taping, and after running with taping. The tape caused a reduction in running time, and a reduction in the EMG activity; however, both reductions were not significant. It was not reported in the study whether the reduction in the EMG activity was due to running or taping.

The mechanism by which gluteal taping improved hip extension in the pilot study conducted by Kilbreath *et al* (2006) is not fully understood. Cowan *et al* (2006) postulated that central nervous system adaptation influenced the timing of vastii activity via the application of therapeutic taping. The central nervous system adaptation to impairments resulting from hemiplegia might also be influenced by the application of therapeutic gluteal taping. The improved hip extension with gluteal taping that was noted in Kilbreath's study may have significant clinical importance on improving gait in stroke survivors. Lack of hip extension, reduced hip flexion moment, and reduced ankle planter flexors strength during walking of people with stroke are documented in the literature as causative factors for the slow walking

speed (Nadeau S *et al* 1999; Olney SJ *et al* 1994). Improving hip extension may increase the hip flexion moment and the plantarflexors activity, contributing to improved walking performance and therefore walking speed.

Thus, the purpose of this study is to further investigate on the effect of gluteal taping on the temporal (step length, cadence, and velocity), and kinematic (joint angles of the hip, knee, and ankle) variables of hemiplegic gait, and the lateral pelvic tilt, at different phases of walking

CHAPTER 2. SYSTEMATIC REVIEW

2.1 INTRODUCTION

Taping/strapping is the application of adhesive tape (elastic or rigid) on the skin, to physically align muscles or bones in a certain position. Taping or strapping has been widely used by physiotherapists as an adjunct to treatment or rehabilitation programs in the management of several neuromusculoskeletal problems. It is also used as a preventive measure in subjects with sports injuries by providing joint support and maintaining proper joint's alignment. Despite the controversy regarding the efficacy of taping, many taping techniques have been developed to decrease pain (Aminaka & Gribble, 2005; Jaraczewska & Long, 2006), alter muscle activity (Cools, Witvrouw, Danneels, & Cambier, 2002; Cowan, 2002) and to maintain proper joint alignment (Aminaka & Gribble, 2005). The effects of taping mostly described in the literature include: facilitation and stimulation of under-active muscle fibres, inhibition of overactive muscle fibres (Alexander, McMullan, & Harrison, 2008; Alexander, Stynes, Thomas, Lewis, & Harrison, 2003; Janwantanakul & Gaogasigam, 2005), maintaining proper joint alignment (Host, 1995), activation of proprioception (MacGregor, Gerlach, Mellor, & Hodges, 2005), modulation of pain (Aminaka & Gribble, 2005; Cools, Witvrouw, Danneels, & Cambier, 2002), and unloading irritable neural tissues (O'Leary, Carroll, Mellor, Scoot, & Vicenzino, 2002)

There are various taping techniques that are usually selected and applied in accordance with the desired effect (Alexander, McMullan, & Harrison, 2008; McCarthy Persson JU, Hooper, & Fleming, 2007). Some clinical uses of taping include patellar taping, gluteal taping, scapular taping, shoulder taping, postural taping, and ankle taping. Therapists tend to differ in their approach to technique selection as well as the method of application. Decision making regarding the type of technique remains subjective.

How taping affects muscle activity is not fully understood. Morrissey (2000) hypothesized that taping might facilitate or inhibit the muscle based upon the way it is applied. He postulated that in order to facilitate a muscle, tape should be applied along the direction of the muscle fibres, but across the fibres to inhibit it. Another assumption is based on the proprioceptive stimulation that is caused by taping (MacGregor, Gerlach, Mellor, & Hodges, 2005). McNutly, (1999) demonstrated that firing of cutaneous afferents through tactile stimulation influences muscle activity, however it has not been directly shown that taping provides this stimulation and therefore this influence.

The mechanism by which taping alters the activity of muscles is not well described. The aim of this review is therefore to better understand the physiologic effect of taping on muscle activity, based on the EMG findings.

2.2 SPECIFIC OBJECTIVES

The primary aim of this systematic review is to better understand the physiologic effect of taping as recorded by electromyography (EMG) on muscle activation.

The following questions will thus be explored:

- What is the effect of different taping maneuvers on muscle activity as measured by EMG readings?
- Is there any difference in the EMG readings between subjects with musculoskeletal problems and subjects without musculoskeletal problems after the application of taping?

2.3 DEFINITIONS

Electromyography EMG:	The recording and the study of the electrical activity of muscle. It is commonly used to refer to nerve conduction studies as well. (O'Sullivan & Schmitz, 2001)
Latency/Electromechanical delay (EMD):	The time that it takes from the stimulus to the response over a predetermined distance, measured in milliseconds.
Vastus medialis obliquus: vastus lateralis (VMO:VL) ratio	It is the ratio of the activity of the VMO to the activity of the VL.
Amplitude:	The size of the potential. In a motor nerve assessment, this represents the summed action potential traveling across one point of that nerve.
H-reflex:	An electrically stimulated reflex that is a physiologic example of the normal reflex arc (entering the spinal cord by way of afferent neurons and exiting via efferent motor neuron).
Root Mean Square:	A method for quantifying EMG in which each EMG value is first squared, then summed and averaged, and finally the root of the products is derived. (Cram, Kasman, & Holtz, 1998)

Concentric Contraction:	The activation of a muscle that is associated with the shortening of its length. (Cram, Kasman, & Holtz, 1998)
Eccentric Contraction:	Muscle contraction generated as a muscle increase in length. (Cram, Kasman, & Holtz, 1998)
Isometric Contraction:	A muscle contraction in which the muscle length, and thus the joint position is kept constant. (Cram, Kasman, & Holtz, 1998)

2.4 REVIEW METHODS

This section describes the systematic process in which articles were retrieved, and assessed. The inclusion and exclusion criteria were set, and partially used as limits in the search strategy. The search strategy used in this review is then thoroughly described, and data extraction and review process are explained. Lastly, the process of evaluation of the included studies in terms of methodological appraisal, and level of evidence is defined.

2.4.1 Inclusion Criteria

2.4.1.1 Types of studies

All randomised controlled trials (RCTs), controlled trials, descriptive, and case studies concerned with studying the physiological effect of taping on muscle activities were eligible to be included in this review. Only studies published in English language were included in this study.

2.4.1.2 Types of participants

Participants were limited to adults over eighteen years of age with and without musculoskeletal problems. Both genders were considered.

2.4.1.3 Types of interventions

Interventions included any technique of taping, whether it is applied directly on the muscle or indirectly through its application on joints that are supported by the muscle being tested.

2.4.1.4 Types of outcome measures

To be included in this review studies must have used EMG to record muscle activity including one or more of the following:

- The EMG amplitude
- The muscles activities ratio
- The timing of the muscle activity
- The latency/electromechanical delay
- The H reflex

2.4.2 Exclusion criteria

Studies were excluded:

- if the EMG sampling rate was less than 700 Hz to minimize the inaccuracy and poor resolution of the EMG signals (International Society of Electrophysiology and Kinesiology, 1997).
- if the intervention included additional courses of exercises besides taping where the changes in the muscle activity could be due to the exercise program and not taping.

2.4.3 Search Strategy

An extensive search was conducted in November and December 2007 in all accessible library databases available at the Medical Library, Stellenbosch University, South Africa. Only studies published in English. The electronic databases included PubMed Central, CINAHL, Cochrane Library, BIOMED Central, SportsDiscus, ScienceDirect, PsychInfo, Web of Science, Proquest, and Pedro. Searching was not limited to specific dates, thus all of the databases were searched since their inception. Different search strategies were developed according to the indexing and searching methods of each database. The main search terms were taping, strapping, EMG, muscle activit*, physiologic* effect. MeSH terms were used where possible. Search strategies are illustrated in Table 2.2. The studies that appeared under related studies in PubMed were also searched for relevant articles. Pearling, where the reference lists of the selected studies are also reviewed for references that were not identified in the primary search, was done. To minimize publication bias, unpublished studies were also identified by looking at Dissertations Abstracts and International Conferences Proceedings, however, we were not able to get the full data for any of the identified unpublished studies. Titles and abstracts were initially screened by the primary reviewer. Full texts of the potentially relevant studies were then retrieved and further screened in accordance with the inclusion and exclusion criteria, to determine their eligibility for this review.

2.4.4 Data extraction

Data were extracted from each relevant included study which included title, author, year of publication, study design, population, intervention, taping method, EMG outcomes, statistical tests results and the quality score. The primary reviewer extracted the data. Studies were further grouped according to the type of tape application. Studies where taping was done on the muscle while not directly affecting any joint ROM or alignment were grouped together. Studies where taping was done directly on the joint were grouped together. The latter was further divided into three sub-categories according to the site of taping application. Those sites included the knee, the ankle, and the scapula (Figure 2.1).

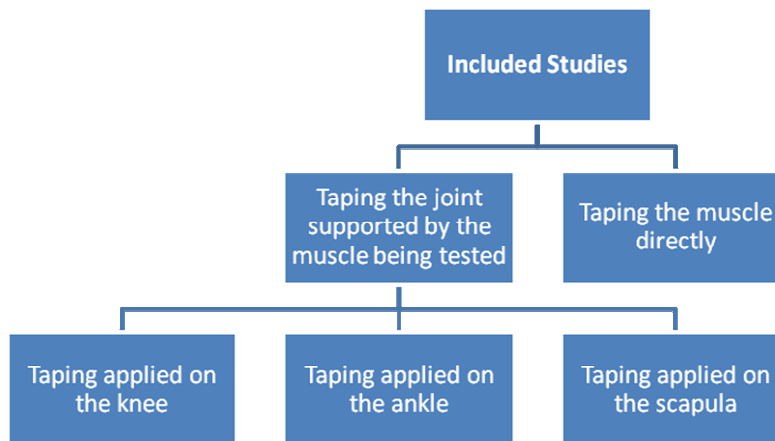


Figure 2.1: Grouping of taping techniques

2.4.5 Level of Evidence appraisal

The evidence of the retrieved studies was assessed using the Joanna Briggs Institute (JBI) levels of evidence (Table 2.1). It determines the possible bias within different study designs, errors within the measurement procedures, and errors interpreting the results.

Table 2.1: JBI level of evidence. (The Joanna Briggs Institute and its collaborating centres and Evidence Translation Groups)

Levels of evidence	Effectiveness
I	Systematic review (with homogeneity) of experimental studies (eg RCT with concealed allocation)
II	Quasi experimental studies (eg without randomisation)
III	3a Cohort studies (with control group) 3b Case controlled 3c Observational studies without control groups
IV	Expert opinion without explicit critical appraisal, or based on physiology, bench research or consensus

2.4.6 Methodological appraisal

The methodological quality of each study was assessed using a generic critical appraisal tool. The tool developed by Downs and Black (1998) was selected for its reported intra-rater and inter-rater reliability (Appendix 6). The tool is divided into five sections looking at reporting, external validity, internal validity-bias, internal validity confounding, and power. Each of those categories contained a number of items. Reporting contained ten items that assessed whether the information in the paper was sufficient to allow the reader to make an unbiased assessment of the findings. External validity contained three items that addressed the extent to which the findings can be generalized. Bias contained seven items that addressed the assessed bias in the measurement of the interventions and the outcomes. Confounding contained six items, which addressed the bias in the selection of study subjects. Power contained one item that assessed whether the negative findings from a study could be due to chance,

Only the criteria relevant to the assessment of potential sources of bias in non randomized control studies were applied for the methodological assessment in this review. Items, for example, assessing the random allocation were not relevant to non randomized trials and were not applied in the checklist used in this review. The primary reviewer appraised all the studies and a randomly selected sample of the studies was appraised by the second reviewer. Differences in opinion were discussed until consensus was reached.

2.5 RESULTS

2.5.1 Description of studies

The results of the search strategy that was used for each database are presented in Table 2.2. From the initial 3531 hits, 50 abstracts were accepted. They included conference proceedings, dissertations, and published articles. Authors of unpublished studies were contacted for full text or study details when possible. None of the unpublished studies were included as nil authors responded. Out of 32 published full text articles, 25 met the inclusion and exclusion criteria and were accepted for the review (Table 2.3). Pearling revealed no additional articles.

Table 2.2: Search strategy

Databases		Keywords / MESH / Major topics	Hits
Pubmed Central	1	Taping	527
	2	Strapping	179
	3	taping AND EMG (MESH)	3
	4	Taping AND EMG	35
	5	taping AND muscle activities	8
	6	taping AND muscle activity	33
	7	Taping and Physiologic effect	0
	8	Taping and Physiological effect	5
	9	Strapping and Physiologic effect	0
	10	strapping and physiological effect	1
	11	strapping AND EMG	5
	12	strapping AND EMG (MESH)	1
	13	Strapping AND muscle activity	3
	14	strapping AND muscle activities	1
CINAHL	1	(DE "Taping and Strapping"	251
	2	(DE "Taping and Strapping") AND EMG	11
	3	(DE "Taping and Strapping") AND physiologic effect	0
	4	(DE "Taping and Strapping") AND physiological effect	0
	5	(DE "Taping and Strapping") AND muscle activity	7
Cochrane Library	1	Taping	22
	2	Strapping	6
	3	EMG	2
	4	1 AND 3	0
	5	2 AND 3	2
BIOMED Central	1	Taping	30
	2	strapping	15
	3	EMG	231
	4	EMG AND taping	1
	5	EMG AND strapping	1
Proquest	1	Taping	63
	2	Taping AND EMG	4
	3	Strapping	16
Total Number of Hits			3531

Databases		Keywords / MESH / Major Topics	Hits
Pedro	1	Taping	62
	2	1 AND EMG	4
	3	1 AND muscle activity	7
	4	Strapping	18
Sports-Discuss	1	Taping	581
	2	Strapping	111
	3	1 AND EMG	15
	4	2 AND EMG	3
	5	1 AND physiologic effect	0
	6	1 AND physiological effect	0
	7	1 AND muscle activity	16
	8	2 AND Physiological effect	0
	9	2 AND physiologic effect	0
	10	2 AND muscle activity	0
Science-Direct	1	Taping	295
	2	Strapping	83
	3	Strapping AND EMG	2
	4	strapping AND muscle activity	2
	5	1 AND EMG	10
	6	1 AND muscle activity	12
	7	1 AND Physiologic effect	0
	8	1 AND Physiological effect	2
PsychInfo	1	Taping	150
	2	Strapping	9
WEB of SCIENCE	1	Taping	433
	2	Strapping	185
	3	1 AND EMG	25
	4	1 AND muscle activity	37
	5	1 AND physiological effect	3

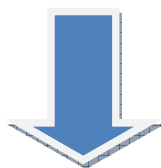


Table 2.3: Search results

Databases	Accepted titles	Accepted abstracts	Accepted Articles	Duplicates with other databases
Pubmed Central	34	22	18	50
CINAHL	17	13	7	
Cochrane Library	0	0	0	
BIOMED Central	1	0	0	
Pedro	11	7	6	
SportsDiscus	24	18	11	
ScienceDirect	12	12	8	
PsychInfo	1	1	1	
WEB of SCIENCE	32	22	19	
Proquest	5	5	5	
Total	137	100	75	

Out of the 25 studies retrieved, 3 studies examined the effect of taping the muscle directly on the muscle electromyography, while 22 studies looked at the indirect effect of taping on muscle electromyography while taping the joint supported by that muscle. Thirteen articles were found on the effect of patellar taping on the Vastus Medialis and/or Vastus Lateralis electromyography. Four studies examined the effect of ankle taping on the peroneal latency and/or activity. Five studies reported on the effect of scapular taping on the electromyographic activity of the para-scapular muscles. (Table 2.4)

Table 2.4: Studies description

Studies		Author and year	Design
Taping a joint supported by group of muscles	Patellar Taping	Cowan <i>et al.</i> 2006	Randomized crossover trial
		Ryan <i>et al.</i> 2006	Randomized crossover trial
		Herrington <i>et al.</i> 1997	Repeated measure design
		Bennel <i>et al.</i> 2006	Randomized crossover within subject trial
		Evangelos A Christou. 2004	Crossover within subject trial
		Herrington <i>et al.</i> 2005	Crossover within subject trial
		Cowan <i>et al.</i> 2002	Randomized within subject repeated measure design
		Gabriel <i>et al.</i> 2002	Randomized within subject repeated measure design
		Salisch <i>et al.</i> 2002	Within subject repeated measure design
		Gilleard <i>et al.</i> 1999	Randomized crossover within subject trial
		Keet <i>et al.</i> 2007	Placebo controlled trial with randomized interventions
		MacGregor <i>et al.</i> 2005	Crossover within subject design
		Parsons <i>et al.</i> 1999	Crossover within subject design
	Scapular Taping	Greig <i>et al.</i> 2007	Within subject repeated measure design
		Cools <i>et al.</i> 2002	Repeated measure design
		Ackermann <i>et al.</i> 2002	3X2X5 Multi factorial design
		Morin <i>et al.</i> 1997	Within subject repeated measure design
		Selkowitz <i>et al.</i> 2007	Multi factorial repeated measure within subject design
Ankle Taping	Stanek <i>et al.</i> 2006	Crossover within subject design	
	Shima <i>et al.</i> 2005	Crossover within subject design	
	Lohrer <i>et al.</i> 1999	Repeated measure design	
	Alt <i>et al.</i> 1999	Repeated measure design	
Taping over the muscle directly	Janwantanakul <i>et al.</i> 2005	Repeated measure design	
	Alexander <i>et al.</i> 2003	Repeated measure design	
	Alexander <i>et al.</i> 2006	Repeated measure design	

2.5.2 Methodological Quality

Table 2.5 summarizes the results of the methodological assessment of the studies using the critical appraisal tool. All of the studies stated the main aims and objects, the outcomes to be measured, and the characteristics of subjects included in the studies. All of the studies described the interventions and the main findings clearly. Only two of the studies did not report on some of the confounding variables. Morin (1997) did not report the age of the participants, and Lohrer (1999) didn't state the age of the participants and their previous history with ankle injuries, or current history of ankle hyper mobility. Findings related to this review were clearly described in all of the studies. Only one study did not report on the random variability of the data (Herrington, 1997). All of the studies reported the actual probability values, and used appropriate statistical tests. Subjects were not blinded to the type of intervention that was given in all of the studies. Only in one study (Cowan, 2006), the assessor was blinded to the intervention groups. Only six studies, (Cowan, 2002; Gabriel, 2002; Salsich, 2002; Alt, 1999; Gilleard, 1999; & Parsons, 1999) reported different measures

to insure better reliability. None of the studies made adjustments for confounding variables while deriving the main conclusions.

Table 2.5: Results of Critical Appraisal tool for each included study

Studies	Reporting								External Validity	Internal Validity – Bias						Confo- under
	Clear aim	Outcomes Described	Patients described	intervention described	Confounders described	Main findings described	Measures of random variability	P-value reported	Subjects represent population	subjects blinded	Assessors blinded	Planned analysis	Appropriate statistics	compliance reliable	Outcome measures reliable	Adjustment for confounders
Item no.	1	2	3	4	5	6	7	10	12	14	15	16	18	19	20	25
Greig et al.	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0
Cowan SM et al.	1	1	1	1	2	1	1	1	0	0	1	1	1	1	0	0
Ryan CG	1	1	1	1	2	1	1	1	0	0	0	1	1	1	0	0
Herrington L, Payton C J	1	1	1	1	1	1	0	1	0	0	0	1	1	1	0	0
Bennel K et al.	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0
Evangelos A Christou	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0
Herrington L et al.	1	1	1	1	2	1	1	1	0	0	0	1	1	1	0	0
Janwantanakul P	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0
Cowan SM et al.	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0
Gabriel YF Ng	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	0
Salisch G B et al.	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	0
Alexander CM et al	1	1	1	1	2	1	0	1	0	0	0	1	1	1	0	0
Alexander C M et al.	1	1	1	1	2	1	0	1	0	0	0	1	1	1	0	0
Cools A M et al.	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0
Ackermann B	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0
Lohrer et al.	1	1	1	1	0	1	1	1	0	0	0	1	1	1	0	0
Alt W et al	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	0
Shima N et al	1	1	1	1	2	1	1	1	1	0	0	1	1	1	0	0
Stanek JM	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0
Morin GE et al	1	1	1	1	0	1	1	1	1	0	0	1	1	1	0	0
Gilleard W et al	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0
Keet JHL et al	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0
MacGregor K	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0
Parsons D, Gilleard W	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0
Selkowitz et al.	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0

2.5.3 Taping over a joint

The majority of the studies identified in this review examined the effect of taping on electromyographic muscle activity when applied over a joint supported by that muscle. Twenty two studies were retrieved, and categorized according to the area of taping application into three groups; knee taping, ankle taping, and scapular taping.

2.5.3.1 Knee Taping

The application of patellar taping was originally developed by McConnell (1986) as a novel approach in the treatment of patella-femoral pain syndrome (PFPS). The original hypothesis was that medial patellar taping causes medial patellar shift, aligning the patella in its track. Although there is no conclusive evidence that patellar taping alter the patellar position, the immediate pain relief after its application is well documented in literature. McConnell (1986) reported an increased activity in the VMO with a manual medial glide of the patella in two subjects. However the findings were inconsistent in the subsequent literature. Recent evidence showed an alteration in the relative timings in the vasti in people with PFPS compared to asymptomatic individuals (Cowan *et al* 2002 & Gilleard *et al* 1998). Medial patellar taping altered the relative timing in the vasti in people with PFPS (Bennel *et al* 2006, Parsons *et al* 1999, Cowan *et al* 2002 & Gilleard *et al* 1998).

The following section describes the effect of patellar taping EMG readings of vasti muscles, including the muscle activity ratio (VMO:VL), muscle activity amplitude, and muscle activity onset, in subjects with and without (PFPS).

a. Effect of taping on VMO:VL ratio in subjects without PFPS

Table 2.6 summarizes all studies in which the effect of taping on the vasti was reported in terms of the VMO:VL ratio. Cowan *et al* (2006) assessed EMG of the vastus medialis (VMO) and vastus lateralis when no tape was applied, with therapeutic tape, as well as with placebo tape application. They hypothesized that changes in the relative activation of the vasti with therapeutic patellar tape may be responsible for the well documented pain relief associated with patellar taping. Although an increase in the VMO:VL ratio with therapeutic taping was noted, the change was insignificant ($p=0.17$). Ryan *et al* (2006) studied the effect of medial glide, lateral glide, neutral glide (tape was pulled equally from medial and lateral sides) techniques, to no taping. Lateral glide taping produced a significant increase in the VMO:VL ratio, compared to the medial ($p=0.007$) and the neutral glide ($p=0.007$), but not to the no tape condition ($p=0.123$). Harrington *et al* (2005) investigated the effect of medial patellar taping and no increase in the VMO:VL ratio was reported ($p>0.05$). Negative findings

were reported by Keet *et al* 2007 as a significant reduction ($p<0.05$) in the VMO:VL ratio was evident with medial patellar taping compared to placebo and no taping. Overall the findings illustrate that there appears to be no significant effect of taping on the VMO ratio due to taping in individuals without patellofemoral pain. The effect size was not calculated for the VMO:VL activity ratio as it doesn't indicate a true increase or decrease in the activity of each muscle

Table 2.6: Ratio of VMO:VL (VMO divided by VL) ratio results in subjects without PFPS

	Activity	N	Medial glide		Lateral glide		Neutral /placebo		No tape	
			Mean ratios of all subjects VMO:VL	SD	Mean	SD	Mean ratio of all subjects VMO:VL	SD	Mean ratio of all subjects VMO:VL	SD
Cowan SM 2006	Step-up	12	1.37	0.34			1.16	0.28	1.21	0.29
Ryan CG 2006	Single-leg squat	25	1.31	0.54	1.38	0.51	1.32	0.53	1.38	0.44
Herrington L 2005	Step-down	10	1.31	Not reported					1.27	Not reported
Gabriel YF NG 2002	Semi- squat	15	1.6 (SD:0.82)-taping according to malalignment						1.8	0.93
Keet 2007	MVIC	20	1	0.3			1	0.2	1	0
	Open chain concentric		1	0.3			1.1	0.2	1	0.2
	Open chain eccentric		0.9	0.4			1	0.2	0.9	0.2
	Step -up		1.1	0.4			1.5	0.6	1.4	0.5
	Step-down		1.1	0.3			1.2	0.4	1.3	0.4

b. Effect of taping on VMO: VL ratio in subjects with PFPS

A total of 4 studies reported on the effects of taping on the VMO:VL ratio in a symptomatic population. Cowan *et al* (2006), reported an increase in the VMO:VL ratio, but it was not statistically significant ($p=0.25$). Similar findings were reported by Herrington *et al* (1997) as an increase in VMO:VL ratio during maximum isometric contraction of the quadriceps at different angles ($p>0.05$).

Gabriel *et al* (2002) studied the effect of patellar taping on VMO:VL ratio on subjects with PFPS and patellar malalignment. Subjects were asked to stand on one leg with a belt on their waist that weighs 20% of their body weight to simulate the acceleration in ascending stairs. Patellar taping was done according to the direction of mal-alignment, and it wasn't standardized for every subject. Contrary to the previous two studies, there was a significant reduction in VMO:VL ratio with taping ($p=0.05$) compared to no taping (see Table 2.7). Similar findings were reported by Keet *et al* (2007) who reported a significant reduction in the VMO:VL ratio after medial patellar taping ($p<0.05$).

Table 2.7 illustrates that there is conflicting evidence that taping increases the VMO:VL ratio in patients with PFP.

Table 2.7: Ratio of VMO:VL (dividing VMO by VL) ratio results for knee taping studies in PFP subjects

	Activity	N	medial glide		Neutral /placebo		No tape	
			Mean ratio of all subjects VMO:VL	SD	Mean ratio of all subjects VMO:VL	SD	Mean ratio of all subjects VMO:VL	SD
Cowan SM 2006	Up	12	1.56	0.33	1.52	0.32	1.40	0.3
Herrington L 1997	MIC (5sec)	20	1.5 at 0 degrees 1.3 at 30 1.6 at 60 1.6 at 90 1.5 at 120				1.2 at 0 1.3 at 30 1.5 at 60 1.5 at 90 1.3 at 120	
Gabriel YF NG 2002	Semi-squat	15	1.6 (SD:0.82)-taping according to malalignment				1.8	0.93
Keet 2007	MVIC	15	0.9	0.3	1.1	0.2	1	0
	Open chain Con		1.1	0.5	1.1	0.2	1	0.2
	Open Chain Ecc		1	0.6	1	0.3	0.9	0.3
	Step-up		1.3	0.6	1.5	0.7	1.5	0.8
	Step-down		1.2	0.5	1.4	0.5	1.4	0.5

c. Effect of taping on EMG activity in subjects without PFPs

A total of 4 studies reported on the effect of patellar taping on the activity of VMO and VL in asymptomatic subjects, and their findings are summarized in Table 2.8. Cowan *et al* (2006) and Ryan *et al* (2006) reported in their previously mentioned studies no significant differences in the activity of the VMO or VL after the application of patellar taping ($p>0.05$).

Harrington *et al* (2005) found a reduction in the activity of the VMO ($p=0.02$) and the VL ($p=0.015$) of the stance leg during stair ascending and descending after the application of medial patellar taping. Keet *et al* (2007) reported a significant reduction in the VMO activity after the application of medial patellar taping ($P<0.05$).

We used the data from the above 3 studies to calculate the effect sizes for medial glide taping compared to no taping and the findings are summarized in Table 2.8. The effect sizes varied from small positive to large negative effects (in favour of taping reducing VMO activity). There was no evidence of a large positive effect in muscle action due to taping.

Table 2.8: Muscle activity findings for knee taping in subjects without PFP.

Author & year	Unit	Activity	N	Medial glide		Lateral glide		Neutral /placebo		No tape	
				Mean Diff [M(tape)-M(no tape)]	SD	Mean Diff [M(tape)-M(no tape)]	SD	Mean Diff [M(tape)-M(no tape)]	SD	Mean	SD
Cowan SM 2006 -Values from graph		VMO step-up	12	0.65	1.58			-0.07	-2.26		
		VL step-up		-0.11	-0.93			-0.75	-0.91		
Author & year	Unit	Activity	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ryan <i>et al</i> /2006	Not given	VMO	25	0.58	0.18	0.60	0.19	0.60	0.18	0.59	0.17
		VL		0.47	0.14	0.46	0.14	0.48	0.14	0.48	0.14
Herrington <i>et al</i> 2005	mV	VMO, step-down	10	61.3	21.8					84.9	33
		VL, step-down		46.6	18.3					67	25.8
Keet <i>et al</i> 2007	% of MVIC	MVIC VMO		105	48			103	21		0
		Con VMO		135	51			134	43		33
		Ecc VMO		111	62			114	40		26
		Step-up VMO		47	15			62	21		23
		Step-up VMO		55	21			65	20		23
		MVIC VL		106	27			110	24		0
		Con VL		136	36			131	41		34
		Ecc VL		118	34			122	42		37
		Up VL		45	16			46	19		17
		Step-down VL		54	19			56	20		25

Note: mV: Millivolt, MVIC: Maximum Voluntary Isometric Contraction, Con: Concentric, Ecc: Eccentric

d. Effect of taping on EMG activity in subjects with PFPS

A total of 5 studies reported on the effect of patellar taping on the activity of VMO and VL in subjects with PFPS, and their findings are summarized in Table 2.9.

Harrington *et al* (1997) reported a reduction in the VMO activity after taping at 0, 30, 90, and 120 degrees of knee flexion. There was an increase at 60. Contrary to the previous study, Christou (2004) reported that patellar taping reduced the activity of VMO through the full range.

Keet *et al* (2007) showed a significant reduction in the activity of VMO by 17% while stepping up, and by 15% while stepping down ($P < 0.05$), with medical taping. No significant difference was found regarding the activity of VL.

Salsich *et al* (2002) showed an insignificant reduction in the activity of the VL after the application of medial patellar taping, while ascending, and descending the stairs.

Cowan *et al* (2006) showed a non-significant increase in the activity of VMO and VL after the application of therapeutic and placebo tapes ($P > 0.05$). Placebo taping produced a slightly higher activity in the VL than that produced by the therapeutic tape.

To examine the proprioceptive effect of taping on muscle activity MacGregor *et al* (2005) studied the effect of stretching the skin over the patella on the activity of the VMO, and the VL. A tape was applied directly over the patella and pulled in three different directions; medial, lateral and upward. EMG was recorded while subjects were maintaining gentle isometric knee contraction at a constant force. The skin stretch was done on the following sequence; ramping up for 3 seconds, hold for 3 seconds, releasing for 3 seconds, and relaxing for 3 seconds. Lateral stretch produced a significant increase in the VMO activity ($P < 0.001$). There was no significant difference with the medial or superior stretch. There were no significant changes in the VL activity between the direction of pull ($P = 0.2$) and the phase of tension ($P = 0.3$). See Table 2.9.

We used the data from Salsich *et al* (2002) and Keet *et al* (2007) to calculate the effect size of medial patellar taping compared to no taping conditions on muscle activity. The findings are summarized in table 2.9. The effect size ranged from negligible positive effect, to medium negative effect in favor of taping reducing the level of activity in VMO and VL.

Table 2.9: VMO & VL activity results for knee taping on subjects with PFPS

Author & year	Unit	Activity	N	medial glide		Lateral glide		Neutral /placebo		No tape		Comments	Effect size
				Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Herrington et al 1997		MIC(5sec)	20	2.4 at 0						2.8 at 0		Values were taken from graph	The effect size was not calculated since SD was not given
				1.95 at 30						2.0 at 30			
				2.5 at 60						1.9 at 60			
				3.05 at 90						3.1 at 90			
				3.15 at 120					3.2 at 120				
Salsich et al 2002	mV	VL Up	10	1.16	0.46					1.26	0.56	Values were taken from graph	-0.20 (small – effect)
		VL Down		1.24	0.64			1.32	0.46				
Keet et al 2007	% of MVIC	MVIC VMO	15	93	27					107	36	Values were taken from graph	-0.37 (small – effect)
		Con VMO		141	71			129	31				
		Ecc VMO		136	87			118	40				
		Up VMO		64	20			77	28				
		Down VMO		72	23			81	22				
		MVIC VL		110	94			97	27				
		Con VL		147	94			127	52				
		Ecc VL		143	58			127	41				
		Up VL		60	36			62	37				
		Down VL		66	34			69	39				
Author & year		Activity	N	Mean Diff [M(tape)-M(no tape)]	SD	Mean Diff [M(tape)-M(no tape)]	SD	Mean Diff [M(tape)-M(no tape)]	SD	Mean Diff [M(tape)-M(no tape)]	SD		Effect size
Cowan SM 2006		VMO Up	10	0.21	1.02			1.297	2.51			Values were taken from graph	Effect size
		VL Up		0.59	1.95			0.43	1.74				
MacGregor et al 2005		Rise	8	-0.08	0.47	0.62	0.3	-0.07	-0.31			Mean diff prop to baseline from graph	The effect size was not calculated since only Mean Difference was given
		Stretch		0	0.47	0.92	0.3	-0.09	-0.31				
		release		0.14	0.49	0.79	0.3	0.09	0.31				

Note: MIC: Maximum Isometric Contraction, Iso Cont: Isometric Contraction.

e. Effect of taping on the onset of activity in VMO and VL in healthy subjects

A total of 3 studies reported on the effect of patellar taping on the activity onset of VMO and VL in asymptomatic subjects, and their findings are summarized in Table 2.10.

Bennel *et al* (2006) investigated the effect of medial patellar taping on the onset of activation of the VMO and the VL during stepping tasks. Twelve asymptomatic subjects with a history of PFP were recruited for the study. The trend of timing deficit was shown in all testing conditions, except with the stair ascent where the VMO was activated before the VL in both the control and therapeutic tape. However, there was no significant change in VMO-VL onset timing between taping conditions ($P>0.05$).

Parsons *et al* (1999) examined the effect of medial patellar glide on the onset of VMO and VL. The VMO and the VL activation onsets occurred later in the movement when the knee was taped compared to the untaped condition while stepping up ($P=0.04$). There was no significant difference between the taped and untaped conditions while stepping down ($P=0.056$). Cowan *et al* (2002) studied the effect of medial patellar taping during three different taping conditions; therapeutic tape, placebo tape, and no tape while performing stepping tasks. There were no significant differences between onsets in different taping or testing conditions ($P>0.05$).

Table 2.10: VMO & VL onset results for knee taping studies of healthy subjects

Author & year	Unit	Activity	N	Medial glide		Neutral /placebo		No tape	
				Mean	SD	Mean	SD	Mean	SD
Bennel <i>et al</i> 2006	knee flexion degrees VMO-VL	step-up	12	0.82	14.12	1.98	12.9	-2.48	13.72
		Step-down		-8.45	21.09	-2.52	13.47	-6.47	17.58
		Wlk Norm		-15.03	21.87	-10.32	20.71	-11.03	23.61
		Wlk Fast		-13.1	22.86	-10.02	20	-10.69	17.72
Cowan <i>et al</i> 2002	ms VMO-VL	Con	12	14	34.64	4.6	34.64	16	31.18
		Ecc		-1.2	51.96	2.4	44.34	13	51.96
Parsons <i>et al</i> 1999	degrees	VMO, step-up	13	80	7.1			84.3	6.4
		VMO, step-down		35	8.6			39.5	7.7
		VL, step-up		79.4	9			84.3	6.4
		VL, step-down		38	11.3			37.2	9.3

f. Effect of taping on EMG activity onset of VMO and VL in subjects with PFPS.

Two studies reported on the effect of patellar taping on the activity onset of VMO and VL in asymptomatic subjects, and their findings are summarized in Table 2.11.

Cowan *et al* (2002) reported no difference between placebo tape and no tape ($P=0.124$ concentric, $P=0.187$ eccentric). However, there was a significant difference between

therapeutic tape and no-tape conditions while going up and down the stairs ($P < 0.003$ concentric, $P < 0.005$ eccentric), and there was a significant difference between therapeutic and placebo tape while going up ($P < 0.002$), but not while going down ($P = 0.025$). VMO was activated before VL after the application of the therapeutic medial patellar tape during the eccentric and concentric conditions.

Gilleard *et al* (1999) examined the effect of medial patellar taping on 14 subjects with PFP while going up and down stairs. Each subject was tested in two conditions; with therapeutic tape, and with no tape. While going up, the VMO was activated significantly before the VL with the therapeutic tape ($P = 0.0008$), and after the VL with no tape. While going down, the VMO was also activated prior to the VL when taped, and after the VL in the no tape condition. See Table 2.11.

Table 2.11: VMO & VL onset results for knee taping studies of PFP subjects

Author & year	Unit	Activity	N	medial glide		Neutral /placebo		No tape	
				Mean	SD	Mean	SD	Mean	SD
Cowan <i>et al</i> 2002	ms VMO-VL	Con	10	20	37.95	-10.5	34.78	16.5	41.11
		Ecc		21.5	71.47	-11	25.93	-20	35.73
Gilleard <i>et al</i> 1998	degrees	VMO, UP	14	75.71	0.89			71.43	0.19
		VMO, Down		29.64	1.28			31.9	1.3
		VL, UP		72.54	0.89			72.71	0.19
		VL, Down		36.77	1.65			30.93	1.98

2.5.3.2 Ankle Taping

A total of 4 studies reported on the physiologic effect of ankle taping as measured by EMG. Table 2.12 summarizes the finding. Lohrer *et al* 1999 studied the neuromuscular response to inversion simulated injury and exercise with and without taping. Forty subjects were assigned randomly into two groups. Each group received a different method of therapeutic ankle taping (Table 2.12). Peroneal activity and proprioceptive amplification ratio were calculated after five simulated ankle inversion injuries and 20 minutes of standardized exercise. The measurements were taken before taping, after the application of two types of taping, after 24 hours of application, and after removal. Compared with the unprotected conditions, there was an increase in the peroneal integrated EMG activity for both groups. After twenty minutes of exercise, there was a reduction in the activity. After 24 hours, the peroneal activity increased again, however, none of those changes were significant between the two groups. Interestingly, after tape application, the proprioceptive amplification ratio increased significantly, and after 20 minutes of exercise, the ratio was reduced significantly, and after 24 hours the ratio significantly increased, and went back to normal after the

removal of the tape. Alt *et al* 1999 investigated the effect of ankle taping on the electromyographic activity and latency in 12 healthy subjects. Two methods of ankle taping (long and short) were used using two different taping materials. EMG of the peroneus longus was recorded in five different conditions; with tape 1 and method 1, with tape 1 and method 2, with tape 2 and method 1, with tape 2 and method 2, and with no tape as a control situation. Subjects had 5 simulated ankle sprains, and 5 jumps on a slope, then 10 minutes on a treadmill, then 10 min of jumping on a slope, as described in the previous study by Lohrer *et al* 1999. Peroneus longus activity was reduced by an average of 18% after taping. After exercise, the trend toward EMG activity reduction was continued. There were no changes in the latencies based on the application or the type of the material that was used. In another study by Shina *et al* 2005, the effect of ankle taping on peroneus longus latency was examined. Eighteen football players participated in the study. Sixteen ankles had a history of sprain injuries, and twenty were healthy. The peroneal reflex latency was measured while the subjects were standing on two platforms.

Subjects were asked to have their weight equally distributed. A drop door on the platform was released to simulate inversion injuries. The trials were done with tape, brace, and no tape. There was no significant interaction between the groups of ankle with regards to the history ($P < 0.05$), however, there was a significant increase in the latency with taping and bracing compared to the control conditions ($P < 0.01$, $P < 0.05$) respectively.

Stanek *et al* 2006 measured in a crossover study the electromechanical delay (EMD) of the peroneus longus muscle during active ankle eversion. Thirty one healthy subjects were assigned randomly into three conditions (tape, brace, and no support). They were asked to stand on one leg supported by hands to minimize postural sway. Then, they were asked to actively evert the ankles and hold for 3 seconds. The EMG showed no significant difference in the EMD between the three external support conditions ($P = 0.09$).

Table 2.12: Results for Ankle taping studies

Author and Year	Method of Taping	Activity	N	Latency		Peroneal Activity		Proprioceptive Amplification Ratio		Comments
				Mean	SD	Mean	SD	Mean	SD	
Lohrer et al 1999	1: dorsoventral, and medialateral 2: completed with a figure of 8	Before	40	63.8						Values were taken from graph
		After tape		T1	83.24	23.35	1.64	0.097		
				T2	90.28	19.61				
		After 20 min		T1	76.65	21.39	1.19	0.56		
				T2	86.1	18.81				
		After 24 h		T1	86.81	29.95	1.45	0.61		
				T2	91	21.92				
		After removal		T1	97.86	23.8	1.01	0.05		
				T2	100	22.82				
		Alt W et al 1999		2 tapes, using 2 methods, short and long	Before	12				
Long	85.97		Not Given							
Short	80		Not Given							
Long	74.66		Not Given							
After	Long		85.22		Not Given					
	Short		78.58		Not Given					
	Long		69.60		Not Given					
	Short		68.02		Not Given					
Stanek JM et al 2006	Mueller Tech	While eversion for 3 sec	31	31.1	5.9				Values are given in ms	
				30.6	5.4					
Shima N et al 2005	Closed basketweave with medial and lateral heel locks and figure of 8	Simulated ankle injury	18	83.89	1.07				Values were taken from a bar graph (ms)	
				80.75	1.11					

2.5.3.3 Scapular Taping

Five studies reported on the effect of scapular taping on the EMG readings were found. Table 2.13 summarizes the findings of those studies. Cools *et al* 2002 investigated the effect of scapular taping on muscular activity in scapular muscles. EMG was recorded from upper, middle, lower trapezius, and serratus anterior. According to the study findings, scapular taping had no influence on EMG activity in all conditions ($P=0.578$). Ackerman *et al* 2002 examined the effect of scapular taping on electromyographic activity and musical performance in professional violinists while playing 3 different music excerpts. One excerpt had to be played fast and loud. The other one was slower, and the third one had some technically difficult sessions. Eight professional violinists participated in the study. Four of them reported experiencing pain. Two of them had lower back pain, and the other two had cervical and upper quadrant pain. EMG was recorded from the upper trapezii muscles, scapular rotators at the level of T5, and the right SCM. Electromyographic data showed a significant increase in the activity of the left upper trapezius muscle with the tape during the piece requiring the highest speed and intensity ($P=0.033$). During playing the other two pieces, the increase in the activity of the left upper trapezius was not significant ($P=0.083$, 0.101).

Morin *et al* 1997 studied the effects of upper trapezius taping on the EMG activity of the upper and middle trapezius. Ten subjects were asked to sit upright holding a rope that was attached to the floor, while the shoulders are in 90° of shoulder abduction and 45° of internal rotation. EMG was recorded from three sites; two on the upper trapezius and one on the middle trapezius while maintaining an isometric contraction in that position. The trial was repeated three times in two conditions (with and without taping). There was a significant increase in the activity at the middle trapezius ($P=0.02$), and a significant decrease at both sites on the upper trapezius ($P=0.001$).

In agreement with Morin's study, Selkowitz *et al* 2007 investigated the effect of scapular taping on 21 subjects with shoulder impingement. Subjects were asked to perform two different activities; abduction in the scapular plane activity (scaption), and shelf activities. EMG recorded the activity of the upper trapezius, lower trapezius, supraspinatus, and serratus anterior. Recorded EMG showed a significant reduction in the activity of the upper trapezius during shelf task elevation with the tape on ($P=0.004$). There was a significant increase in the activity of the lower trapezius with the tape versus no tape ($P=0.043$). No significant differences were found in the activities of other muscles among different activities or taping conditions ($P>0.05$).

In contrast with the previous two studies, Greig *et al*/2007 found no significant changes in the upper and lower trapezius after taping. The physiologic effect of taping was examined in 15 women with kyphosis and a history of osteoporotic vertebral fracture. EMG of obliquus externus, externus abdominis, rectus abdominis, erector spinae, and upper and lower trapezius were recorded during quiet standing on a flat surface with eyes open, with eyes closed, and standing on a short base with eyes open. The test was done using therapeutic taping, control taping, and no taping. The EMG recordings showed no changes after the application of the tape in the activities of any of the tested muscles ($P>0.139$).

Table 2.13: Scapular Taping results

	Author and year	Design	Activity	Taping method	N	Muscle Activity
Healthy	Cools AM et al 2002	repeated measure design	Abduction and forward flexion (concentrically, and eccentrically, in four main conditions: resistance with tape/no tape, no resistance with tape/no tape..	from the border of the clavicle anteriorly to the medial edge close to the inferior angle of the scapula posteriorly	20	There was no significant difference between tape factor and any other factor associated with movement or muscle.
	Ackermann B et al 2002	3x2x5 factorial design	EMG was recorded of 5 different muscles, while the violinists were playing 3 different music pieces under 2 conditions, (with scapula tape, and no tape)	One strip of tape was applied from the acromion to the level of T8, and another from the acromion to the level of T4.	8	There was a significant increase in the activity of the trapezius muscle with the difficult music piece, while it there was no significant increase when the violinists played the easy pieces.
	Morin GE et al 1997	within subject repeated measure design	Isometric contraction while shoulder in 90 of abduction and 45 internal rotation	over the muscle belly of the Rt upper trapezius	10	Significant decrease in RMS at both sites on upper trapezius, and significant increase at the middle trapezius.
MSD	Selkowitz DM et al	Multifactorial repeated measure, within subject design	Scaption, and shelf activities. EMG recorded from Upper and lower trapezius, supraspinatus, and serratus anterior	From the clavicle anteriorly, to the paraspinal area close to T5	21	Significant increase in Upper trapezius activity and significant decrease in lower during shelf task elevation. During shoulder abduction, there was significant decrease in upper trapezius activity, but no significant changes in the other muscles.
	Greig AM et al 2007	within subject repeated measure design	Standing on a flat surface with eyes open, with eyes closed, and standing on a short base with eyes open. EMG recorded from obliquus internus, externus abdominis, rectus abdominis, erector spinae, and upper and lower trapezius	From the acromion-clavicular joint crossing over the upper trapezius to T6	15	There were no changes in EMG after the application of the tape for any muscle.

2.5.4 Taping over muscles

A total of three studies reported on the physiological effect of taping on the muscle activity when the tape was applied directly over the muscle. Findings are summarized in table 2.14. Janwantankul *et al* 2005 investigated the effect of taping across and along the fibers of VL during stepping tasks. VL muscle activity was recorded during 3 conditions; while taping along the fibers, across the fibers, and without taping. Thirty healthy female subjects participated in the study. No significant difference was found between the three testing conditions while going up and down the steps in VMO ($P=0.984$) and VL ($P=0.684$). In another study, Alexander *et al* 2003 examined the effect of taping along the fibers of the lower trapezius on the muscle activity of the lower trapezius muscle. Eighteen subjects were asked to do 10-20% of their maximum voluntary contraction (MVC) of the lower trapezius by retraction and depression of the shoulders during four conditions; no tape, with undertape, with rigid tape over the undertape, and after removal. The results showed that undertape inhibited the H-reflex in the lower trapezius by 4%, while the rigid tape inhibited the H-reflex by 22%. The H-reflex amplitude returned back to normal after the removal of the tape. Alexander CM *et al* 2007 did another similar study to assess the change in the motor neuron excitability of triceps sura in response to taping along or across the muscle. Fourteen subjects participated in the study. Tibial nerve was electrically stimulated to provoke an H-reflex while the M-wave was maintained constant. H-reflex was measured without taping, with undertape along the muscle, with undertape across the muscle, with rigid tape along the muscle, with rigid tape across the muscle, and after tape removal. With the tape was applied along the muscle, the H-reflex decreased by 7% with undertape, and by 19% with the rigid tape. Taping across the muscle fibers didn't change the H-reflex significantly in all testing conditions.

Table 2.14: Taping over muscles results

Author and year	Design	Intervention	Taping method	N	Outcome	Muscles and conditions	Mean	SD	SEM	
Janwantanakul P et al 2005	repeated measure design	Stair ascend and descent	taping across the fibers of the vastis lateralis (inhibiting), taping along the fibers of vastis lateralis (stimulating)	40	Activity	VL	Inhibition tape	153.1	46.2	
							Facilitation tape	161.2	71.7	
							No tape	148.9	44.7	
						VMO	Inhibition tape	179.1	105.4	
							Facilitation tape	184.1	104.3	
							No tape	182.2	113.1	
Alexander CM et al 2003	repeated measure design	MVC of lower trapezius by retraction and depression of the shoulder, during 4 conditions. No tape, under tape, rigid tape, and after tape removal.	Taping along the fibers of the lower trapezius	18	H reflex		Pre tape	1.46		0.02
							Under tape	1.39		0.02
							Rigid tape	1.14		0.02
							Post tape	1.43		0.02
Alexander CM et al 2006	repeated measure design	Measurement was done while simulating inversions injuries	taping across the fibers of the MG (inhibiting), taping along the fibers of vastis lateralis (stimulating)	14	H-reflex		Pre tape	1.57		0.09
							Under tape	1.45		0.09
							Rigid tape	1.27		0.08
							Post tape	1.54		0.08

2.6 DISCUSSION

The present review shows a lot of speculation about the probably neurophysiologic mechanisms of taping in general. The available evidence indicates that the effect of taping appears to be intricately complex. The results of this review are discussed in details below.

2.6.1 Taping over a joint

2.6.1.1 Knee taping

Although patellar taping is an inexpensive and widely used technique in the treatment of patellofemoral pain syndrome (PFPS), the mechanism of its effect is still unresolved. The present review confirms why there is such a lot of speculation about the probable neurophysiologic mechanisms of taping in general. The available evidence indicates that the effect of taping is intricately complex.

McConnell (1986) described medial patellar taping as a long term treatment for PFPS. She hypothesized that patellar taping can alter the position of the patella, and enhance the activity of the VMO. The technique has been proven to reduce pain immediately by 50% to 80% after the application of the tape. Wilson *et al* (2003) found that patellar taping produced immediate relief of pain and improvement in function in people with patellofemoral pain irrespective of the method of application and the direction of the glide. This suggests that the mechanism of action with patellar taping does not depend on the position of the patella. Gigante *et al* (2001), in a computed tomography study, showed that patellar taping did not significantly affect patellar lateralization and tilt. Proprioceptive stimulation was thought to be one of the mechanisms with which patellar taping might work, however, it was found that taping did not alter the active angle reproduction, and passive angle reproduction in people with PFP (Callaghan *et al* 2007). The neuromuscular response to taping as assessed by the changes in muscle activation was the focus of different studies. According to the findings of this review there is insufficient and contradictory evidence that patellar taping alters the recruitment of the vastii. Medial patellar taping changed the onset of the vastii activity where VMO was activated before VL in subjects with PFP (Cowan *et al* 2002, and Gilleard *et al* 1999). Interestingly, there were no significant changes in the onset of activation between the VMO and the VL in healthy subjects (Bennel *et al* 2006, Cowan *et al* 2002, Parsons *et al* 1999).

The results of this review showed a lot of variation in the behaviour of the EMG amplitude and muscle activity ratio between VMO and VL after taping. This may be due to the lack of standardization in the taping technique that was used. Most of the studies investigated the effect of medial glide, and compared it to other taping conditions. However, the medial glide was also not standardized among the studies. Medial patellar glide was described in some studies as McConnell glide (Herrington *et al* 2005, Parsons *et al* 1999, Keet *et al* 2007, Salsich *et al* 2002) which includes medial glide, tilt, and rotation components (McConnell, 1986). In the study of Herrington *et al* (1997), the taping procedure was not the same for every subject. Taping was applied in the direction where it produced the least pain. In addition to the variation in taping methods, the tasks that the subjects had to do varied between the studies. Salsich *et al* (2002), Keet *et al* (2007), Cowan *et al* (2002), Bennel *et al* (2006), Gilleard *et al* (1999), and Parsons *et al* (1999) used stepping up and down tasks while investigating the effect of taping on the electromyographic activity. Cowan *et al* (2006) chose stair ascending as a task, while Herrington *et al* (2005) selected stair descending. Evangelos *et al* (2004) used the isokinetic press while recording VMO and VL activity, Herrington *et al* (1997) asked the subjects to do maximum isometric contraction, while Ryan

et al (2006) and MacGregor *et al* (2005) recorded EMG while subjects were doing submaximal isometric contractions.

2.6.1.2 *Ankle taping*

Peroneal activity was reduced after taping in response to simulated inversion ankle injuries in both identified studies (Alt W, 1999) (Lohrer H, 1999). This could be due to the fact that control of inversion forces afforded by ankle taping took part of the peroneal role to control the sudden inversion. (Lohrer H, 1999) found that ankle taping produced a significant increase in the proprioceptive amplification ratio which was described as a measure of functional stability just after the application of the ankle taping. Peroneal latency increased significantly in two studies (Lohrer H, 1999) (Shima N, 2005) and remained constant in the other two studies (Alt W, 1999) (Stanek JM, 2006). In the study by (Stanek JM, 2006), the EMG was recorded while subjects were standing on one leg, and actively evertng their ankles. While the other three studies exposed the subjects to simulated inversion injuries. Therefore, the lack of similarities in the results can be due to the difference in the type of activities. In addition, Alt (1999) reported that an increase in the latency would be more pronounced with ligaments laxity and chronic ankle instabilty which were not tested in most of the previous studies.

2.6.1.3 *Scapular taping*

It has been found that in shoulder impingement, there is usually an increase in the activity of the upper trapezius, and decrease in the activity of the lower trapezius and serratus anterior (Paterson & Sparkes, 2006, de Morais, et al., 2008, Selkowitz DM, 2007). The current review identified five studies that investigated the effect of taping on the scapular muscles activities. Only one study was done on subjects with shoulder impingement (Selkowitz DM, 2007). The results of the study showed an inhibition in the upper trapezius and stinulation of the lower trapezius with taping. This agrees with the findings of the other identified study by (Morin GE, 1997) who studied the effect of scapular taping on normal subjects. In contrast, (Cools AM, 2002) found no significant changes in the activity of the scapular muscles after scapular taping during active abduction and forward should flexion movements with and without resistance. Again the variation in the intervention and the type of participants recruited in those studies made it difficult to come to a solid conclusion due to the conflicting results between the different studies.

2.6.2 Taping over muscles

Due to the stabilizing of the altered joint condition as a result of taping, authors hypothesize a potential difference in the muscle activity when the tape is applied on a joint, and when it is applied over a muscle. Three studies met the inclusion criteria for this aspect in this review. It has been speculated that taping along the muscle fibers would increase the actin-myosin overlap and facilitate more action potential and electrical activity while taping across the muscle may hold the muscle in a lengthened position, thus decreasing the actin-myosin overlap (Morrissey, 2000). Contrary to the previous hypothesis, the results of this review showed an inhibition of the H reflex when the tape was applied along the muscle fibers in two of the studies, and no changes in the activity was reported in the other study. Taping across the muscle didn't cause any changes in EMG amplitude or the H reflex. Inhibition of a muscle indicates less motorneuron activity. Interestingly, the inhibition started, however, not significantly, with the undertape, and increased significantly with the rigid tape. This may suggest a proprioceptive cutaneous and subcutaneous effect of taping when applied directly over a muscle.

2.7 LIMITATIONS

The current review examined the available evidence on the physiologic effect of taping as investigated by EMG studies. The issues of EMG and measurement reliabilities were not well described in most of the studies. In addition the qualities of the studies were moderate to fair. The limitations of most of the reviewed studies should be clearly addressed so that future studies can have better qualities to provide stronger evidence. The variations and the confounders in this review made it very difficult to come to a conclusion. Types of participants, interventions, and outcomes varied grossly between the different studies.

2.8 CONCLUSION

The physiological effect of taping as investigated by EMG is still not clear. Although it has been shown that taping plays an important role in reducing pain and increasing function in people with MSD, the mechanism of action is still not fully understood. There is a very little evidence to support the effect of taping on muscle activity onset in people with patella-femoral pain syndrome. No significant effect was reported regarding onset of muscle activity in normal subjects. The effects of taping on muscle activity onset in different groups of muscles were not reported in the literature. The effect on other muscles around other joints should be investigated in order to provide more conclusive evidence for this. More studies are also needed to be done on other people with different neuro-musculoskeletal conditions. In contrast to this, the studies on the ankle offered a little support that taping can reduce

muscle activity, and increase the muscle latency in the peroneus longus. There was a very little evidence to support the effect of scapular taping in reducing the activity of the upper trapezuis, and increasing the activity of the middle and lower trapezius. There was also a little evidence that taping reduces the H reflex when applied directly on the muscles. More studies need to be done to confirm the previous findings, with more conclusive evidence. The physiologic effects of taping as studied with EMG are still inconclusive. While some studies reported muscle activation due to taping, other studies reported inhibition, and some other reported no difference in the amplitude of muscle activity between the different taping conditions. However, the reduction in pain, the increased range of motion, and the improvement in function suggest a different mechanism in which taping works.

This review was limited to the studies on the physiological effect of taping represented by different electromyographic variables. More reviews are needed to investigate the mechanical as well as the proprioceptive effect of taping in order to more accurately explain the mechanisms of taping on perceived pain and function. The inconclusive findings of this systematic review are therefore considered inadequate to strongly motivate studying the effect of gluteal taping on the gait of ambulant adults with hemiplegia. However, the findings are still valid as they suggest different mechanisms to be investigated in future research.

CHAPTER 3. METHODOLOGY

The current study consisted of two phases. The specific procedures for each of these are presented in this chapter. The research questions, aims, and objectives of the study are described.

The first phase of the study was used to investigate the test-retest reliability of the Moven System in measuring the temporal-spatial, and the kinematic parameters in subjects with stroke. The second phase involved the investigation of the effect of gluteal taping on walking in people with stroke.

3.1 RESEARCH QUESTIONS

1. Is the Moven 3D gait analysis system a reliable tool for measuring temporal, spatial and kinematic parameters in ambulant patients with hemiplegia?
2. What is the effect of therapeutic gluteal taping on gait parameters (temporal spatial, and sagittal kinematic), and lateral pelvic tilt in ambulant adults with hemiplegia?

3.2 MAIN AIM OF STUDY

The main aim of this study was to assess the effect of gluteal taping on gait variables and walking symmetry.

3.3 OBJECTIVES OF STUDY

The objectives of the current study were:

- To assess the repeatability of temporal spatial and kinematic gait parameters using the Moven system in subjects with stroke.
- To describe the immediate effect of gluteal taping in subjects with stroke on improving:
 - temporal spatial parameters (step length, cadence, and velocity)
 - Sagittal kinematic parameters of the paretic leg (joint angles of the hip, knee, and ankle) and
 - lateral pelvic tilt

3.4 STUDY DESIGN

	The study	The design
Phase 1	Reliability of the Moven system	Test-retest design
Phase 2	The effect of gluteal taping on gait parameters in subjects with hemiplegia	Prospective quasi experimental study of single factor one way design for repeated measure.

3.5 RESEARCH SETTING

Most of the data was collected at Western Cape Rehabilitation Centre (WCRC), Mitchells Plain, Cape Town, South Africa. WCRC is the largest rehabilitation centre in Cape Town. It provide in-patient, and out patients rehabilitation services for various conditions, including stroke and head injuries, spinal cord injuries, amputations, etc...

In addition to the in-patient wards, it includes three therapy units. Each unit has a physiotherapy gym, and an occupational therapy gym. Apart from the therapy unit, WCRC has a hydrotherapy gym where the recording and data collection were done. The hydrotherapy gym has a large gym area in addition to the swimming pool where a walking distance of ten meters was measured and prepared for the trials. The area was a quite area, where the subject had no chance to get distraction by the presence of other patients. All subjects recruited from WCRC were receiving individual rehabilitation programs, including physiotherapy, occupational therapy, and speech therapy as in-patients.

Some of the data was collected at the Physiotherapy Gym, Faculty of Health Sciences, Stellenbosch University, Cape Town, South Africa. The Physiotherapy Gym has a large space where a ten meters distance was drawn on the floor. The gym was booked completely for the subjects being tested during testing to minimize distraction. Subjects who were tested at the Physiotherapy Gym were recruited from the Bishop Lavis Community Health Centre where patients receive community-based rehabilitation programs. The centre includes physiotherapy and occupational therapy services. All subjects recruited from Bishop Lavis Community Health Centre were out-patients.

3.6 SAMPLING

3.6.1 Population

The population of this study included ambulant adults with hemiplegia following CVA or traumatic brain injury, admitted to or treated at Community Health Centers in the Western Cape Province of South Africa, and the Western Cape Rehabilitation Center (WCRC).

3.6.2 Sample Recruitment

Therapists from the various centers were asked to provide names of subjects with hemiplegia who had had stroke during the last year, and are able to walk for a distance of 10 meters without support and assistive devices.

Subjects were approached by their therapists and were booked for an initial interview with the principle investigator. Before the interview, the files of the potential subjects were studied. Information regarding the patient age, gender, the onset of stroke or head injury, and the subjects' medical histories were recorded. Subjects were then interviewed and been asked about previous medical, neurological or musculoskeletal problems. The testing procedure was explained, and an informed written consent was sought.

Due to the lack of subjects with stroke who were able to walk during the short period of data collection, convenience sampling was used. Participants were eventually selected based on availability as it was difficult to get subjects that were matching the inclusion criteria.

3.6.3 Sample Size

Based on the statistical finding of the pilot study of Kilbreath *et al* (2006), it was determined that thirty patients needed to be included in this study. The sample estimation was done by Prof. Martin Kid, a statistician at Stellenbosch University. Figure1 demonstrates estimated calculation of the sample size. In order to consider a change of 6 degrees in hip angle significant, 30 subjects were needed.

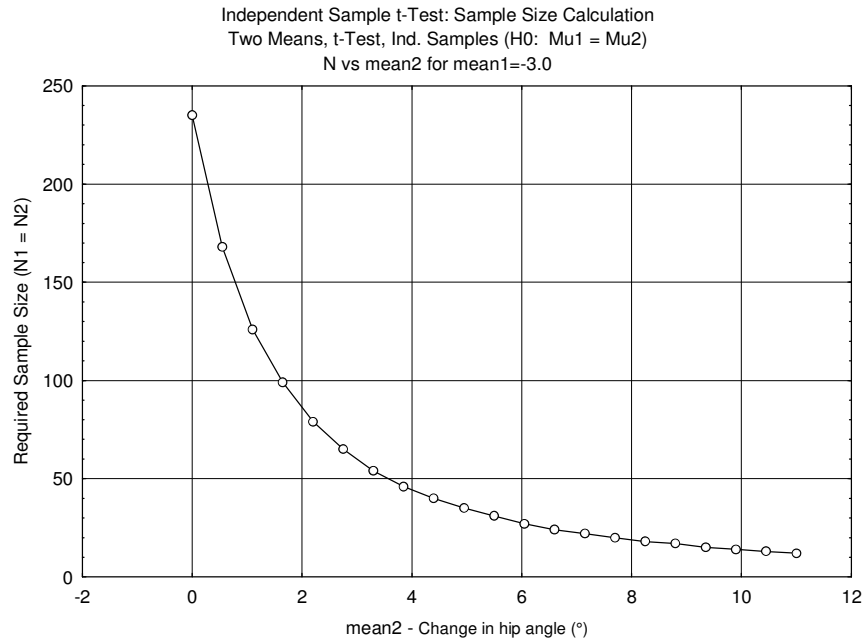


Figure 3.1: Sample size calculation

3.6.4 Sample Characteristics

The following criteria were used to determine eligibility for participation in the current study:

3.6.4.1 Inclusion criteria

To be included in the study, subjects had to:

- be adults, male or female
- present with unilateral hemiplegia following stroke or traumatic brain injury
- have had a single stroke.
- be able to walk at least 10 meters, without walking aids or ankle foot orthosis (AFOs).

3.6.4.2 Exclusion criteria

Subjects were excluded from the study if they presented with:

- any significant musculoskeletal problem caused by anything other than the stroke.
- any other motor disorder (e.g. ataxia)
- a history of skin allergy
- hairy skin over the gluteal area

- comprehensive aphasia that limited them from understanding simple commands.
- current history of unstable cardiovascular problem (e.g. uncontrolled blood pressure)

3.7 INSTRUMENTATION

The Moven inertial motion capture system is a product by Xsens Technologies B.V, The Netherland, is an easy to use, cost effective, tool for full body human motion capture. The Moven system is based on the Xsens miniature inertial sensors and wireless communication solution combined with advanced sensor fusion algorithms taking into account biomechanical constraints. The Moven is a completely portable system. It is not restricted to a studio or a laboratory. It can be used anywhere: outside, in the office and on the work floor. There are no limitations in measurement volume, except the wireless range which is up to 150m. Therefore it can be used anywhere where subjects are available.

A full body Moven system contains 16 inertial motion trackers. Each sensor modules comprises 3D gyroscopes, 3D accelerometers and 3D magnetometers. Using advanced sensor fusion algorithms, the inertial motion trackers give absolute orientation estimates which are used to calculate the 3D linear acceleration which in turn give translation estimates of body segments. Each joint is modeled as a ball and socket joint specified by different statistical parameters in both position and orientation. 3D joint positions and positions of palpable bony landmarks are determined by automated calibration procedure and regression equations.

3.8 SENSORS PLACEMENT

The movements are monitored by 16 inertial motion trackers that was placed (strapped and taped) on the anatomical locations as in Table 1.

Table 3.1: Placement of sensors on the body

Head	Any comfortable position
Hands	Backside of the hands
Fore arm	Lateral side of the wrist
Upper arm	Lateral side above elbow
Shoulder	On both scapulae
Pelvis	On the sacrum
Upper leg	Lateral side above knee
Lower leg	Shin bone (tibia)
Foot	Middle of top of foot

3.9 ANTHROPOMETRIC MEASUREMENTS

A tape measure was used to measure all the anthropometric measurements.

Table 3.2: Anthropometric measurements

Parameter Description	Measurement
Body height (cm)	Standing barefoot against the wall
ASIS breadth (mm)	With a tape measure, the distance the ASISs was measured
Leg length (mm)	Tape measure, the vertical distance between the superior point of the greater trochanter of the femur, and the floor was measured.
Lower leg length (mm)	Tape measure, the vertical distance between the superior margin of the lateral tibia and the floor
R&L foot length (mm)	the distance from the posterior margin of the heel to the tip of the longest toe
malleolus height (mm)	The vertical distance from the floor to the lateral malleolus
Shoulders' width	the distance between the distal tips of the right and left acromions.
Arm span	The distance between the tips of the right and left middle fingers in T-pose

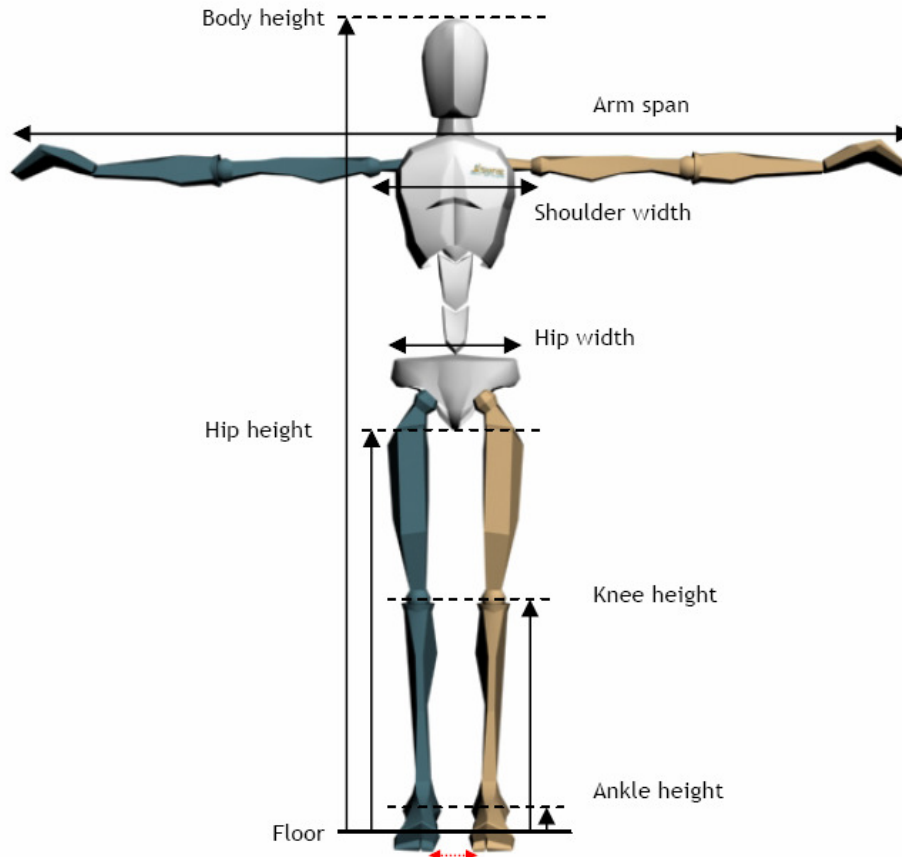


Figure 3.2: Anthropometric measurements

3.10 PILOT STUDY

A pilot study was done initially to standardize the testing procedure, and minimize the sources of measurements errors. Eight subjects had to follow the following testing procedure while putting the Moven suit on. The data of those subjects were not used, since a massive measurement error was noticed using the suit. That was probably due to the movement of the sensors in the suit while walking, in addition to the disturbance of the alignment of the sensors in the suit, while removing and putting it back in between the trials. Therefore, the sensors were stucked directly on the skin, and strapped.

3.11 PHASE 1: RELIABILITY OF THE MOVEN SYSTEM

3.11.1 Aim

To determine the test-retest reliability of the Moven system in measuring temporal spatial and kinematic parameters in subjects with stroke

3.11.2 Study Design

Test-retest design

3.11.3 Procedure

Eight subjects were recruited for this study. The Moven System's calibration was done by research assistance (engineer), prior to testing, and as needed in case of a system crash. Data capturing and processing was also done by the engineer on an MS Excel file. Preparation and sensor placements were done by the principle investigator. Subjects were asked to walk without orthotics barefoot on a 10m walkway at their self-selected walking speed. Subjects were then asked to walk again but this time at their maximum speed. Subjects were asked to rest for a period of 5 minutes after they report their readiness to walk to avoid the influence of fatigue. This procedure was repeated again to test the inter-trial reliability. See figure 3.3

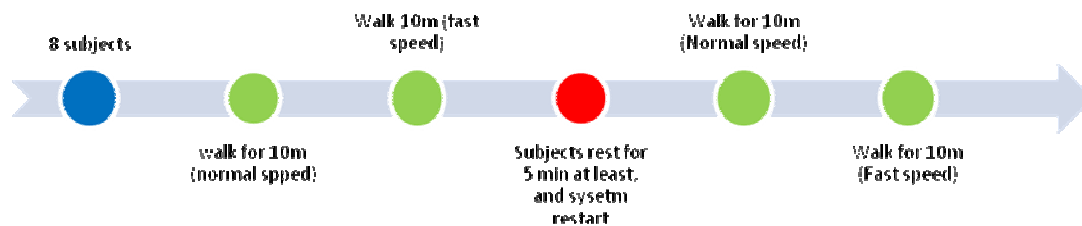


Figure 3.3: The procedure steps during the reliability study

3.12 PHASE 2: EFFECT OF GLUTEAL TAPING

3.12.1 Aim

This part of the study aimed to describe the effect of gluteal taping on gait variables and walking symmetry in subjects with adult hemiplegia following stroke.

3.12.2 Study Design

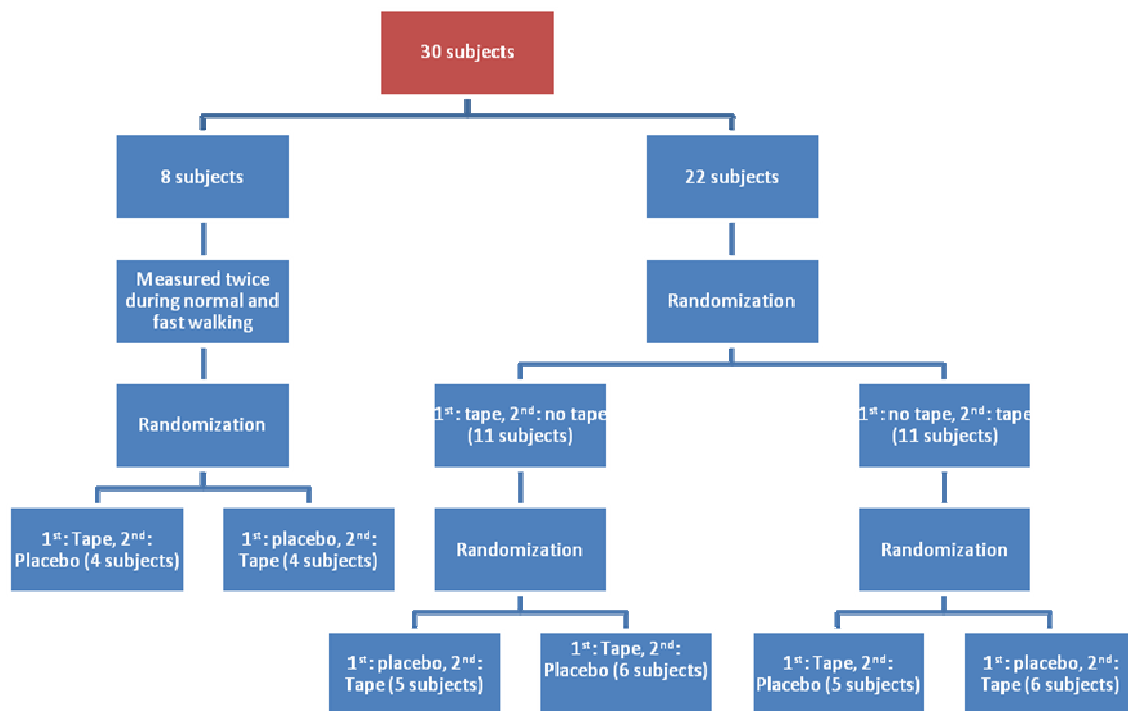
Prospective quasi experimental study of single factor one way design for repeated measures

3.12.3 Procedure

Thirty subjects were recruited for the main study. After sensor replacement and system calibration, subjects were asked to walk a distance of 10 meters at their normal self selected

speed, and then at their maximum speed. To minimize exposing subjects to many testing sessions while insuring better reliability the data of the eight subjects of phase 1 was included in this phase.

This procedure was repeated with both therapeutic and placebo gluteal taping. Subjects were given extra five minutes to rest after they report their readiness to walk before going into every following trial. The order of walking under therapeutic, and placebo gluteal taping conditions was randomized according to the flow diagram bellow. The order was alternated between the patients. After tape removal subjects were asked to walk again for the last time on their self selected speed, and maximum speed. To minimize selection bias during data extraction while analyzing the two walking trails under the no tape conditions, the names of participants were sorted alphabetically, and only one of the two trials measured at the beginning and at the end of the testing session was chosen on alternative order.



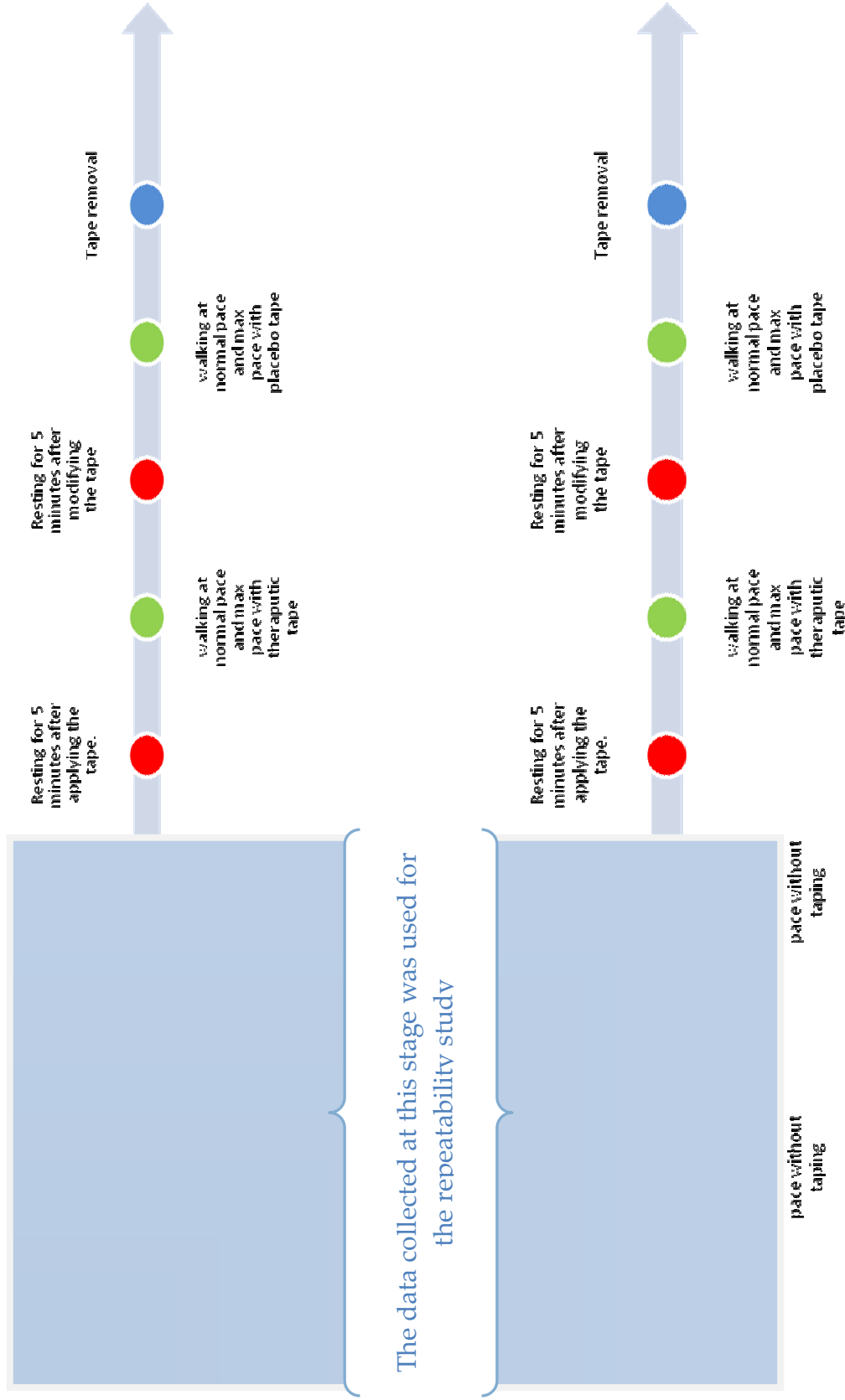


Figure 3.4: The testing procedure followed with the subjects recruited for the test-retest reliability study



Figure 3.5: The testing procedure followed with rest of the subjects recruited in the study

3.12.4 Taping Procedure:

Calamine lotion was applied to the skin, and left to dry. An underwrap (hypo-allergic tape) was applied as shown in Figure 3.6 without causing any tension on the skin, just as a second skin. The first strip was started from the medial aspect of the gluteal fold, and inserted mid way between the anterior superior iliac spine, and the greater trochanter. The second strips was fixed on the starting point of the first strip, and directed vertically up and fixed on the posterior superior iliac spine. The third strip was applied from the end of the second strip, toward the end of the first strip. A rigid strapping tape was applied over the underwrapping tape pulling the muscles as shown in Figure 3.6, while maximum pulling in the illustrated directions was applied. To insure maximum gluteal lifting, while subject is in standing position, the buttock was lifted with one hand while pulling up the rigid strips with the other hand.



© Kilbreath *et al* (2006)
Figure 3.6: Taping technique

Removal of the tape was done by carefully peeling the tape slowly back over itself while pushing the skin in the opposite direction. Baby oil was used at the edge of the tape to facilitate its removal. Alcohol rub was used on the skin after the tape was removed to help toughen the skin. Placebo taping was applied in the same way using only the underwrapping tape without applying any tension.

3.13 DATA COLLECTION

3.13.1 Instrument

1. Moven Xsens System
2. Tape measure

3.13.2 Outcome Measure

1. Temporal spatial measurements including step length, cadence, and velocity.
2. Kinematic parameters including angles of flexion and extension of hip, knee, and ankle of the paretic leg during: initial contact, mid stance, terminal stance and mid-swing.
3. Lateral pelvis displacement to both sides during mid-stance.

All outcome measures were recorded at self selected walking speed, and maximum walking speed.

3.14 DATA EXTRACTION

Temporal, spatial and kinematic gait parameters of the three middle steps of the paretic leg were extracted from the Excel file for each trial. The timeframes of the initial contact, mid stance, terminal stance, and mid swing phases of the gait cycle were identified on the Moven file. The identified timeframes were then matched on the Excel file to get the kinematic values of the hip, knee, and ankle, in addition to the lateral pelvic tilt during each phase of the gait cycle. See figure 3.7

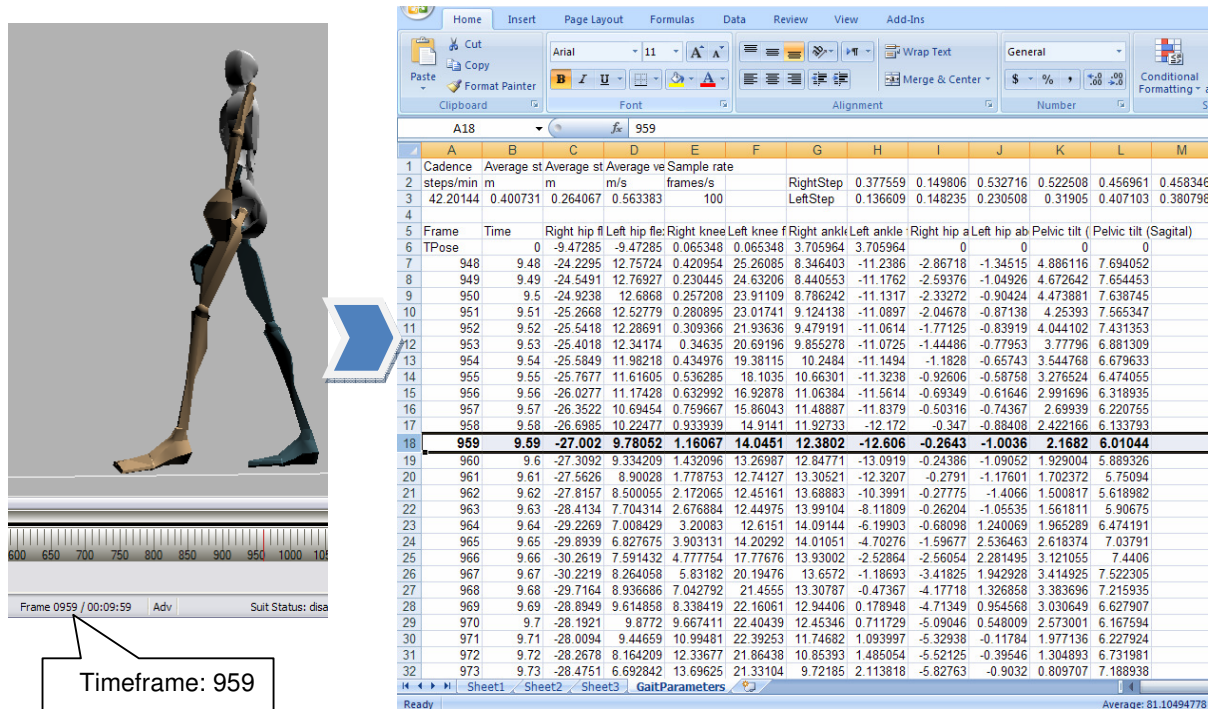


Figure 3.7: The initial contact phase of the left leg occurred in this example at timeframe 0959. The timeframe was then matched on the Excel file of the same trial, and the values were extracted.

The examined phases of the gait cycle were identified as the following:

- The initial contact was identified on the Moven file as soon as the foot touches the floor as in figure 3.8
- The mid stance was identified when the toes of the sound foot reaches the heel of the paretic leg in a sagittal view. See figure 3.9
- The terminal stance was identified just before the forefoot of the paretic leg leaves the floor in a sagittal view. See figure 3.10
- The mid swing phase was identified when the toes of the paretic foot reaches the heel of the sound leg in a sagittal view. See Figure 3.11

The values of each joint angle during the examined phases of the gait cycle of the middle three steps were averaged. The temporal spatial values of the middle three steps were also averaged. The averaged values were recorded on an Excel spreadsheet for further analysis.

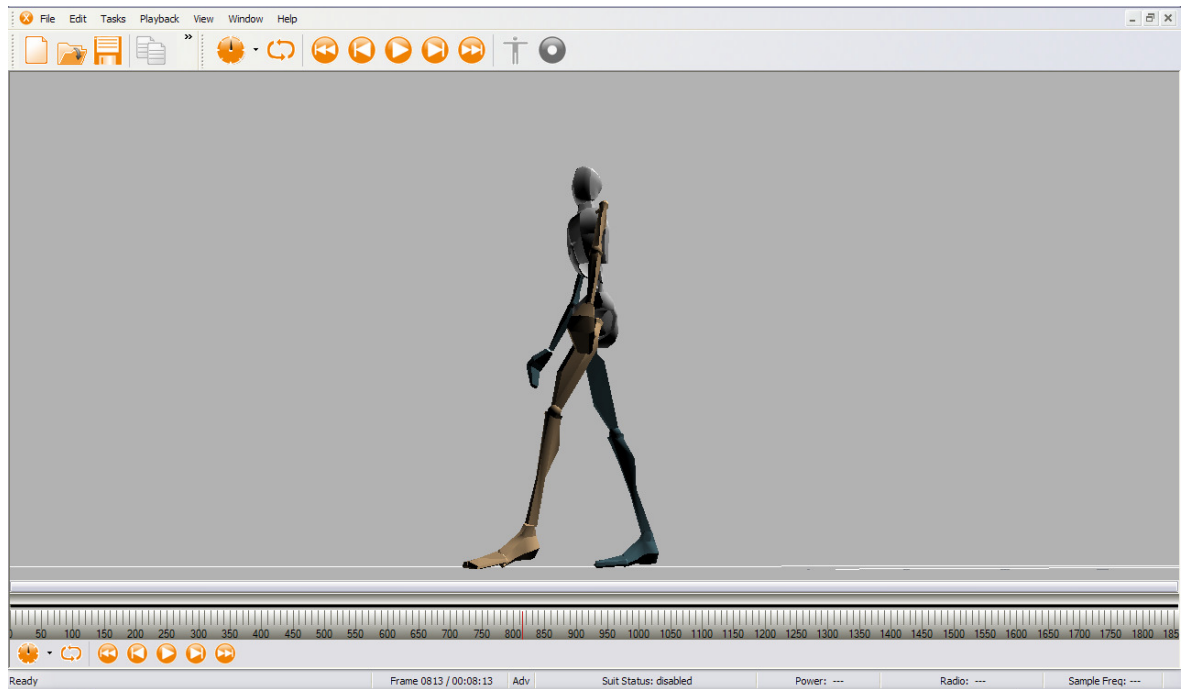


Figure 3.8: An example of initial contact phase of the left foot

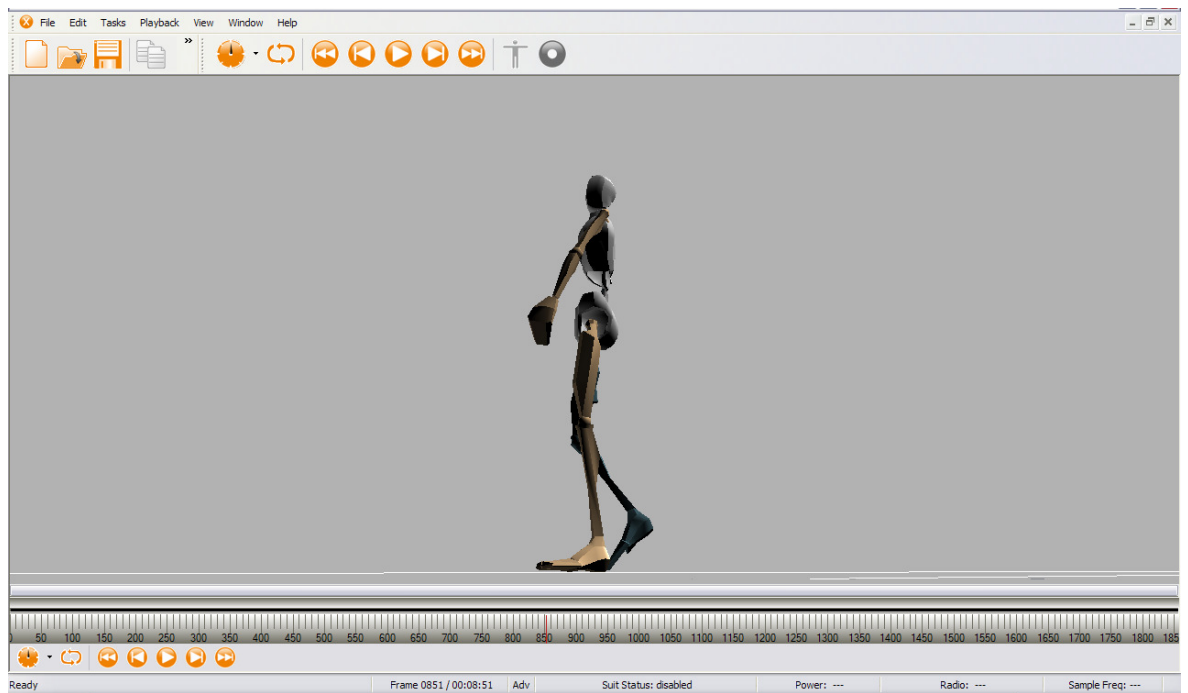


Figure 3.9: An example of the mid stance phase of the left foot

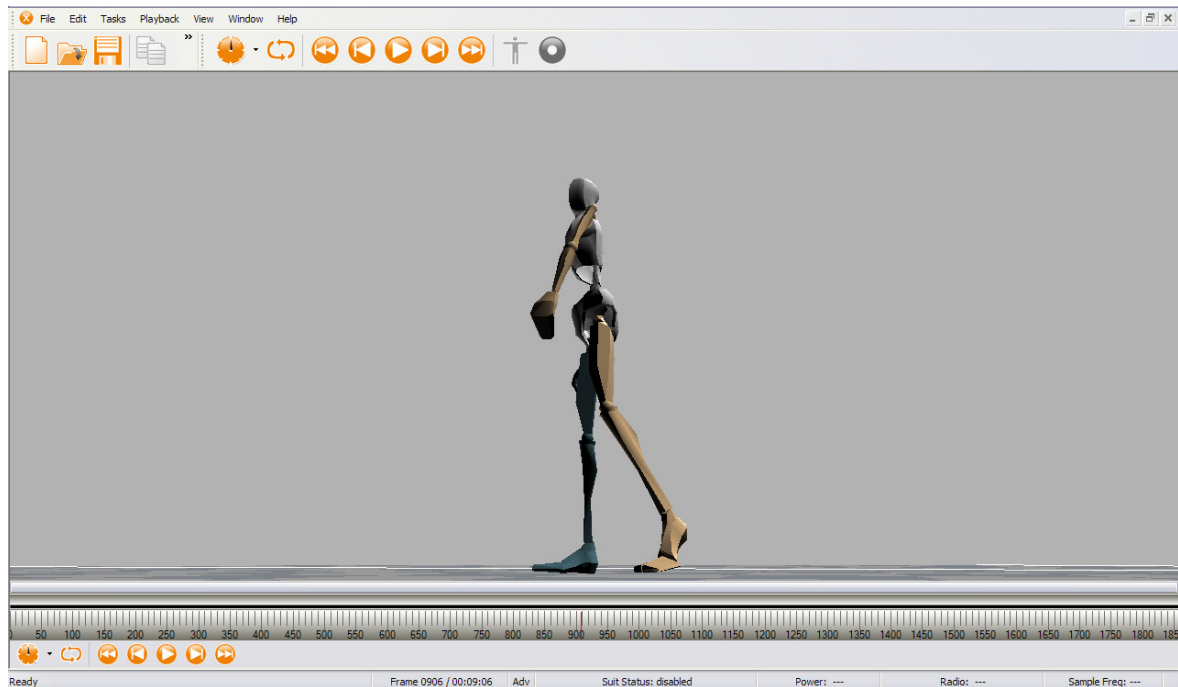


Figure 3.10: An example of the terminal stance phase of the left foot

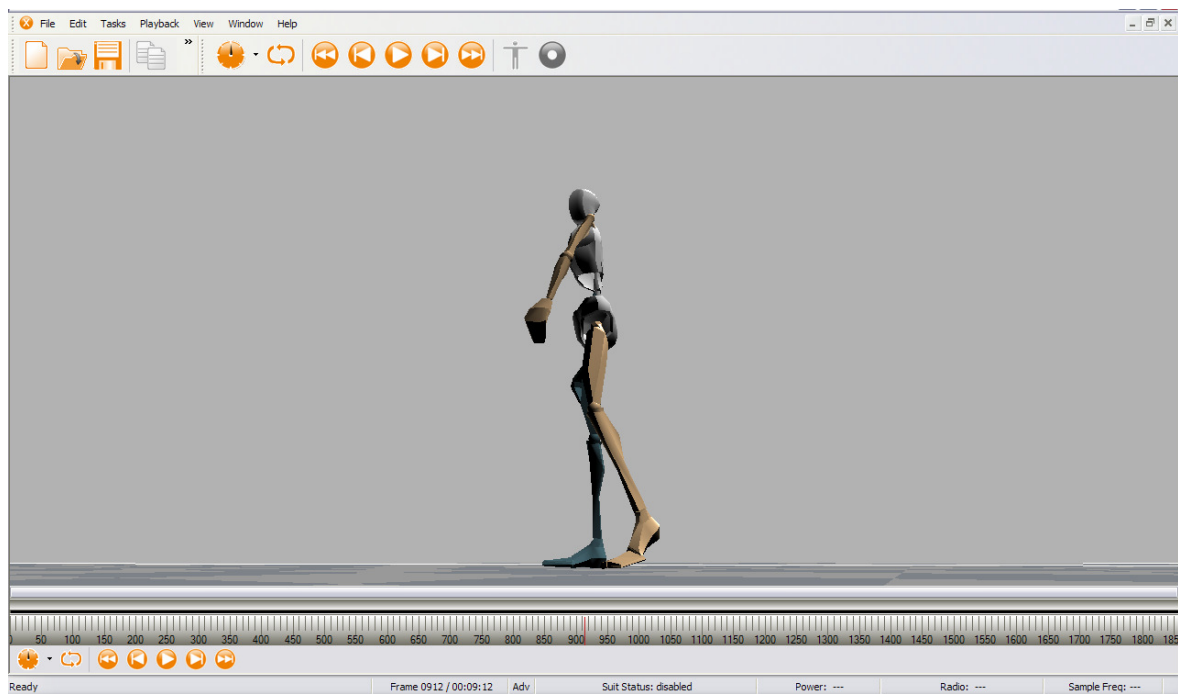


Figure 3.11: An example of the mid swing phase of the left leg

3.15 STATISTICAL ANALYSIS

Statistica version 8 was used to analyze data and analysis was conducted under the supervision of Dr Martin Kidd, a statistics consultant from the Centre of Statistical Analysis, Stellenbosch University.

The test retest reliability of the Moven system in measuring different kinematic and temporal spatial parameters was examined using the Intra-class correlation coefficient ICC determined around 95% confidence intervals. ICC, 2 way model, was used to measure the agreement between the measurements in the two trials, and the consistency in recording the measurements. ICC values above 0.75 were considered to represent excellent reliability. Values between 0.40 and 0.75 represent moderate reliability, while values less than 0.40 represent poor reliability (Salter *et al* 2005).

The data was collected on Microsoft Excel Sheet, and processed using Statistica and a written statistical program "R". Repeated Measure Analysis of Variance was used to study the different variables behaviors during the three situations (i.e. without taping, with therapeutic taping, and with placebo taping).

3.16 ETHICAL CONSIDERATIONS

The following ethical aspects were taken into account and addressed throughout the study:

1. Permission was obtained from the Department of Health in Western Cape to recruit patients from community health centers in Western Cape. Appendix 2
2. Permission was obtained from Western Cape Rehabilitation Centre to access patients' records, recruit patients, and conduct the testing there. Appendix 3
3. Permission was obtained from the physiotherapy department at Stellenbosch University to use the Physiotherapy Gym at the Faculty of Health Science for testing subjects close to the faculty's premises.
4. Subjects were assured that all personal information obtained will remain confidential, and the results of the study will be mentioned without disclosure of the subjects' identity.
5. Informed written consent to participate in the study was obtained from all subjects, and each of them had a copy of the consent he/she had signed. All subjects had the option to agree/disagree to have their photos or video recordings to be used for scientific presentations, congresses or publication. Appendix 4
6. The study was approved and registered with the Research and Ethics Committee in the Faculty of Health Sciences, Stellenbosch University. Appendix 1
7. Participation in the study was voluntary and not forced, and it could be withdrawn at any time.
8. The booking of subjects for testing at WCRC was done by the therapists appointed by the chief physiotherapist, so that the testing session would not clash with subjects' therapeutic schedule, and their rehabilitation process wouldn't be affected.

9. An indemnity form was signed by all subjects who required and were provided with transportation between the community health centers, and the Physiotherapy Gym at the Faculty of Health Sciences. Those who used their own transport were reimbursed for the transportation cost. Appendix 5

CHAPTER 4. RESULTS

The main findings of the two phases of the study are presented in this chapter according to the objectives of the study.

4.1 SAMPLE DESCRIPTION

Thirty subjects who met the inclusion criteria of the main study were recruited for this study. Table 4.1 shows the characteristics of those subjects. Eighteen males and 12 females participated in the study. The mean age of subjects was 51.2 ± 10.1 years. Ten of the subjects had left side hemiplegia and 20 had right side hemiplegia. The mean duration since the time of stroke onset was 4 ± 2.7 months. Twenty five subjects were recruited and tested at Western Cape Rehabilitation Center (WCRC). The remaining five subjects were recruited at Bishop Lavis Community Health Centre, and tested at the physiotherapy gym at the Faculty of Health Sciences, Stellenbosch University.

Table 4.1: Characteristics of subjects

N	Age	Gender	Side of Hemiplegia	Duration since onset	location
1	59	M	Right side	3 months	WCRC
2	62	M	Right side	2 months	WCRC
3	54	M	Right side	2 months	WCRC
4	48	F	Left side	4 months	WCRC
5	52	F	Left side	3 months	WCRC
6	25	F	Left side	2 months	WCRC
7	62	M	Right side	6 months	WCRC
8	38	F	Right side	3 months	WCRC
9	35	F	Left side	4 months	WCRC
10	43	M	Left side	4 months	WCRC
11	58	M	Right side	2 months	WCRC
12	49	M	Right side	1 month	WCRC
13	47	M	Left side	2 months	WCRC
14	44	M	Left side	1 month	WCRC
15	58	M	Right side	3 months	WCRC
16	32	M	Right side	2 months	WCRC
17	53	F	Right side	2 months	WCRC
18	61	F	Right side	2 months	WCRC
19	56	F	Right side	11 months	CHC
20	54	M	Right side	10 months	CHC
21	38	M	Left side	2 months	WCRC
22	59	F	Right side	7 months	CHC
23	57	M	Right side	6 months	WCRC
24	62	M	Right side	3 months	WCRC
25	49	M	Right side	4 months	WCRC
26	64	M	Right side	2 months	WCRC
27	62	F	Right side	8 months	CHC
28	43	F	Left side	3 months	WCRC
29	59	F	Right side	10 months	CHC
30	52	M	Left side	5 months	WCRC

4.2 PHASE ONE

The objective of this study was to examine the reliability of the Moven system in measuring the temporal spatial (step length, cadence, and velocity) and selected kinematic parameters (lateral pelvic tilt, hip flexion/extension, knee flexion/extension, and ankle dorsi/planter flexion) of both the paretic and the sound/unaffected legs during four phases of walking, (initial contact, mid stance, terminal stance, and at mid swing). The kinematic measurements of the hemi affected leg were recorded when the hemi leg goes into the four selected phases of walking, and the kinematic parameters of the unaffected leg were measured spontaneously while the other leg is into the four selected phases of walking. The data were captured during self-selected and maximum pace of walking.

The first eight subjects in table 4.1 highlighted in blue, were recruited for the pilot trial. A total of 4 males and 4 females with a mean age 50 ± 12.9 year participated in this study. Five of them had right sided hemiplegia, and 3 had left sided hemiplegia. The mean duration since the time of onset was 3.1 ± 1.4 months. All eight subjects were tested in the same gym at WCRC. Below are the results of the reliability study during self-selected and maximum walking speeds during the different phases of the walking cycle.

4.2.1 Temporal spatial parameters during normal walking

Table 4.2 presents the Inter-class correlation (ICCs) findings for velocity, cadence and step length during self selected normal pace of walking. The ICC values indicate excellent reliability of the Moven system in measuring the velocity, cadence, and the step length in the hemi side, but not for the step length of the sound leg ($p=0.1934$) (Table 4.2).

Table 4.2: The reliability of the Moven in measuring the temporal spatial parameters during self selected pace of walking

Variables (self-selected speed)	ICC (Agreement)	ICC (Consistency)	Pearson's r	P
Velocity	0.868(0.366;0.974)	0.911(0.622;0.981)	0.9109	0.002
Cadence	0.837(0.018;0.971)	0.930(0.693;0.986)	0.9300	<0.001
Hemi side Step Length	0.908(0.083;0.985)	0.967(0.847;0.993)	0.9682	<0.001
Sound side Step length	0.484(-0.363;0.874)	0.452(-0.307;0.859)	0.5131	0.1934

4.2.2 Temporal spatial parameters during fast walking

During walking at maximum speed, the Moven showed excellent reliability in measuring all time-distance parameters, including cadence, velocity, and the step length of both sound and hemi leg with ICCs ranging between 0.797 and 0.941 (Table 4.3).

Table 4.3: The reliability of the Moven in measuring the temporal spatial parameters during fast walking

Variables (maximum speed)	ICC (Agreement)	ICC (Consistency)	Pearson's r	P
Velocity	0.941(0.300;0.990)	0.975(0.882;0.995)	0.9784	<0.001
Cadence	0.922(0.536;0.985)	0.949(0.767;0.990)	0.9571	<0.001
Hemi side Step Length	0.922(0.665;0.984)	0.914(0.632;0.982)	0.9167	0.001
Sound side step length	0.797(-0.054;0.964)	0.925(0.674;0.984)	0.9249	0.001

4.2.3 Kinematic parameters during self selected walking speed

4.2.3.1 At initial contact

There were excellent correlations between the two measurements while measuring both hips, the sound knee, and lateral pelvic tilt, with ICCs ranging between 0.888 and 0.951. Moderate correlations were found while measuring the angles of both ankles, and the hemi knee at the initial contact phase of the affected leg with ICCs ranging between 0.668 and 0.746. (Table 4.4)

Table 4.4: The reliability results while the affected leg is at the initial contact phase of selected pace of walking

Variables (self-selected speed)	ICC (Agreement)	ICC (Consistency)	Pearson's r	P
Hemi hip	0.888(0.437;0.978)	0.923(0.667;0.984)	0.9598	<0.001
Sound hip	0.917(0.566;0.984)	0.942(0.739;0.988)	0.9461	<0.001
Hemi knee	0.668(0.058;0.922)	0.672(0.010;0.924)	0.7206	0.044
Sound knee	0.905(0.493;0.981)	0.936(0.715;0.987)	0.9518	<0.001
Hemi ankle	0.746(0.116;0.944)	0.720(0.103;0.937)	0.7363	0.037
Sound ankle	0.719(0.052;0.938)	0.691(0.045;0.929)	0.6934	0.057
Lateral Pelvic tilt	0.951(0.792;0.990)	0.948(0.766;0.989)	0.9503	<0.001

4.2.3.2 Mid stance

The angle of the hemi ankle at the mid stance showed the highest discrepancy between the two measures with an ICC of 0.724, and a large confidence interval (0.095; 0.938). The Moven showed excellent reliability in measuring the other joint angles at the mid stance phase of self-selected walking speed as well as the lateral pelvic tilt, with ICCs ranging between 0.778 and 0.973 (Table 4.5).

Table 4.5: The reliability results while the affected leg is at the mid stance phase of selected pace of walking

Variables (self-selected speed)	ICC (Agreement)	ICC (Consistency)	Pearson's r	P
Hemi hip	0.778(0.250;0.951)	0.820(0.339;0.961)	0.8364	0.01
Sound hip	0.914(0.663;0.982)	0.916(0.641;0.983)	0.9723	<0.001
Hemi knee	0.898(0.586;0.978)	0.913(0.628;0.982)	0.9187	0.001
Sound knee	0.973(0.882;0.995)	0.975(0.882;0.995)	0.9824	<0.001
Hemi ankle	0.724(0.095;0.938)	0.703(0.069;0.933)	0.7140	0.0467
Sound ankle	0.894(0.566;0.978)	0.883(0.527;0.975)	0.9157	0.001
Lateral Pelvic tilt	0.948(0.763;0.989)	0.941(0.737;0.988)	0.9417	<0.001

4.2.3.3 Terminal stance

The Moven showed Moderate reliability while measuring the hemi hip, knee and ankle angles at the terminal stance phase of walking during self-selected speed with ICCs of 0.622 and 0.596 respectively. The measurements of all other joints' angles, as well as the lateral pelvic tilt showed excellent reliability with ICCs ranging between 0.893 and 0.945 (Table 4.6).

Table 4.6: The reliability results while the affected leg is at the terminal stance phase of selected pace of walking

Variables (self-selected speed)	ICC (Agreement)	ICC (Consistency)	Pearson's r	P
Hemi hip	0.681(0.091;0.925)	0.692(0.047;0.930)	0.7286	0.04
Sound hip	0.897(0.589;0.978)	0.890(0.548;0.977)	0.79	0.02
Hemi knee	0.622(0.010;0.908)	0.649(-0.030;0.918)	0.657	0.08
Sound knee	0.946(0.765;0.989)	0.941(0.736;0.988)	0.942	<0.001
Hemi ankle	0.596(-0.160;0.905)	0.570(-0.155;0.896)	0.571	0.139
Sound ankle	0.893(0.583;0.977)	0.888(0.541;0.976)	0.927	<0.001
Lateral Pelvic tilt	0.889(0.533;0.977)	0.875(0.500;0.974)	0.875	0.004

4.2.3.4 Mid Swing

During the mid swing phase of walking of the hemi leg, the Moven showed excellent reliability with all the measurements with ICCs ranging between 0.844, and 0.985 (Table 4.7).

Table 4.7: The reliability results while the affected leg is at the mid swing phase of selected pace of walking

Variables (self-selected speed)	ICC (Agreement)	ICC (Consistency)	Pearson's r	P
Hemi hip	0.909(0.372;0.983)	0.949(0.768;0.990)	0.9527	<0.001
Sound hip	0.948(0.777;0.989)	0.953(0.785;0.990)	0.9538	<0.001
Hemi knee	0.943(0.735;0.988)	0.953(0.785;0.990)	0.9540	<0.001
Sound knee	0.965(0.851;0.993)	0.965(0.838;0.993)	0.9707	<0.001
Hemi ankle	0.844(0.398;0.967)	0.828(0.361;0.963)	0.8799	0.004
Sound ankle	0.908(0.603;0.981)	0.896(0.570;0.978)	0.8970	0.003
Lateral Pelvic tilt	0.845(0.408;0.967)	0.831(0.368;0.964)	0.8306	0.011

4.2.4 Kinematic parameters during fast walk

4.2.4.1 Initial contact

The measurements of the sound hip and ankle showed the highest discrepancy between the two measurements with ICCs of 0.661 and 0.742 respectively, indicating moderate reliability. There were excellent agreements between the two measurements of all other joints' angles with ICCs ranging between 0.756 and 0.977 (Table 4.8)

Table 4.8: The reliability results while the affected leg is at the initial contact phase of maximum pace of walking

Variables (maximum speed)	ICC (Agreement)	ICC (Consistency)	Pearson's r	P
Hemi hip	0.867(0.465;0.972)	0.852(0.430;0.969)	0.869	0.005
Sound hip	0.661(0.070;0.919)	0.697(0.057;0.931)	0.698	0.054
Hemi knee	0.877(0.523;0.974)	0.893(0.561;0.978)	0.921	0.001
Sound knee	0.977(0.888;0.995)	0.974(0.874;0.995)	0.974	<0.001
Hemi ankle	0.756(0.172;0.946)	0.737(0.139;0.941)	0.771	0.025
Sound ankle	0.742(0.209;0.941)	0.767(0.206;0.949)	0.772	0.025
Lateral Pelvic tilt	0.949(0.269;0.992)	0.981(0.908;0.996)	0.982	<0.001

4.2.4.2 Mid stance

During the mid stance phase of the hemi leg during fast walking, there was excellent reliability in all measurements except the sound ankle angle measurements with ICCs ranging between 0.890 and 0.950. The Moven showed moderate reliability while measuring the sound ankles' angle with an ICC of 0.736 (Table 4.9).

Table 4.9: Reliability results while the affected leg is at the mid stance phase during maximum walking speed

Variables (maximum speed)	ICC (Agreement)	ICC (Consistency)	Pearson's r	P
Hemi hip	0.890(0.568;0.977)	0.883(0.525;0.975)	0.9173	0.001
Sound hip	0.938(0.722;0.987)	0.930(0.693;0.986)	0.9326	<0.001
Hemi knee	0.950(0.773;0.990)	0.944(0.748;0.989)	0.9472	<0.001
Sound knee	0.963(0.784;0.993)	0.973(0.874;0.995)	0.9755	<0.001
Hemi ankle	0.894(0.598;0.977)	0.896(0.570;0.978)	0.8985	0.002
Sound ankle	0.736(0.146;0.941)	0.796(0.277;0.956)	0.7972	0.018
Lateral Pelvic tilt	0.898(0.518;0.979)	0.925(0.672;0.984)	0.9245	0.001

4.2.4.3 Terminal stance

During the terminal stance of the hemi leg, the highest discrepancy between the two measurements was seen while measuring the hemi knee angles, with an ICC of 0.736, indicating moderate reliability. The Moven demonstrated excellent reliability in measuring all other joints angles in both legs with ICCs ranging between 0.794 and 0.953 (Table 4.10).

Table 4.10: Reliability results while the affected leg is at the terminal stance phase during maximum walking speed

Variables (maximum speed)	ICC (Agreement)	ICC (Consistency)	Pearson's r	P
Hemi hip	0.891(0.541;0.977)	0.877(0.507;0.974)	0.878	0.004
Sound hip	0.917(0.659;0.983)	0.928(0.684;0.985)	0.931	<0.001
Hemi knee	0.736(0.167;0.940)	0.728(0.120;0.939)	0.731	0.039
Sound knee	0.924(0.691;0.984)	0.920(0.657;0.984)	0.923	0.001
Hemi ankle	0.857(0.434;0.970)	0.841(0.398;0.966)	0.841	0.009
Sound ankle	0.794(0.157;0.957)	0.865(0.469;0.971)	0.869	0.005
Lateral Pelvic tilt	0.953(0.789;0.990)	0.959(0.810;0.992)	0.977	<0.001

4.2.4.4 Mid Swing

During the mid swing phase of walking of the hemi leg, there was excellent reliability in recording the measurements of all joints' angles as well as lateral pelvic tilt, with ICCs ranging between 0.815, and 0.959 (Table 4.11).

Table 4.11: Reliability results while the affected leg is at the mid swing phase during maximum walking speed

Variables (maximum speed)	ICC (Agreement)	ICC (Consistency)	Pearson's r	<u>P</u>
Hemi hip	0.932(0.701;0.986)	0.924(0.670;0.984)	0.928	<0.001
Sound hip	0.878(0.536;0.974)	0.873(0.494;0.973)	0.889	0.003
Hemi knee	0.959(0.811;0.992)	0.954(0.790;0.991)	0.961	<0.001
Sound knee	0.946(0.717;0.989)	0.960(0.814;0.992)	0.961	<0.001
Hemi ankle	0.815(0.303;0.960)	0.795(0.273;0.955)	0.836	0.009
Sound ankle	0.862(0.476;0.970)	0.882(0.523;0.975)	0.887	0.003
Lateral Pelvic tilt	0.916(0.655;0.982)	0.910(0.618;0.981)	0.912	0.001

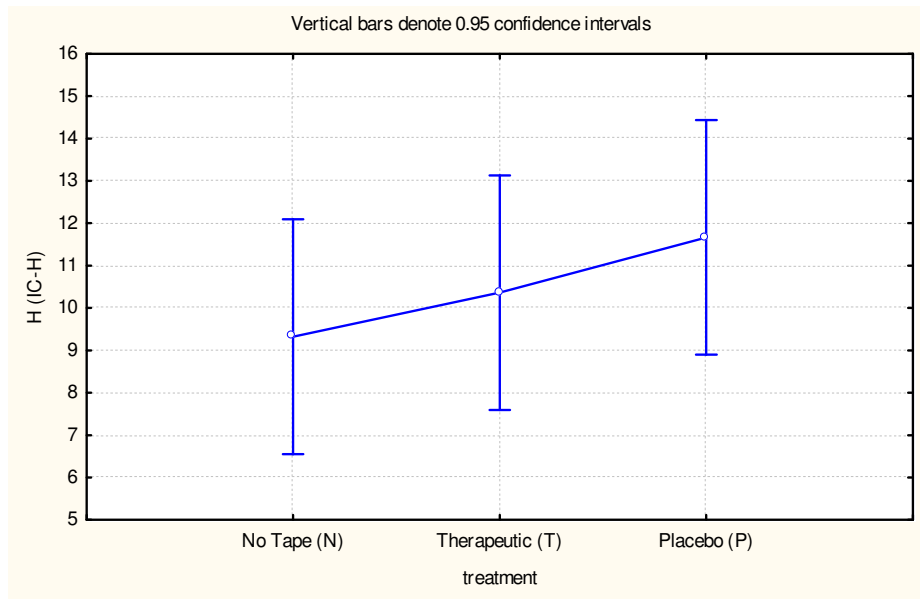
4.3 PHASE 2

In this section the results of the effect of gluteal taping on gait in ambulant adults with stroke are reported. The means of all the measurements of the lateral pelvic tilt kinematic parameters in the sagittal plane of the hip, knee, and ankle were compared during three conditions: with no tape, with therapeutic tape, and with placebo tape. Flexion/extension angles of the hip, knee and ankle of the hemi leg were measured under the three conditions during four phases of walking; initial contact, mid stance, terminal stance and mid swing. The effects of gluteal taping on temporal spatial parameters including, step length, cadence and velocity, are also reported.

4.3.1 Kinematic parameters

4.3.1.1 *At initial contact*

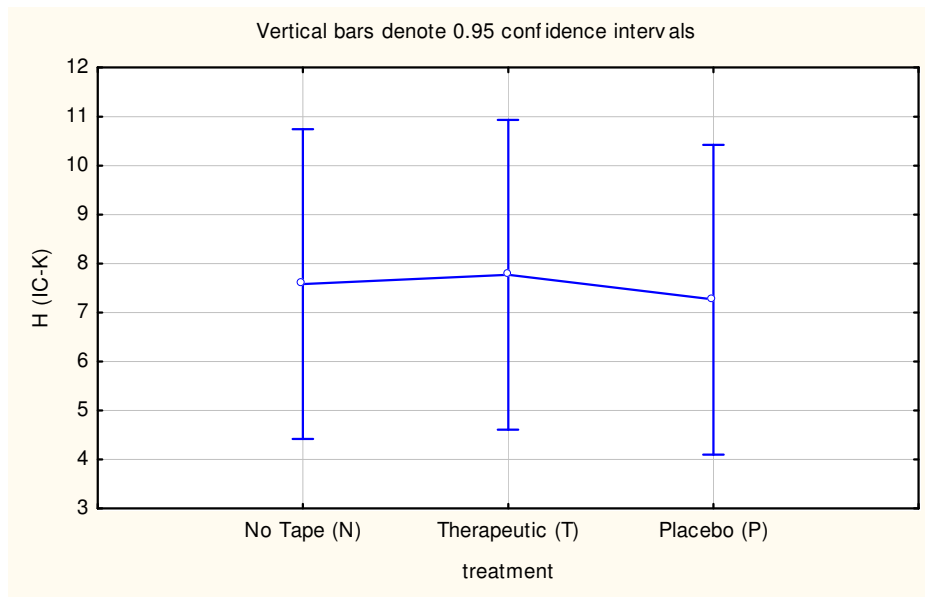
There was a trend toward increased hip flexion after the application of the therapeutic tape (T). Hip flexion increased more with the application of the placebo tape (P); however, there was no significant difference between the three conditions ($p=0.051$) (Figure 4.1)



H: Hemi side. (IC-H): (Initial contact – hip)

Figure 4.1: Hemi hip at initial contact

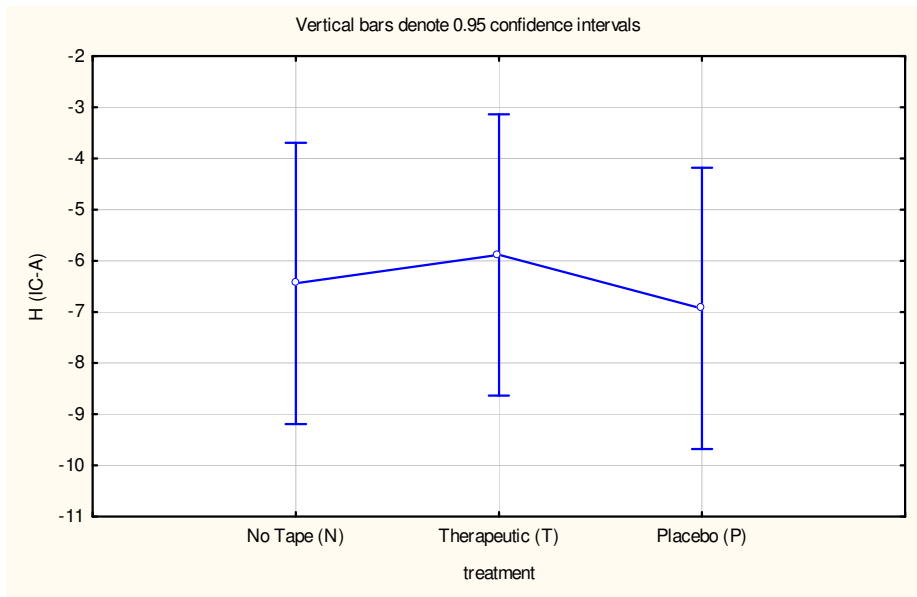
Neither the therapeutic tape nor the placebo tape caused a change to the knee angle at the initial contact ($p=0.78$) (Figure 4.2).



H: Hemi side. (IC-K): (Initial contact – knee)

Figure 4.2: Hemi knee at initial contact

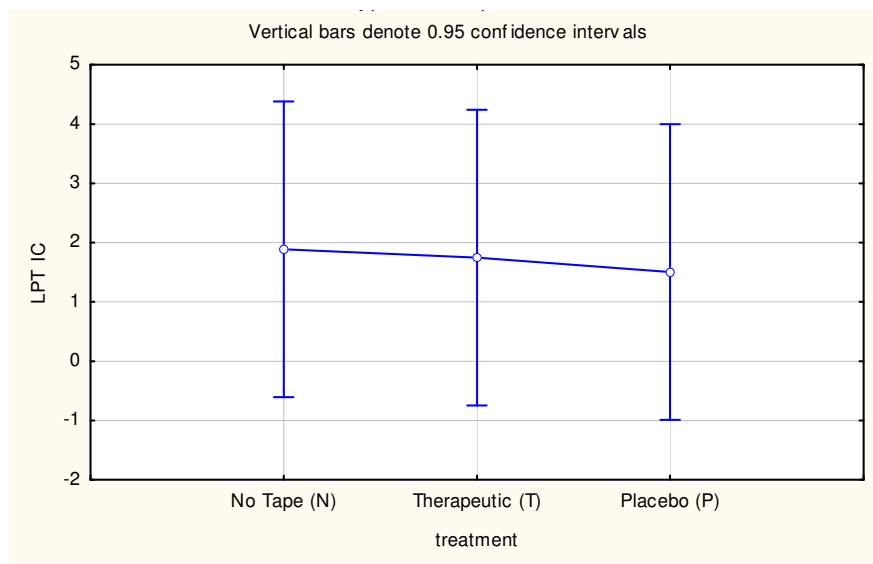
There were no significant changes in the affected ankle sagittal kinematics at the initial contact phase of walking after the application of any of the taping conditions. ($p=0.326$) (Figure 4.3)



H: Hemi side. (IC-A): (Initial contact – ankle)

Figure 4.3: Hemi Ankle at initial contact

The lateral pelvic tilt was not significantly influenced with the taping. The mean values show a trend toward more leveling, but the changes were negligible ($p=0.69$) (Figure 4.4).

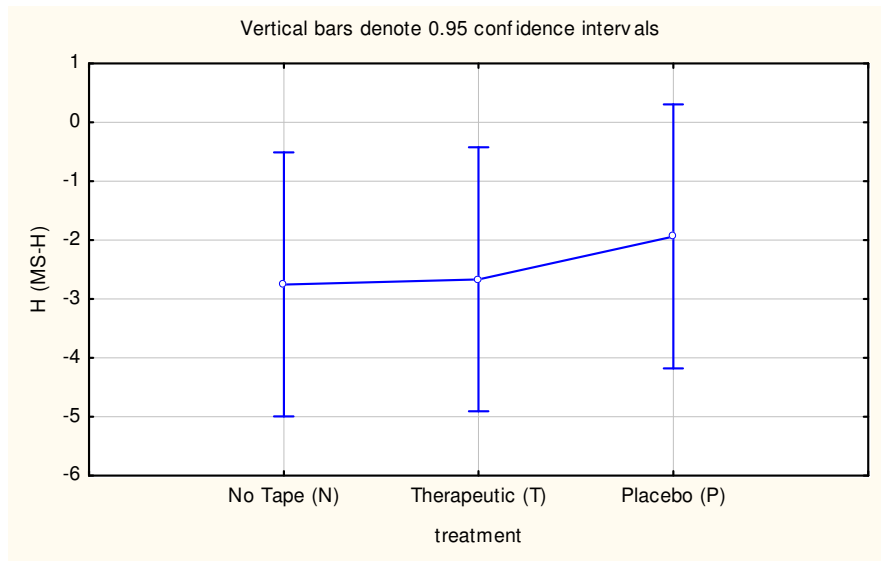


LPT IC: Lateral Pelvic tilt – Initial contact

Figure 4.4: Lateral pelvic tilt at initial contact

4.3.1.2 At mid stance

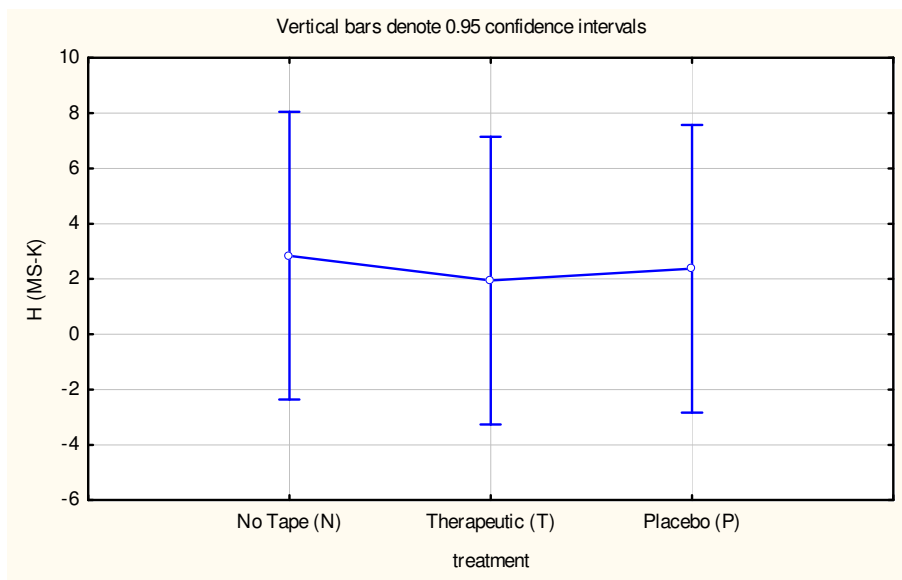
Therapeutic taping made no change to the hip angle at the mid stance of walking at self-selected speed after the application of both the therapeutic and placebo tapes (Figure 4.5).



H: Hemi side. (MS-H): (Mid stance – hip)

Figure 4.5: Hemi hip at mid stance

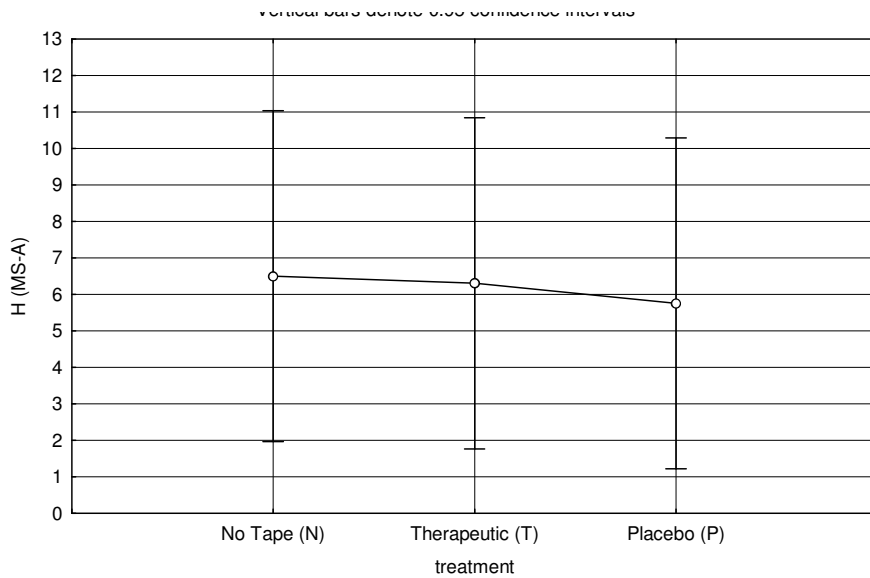
There were no significant differences in the knee angle measurements after the application of the therapeutic and placebo tape. The tape caused a slight reduction of about one degree in knee flexion ($p=0.587$) (Figure 4.6).



H: Hemi side. (MS-K): (Mid stance – knee)

Figure 4.6: Hemi knee at mid stance

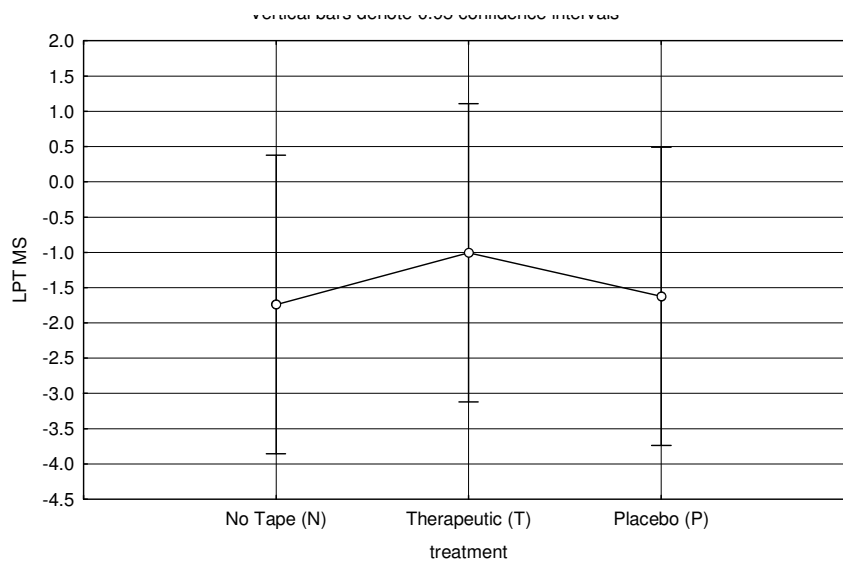
Neither of the two tapes caused significant changes to the ankle's angle at mid stance ($p=0.35$) (Figure 4.7).



H: Hemi side. (MS-A): (Mid stance – ankle)

Figure 4.7: Hemi ankle at mid stance

Both taping methods showed the similar trend toward more pelvis levelling, however, the change was not significant ($p=0.35$).

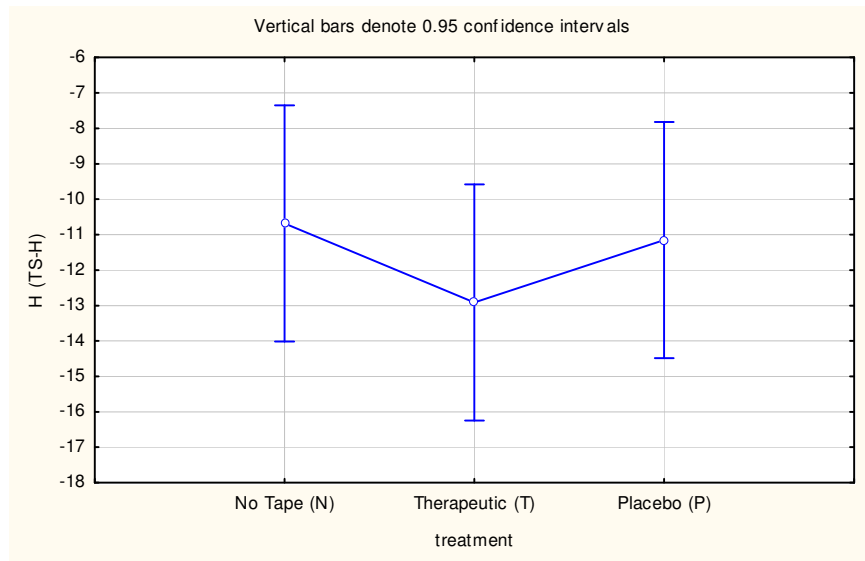


LPT MS: Lateral Pelvic tilt – Mid Stance

Figure 4.8: Lateral pelvic tilt at mid stance

4.3.1.3 At terminal stance

The therapeutic tape resulted in a significant increase in hip extension compared to the no tape condition ($p=0.01$) and placebo tape ($p=0.04$). There was no significant difference between the placebo tape, and the no tape conditions ($p=0.87$) (Figure 4.9 and Table 4.12).



H: Hemi side. (TS-H): (Terminal stance – hip)

Figure 4.9: Hemi hip at terminal stance

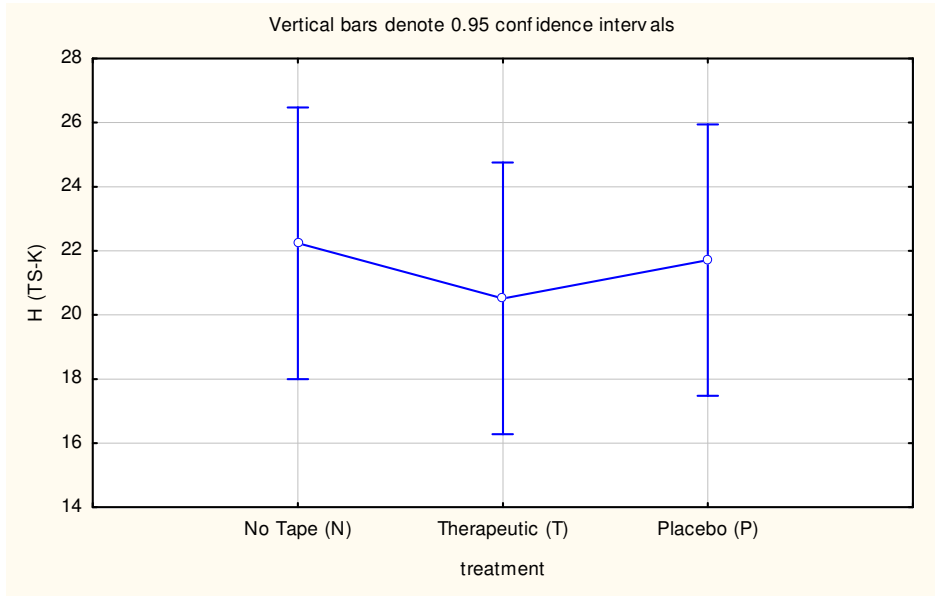
Table 4.12: Mean differences, SDs, and p values of the hip angles at terminal stance

1st Mean	2nd Mean	Mean Differ.	Standard Error	p	-95.00% Cnf.Lmt	+95.00% Cnf.Lmt
N	T	2.23130	0.866931	0.012636	0.49595	3.966651
N	P	0.47166	0.866931	0.588487	-1.26369	2.207011
T	P	-1.75964	0.866931	0.046979	-3.49499	-0.024290

The therapeutic tape significantly reduced the knee flexion at the terminal stance compared to the no tape condition ($p=0.047$); however, the reduction was not significant compared to the placebo tape ($p=0.16$) (Table 4.13 and Figure 4.10).

Table 4.13: Mean differences, SDs, and p values of the knee angles at terminal stance

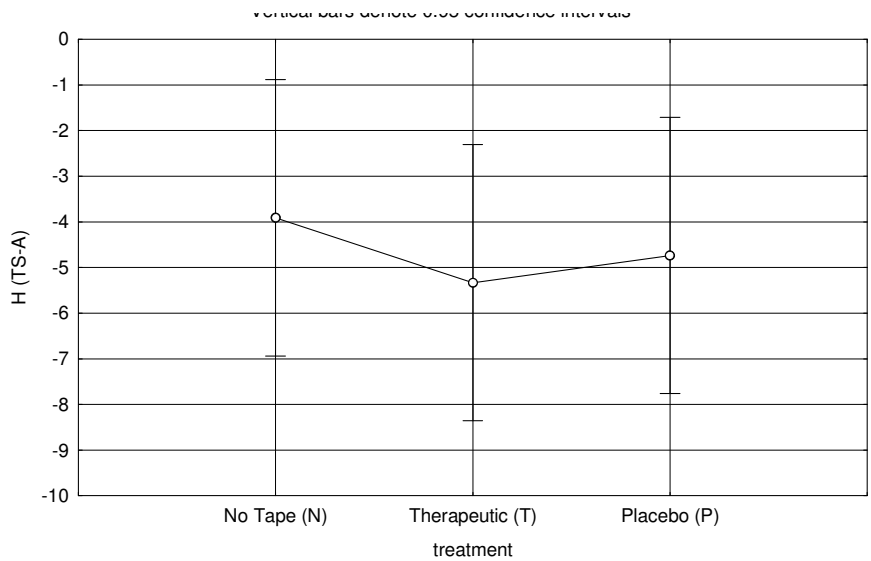
1st Mean	2nd Mean	Mean Differ.	Standard Error	p	-95.00% Cnf.Lmt	+95.00% Cnf.Lmt
N	T	1.72394	0.851681	0.047567	0.01912	3.428769
N	P	0.52967	0.851681	0.536439	-1.17516	2.234494
T	P	-1.19428	0.851681	0.166168	-2.89910	0.510549



H: Hemi side. (TS-K): (Terminal stance – knee)

Figure 4.10: Hemi knee at terminal stance

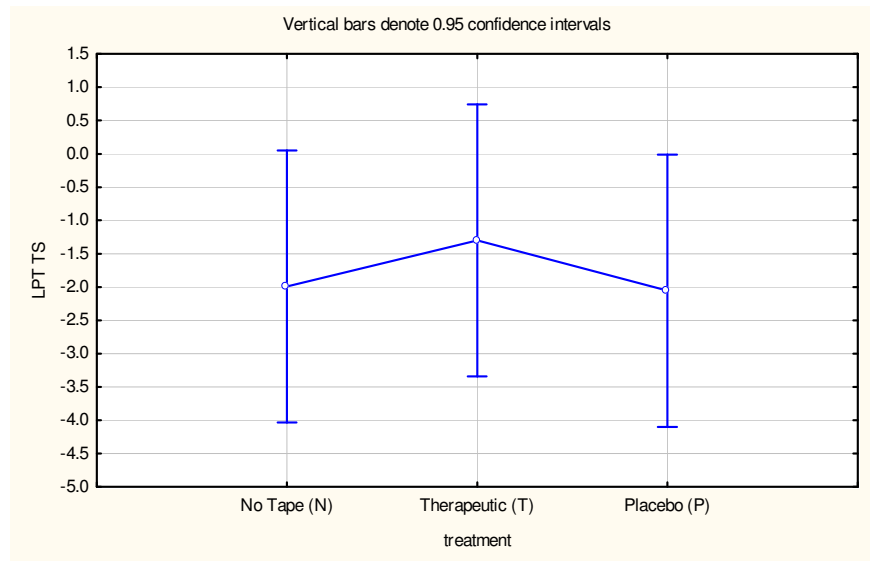
Therapeutic taping showed a trend towards increased plantar flexion at the terminal stance phase of walking compared to both the no tape and the placebo tape conditions. However, the reduction was not significant ($p=0.66$) (Figure 4.11).



H: Hemi side. (TS-A): (Terminal stance – ankle)

Figure 4.11: Hemi ankle at terminal stance

There was a trend toward more leveling of the pelvis through reducing the lateral pelvic tilt with the use of the therapeutic tape, however, the reduction was not significant. ($p=0.69$) (Figure 4.12)

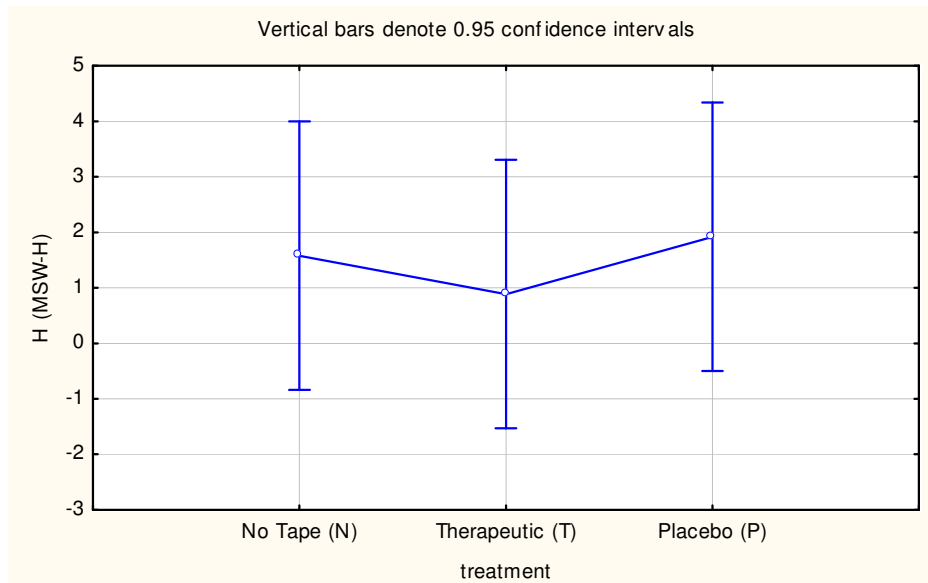


LPT TS: Lateral pelvic tilt – Terminal stance

Figure 4.12: Lateral pelvic tilt at terminal stance

4.3.1.4 At mid swing

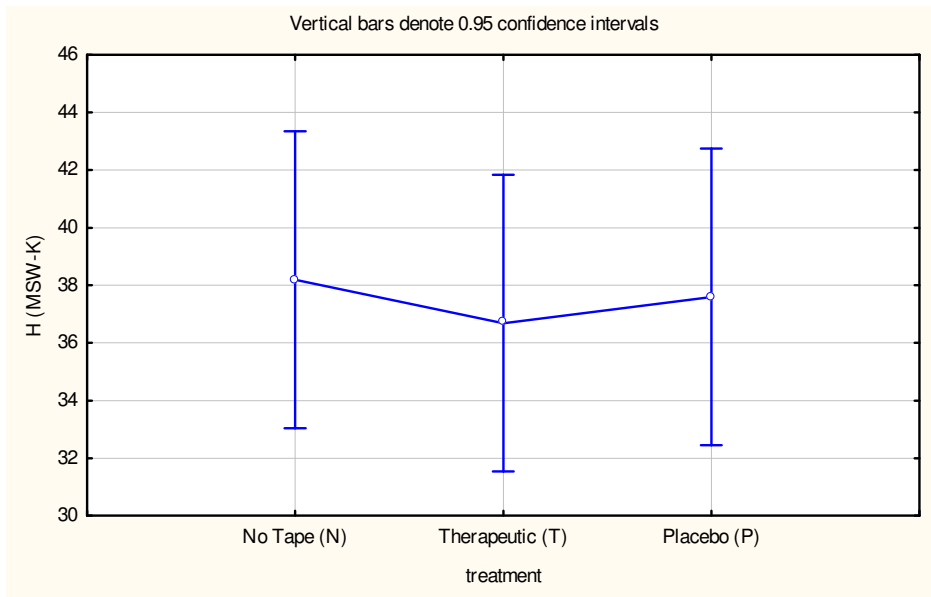
The therapeutic tape showed a trend toward a slight insignificant reduction in hip flexion compared to placebo, and the no tape conditions.



H: Hemi side. (MSW-H): (Mid swing – hip)

Figure 4.13: Hemi hip at mid swing

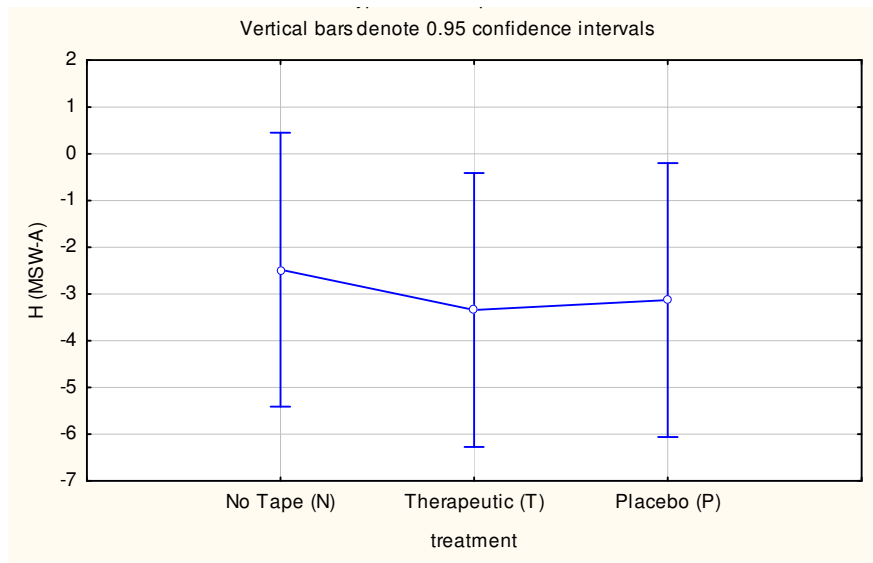
There was no significant change in the angle of the knee during the mid swing phase of walking after the application of the two taping methods ($p=0.3$) (Figure 4.13)



H: Hemi side. (MSW-K): (Mid swing – knee)

Figure 4.14: Hemi knee at mid swing

There was no significant changes in the hemi ankle during the mid swing phase of walking after the application of both therapeutic and placebo tape (Figure 4.14)



H: Hemi side. (MSW-A): (Mid swing – ankle)

Figure 4.15: Hemi ankle angle at mid swing

The therapeutic tape caused more leveling in the pelvis during the mid swing phase of walking as well, however, the change was not significant. (p=0.51) (Figure 4.15)

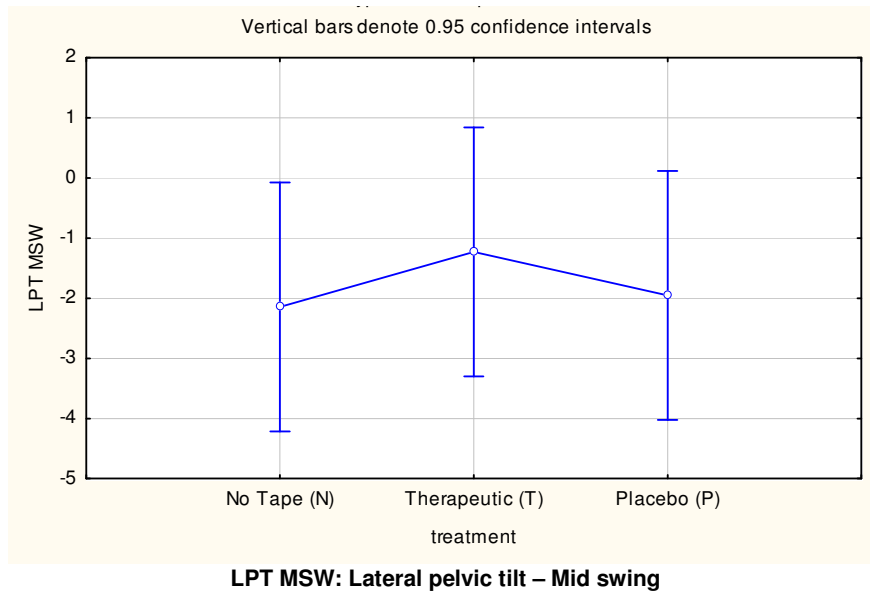


Figure 4.16: Lateral pelvic tilt at mid swing

All sagittal kinematic parameters in the unaffected leg remained the same, and no significant changes were noticed (Appendix 7)

4.3.2 Temporal spatial parameters

Both the therapeutic and placebo tape showed an increase in the step length on the hemi side; however the increase was not significant ($p=0.1$). The therapeutic tape resulted in the same changes for step length as with placebo tape (Figure 4.16).

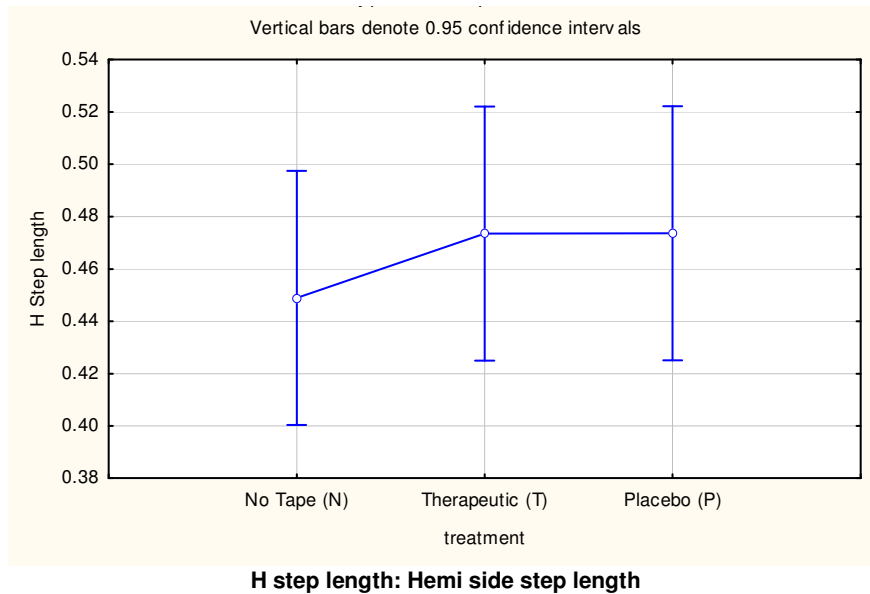


Figure 4.17: Effect of taping on the unaffected leg step length

Both tapes caused an increase in the step length in the unaffected step length as well, however the increase was not significant. ($p=0.15$) (Figure 4.17)

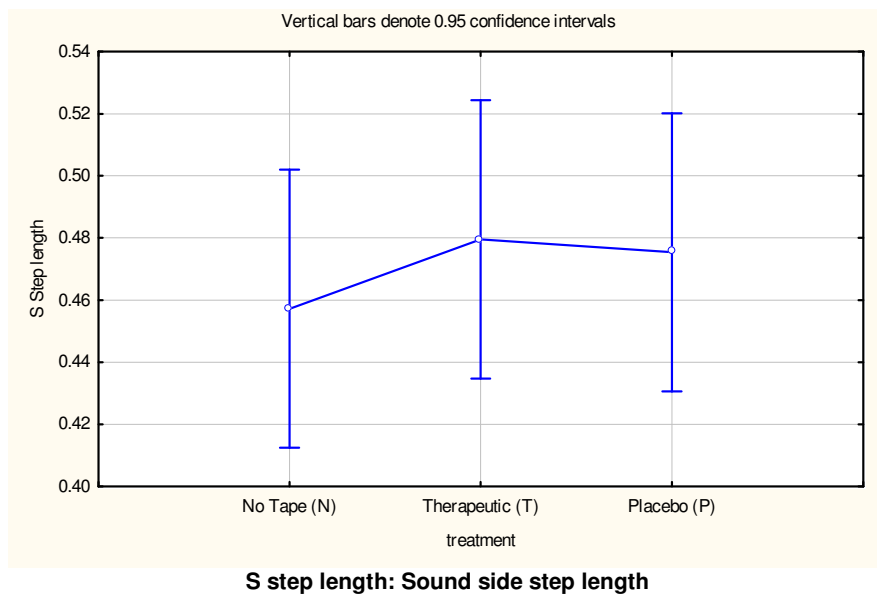


Figure 4.18: Effect of taping on the unaffected leg step length

There was a significant increase in cadence shown with both therapeutic and placebo tape conditions ($p<0.001$). There was no significant difference between therapeutic tape and placebo tape conditions (Figure 4.18 & Table 4.14)

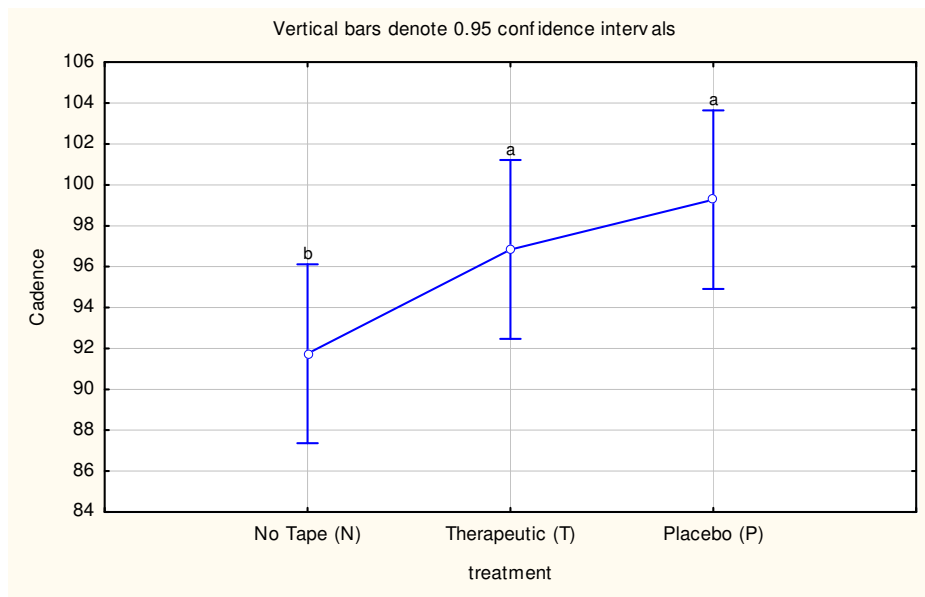


Figure 4.19: Effect of taping on cadence

Table 4.14: Effect of taping on cadence

1st Mean	2nd Mean	Mean Differ.	Standard Error	p	-95.00% Cnf.Lmt	+95.00% Cnf.Lmt
N	T	-5.09915	1.726010	0.004522	-8.5541	-1.64417
N	P	-7.53254	1.726010	0.000053	-10.9875	-4.07755
T	P	-2.43338	1.726010	0.163929	-5.8884	1.02160

There was a significant increase in the step velocity seen during both taped conditions. There was however no significant difference between the therapeutic and placebo tape conditions (Table 4.16 and Figure 4.21).

Table 4.15: Effect of taping on velocity

1st Mean	2nd Mean	Mean Differ.	Standard Error	p	-95.00% Cnf.Lmt	+95.00% Cnf.Lmt
N	T	-0.073868	0.023267	0.002401	-0.120443	-0.027294
N	P	-0.080928	0.023267	0.000964	-0.127503	-0.034354
T	P	-0.007060	0.023267	0.762651	-0.053635	0.039515

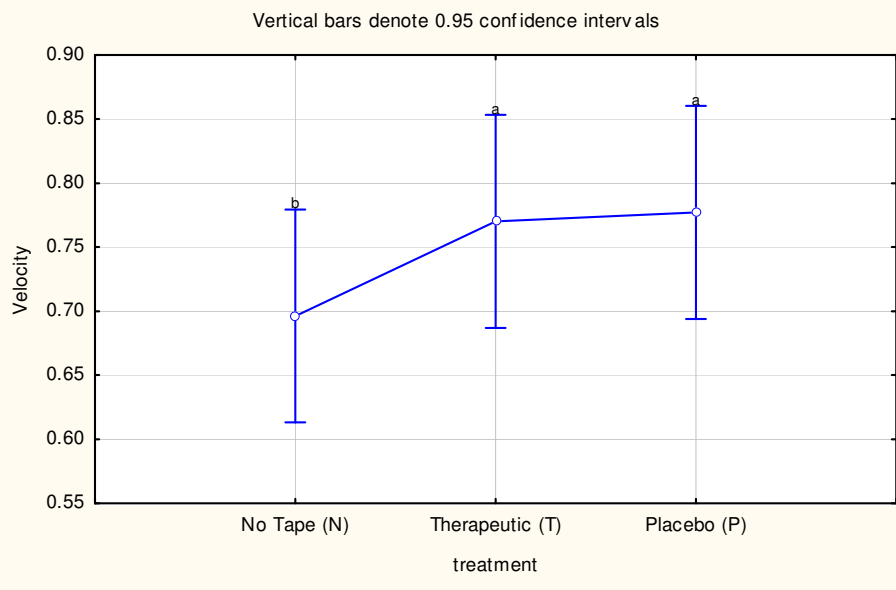


Figure 4.20: Effect of taping on velocity

CHAPTER 5. DISCUSSION

In this chapter the results of the preliminary study (phase one) and the taping study (phase 2) are discussed.

Walking has been identified as one of the most important elements in the Activities and Participation in the International Classification of Function, ICF (Geyh, Cieza, Schouten, & Dickson *et al* 2004). Optimizing recovery of motor skills and gait performance is therefore a major aim in stroke rehabilitation (Richards, Malouin & Dean 1999).

Evaluation of recovery and gait performance has been extensively studied in the literature using different gait analysis systems and methods (Milot, Nadeau & Gravel 2006; Chen, Chen & Tang 2003; Lamontagne, Richards, & Malouin 2000; Gaviria, D'Angeli, Chavet 1996). The Moven System uses an advanced technology that enables clients to be tested in their own environment. It is easy to set up, and it can be used as a live feedback for the client's performance.

5.1 PHASE ONE

In this study the test-retest reliability of the Moven system in measuring the sagittal kinematic data of the lower limbs, lateral pelvic tilt, step length, cadence, and speed in ambulant adults with stroke, was examined during walking at self selected speed, and maximum speed. This is the first known study to investigate the reliability of the Moven system to analyze the gait of people post stroke.

The assessment of reliability is a broad concept. Over the last decade the analysis has developed from using standard correlation coefficients to more comprehensive sets of statistical methods (Stratford & Goldsmith 1997). Even though there is no solid conclusion as to which statistical method is the best to be used, it is recommended that the analysis should include the agreement between measurements, as well as systematic changes in the mean and measurement errors (Atkinson & Nevill 1998; Bland & Altman 1999; Hopkins 2000; Rankin & Stokes 1998). In this study, the Pearson correlation coefficient as well as the intra-class correlation coefficient (ICC) was used to assess the agreement and the consistency between the two trials.

This study revealed an acceptable test-retest reliability of temporal spatial parameters, sagittal kinematic parameters, and lateral pelvic tilt at both self selected and maximum walking speed in people with stroke by this relatively new Moven system.

Moderate to excellent agreement was found for all measurements with ICCs ranging between 0.484 to 0.977 indicating moderate to excellent reliability (Salter, Jutai, Teasell 2005).

To insure the resting periods were adequate and did not potentially contribute to the outcome, extra five minutes from the moment the subject reported readiness to stand up and walk was included. It is thus unlikely that exertion and fatigue bias could have influenced the findings of the study. The discrepancy noticed between some of the measurements may thus be attributed to intra-subject variability for those particular measures during different phases of walking in subject performance. This explanation can be illustrated by the few outliers seen where the ICC was low in some of the trials (Appendix 8). The lack of consistency in the ICC findings noticed sometimes between fast and normal walking trials for the same phase of walking and the same joint, could also be due to intra-subject variability. Despite the excellent repeatability noticed for most of the gait parameters assessed, there were wide confidence intervals (CI) in most of the assessed gait parameters (Chapter 4). The wide CI's indicate that the use of two consecutive measurements to interpret a change in an individual patient may not be sensitive enough to monitor progress, since the CIs take into account the random and systematic errors (Oken, Yavuzer, Ergocen, Yorgancioglu & Stam 2008). Yavuzer *et al* (2008) suggested some strategies to decrease systematic error sources. The authors suggest increasing data collection per measurements, using serial measurements on each patient, or using less rigorous CIs (Hill, Goldie, Baker & Greenwood 1994). In the current study, it was not possible to increase the data collection per measurement since subjects with stroke have limited endurance. In our case, subjects who were recruited in this study were part of the main study where they still had to walk under different taping conditions. Another factor that might have influenced the reliability was the small sample size of only eight subjects. It has been recommended that the sample size of test-retest reliability studies should be at least 30, and preferably 50 (Hopkins 2000 & Donnar, Eliasziw 1987).

Furthermore the protocol was standardized as much as possible through providing the same commands, and using the same testing environment. Thus with all conditions as stable as possible, any discrepancy between the two testing trials in the current study is taken to represent mainly the variability in the intra-subjects measurement parameters.

5.2 PHASE 2

The purpose of this second phase of the study was to further investigate the effects of gluteal taping on various gait parameters in ambulant adults with hemiplegia. The effect of gluteal taping, placebo taping and no tape was therefore examined the selected four phases of walking (initial contact, mid stance, terminal stance, and at mid swing). Sagittal kinematic parameters of the lower limbs, lateral pelvic tilt, as well as the temporal-spatial parameters were studied. This is the first known study to use the Moven system to investigate the effects of gluteal taping on hemiparetic gait.

5.2.1 Kinematic parameters

5.2.1.1 Effect of taping at initial contact

Hip flexion angle at the initial contact increased with the application of both taping methods (therapeutic and placebo conditions). No changes were found for any of the taping or no taping conditions for the knee and the ankle angle measures or for the pelvic lateral tilt. The increased hip flexion angle noted following both taping methods in the current study however might not have a clinical significance as it has been reported that patients with hemiplegia may exhibit hip motions that range from not being significantly different from normal people, to having reduced hip flexion at initial contact (Richards & Knutsson 1974), or even more hip flexion at initial contact (Lehmann, Condon, Price & deLateur 1987; Burdette, Borello-France, Blatchly & Potter 1988; Pinzur, Sherman, DiMonte-Levine, Trimble 1987). Hip flexion increased more with the placebo tape as compared to the therapeutic tape. There was however no significant difference between the effects of the two taping methods. This variation in range of hip flexion angle in this population is probably due to the level of severity and impairments of these subjects (Olney and Richards 1996). Future research might be needed to investigate the effect of gluteal taping on patients with reduced hip flexion at initial contact, and patients with increased hip flexion at initial contact.

5.2.1.2 Effect of taping at mid stance

No significant changes were noticed in the affected hip, knee, ankle, and lateral pelvic tilt angles during any of the three testing conditions. This is probably related to the lack of consistent gait differences between people with hemiplegia and normal population in the kinematic measurements during the mid stance phase of walking (Olney, Colborne, & Martin 1989; Trueblood, Walker, Perry, Gronley 1989; Richards *et al* 1974; Pinzur *et al* 1987). Chen *et al* (2005) identified a long list of consistent differences between people with hemiplegia, and control subjects at matched speed. No consistent kinematic differences during the mid stance phase of walking were identified.

5.2.1.3 *Effect of taping at terminal stance*

Significant increase was noticed at the terminal stance phase of walking in hip extension. These findings were also reported by Kilbreath *et al* (2006) who reported significant hip extension after the application of gluteal taping. The increased hip extension after the application of the therapeutic tape was associated with a significant reduction in knee flexion, and a trend toward more of plantar flexion in the affected leg during the terminal stance phase of walking.

The lack of hip extension seen usually in the ambulant adults with stroke at terminal stance is not necessarily due to a muscle contracture of the hip flexors. A study by Schindler-Ivens, Desimone, Grubish, Kelley, Sanghvi & Brown (2008) reported that ambulant adults with hemiplegia with residual neuromuscular impairments had more PROM in hip extension compared to age matched able bodied subjects. Olney, Griffin, Monga, & McBride (1991) studied the sagittal kinematic parameters of the hip, knee and ankle, in three groups of subjects with hemiplegia, i.e. fast walkers, moderate walkers, and slow walkers. At the terminal stance, the hip extended about 10° in the fast walker, about 2° in the moderate walkers, and was short of neutral in the slow walkers. Knee flexion was less at the terminal stance in the fast walker compared to the slow walkers, and very much comparable to the norms of the able bodied population. In the same study, the average affected ankle profile varied slightly between the three groups, with the slowest showing about 3 degrees or less of plantar flexion in the terminal stance compared to the other two groups. Therefore, the effect that was shown due to the application of taping, and especially the therapeutic tape on the kinematic parameters during the terminal stance may have a clinical significance particularly with regard to increasing propulsion and therefore gait efficiency and velocity.

5.2.1.4 *Effect of taping at mid swing*

During the mid swing phase of walking, taping had no significant changes on the kinematic parameters of the hip, knee, and ankle of the paretic leg. However, the lateral pelvic tilt continued to show more leveling although this change was not significant. Contrary to our expectation, taping did not increase hip and knee flexion during the mid swing phase of walking. This could be probably due to the mechanical effect of taping in holding the hip in extension (Kilbreath *et al* 2006). However, this doesn't explain the increase in hip flexion noticed during the initial contact phase of walking.

5.2.2 Temporal-spatial parameters

5.2.2.1 Effect of taping on step length, cadence and velocity

Step length increased insignificantly by about 2.5 cm in the affected side, and 2.0 cm in the unaffected side after the application of both therapeutic and placebo taping methods. That was associated with a significant increase in both cadence and velocity after the application of both taping methods. The lack of significant difference between the therapeutic tape and the placebo in improving the walking speed, and cadence, suggests a proprioceptive effect.

A strong positive correlation was found in the literature between gait performance and walking speed (Kim, & Eng 2003; Baer & Smith 2001; Chen, Chen, Tang, Wu, Cheng & Hong 2003; Hsu, Tang & Jan 2003; Lin, Yang, Cheng, & Wang 2006; Kim, & Eng 2004). However, gait asymmetry was not associated with gait performance (Titianova & Tarkka 1995). Griffin, Olney & McBride (1995) reported that asymmetric variables seem to play a more important role than symmetric variables in promoting speed in subjects with hemiplegia. This might explain the improved gait velocity found in our study, without improving the asymmetry between the two step lengths. In Kilbreath's study, there was an increased step length in the unaffected side, bringing more symmetry in the gait cycle between the two step lengths, and that was not associated with increasing gait velocity or cadence. The

5.2.3 The mechanism by which gluteal taping works

Many studies have been done to understand the mechanism in which taping works (Chapter 2). One of the assumptions is that taping has a cutaneous proprioceptive effect altering the underlying muscle's activity (MacGregor, Gerlach, Mellor, & Hodges, 2005). The significant increase in hip extension in the terminal stance phase of walking compared to the no tape, and placebo taping conditions, suggests a mechanical effect, through putting the hip extensors in a shorter position, bringing the hip passively into extension. Changes in the mechanical properties of muscle can be assumed to contribute to the movements on the paretic leg (Dietz & Berger 1984). However, the increase in hip flexion noticed after the application of both tapes, and the lack of the presence of other significant differences between the therapeutic and the placebo taping during the different phases of walking, and the significant increase in walking velocity and cadence caused by the two tapes, strongly suggests a proprioceptive effect. McNutly, (1999) demonstrated that firing of cutaneous afferents through tactile stimulation influences muscle activity. The cutaneous stimulation caused by both tapes on hip extensors, as well as the mechanical effect of the rigid tape, might have influenced the activity of the hip extensors, increasing the hip flexors moment,

providing more support during the stance phase of walking (Requiao, Nadeau, Milot, Gravel, Bourbonnais & Gagnon 2005; Pandy 2003), providing selective control of the proximal lower limb, improving velocity (Chen *et al* 2003), and helping the body more in forward progression (Neptune, Zajac, & Kautz 2004). Due to the mechanical pulling effect of taping on the hip towards extension, there is a possibility that gluteal taping caused a kind of discomfort, increasing the efforts of subjects to more activate proximal muscle groups so they can counteract the restriction of free smooth movements (Ackermann B 2008).

CHAPTER 6. CONCLUSION, LIMITATIONS, AND RECOMMENDATIONS

6.1 CONCLUSION

6.1.1 Moven reliability in measuring gait of subjects with stroke

The Moven System showed moderate to excellent reliability in measuring temporal-spatial, lateral pelvic tilt and sagittal kinematic parameters in ambulant adults with hemiplegia at self selected and maximum walking speed. During walking at the subjects' normal, comfortable walking speed, the Moven showed moderate reliability while measuring the step length in the sound leg, the hemi knee at initial contact, both ankles angles at the initial contact phase of the hemi leg, the affected ankle at the mid stance phase, and while measuring the hemi hip, knee and ankle angles at the terminal stance.

During walking at the subjects' maximum speeds, the Moven demonstrated moderate reliability while measuring the sound hip and ankle at initial contact, sound ankle at mid stance, and while measuring only the affected knee at the terminal stance phase of walking.

The Moven showed excellent reliability in measuring all other sagittal kinematic parameters of the hip, knee and ankle during the selected four phases of walking. The Moven showed excellent reliability in measuring the lateral pelvic tilt at all phases of walking. Excellent reliability was noticed in measuring the cadence and the speed during the normal and fast paces of walking.

As the Moven system was shown to be reliable for test-retest over a short period of time for most temporal spatial and kinematic parameters during gait, and were used for investigating the immediate effects of gluteal taping on all sagittal kinematic parameters of the lower limbs, lateral pelvic tilt, step lengths, cadence, and velocity.

6.1.2 The effect of gluteal taping on gait performance

Our current study provides further evidence that supports gluteal taping to be an effective therapeutic strategy to improve hip extension, and gait performance. The rigid tape caused a significant increase in hip extension compared to the placebo and the no tape condition. However, both taping conditions showed a trend toward increasing hip flexion at initial contact, reducing knee flexion at terminal stance, and slightly increasing planter flexion at terminal stance. No changes were found during the mid swing phase of walking.

Both taping conditions caused an increase in the step length in both legs, and a significant increase in the walking speed and cadence suggesting improvement in gait performance. Gluteal taping should be considered as an adjunct to gait rehabilitation in the stroke population as it may impact significantly on long term gait performance.

6.2 LIMITATIONS

6.2.1 Limitations in the reliability study

- The small sample size of only eight participants might have influenced the results negatively due to intra-subject variability which was noticed in the relatively wide confidence intervals.
- Increasing the frequency of measurements was not done in the current study. This would have had an impact on the results of the main study, as all of the participants in the reliability study were part of the main study, and they generally have low endurance.
- Only the intra trial reliability was measured as only the immediate effect of gluteal taping was investigated by the current study. Inter trial reliability needs to be determined if the Moven system is to be used for detecting change over time in the same variables following intervention

6.2.2 Limitations in the taping study

- The reliability of the Moven system was studied so that we can measure the potential changes caused by taping relatively to the no taping conditions. As validity of the Moven system has not been examined in a wider population with stroke, it is difficult to describe and therefore precisely understand the changes in the behavior of each joint after the application of the tape.
- Even with the significant differences noticed with the taping applications, the wide confidence intervals indicate a lot of variations between subjects. More stringent classification of subjects or participants into groups according to their conditions severity, and gait performance is recommended.
- The Moven System is too sensitive to any electromagnetic field. Therefore, it was technically impossible to examine the effect of gluteal taping on the kinematic parameters as a match speed using a treadmill, as there would be a massive interference between the Moven, and the electromagnetic field of the treadmill.
- There was a lot of variation between participants with regards to body mass index, and this may also have contributed to the effectiveness of taping in pulling

the muscle fibers in people with a lot of adipose tissues compared to people with lower body mass index.

6.3 RECOMMENDATIONS

- The inter trial reliability as well as the validity of the Movien system in measuring kinematic and temporal spatial parameters should be evaluated in subjects with hemiplegia.
- Further research should include a larger sample of participants to measure the reliability of the Movien, as this may provide more robust information on the reliability of the system.
- Further research should be done using another movement analysis system that is not sensitive to the electromagnetic field to investigate the effectiveness of gluteal taping on different kinematic parameters at a matched speed.
- The Movien System can be used clinically to provide the clinicians and the patients with live feed back of gait performance, and to compare different gait variables between pre and post-intervention during the therapeutic session.
- Further studies need to be done to investigate the effect of gluteal taping on gait performance in sub groups of people with hemiplegia.
- Further research should be done to further explain the effect of taping, and describe the mechanism of its action on the gluteal muscles using kinetic as well as electromyographic measurement tools.
- The intermediate and long term effect of gluteal taping as an adjunct technique in gait rehabilitation should be examined.
- Clinicians should consider the application of gluteal taping during gait rehabilitation of stroke patients to achieve better walking performance.

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Appendix 1
Approval from the Ethics committee

12 September 2007
Mr W Labban
Division of Physiotherapy
Dept of Interdisciplinary Health Sciences

Dear Mr Labban

RESEARCH PROJECT "THE EFFECT OF GLUTEAL TAPING ON GAIT IN AMBULANT ADULTS WITH HEMIPLEGIA"
PROJECT NUMBER : N07/07/157

At a meeting of the Committee for Human Research that was held on 1 August 2007 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 12 September 2007 **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). Annually a number of projects may be selected randomly and subjected to an external audit.

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/pm

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Appendix 2
Permission from community health centers

Wasim Labban
Stellenbosch University

RE: Permission to conduct research

Permission is hereby granted to conduct your research. When visiting the Community Health Centres consent and co-operation must be obtained from the local manager and physiotherapist, and service delivery must not be compromised. Consent must also be obtained from each client and the clients' privacy must be respected.

Please provide the facility managers with an approval certificate from the Medical Ethics Board at your University.

Once the research is completed, please submit a report to this office.

Yours sincerely

Caroline de Wet
Chief Physiotherapist
Head Physiotherapy
MDHS

Appendix 3
Permission letter from WCRC

Subject: RESEARCH STUDY

Dear Gakeemah

I have perused the protocol and it looks fine to me.

I would just ask that Elsje act as the liaison person in respect of the practical logistics of the study.

The request from our side is also that our library be provided with a hard copy of the final research report, and that the student does a presentation of his findings to our staff on completion and evaluation of the project.

Kindly also acknowledge the WCRC in all written and oral presentations.

Sounds very impressive!!

Kind regards

Jenny

Jennifer Anne Hendry

Deputy Director

Western Cape Rehabilitation Centre

Tel: +27 21 370 2312

Fax: +27 21 370 2400

Mobile: 082 420 5692

jahendry@pgwc.gov.za

Appendix 4
Participant information leaflet and consent form

TITLE OF THE RESEARCH PROJECT: The effect of gluteal taping on gait in ambulant adults with stroke.

REFERENCE NUMBER:

PRINCIPAL INVESTIGATOR: Wasim Labban

ADDRESS: University of Stellenbosch
Faculty of Health Sciences
Division of Physiotherapy

CONTACT NUMBER: 072 4489574

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 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 Moven System is a new system that was developed to analyze body movement. The aim of this study is to measure the accuracy of the system in analyzing the walking pattern of people with stroke, and to measure the effect of buttock taping on the walking pattern of people with stroke. You will be only assessed, and will not receive any treatment or therapy other than that which you are already receiving. Testing will be done at the Western Cape Rehabilitation Centre (WCRC)/ Or at the Physiotherapy Gym at the medical school of Stellenbosch University, Cape Town.

WHAT DO YOU NEED TO DO?

Your body measurement including your height, leg length, and foot measurement will be done. Then you will be asked to put a special suit or straps on, and walk on a leveled walking track. Your walking will be recorded on video for later analysis. You need to walk without taping, and with two different methods of taping. Taping and your body measurements will be done by a physiotherapist. None of these testing procedures will cause pain.

WHY HAVE YOU BEEN INVITED TO PARTICIPATE?

You have been invited to take part in this study as you fulfill all the criteria for inclusion into this study. You are an adult with a single onset of stroke that affected half of your body and you are able to walk independently without any support.

WHAT WILL YOUR RESPONSIBILITIES BE?

You have to use your own transport from your place to the testing venue and back if needed. You will be reimbursed for your transport cost. Should public transport not be available, then transport will be provided for you and you will be requested to sign an indemnity form.

WILL YOU BENEFIT FROM TAKING PART IN THIS RESEARCH?

As the study does not involve any form of treatment, you may not benefit directly, however, knowledge gained from this study should enable therapists to make better assessment and therefore better decisions regarding your future treatment plan. Participation in this study will not cost you anything. You will not be paid to take part in this study.

ARE THERE ANY RISKS INVOLVED IN YOUR TAKING PART IN THIS RESEARCH?

No side effects or risk have been reported for any testing that you will undergo. Should you however hurt your self accidentally during testing, a physiotherapist will attend to your needs immediately.

WHO WILL HAVE ACCESS TO YOUR MEDICAL RECORDS?

None of your personal details will be made public to anyone other than the study staff, and will not be published in any form. The data of your testing will be stored and presented anonymously. All video recordings will be destroyed after the completion of the study, unless you agree to keep them for scientific presentations.

Is there any thing else that you should know or do?

You are welcome to address any question to **Wasim Labban** on 072 4489574 if you have any further queries or encounter any problems at anytime during this study. You are also welcome to contact the Committee for Human Research at 021-938 9207 if you have any concerns or complaints that have not been adequately addressed by the study staff.

You will receive a copy of this information and consent form for your own records. If you wish, you will be sent the results of the study as soon as they become available which you will be able to discuss with your physiotherapist.

Declaration by participant

By signing below, I agree to take part in a genetic research study entitled: ***The effect of gluteal taping on improving gait in ambulant adults with hemiplegia.***

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 study doctor or researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

I declare that I agree/disagree to have my photos or video recordings to be used for scientific presentations in congresses and other scientific meetings.

Signed at (*place*) on (*date*) 2007.

.....
Signature of participant

.....
Signature of witness

Declaration by investigator

I *Wasim Labban* 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*) 2007.

.....
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 Afrikaans/Xhosa.
- 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*) 2007

.....
Signature of translator

.....
Signature of witness

Appendix 5
Consent and indemnity for transport of participants

I, the undersigned, hereby consent to my transportation to the Medical School, Stellenbosch University by motor vehicle in the accompaniment of either the researcher or research assistant for the purpose of participating in the study entitled: The effect of gluteal taping on gait in ambulant adults with stroke.

I accept all financial responsibilities for all damages and/ or loss in connection with the transportation of my child (in case of an accident, theft of property from the motor vehicle or hijacking), whether the vehicle is parked at the testing venue or while on route on a public road.

SIGNATURE

WITNESS: 1.

Place:

2.

Date:

Appendix 6 Critical Appraisal Tool

Appendix

Checklist for measuring study quality

Reporting

1. *Is the hypothesis/aim/objective of the study clearly described?*

yes	1
no	0

2. *Are the main outcomes to be measured clearly described in the Introduction or Methods section?*

If the main outcomes are first mentioned in the Results section, the question should be answered no.

yes	1
no	0

3. *Are the characteristics of the patients included in the study clearly described?*

In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given.

yes	1
no	0

4. *Are the interventions of interest clearly described?*

Treatments and placebo (where relevant) that are to be compared should be clearly described.

yes	1
no	0

5. *Are the distributions of principal confounders in each group of subjects to be compared clearly described?*

A list of principal confounders is provided.

yes	2
partially	1
no	0

6. *Are the main findings of the study clearly described?*

Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions. (This question does not cover statistical tests which are considered below).

yes	1
no	0

7. *Does the study provide estimates of the random variability in the data for the main outcomes?*

In non normally distributed data the inter-quartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.

yes	1
no	0

8. *Have all important adverse events that may be a consequence of the intervention been reported?*

This should be answered yes if the study demonstrates that there was a comprehensive attempt to measure adverse events. (A list of possible adverse events is provided).

yes	1
no	0

9. *Have the characteristics of patients lost to follow-up been described?*

This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered no where a study does not report the number of patients lost to follow-up.

yes	1
no	0

10. *Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?*

yes	1
no	0

External validity

All the following criteria attempt to address the representativeness of the findings of the study and whether they may be generalised to the population from which the study subjects were derived.

11. *Were the subjects asked to participate in the study representative of the entire population from which they were recruited?*

The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant

population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.

yes	1
no	0
unable to determine	0

12. *Were those subjects who were prepared to participate representative of the entire population from which they were recruited?*

The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.

yes	1
no	0
unable to determine	0

13. *Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive?*

For the question to be answered yes the study should demonstrate that the intervention was representative of that in use in the source population. The question should be answered no if, for example, the intervention was undertaken in a specialist centre unrepresentative of the hospitals most of the source population would attend.

yes	1
no	0
unable to determine	0

Internal validity - bias

14. *Was an attempt made to blind study subjects to the intervention they have received?*

For studies where the patients would have no way of knowing which intervention they received, this should be answered yes.

yes	1
no	0
unable to determine	0

15. *Was an attempt made to blind those measuring the main outcomes of the intervention?*

yes	1
no	0
unable to determine	0

16. *If any of the results of the study were based on "data dredging", was this made clear?*

Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.

yes	1
no	0
unable to determine	0

17. *In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and outcome the same for cases and controls?*

Where follow-up was the same for all study patients the answer should be yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. Studies where differences in follow-up are ignored should be answered no.

yes	1
no	0
unable to determine	0

18. *Were the statistical tests used to assess the main outcomes appropriate?*

The statistical techniques used must be appropriate to the data. For example non-parametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.

yes	1
no	0
unable to determine	0

19. *Was compliance with the intervention's reliable?*

Where there was non compliance with the allocated treatment or where there was contamination of one group, the question should be answered no. For studies where the effect of any misclassification was likely to bias any association to the null, the question should be answered yes.

yes	1
no	0
unable to determine	0

20. *Were the main outcome measures used accurate (valid and reliable)?*

For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.

yes	1
no	0
unable to determine	0

Internal validity - confounding (selection bias)

21. Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population?

For example, patients for all comparison groups should be selected from the same hospital. The question should be answered unable to determine for cohort and case-control studies where there is no information concerning the source of patients included in the study.

yes	1
no	0
unable to determine	0

22. Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same period of time?

For a study which does not specify the time period over which patients were recruited, the question should be answered as unable to determine.

yes	1
no	0
unable to determine	0

23. Were study subjects randomised to intervention groups?

Studies which state that subjects were randomised should be answered yes except where method of randomisation would not ensure random allocation. For example alternate allocation would score no because it is predictable.

yes	1
no	0
unable to determine	0

24. Was the randomised intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable?

All non-randomised studies should be answered no. If assignment was concealed from patients but not from staff, it should be answered no.

yes	1
no	0
unable to determine	0

25. Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?

This question should be answered no for trials if: the main conclusions of the study were based on analyses of treatment rather than intention to treat; the distribution of known confounders in the different treatment groups was not described; or the distribution of known confounders differed between the treatment groups but was not taken into account in the analyses. In non-randomised studies if the effect of the main confounders was not investigated or confounding was demonstrated but no adjustment was made in the final analyses the question should be answered as no.

yes	1
no	0
unable to determine	0

26. Were losses of patients to follow-up taken into account?

If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.

yes	1
no	0
unable to determine	0

Power

27. Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5%?

Sample sizes have been calculated to detect a difference of x% and y%.

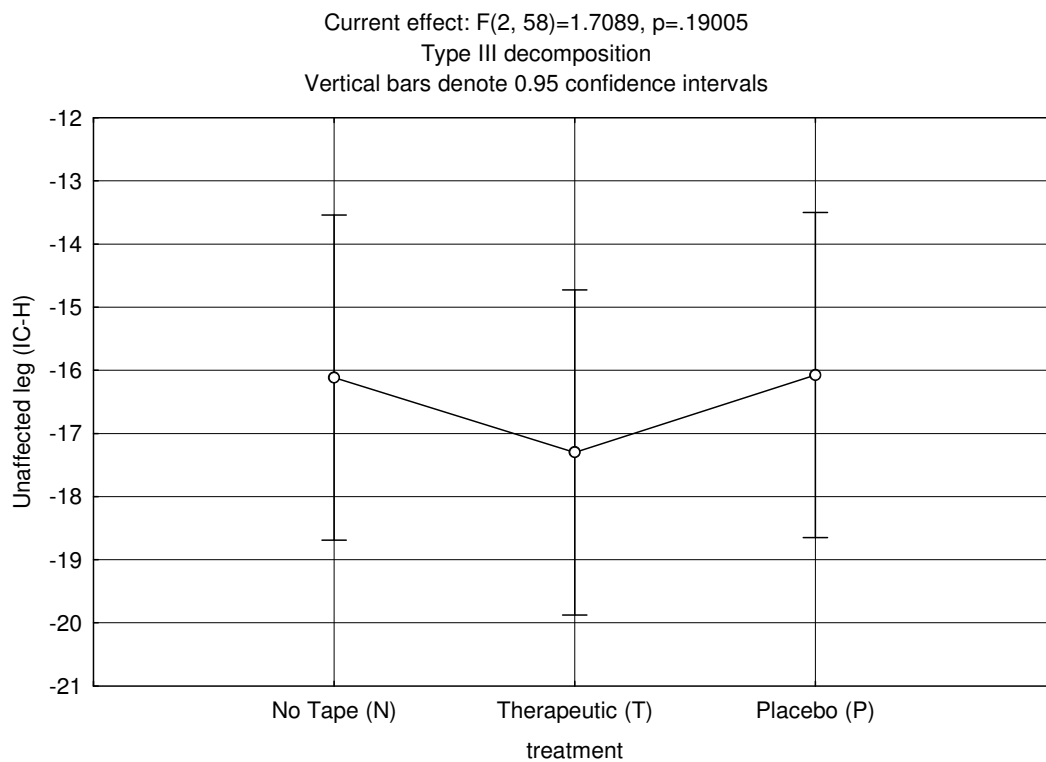
	Size of smallest intervention group	
A	<n ₁	0
B	n ₁ -n ₂	1
C	n ₁ -n ₃	2
D	n ₁ -n ₄	3
E	n ₁ -n ₅	4
F	n ₅ +	5

Appendix 7 Results of gluteal taping on the unaffected side

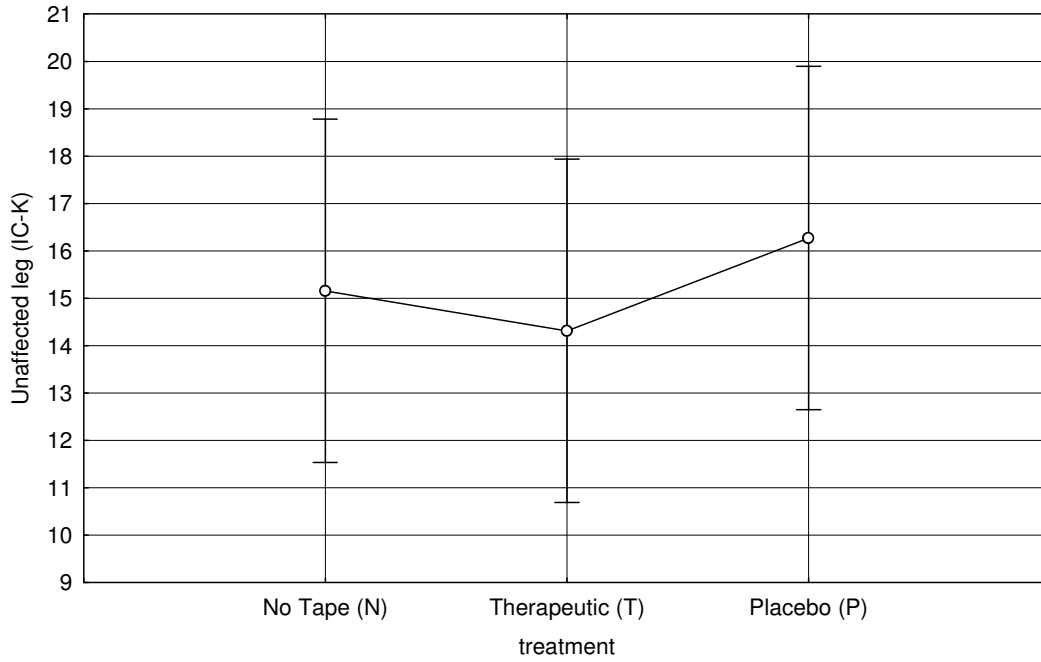
Bellow are the results of gluteal taping on the unaffected side, while the affected side is going through the four selected phases of walking; initial contact, mid stance, terminal stance, and mid swing.

Abbreviation used in the graphs:

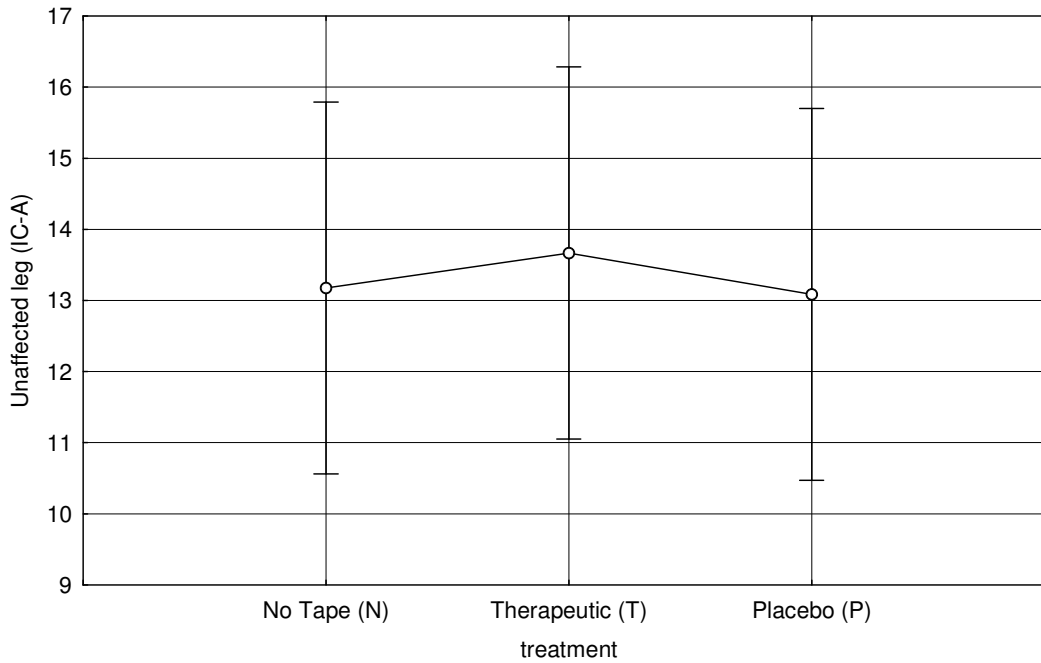
- IC : Initial contact
- MS : Mid stance
- TS : Terminal stance
- MSW : Mid swing
- H : Hip
- K : Knee
- A : Ankle



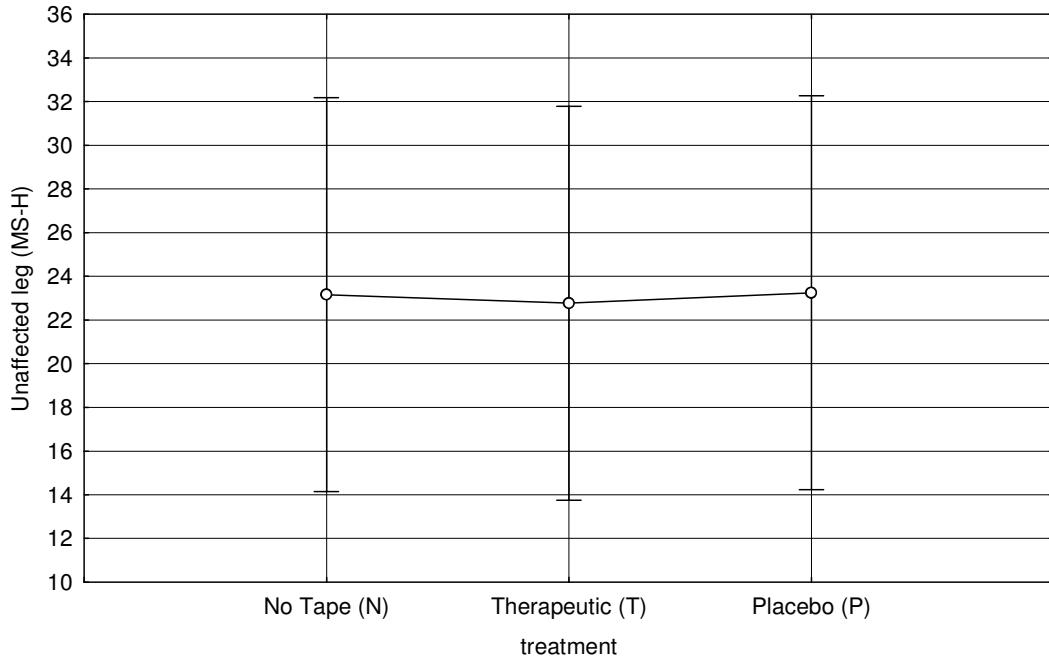
Current effect: $F(2, 58)=2.1686, p=.12352$
Type III decomposition
Vertical bars denote 0.95 confidence intervals



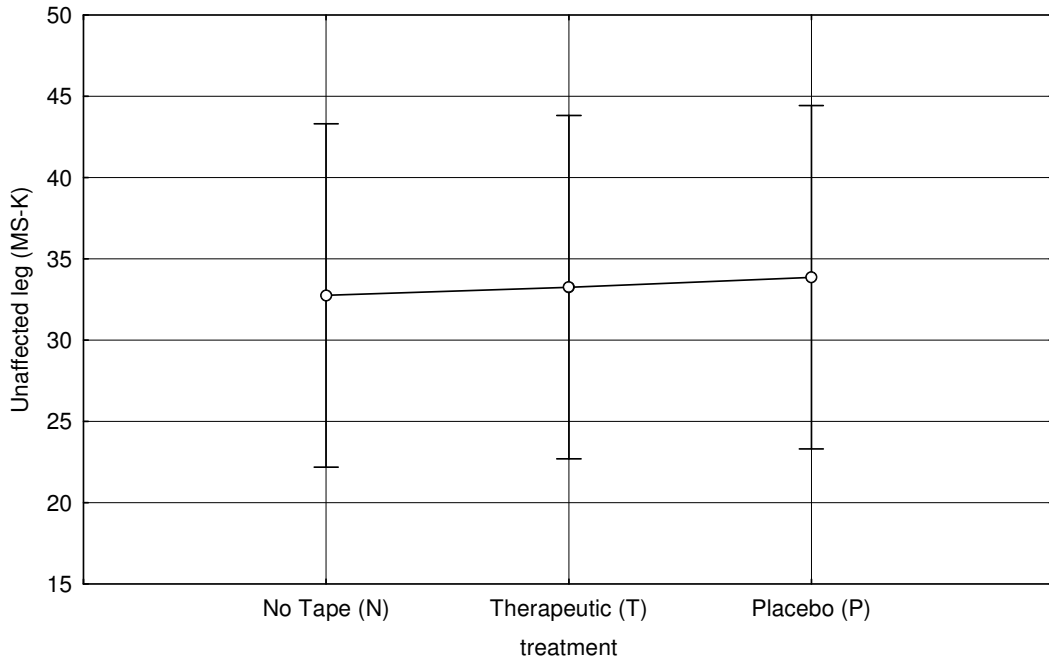
Current effect: $F(2, 58)=.21134, p=.81012$
Type III decomposition
Vertical bars denote 0.95 confidence intervals



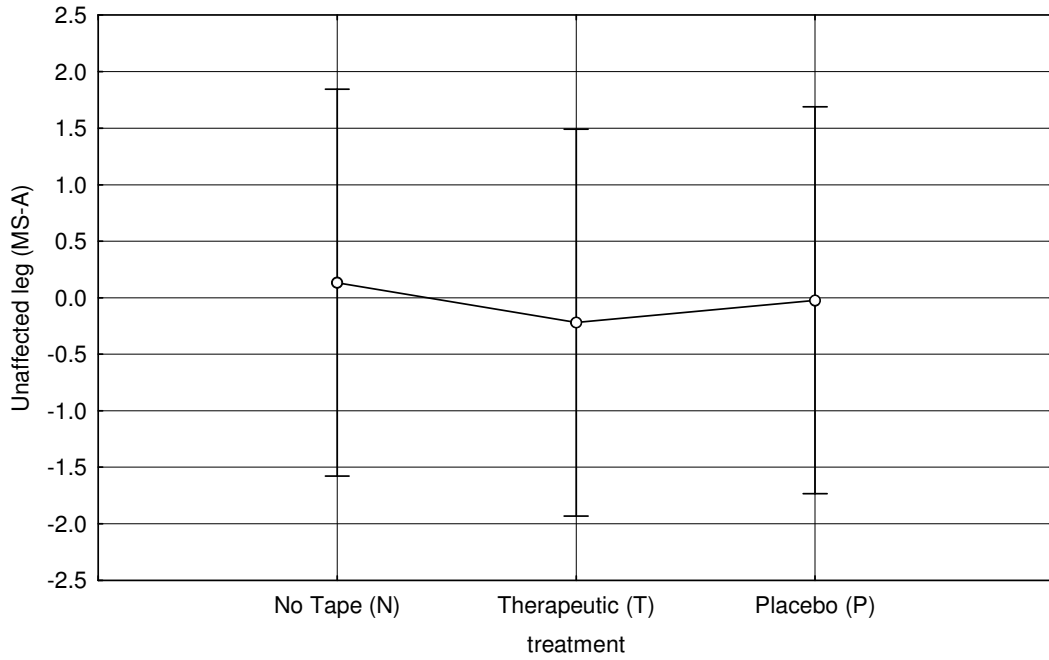
Current effect: $F(2, 58)=.21382, p=.80813$
Type III decomposition
Vertical bars denote 0.95 confidence intervals



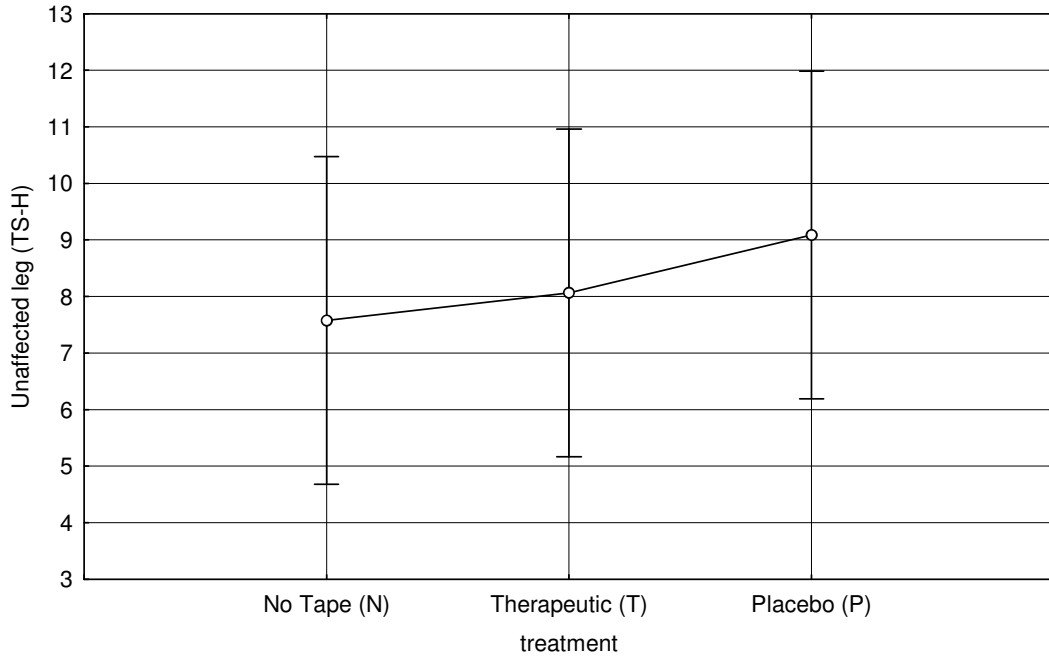
Current effect: $F(2, 58)=1.3764, p=.26060$
Type III decomposition
Vertical bars denote 0.95 confidence intervals



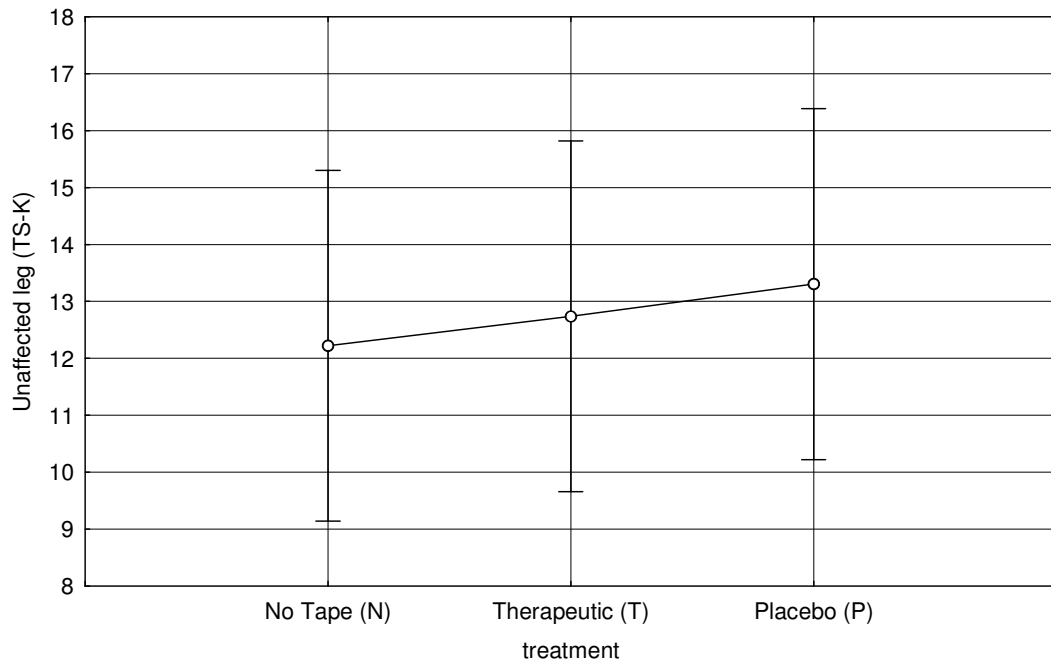
Current effect: $F(2, 58) = .13651, p = .87268$
Type III decomposition
Vertical bars denote 0.95 confidence intervals



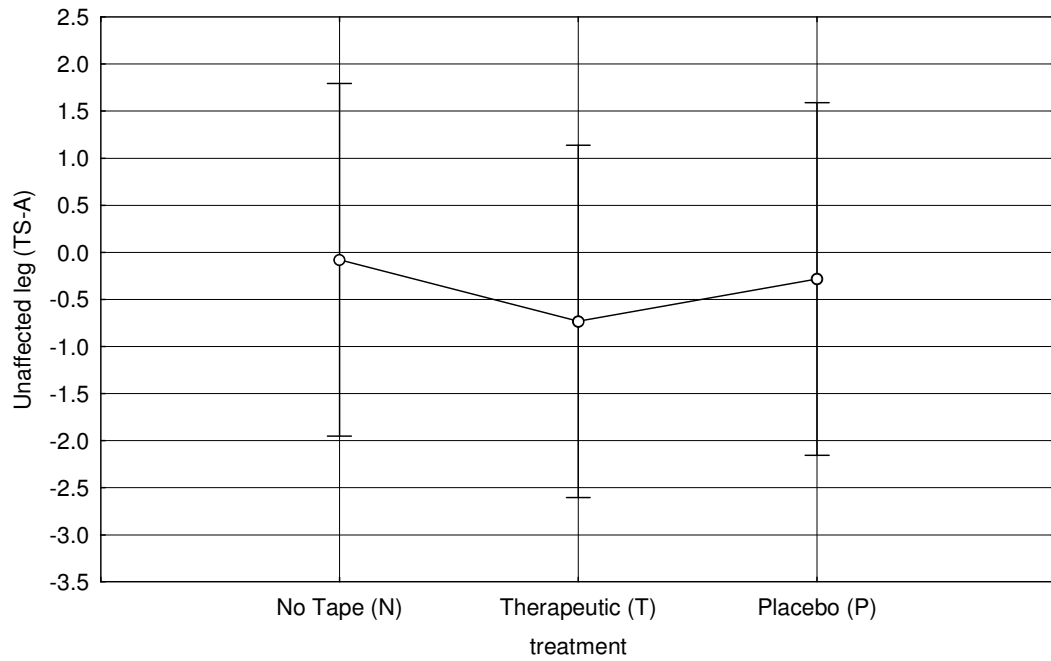
Current effect: $F(2, 58) = 1.2248, p = .30130$
Type III decomposition
Vertical bars denote 0.95 confidence intervals



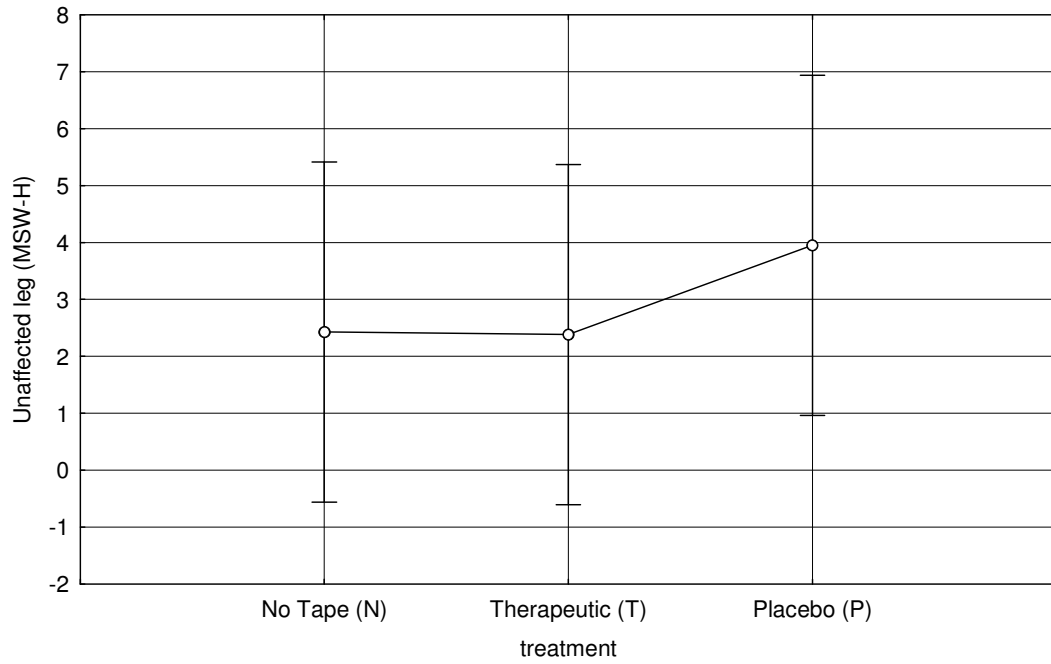
Current effect: $F(2, 58)=1.4867, p=.23461$
Type III decomposition
Vertical bars denote 0.95 confidence intervals



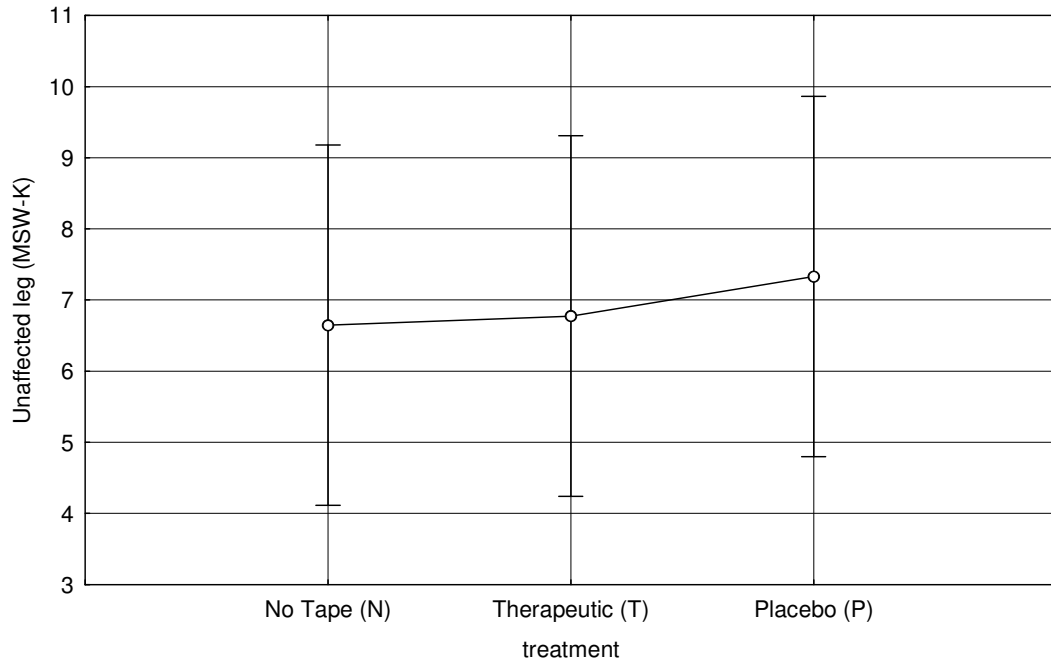
Current effect: $F(2, 58)=.70076, p=.50036$
Type III decomposition
Vertical bars denote 0.95 confidence intervals



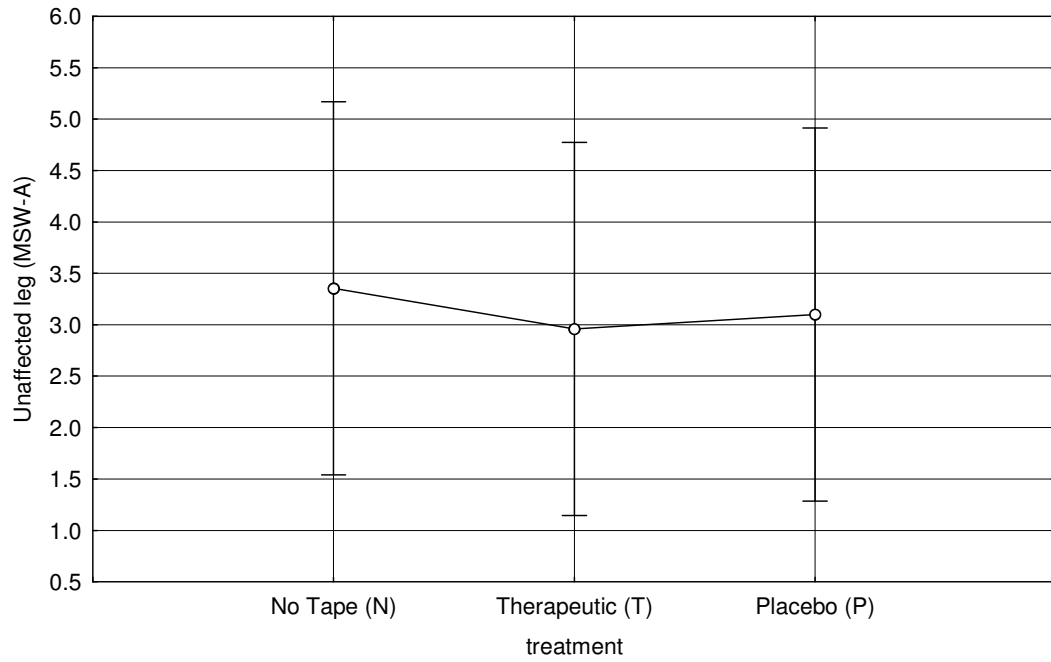
Current effect: $F(2, 58)=1.8176$, $p=.17154$
Type III decomposition
Vertical bars denote 0.95 confidence intervals



Current effect: $F(2, 58)=1.0050$, $p=.37235$
Type III decomposition
Vertical bars denote 0.95 confidence intervals



Current effect: $F(2, 58) = .33230, p = .71863$
Type III decomposition
Vertical bars denote 0.95 confidence intervals



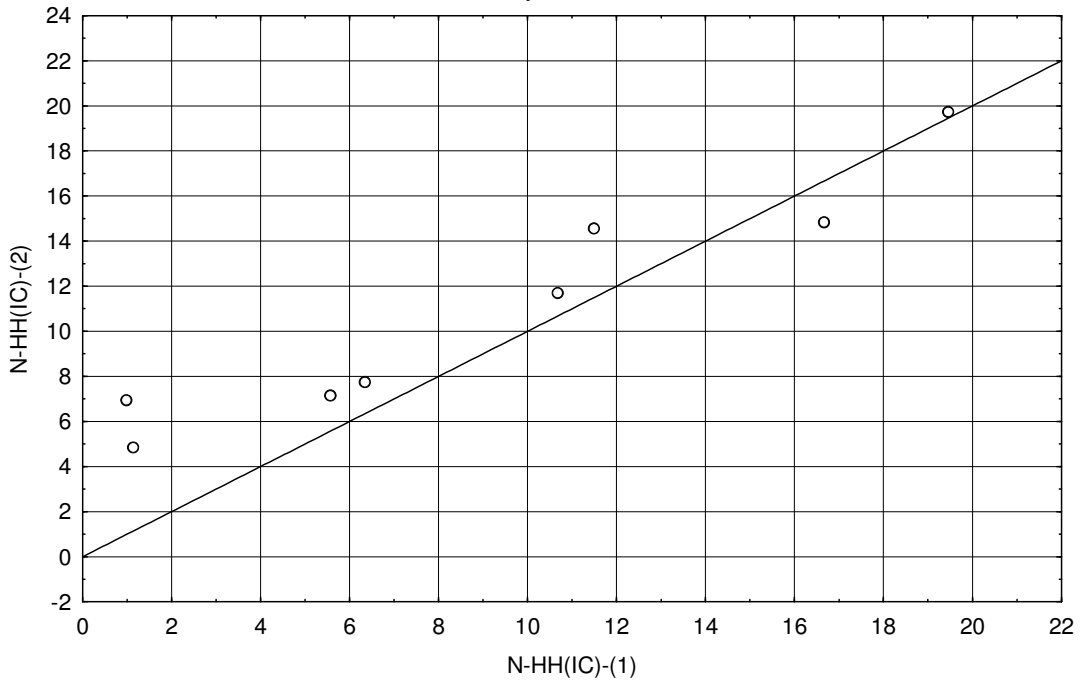
Appendix 8 Reliability Results

Normal walk and fast walk

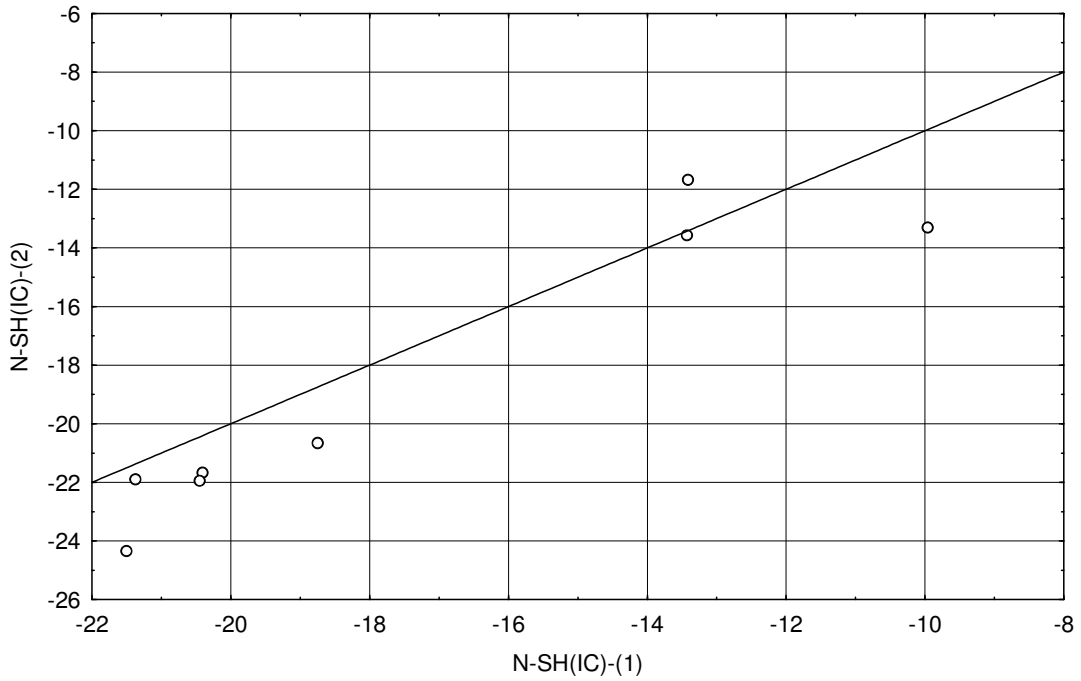
Abbreviations :

- N : Normal walk
- F : Fast walk
- HH : hemi/affected hip
- SH : Sound/unaffected hip
- HK : hemi/affected knee
- SK : Sound/unaffected knee
- HA : hemi/affected ankle
- SA : Sound/unaffected ankle
- LPT : Lateral Pelvic tilt
- IC : Initial contact
- MS : Mid stance
- TS : Terminal stance
- MSW : Mid swing

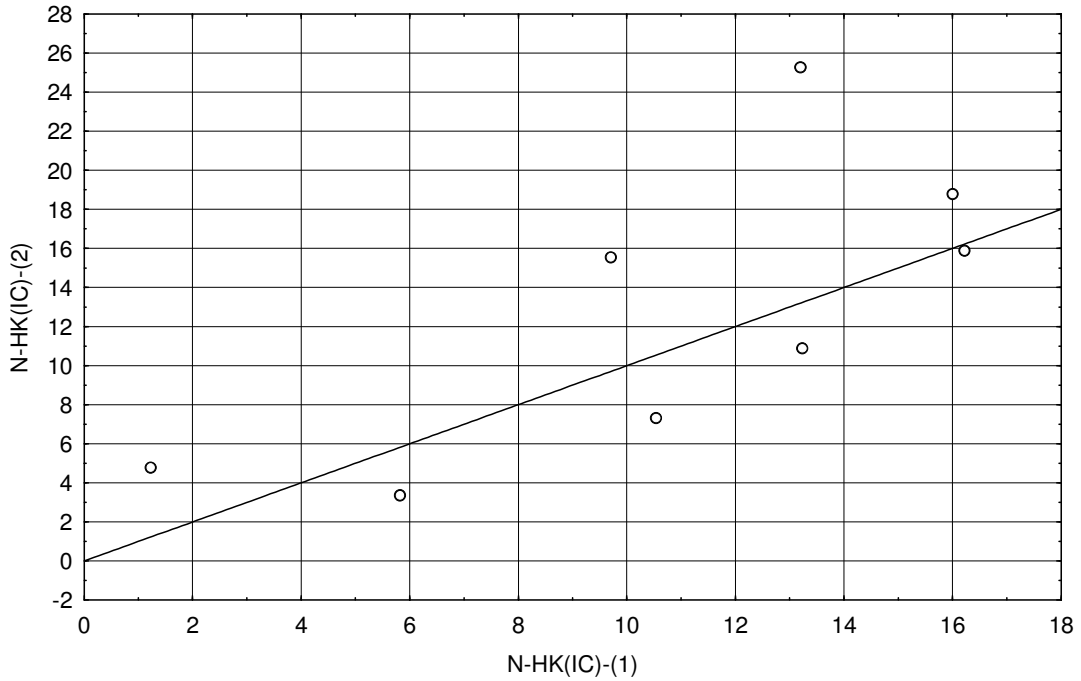
N-HH(IC)-(1):N-HH(IC)-(2): $r = 0.9598$, $p = 0.0002$
 Spearman $r = 0.98$ $p=0.00$
 ICC(agreement)=0.888(0.437;0.978) ICC(consistency)=0.923(0.667;0.984)
 x=y line



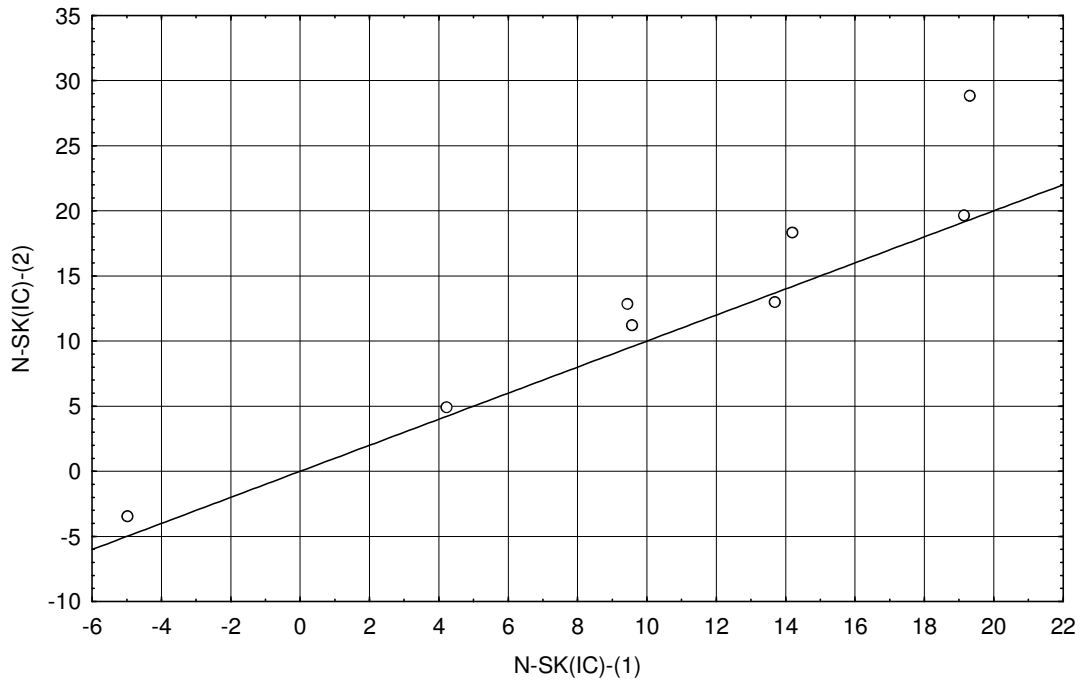
N-SH(IC)-(1):N-SH(IC)-(2): $r = 0.9461$, $p = 0.0004$
 Spearman $r = 0.95$ $p=0.00$
 ICC(agreement)=0.917(0.566;0.984) ICC(consistency)=0.942(0.739;0.988)
 x=y line



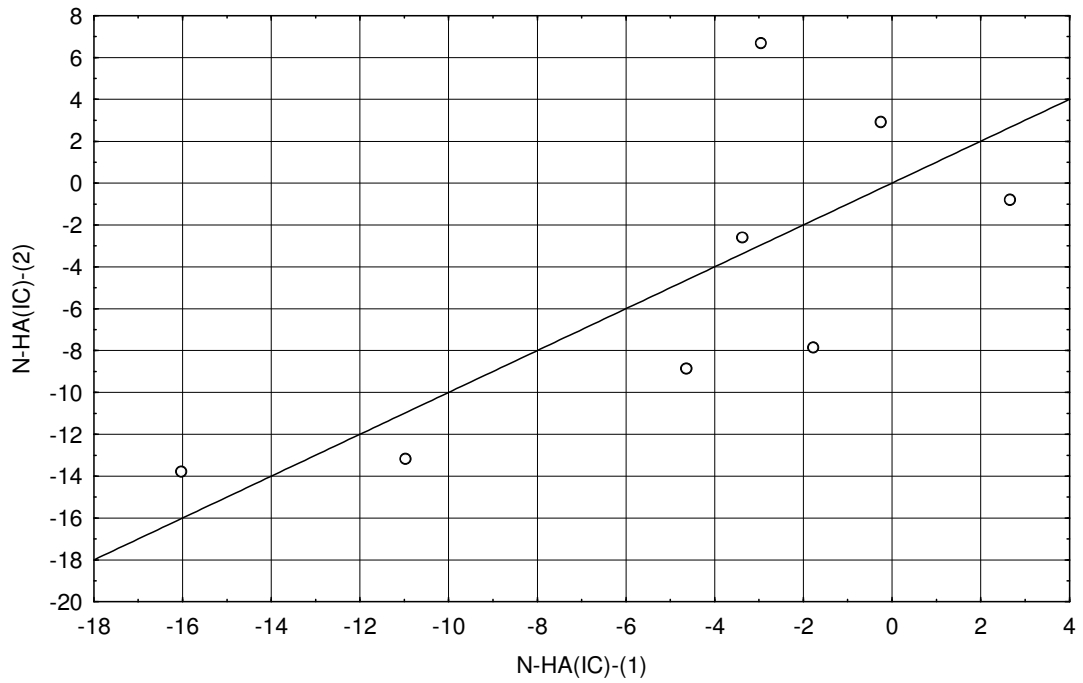
N-HK(IC)-(1):N-HK(IC)-(2): $r = 0.7206$, $p = 0.0437$
 Spearman $r = 0.71$ $p=0.05$
 ICC(agreement)=0.668(0.058;0.922) ICC(consistency)=0.672(0.010;0.924)
 x=y line



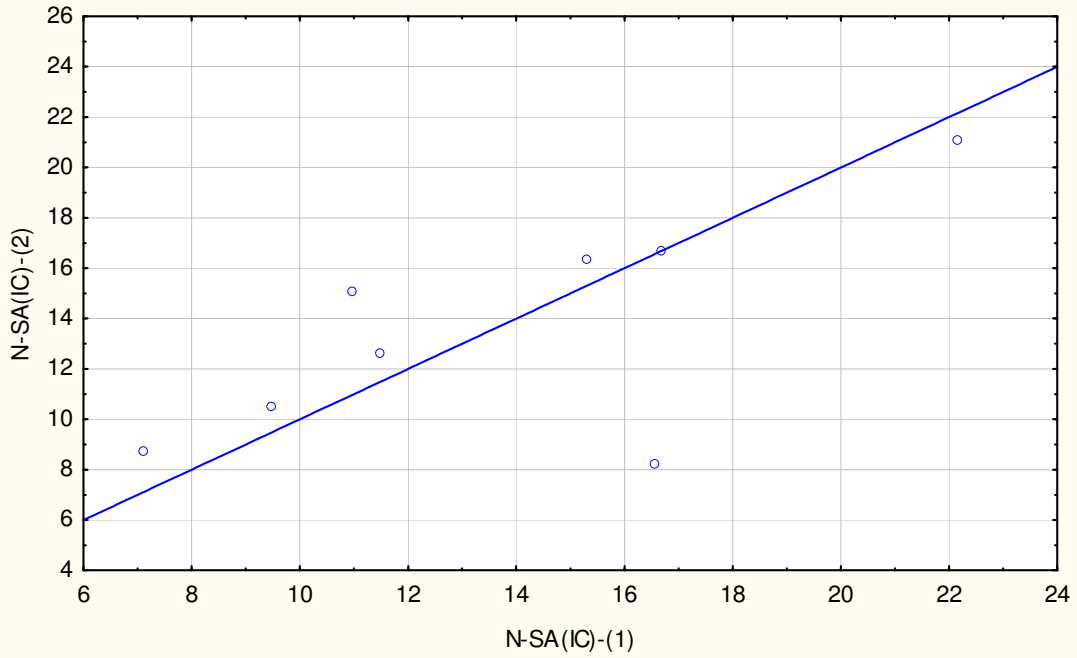
N-SK(IC)-(1):N-SK(IC)-(2): $r = 0.9518$, $p = 0.0003$
 Spearman $r = 0.98$ $p=0.00$
 ICC(agreement)=0.905(0.493;0.981) ICC(consistency)=0.936(0.715;0.987)
 x=y line



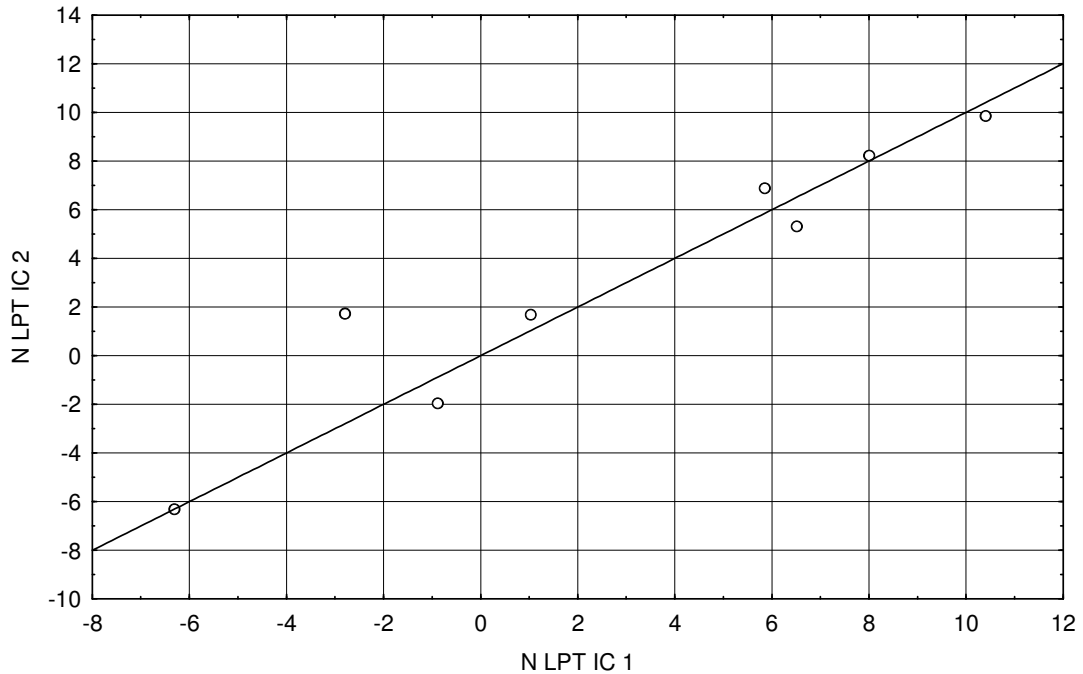
N-HA(IC)-(1):N-HA(IC)-(2): $r = 0.7363$, $p = 0.0373$
 Spearman $r = 0.79$ $p=0.02$
 ICC(agreement)=0.746(0.116;0.944) ICC(consistency)=0.720(0.103;0.937)
 x=y line



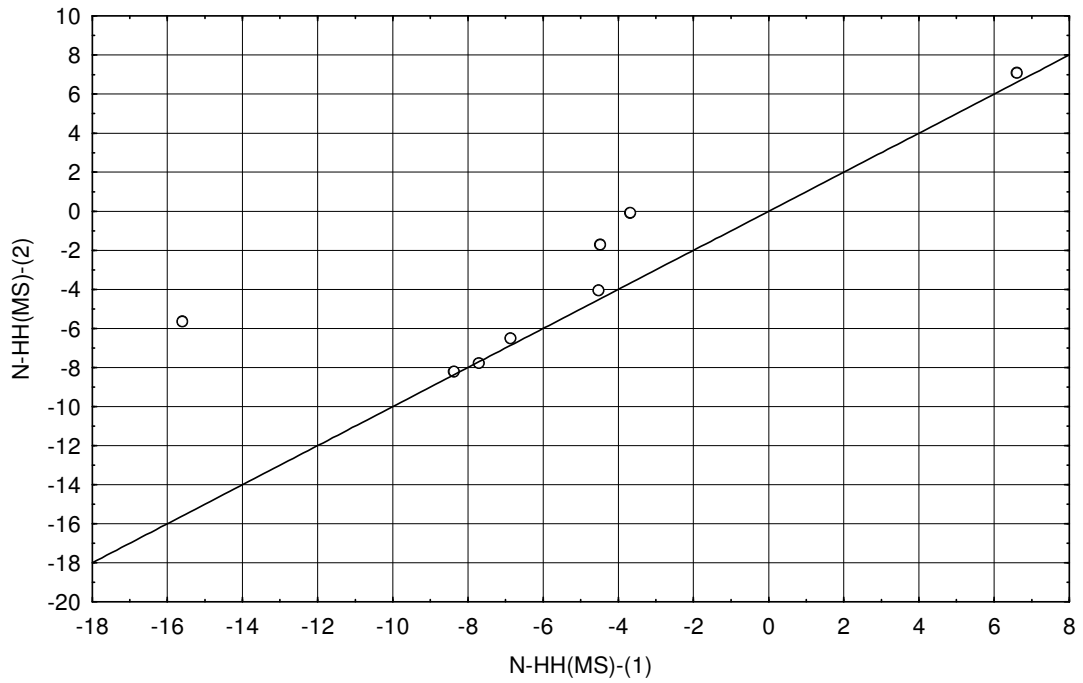
N-SA(IC)-(1):N-SA(IC)-(2): $r = 0.6934$, $p = 0.0565$
 Spearman $r = 0.62$ $p=0.10$
 ICC(agreement)=0.719(0.052;0.938) ICC(consistency)=0.691(0.045;0.929)
 x=y line



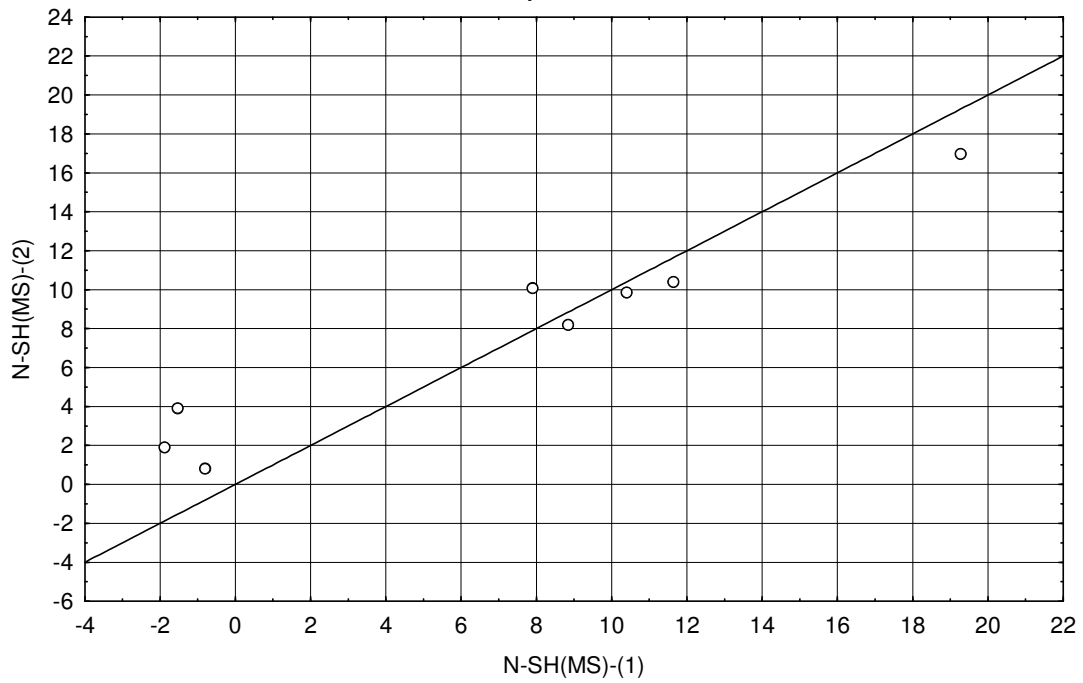
N LPT IC 1:N LPT IC 2: $r = 0.9503$, $p = 0.0003$
 Spearman $r = 0.90$ $p=0.00$
 ICC(agreement)=0.951(0.792;0.990) ICC(consistency)=0.948(0.766;0.989) SEM=1.288
 x=y line



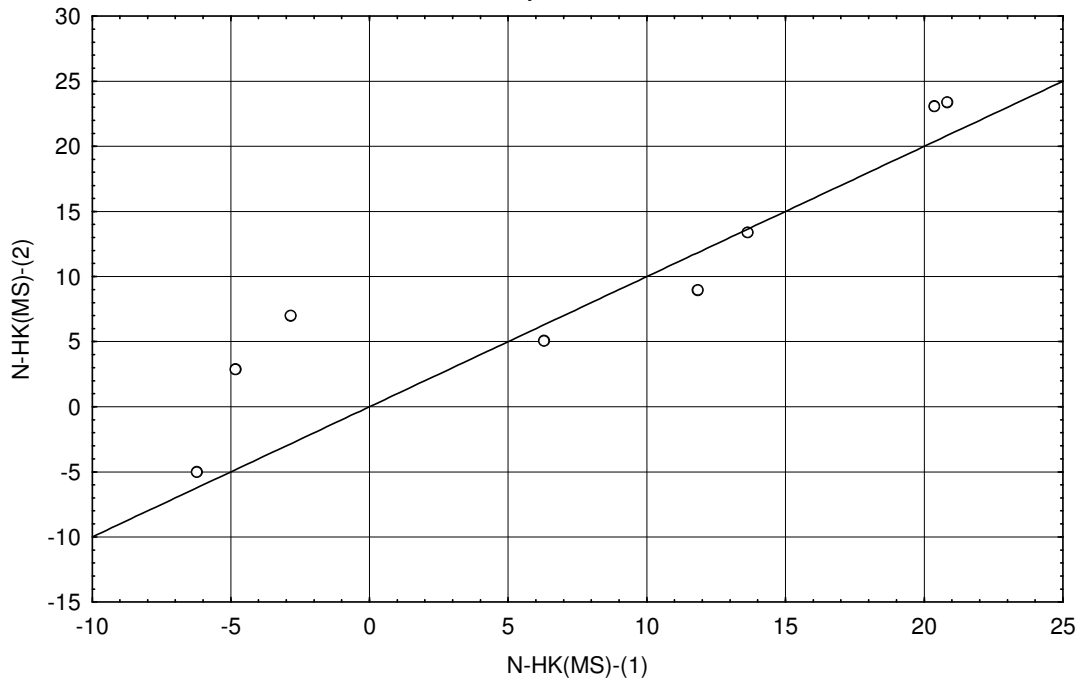
N-HH(MS)-(1):N-HH(MS)-(2): $r = 0.8364$, $p = 0.0097$
Spearman $r = 0.86$ $p=0.01$
ICC(agreement)=0.778(0.250;0.951) ICC(consistency)=0.820(0.339;0.961)
x=y line



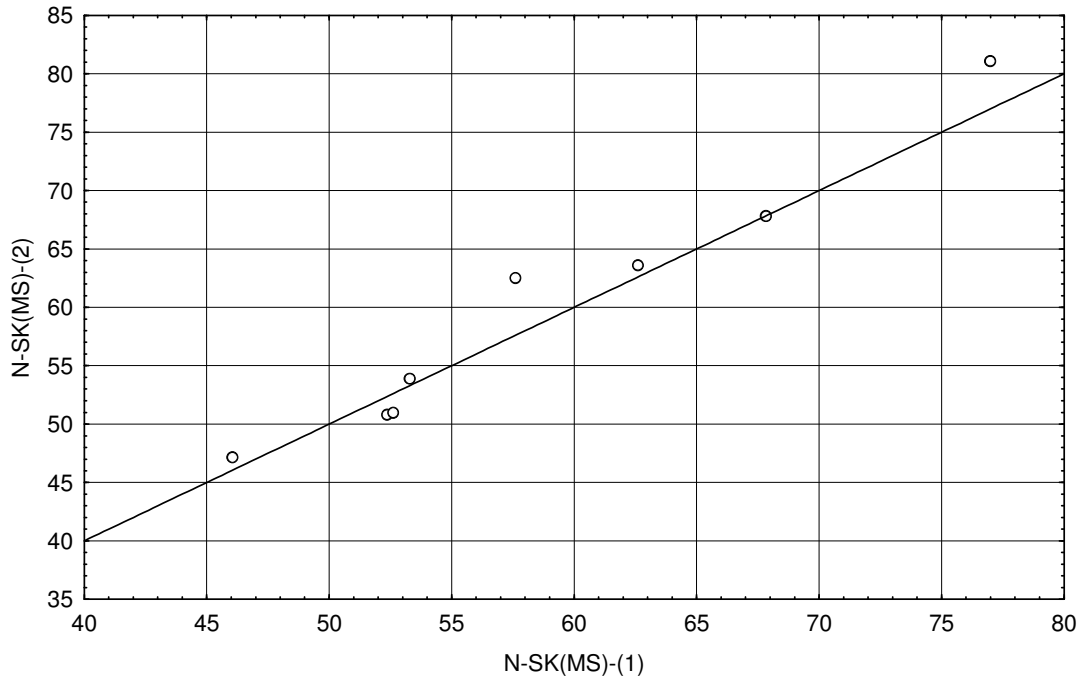
N-SH(MS)-(1):N-SH(MS)-(2): $r = 0.9723$, $p = 0.00005$
 Spearman $r = 0.86$ $p=0.01$
 ICC(agreement)=0.914(0.663;0.982) ICC(consistency)=0.916(0.641;0.983)
 x=y line



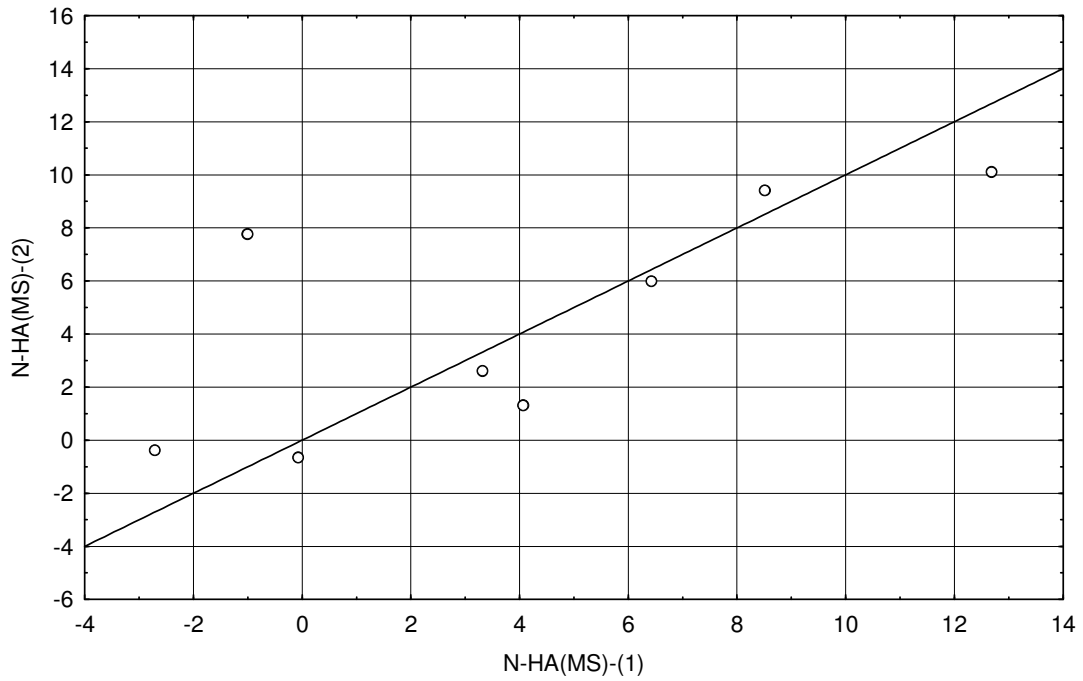
N-HK(MS)-(1):N-HK(MS)-(2): $r = 0.9187$, $p = 0.0013$
 Spearman $r = 0.98$ $p=0.00$
 ICC(agreement)=0.898(0.586;0.978) ICC(consistency)=0.913(0.628;0.982)
 x=y line



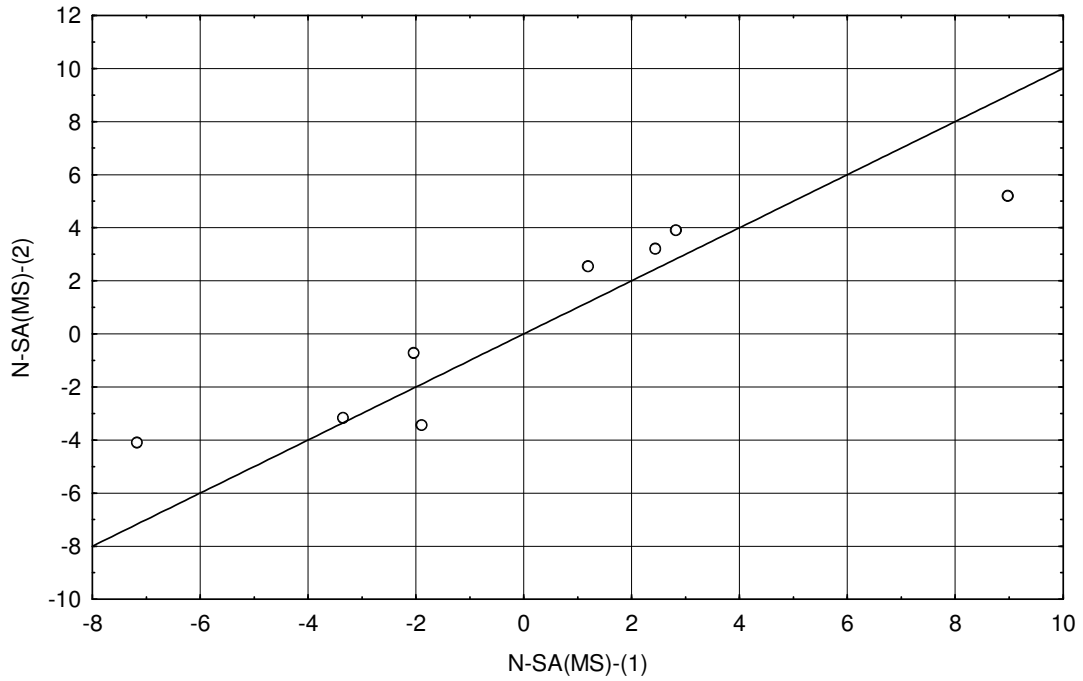
N-SK(MS)-(1):N-SK(MS)-(2): $r = 0.9824$, $p = 0.00001$
 Spearman $r = 1.00$ $p = 9999.00$
 ICC(agreement)=0.973(0.882;0.995) ICC(consistency)=0.975(0.882;0.995)
 x=y line



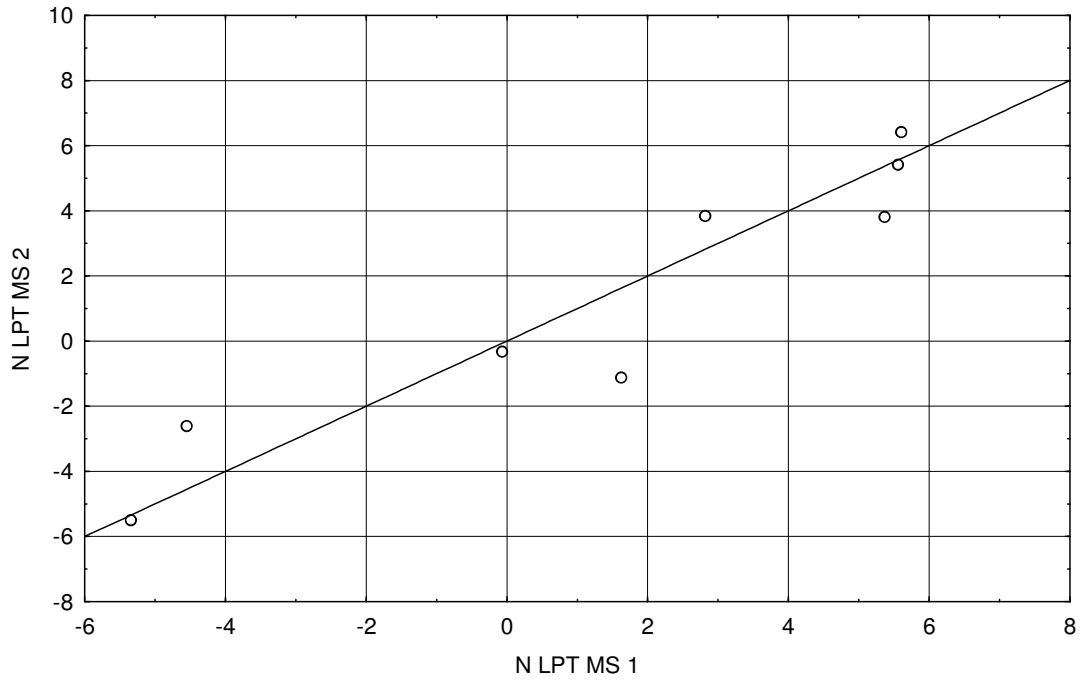
N-HA(MS)-(1):N-HA(MS)-(2): $r = 0.7140$, $p = 0.0467$
 Spearman $r = 0.69$ $p = 0.06$
 ICC(agreement)=0.724(0.095;0.938) ICC(consistency)=0.703(0.069;0.933)
 x=y line



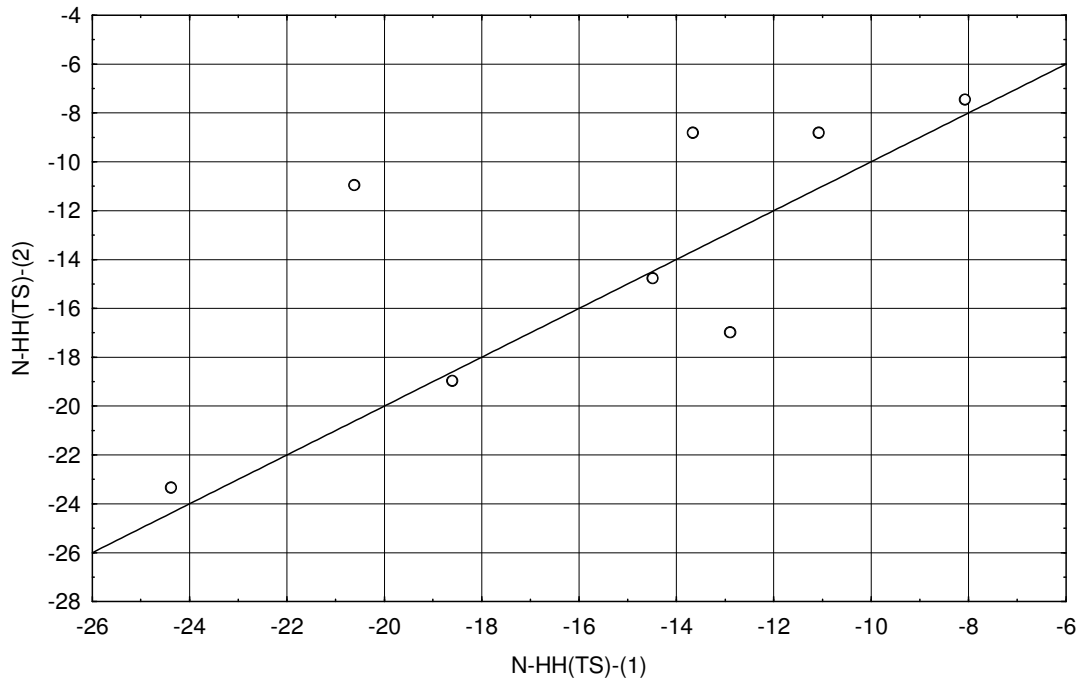
N-SA(MS)-(1):N-SA(MS)-(2): $r = 0.9157, p = 0.0014$
 Spearman $r = 0.93, p = 0.00$
 ICC(agreement)=0.894(0.566;0.978) ICC(consistency)=0.883(0.527;0.975)
 x=y line



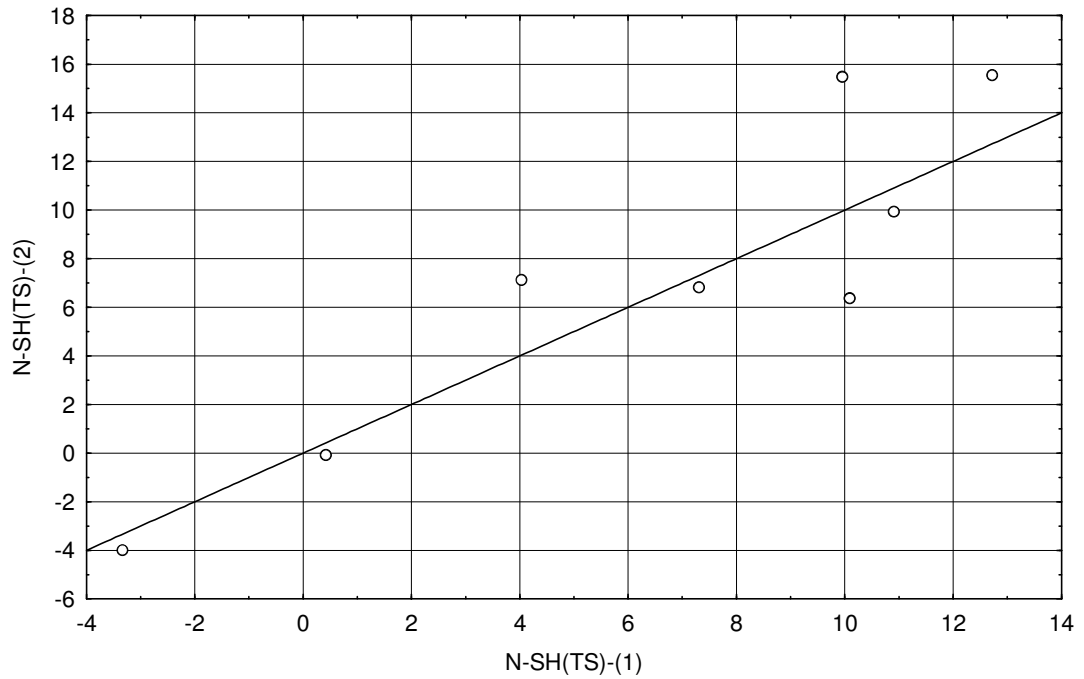
N LPT MS 1:N LPT MS 2: $r = 0.9417, p = 0.0005$
 Spearman $r = 0.95, p = 0.00$
 ICC(agreement)=0.948(0.763;0.989) ICC(consistency)=0.941(0.737;0.988) SEM=1.049
 x=y line



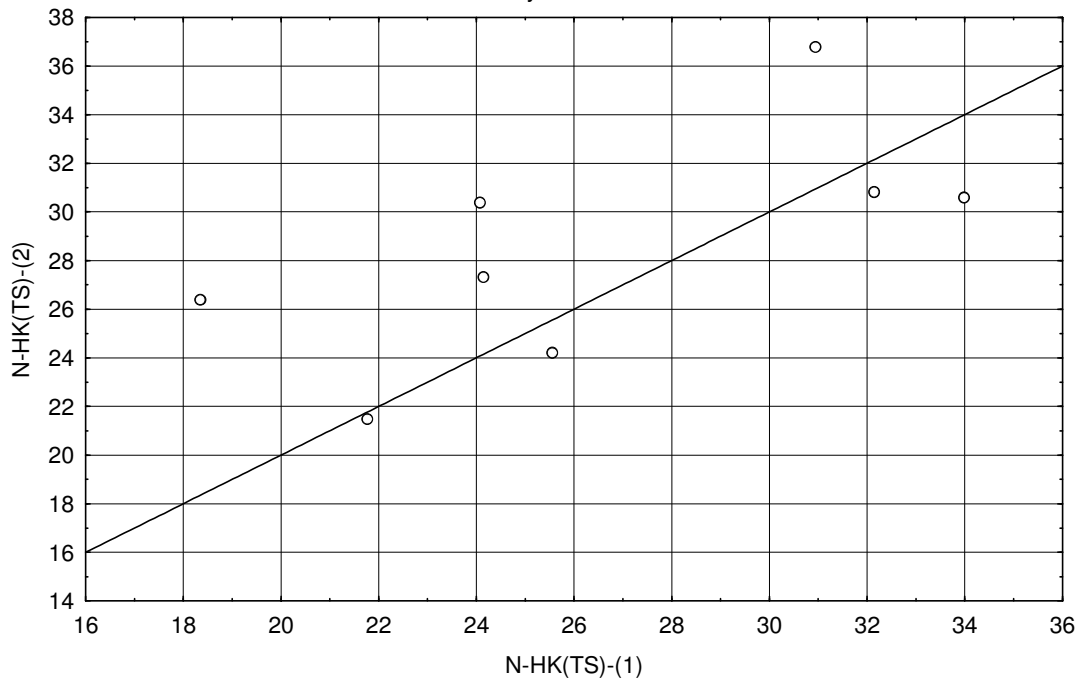
N-HH(TS)-(1):N-HH(TS)-(2): $r = 0.7276$, $p = 0.0408$
 Spearman $r = 0.71$ $p=0.05$
 ICC(agreement)=0.681(0.091;0.925) ICC(consistency)=0.692(0.047;0.930)
 x=y line



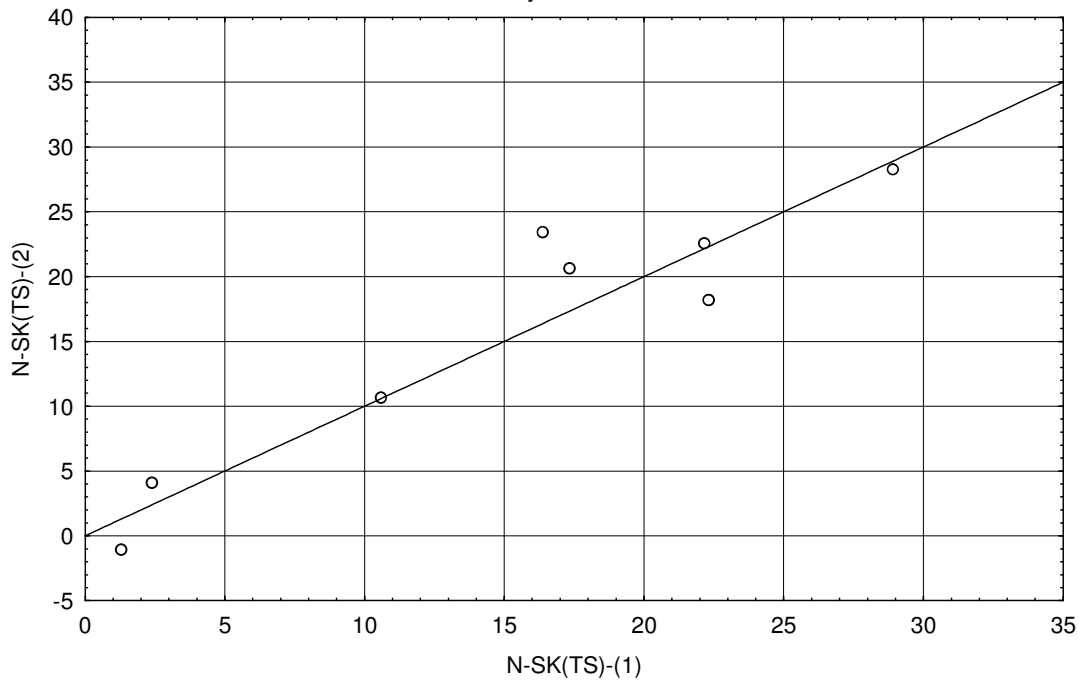
N-SH(TS)-(1):N-SH(TS)-(2): $r = 0.9052$, $p = 0.0020$
 Spearman $r = 0.79$ $p=0.02$
 ICC(agreement)=0.897(0.589;0.978) ICC(consistency)=0.890(0.548;0.977)
 x=y line



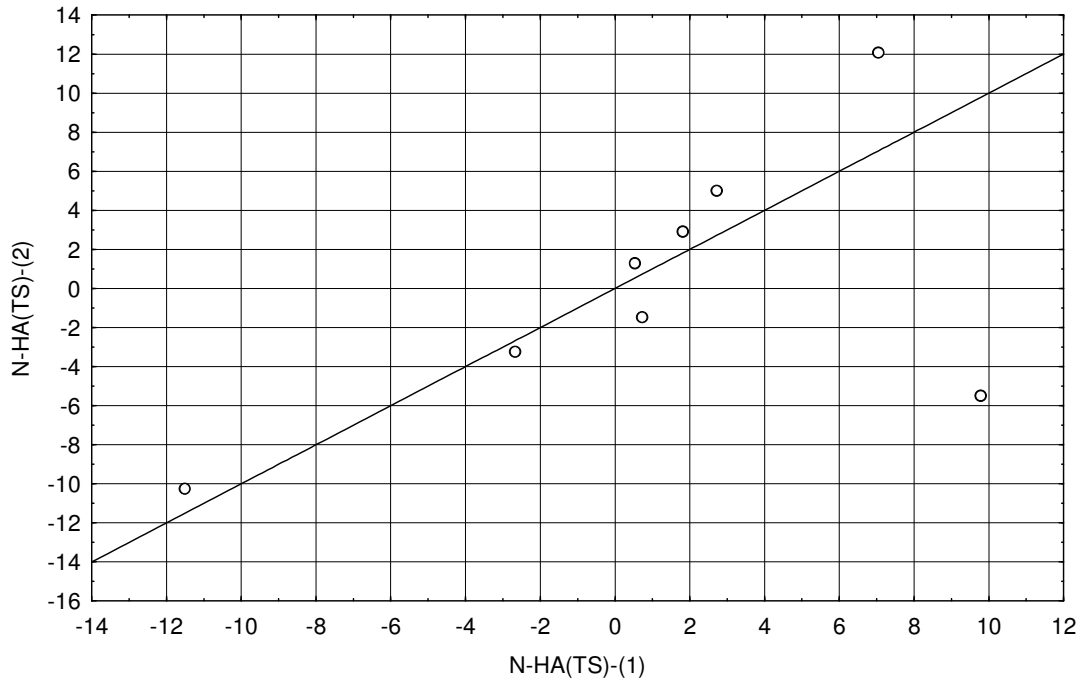
N-HK(TS)-(1):N-HK(TS)-(2): $r = 0.6562, p = 0.0772$
 Spearman $r = 0.69, p = 0.06$
 ICC(agreement)=0.622(0.010;0.908) ICC(consistency)=0.649(-0.030;0.918)
 x=y line



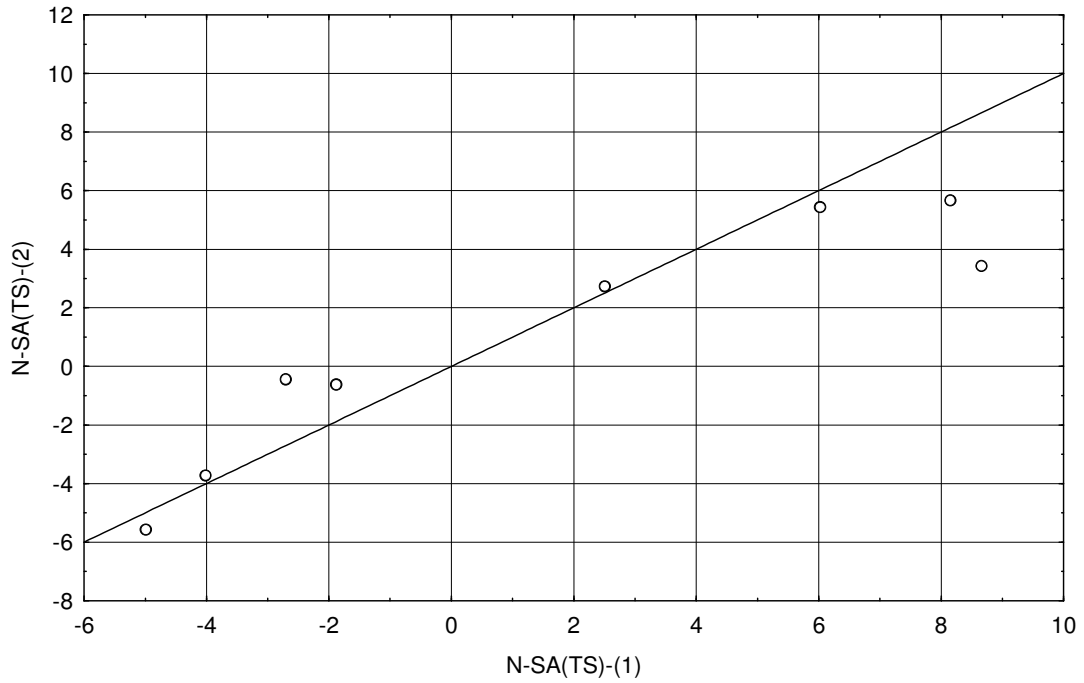
N-SK(TS)-(1):N-SK(TS)-(2): $r = 0.9419, p = 0.0005$
 Spearman $r = 0.79, p = 0.02$
 ICC(agreement)=0.946(0.765;0.989) ICC(consistency)=0.941(0.736;0.988)
 x=y line



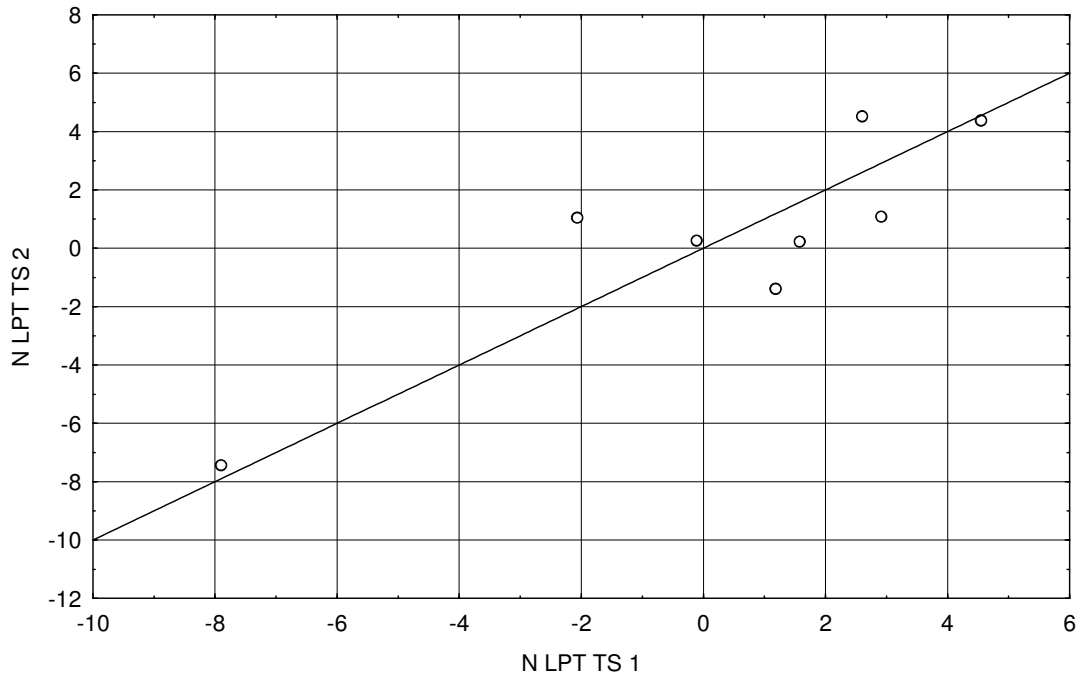
N-HA(TS)-(1):N-HA(TS)-(2): $r = 0.5713$, $p = 0.1390$
 Spearman $r = 0.48$ $p=0.23$
 ICC(agreement)=0.596(-0.160;0.905) ICC(consistency)=0.570(-0.155;0.896)
 x=y line



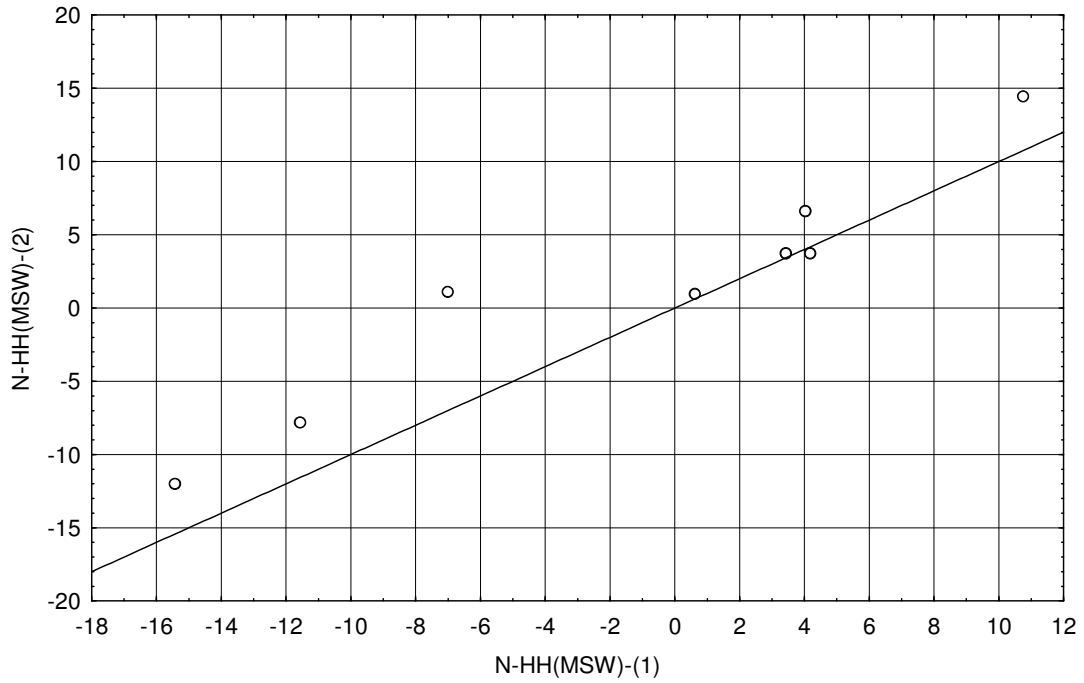
N-SA(TS)-(1):N-SA(TS)-(2): $r = 0.9273$, $p = 0.0009$
 Spearman $r = 0.90$ $p=0.00$
 ICC(agreement)=0.893(0.583;0.977) ICC(consistency)=0.888(0.541;0.976)
 x=y line



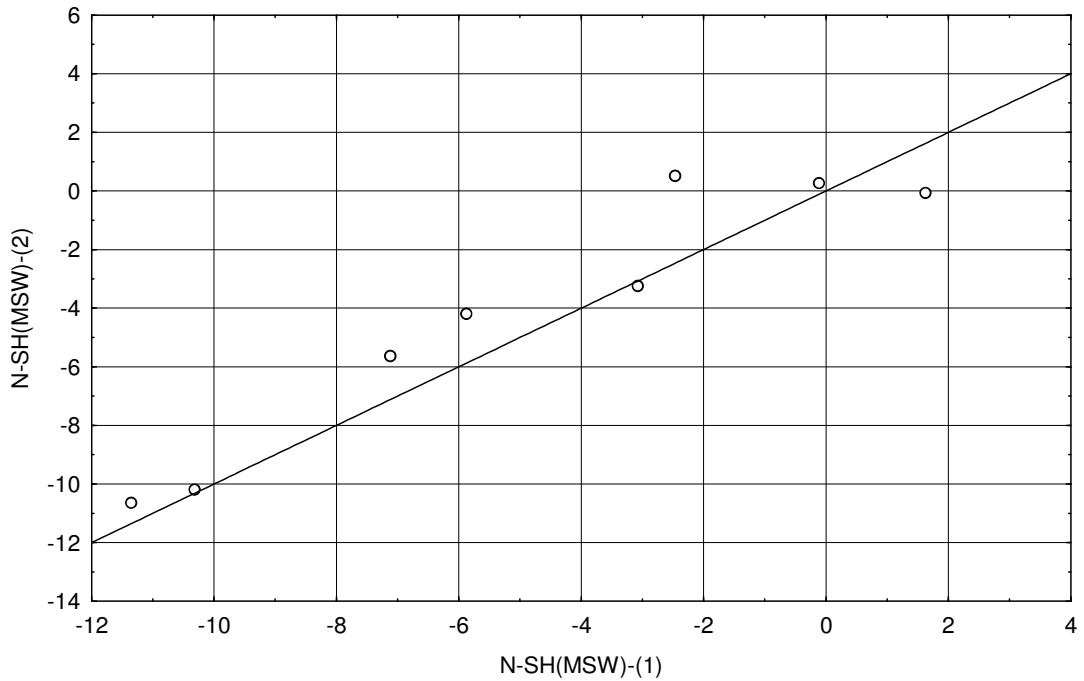
N LPT TS 1:N LPT TS 2: $r = 0.8754$, $p = 0.0044$
Spearman $r = 0.71$ $p=0.05$
ICC(agreement)=0.889(0.533;0.977) ICC(consistency)=0.875(0.500;0.974) SEM=1.35
x=y line



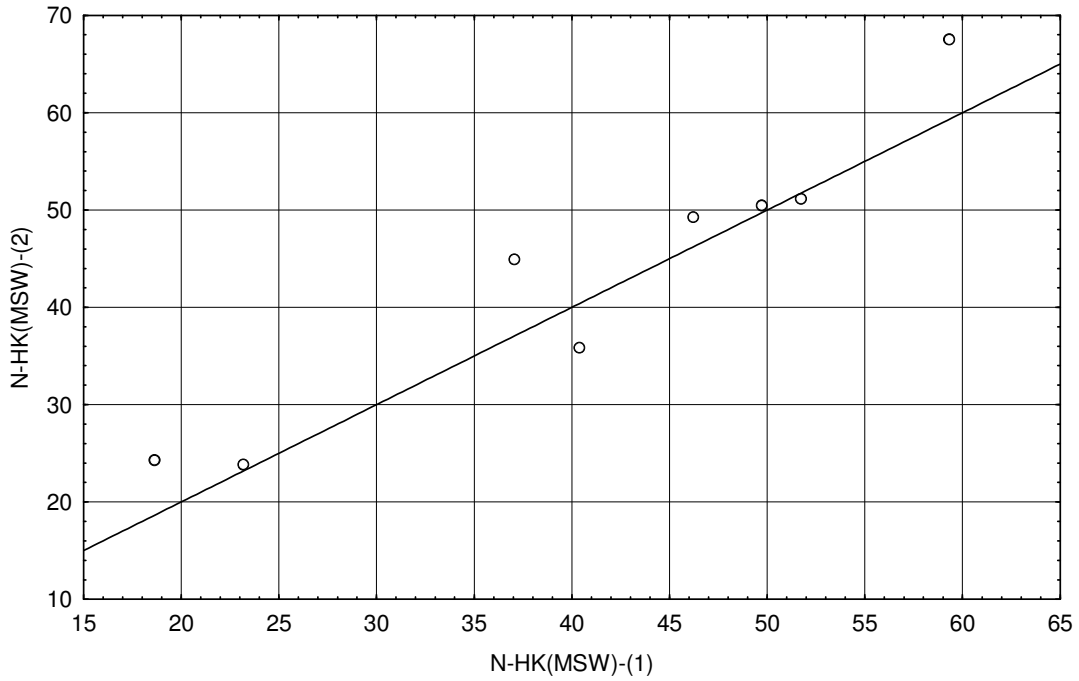
N-HH(MSW)-(1):N-HH(MSW)-(2): $r = 0.9527$, $p = 0.0003$
 Spearman $r = 0.95$ $p=0.00$
 ICC(agreement)=0.909(0.372;0.983) ICC(consistency)=0.949(0.768;0.990)
 x=y line



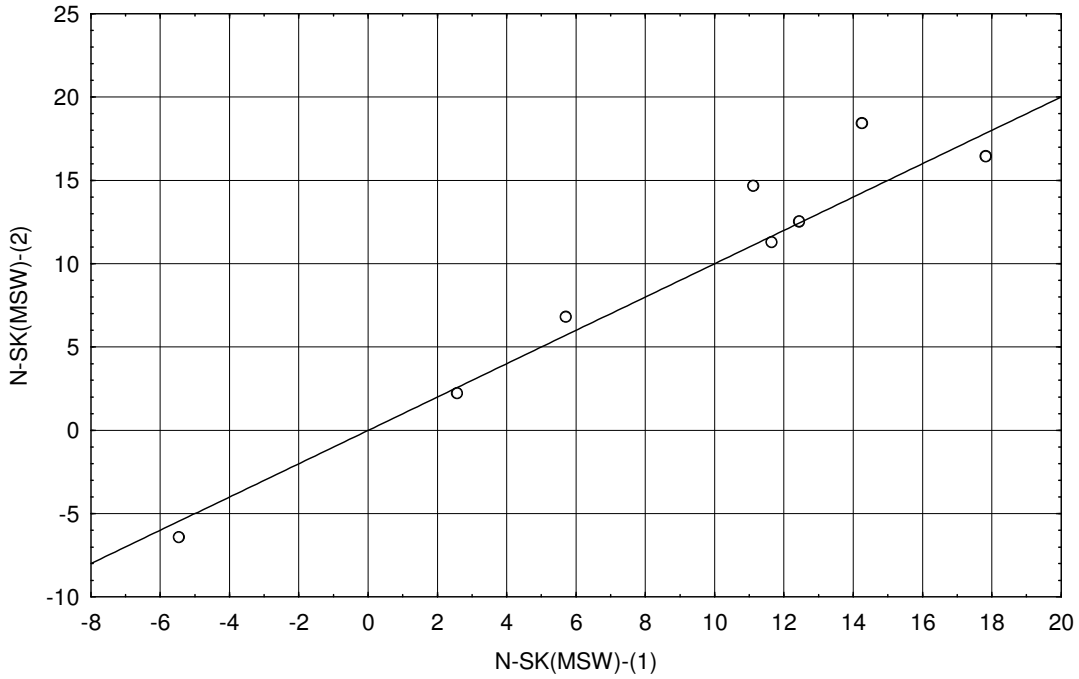
N-SH(MSW)-(1):N-SH(MSW)-(2): $r = 0.9538$, $p = 0.0002$
 Spearman $r = 0.90$ $p=0.00$
 ICC(agreement)=0.948(0.777;0.989) ICC(consistency)=0.953(0.785;0.990)
 x=y line



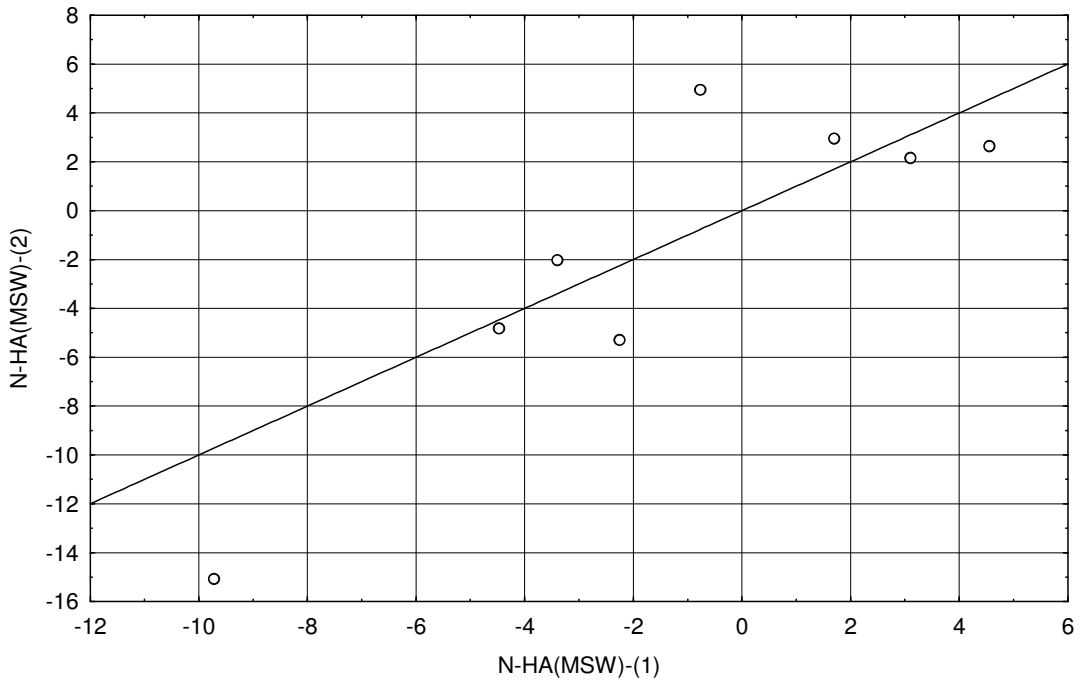
N-HK(MSW)-(1):N-HK(MSW)-(2): $r = 0.9540$, $p = 0.0002$
 Spearman $r = 0.95$ $p=0.00$
 ICC(agreement)=0.943(0.735;0.988) ICC(consistency)=0.953(0.785;0.990)
 x=y line



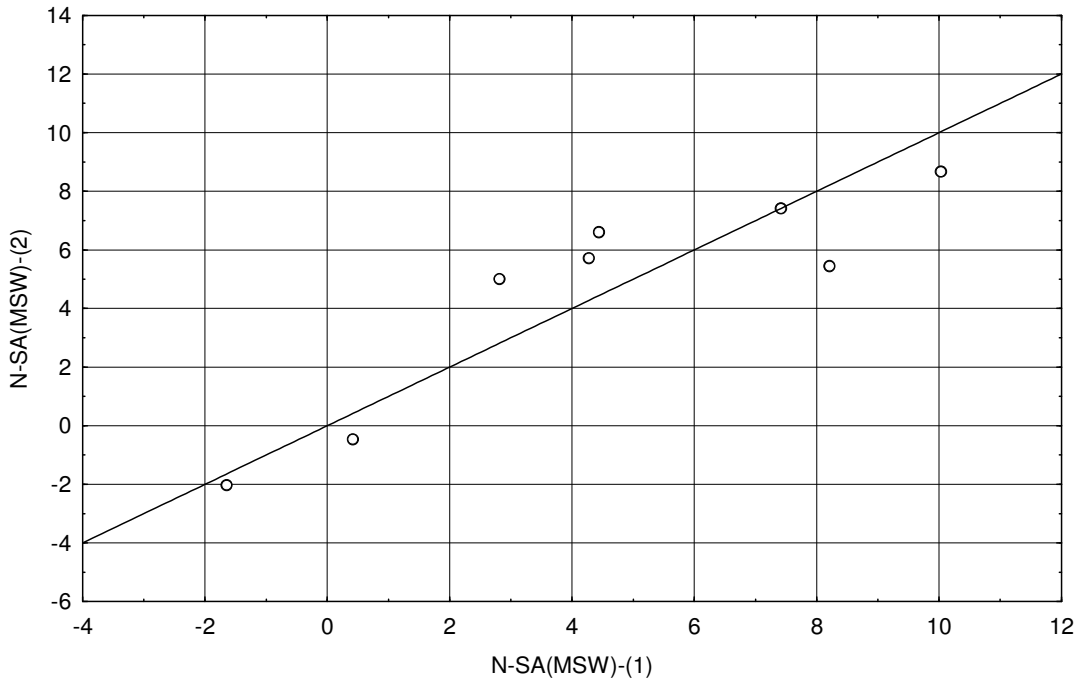
N-SK(MSW)-(1):N-SK(MSW)-(2): $r = 0.9707$, $p = 0.00006$
 Spearman $r = 0.90$ $p=0.00$
 ICC(agreement)=0.965(0.851;0.993) ICC(consistency)=0.965(0.838;0.993)
 x=y line



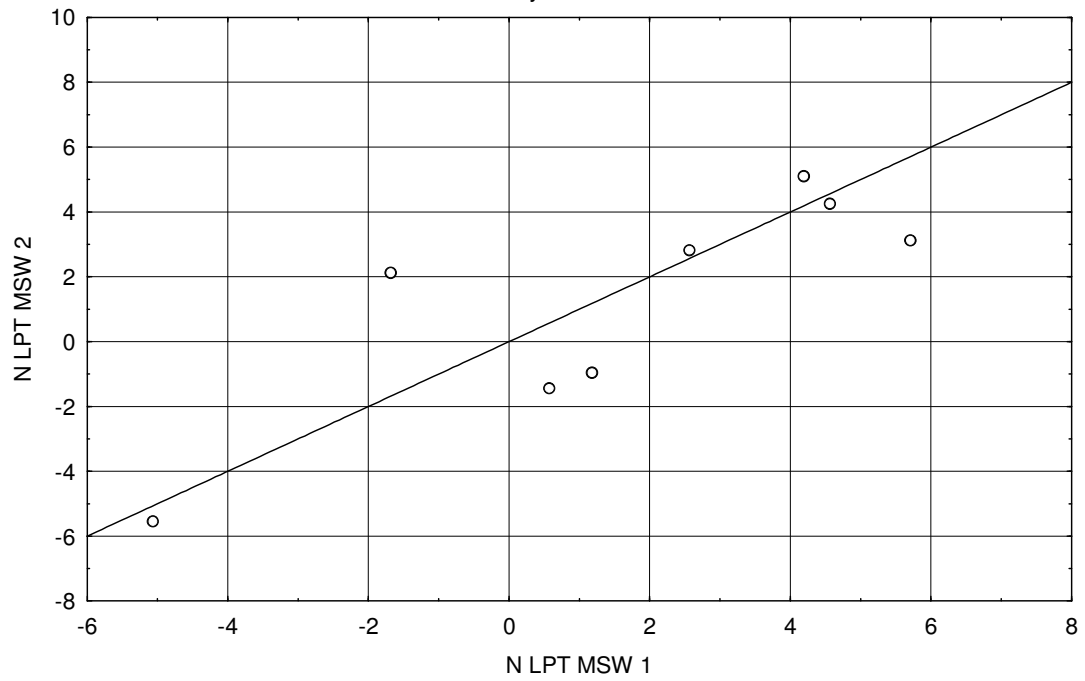
N-HA(MSW)-(1):N-HA(MSW)-(2): $r = 0.8799$, $p = 0.0040$
Spearman $r = 0.71$ $p=0.05$
ICC(agreement)=0.844(0.398;0.967) ICC(consistency)=0.828(0.361;0.963)
x=y line



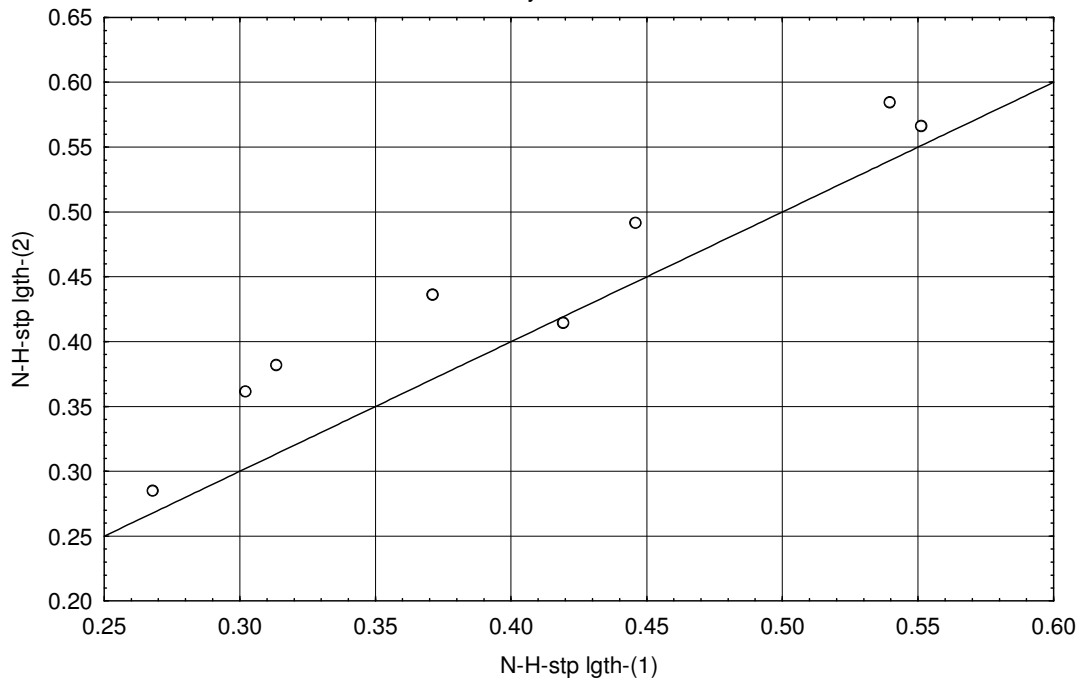
N-SA(MSW)-(1):N-SA(MSW)-(2): $r = 0.8970$, $p = 0.0025$
Spearman $r = 0.86$ $p=0.01$
ICC(agreement)=0.908(0.603;0.981) ICC(consistency)=0.896(0.570;0.978)
x=y line



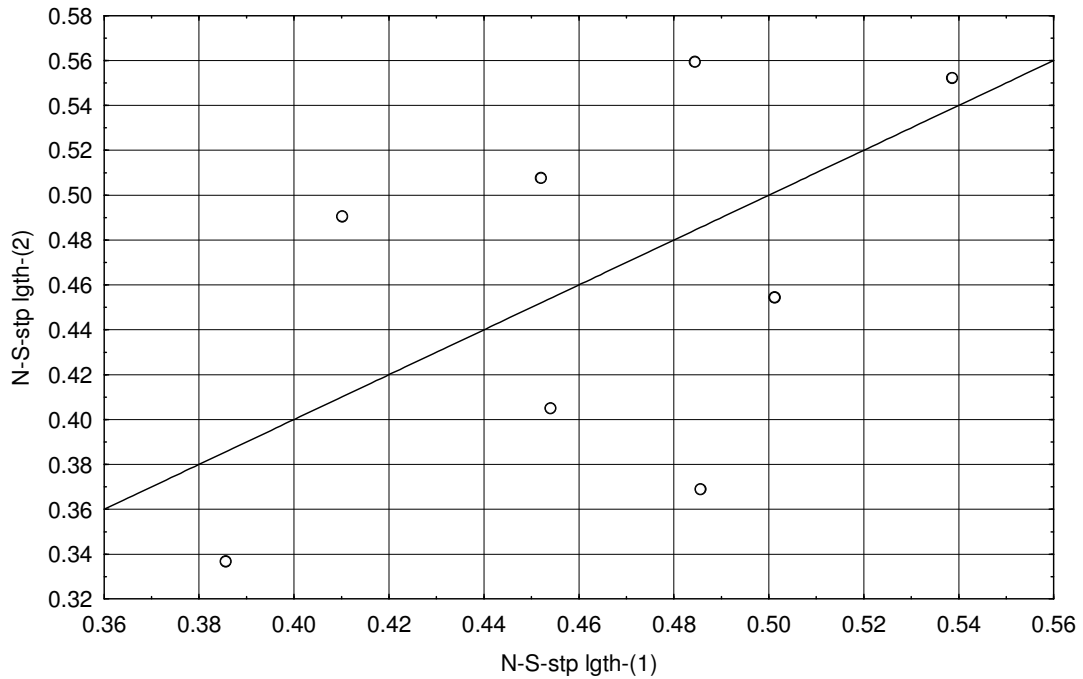
N LPT MSW 1:N LPT MSW 2: $r = 0.8306$, $p = 0.0107$
Spearman $r = 0.83$ $p=0.01$
ICC(agreement)=0.845(0.408;0.967) ICC(consistency)=0.831(0.368;0.964) SEM=1.47
x=y line



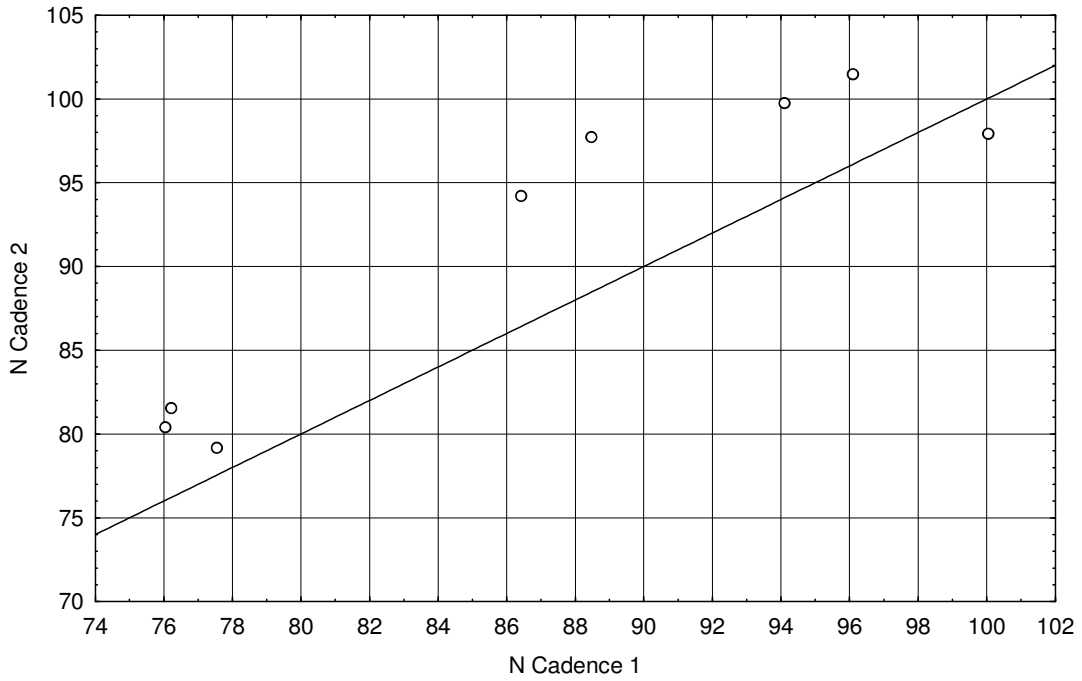
N-H-stp lgth-(1):N-H-stp lgth-(2): $r = 0.9682$, $p = 0.00008$
Spearman $r = 0.95$ $p=0.00$
ICC(agreement)=0.908(0.083;0.985) ICC(consistency)=0.967(0.847;0.993)
x=y line



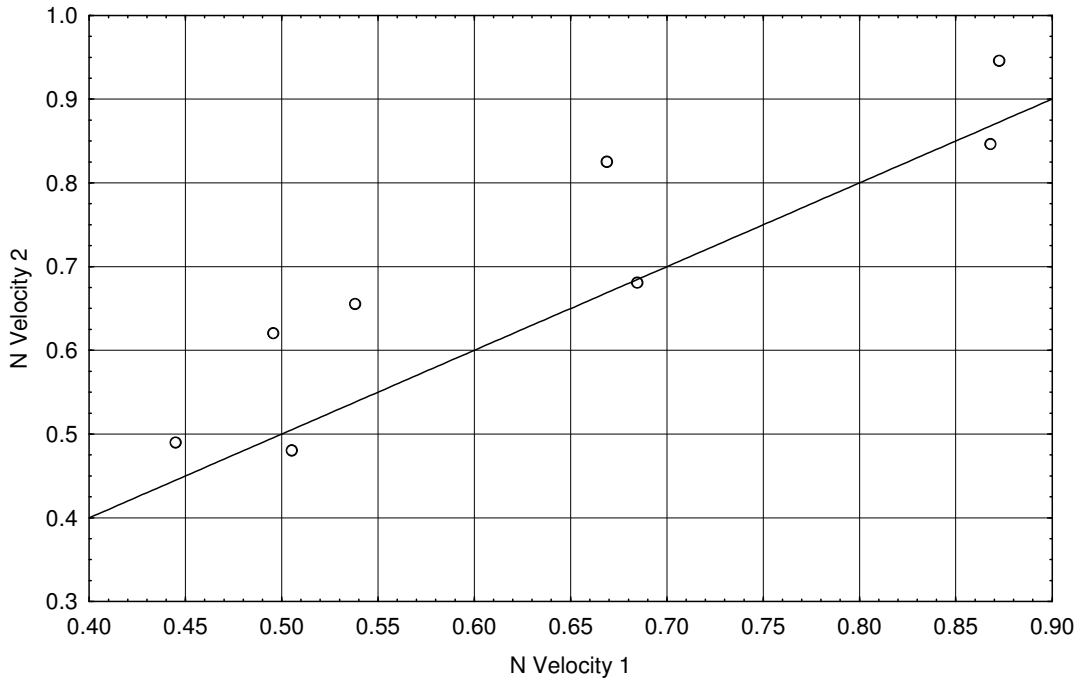
N-S-stp lgth-(1):N-S-stp lgth-(2): $r = 0.5131$, $p = 0.1934$
Spearman $r = 0.36$ $p=0.39$
ICC(agreement)=0.484(-0.363;0.874) ICC(consistency)=0.452(-0.307;0.859)
x=y line



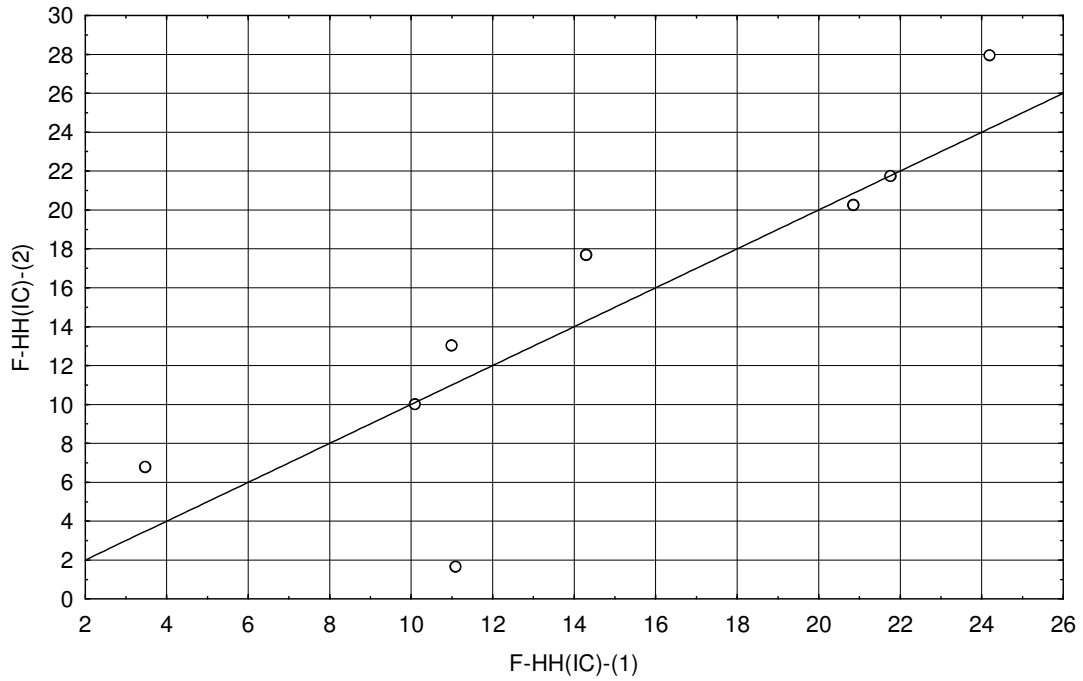
N Cadence 1:N Cadence 2: $r = 0.9300$, $p = 0.0008$
Spearman $r = 0.86$ $p=0.01$
ICC(agreement)=0.837(0.018;0.971) ICC(consistency)=0.930(0.693;0.986) SEM=2.51
x=y line



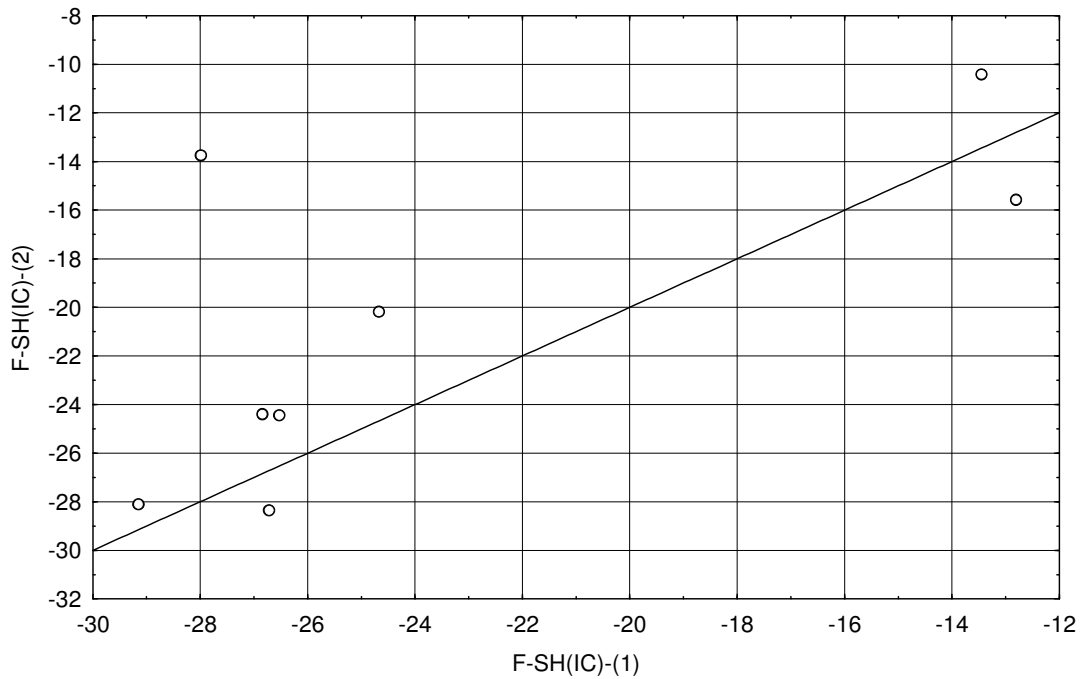
N Velocity 1:N Velocity 2: $r = 0.9109$, $p = 0.0017$
Spearman $r = 0.90$ $p=0.00$
ICC(agreement)=0.868(0.366;0.974) ICC(consistency)=0.911(0.622;0.981) SEM=0.05
x=y line



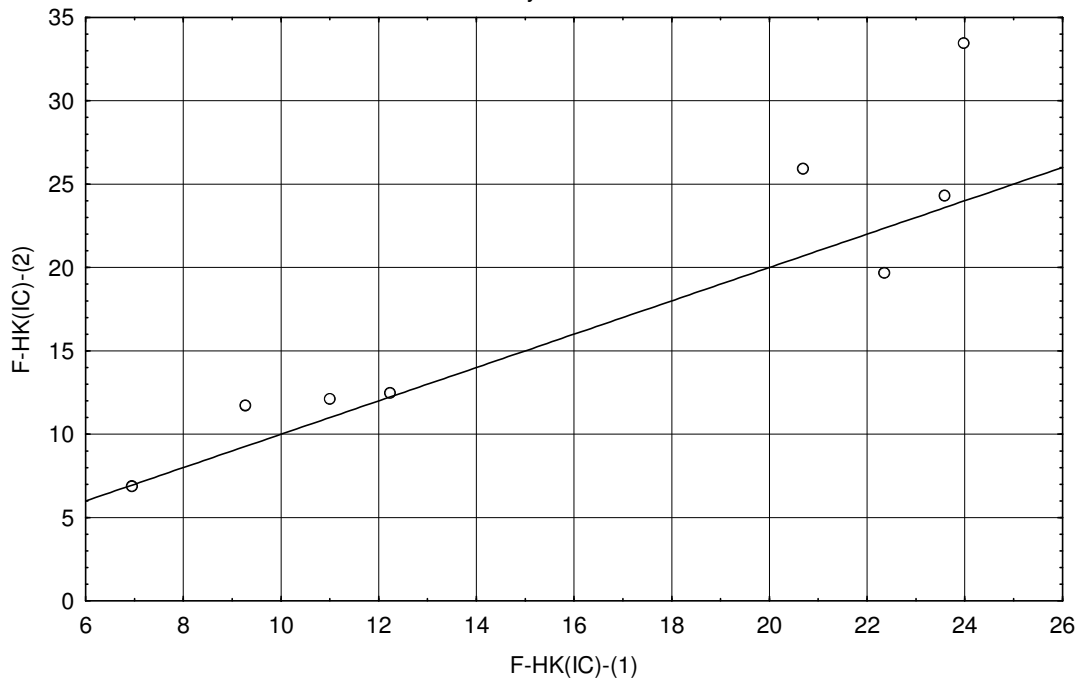
F-HH(IC)-(1):F-HH(IC)-(2): $r = 0.8688$, $p = 0.0051$
 Spearman $r = 0.86$ $p=0.01$
 ICC(agreement)=0.867(0.465;0.972) ICC(consistency)=0.852(0.430;0.969)
 x=y line



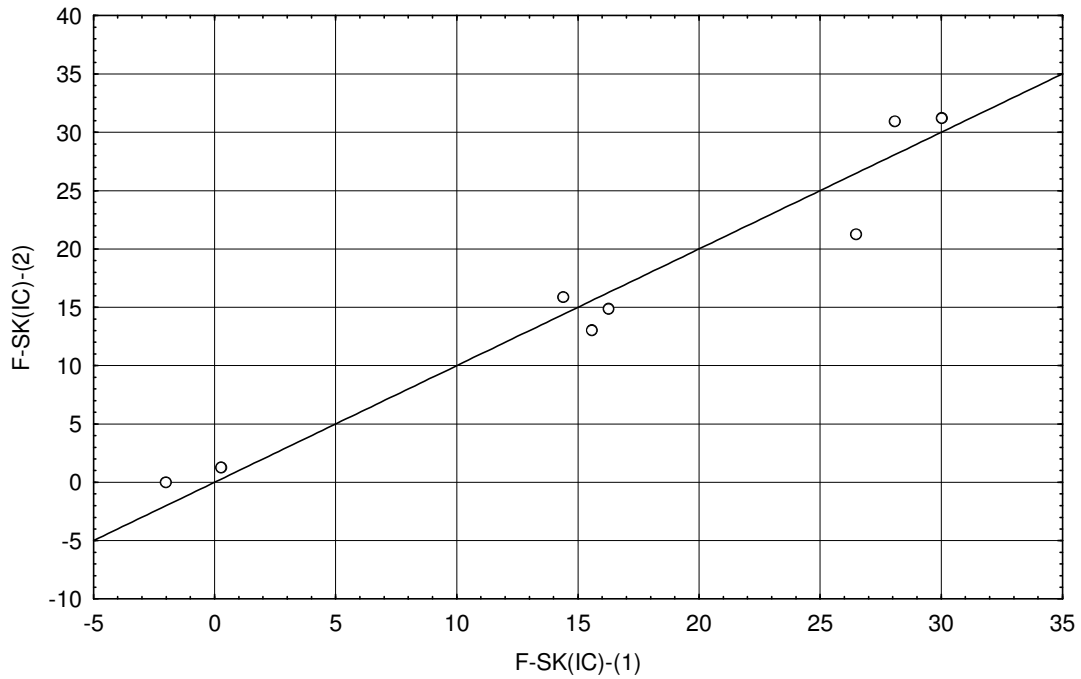
F-SH(IC)-(1):F-SH(IC)-(2): $r = 0.6975$, $p = 0.0544$
 Spearman $r = 0.45$ $p=0.26$
 ICC(agreement)=0.661(0.070;0.919) ICC(consistency)=0.697(0.057;0.931)
 x=y line



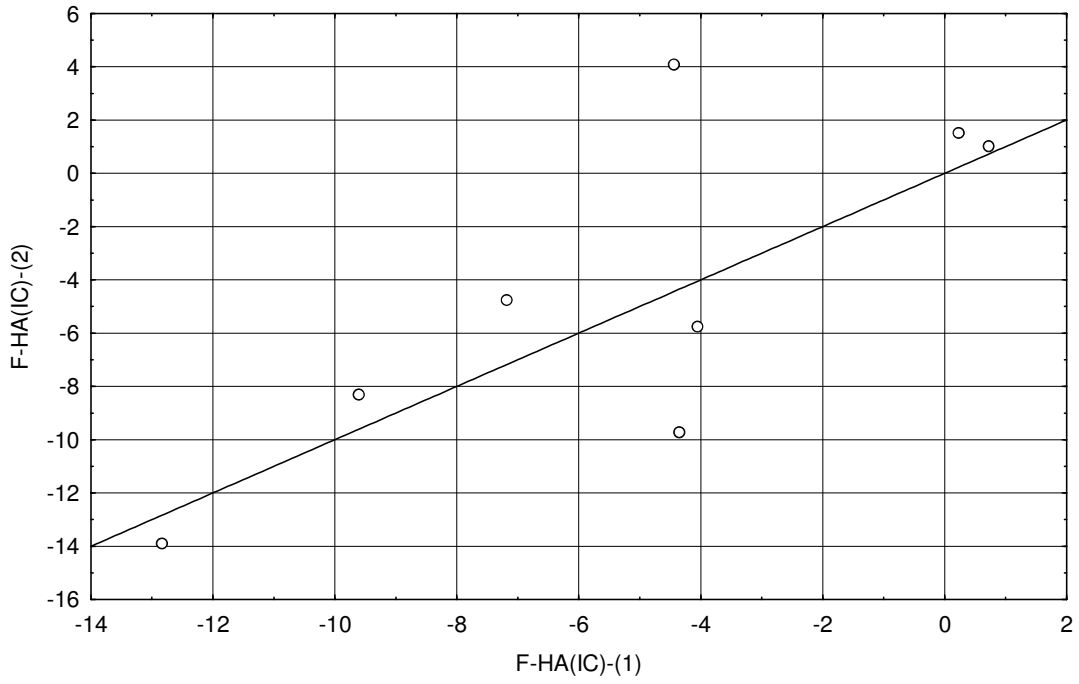
F-HK(IC)-(1):F-HK(IC)-(2): $r = 0.9207$, $p = 0.0012$
 Spearman $r = 0.93$ $p=0.00$
 ICC(agreement)=0.877(0.523;0.974) ICC(consistency)=0.893(0.561;0.978)
 x=y line



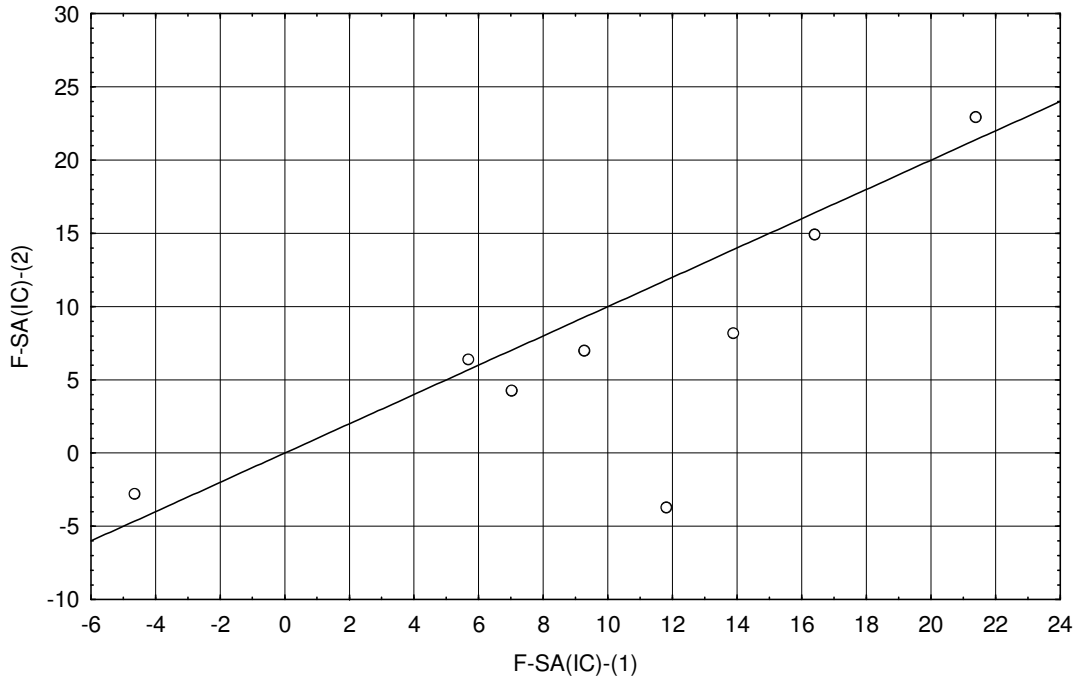
F-SK(IC)-(1):F-SK(IC)-(2): $r = 0.9740$, $p = 0.00004$
 Spearman $r = 0.93$ $p=0.00$
 ICC(agreement)=0.977(0.888;0.995) ICC(consistency)=0.974(0.874;0.995)
 x=y line



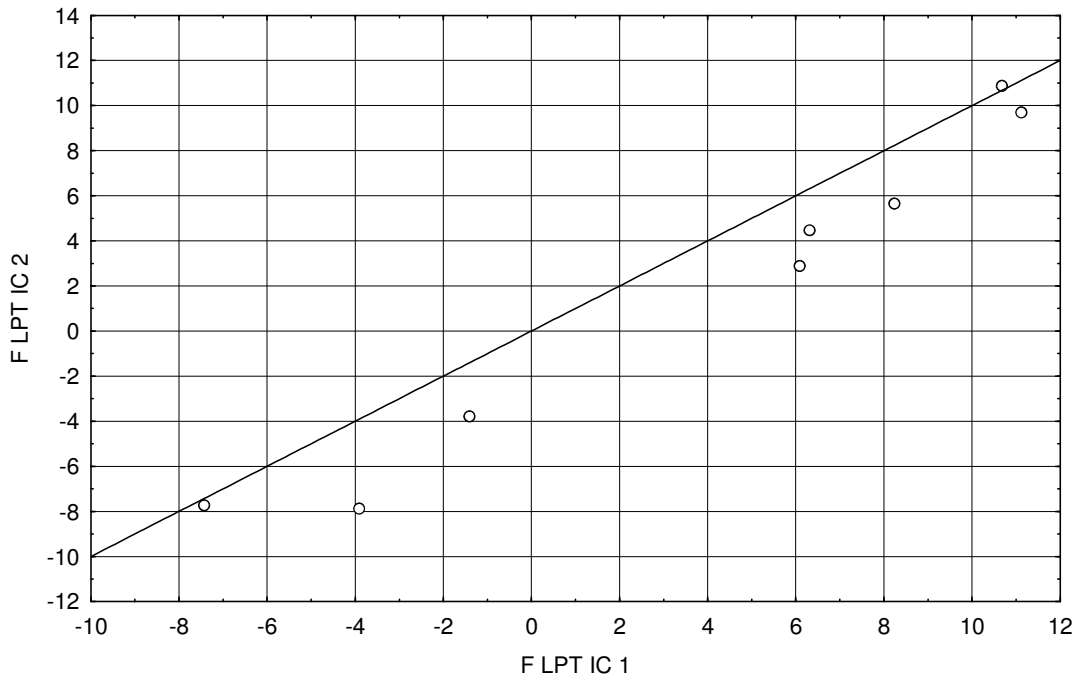
F-HA(IC)-(1):F-HA(IC)-(2): $r = 0.7709$, $p = 0.0251$
 Spearman $r = 0.55$ $p=0.16$
 ICC(agreement)=0.756(0.172;0.946) ICC(consistency)=0.737(0.139;0.941)
 x=y line



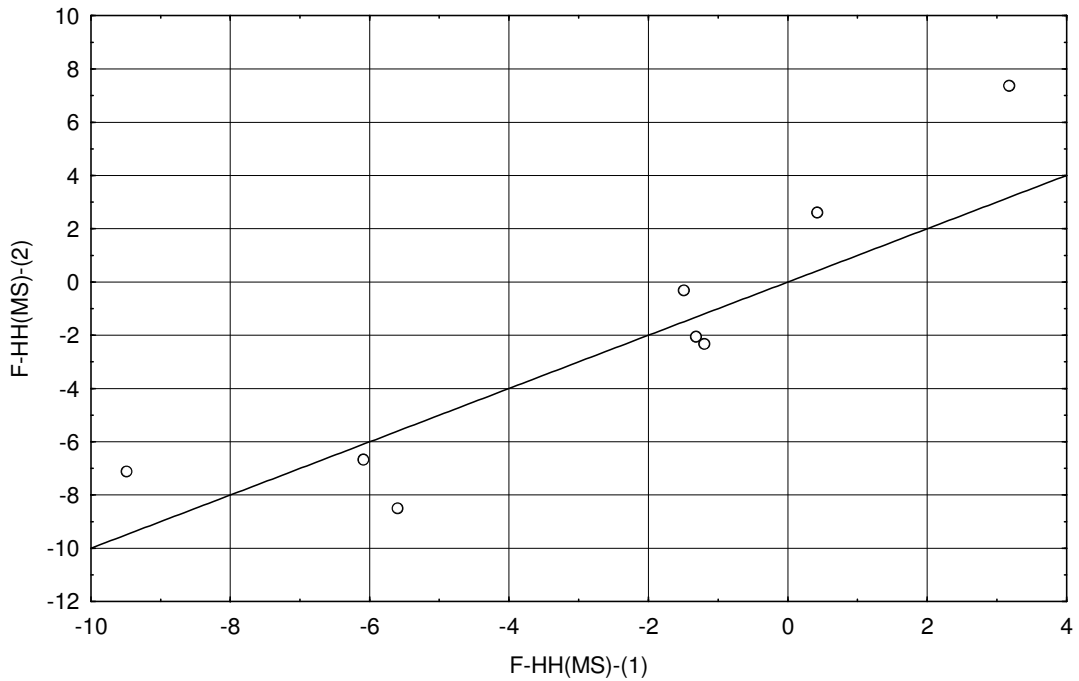
F-SA(IC)-(1):F-SA(IC)-(2): $r = 0.7716$, $p = 0.0249$
 Spearman $r = 0.74$ $p=0.04$
 ICC(agreement)=0.742(0.209;0.941) ICC(consistency)=0.767(0.206;0.949)
 x=y line



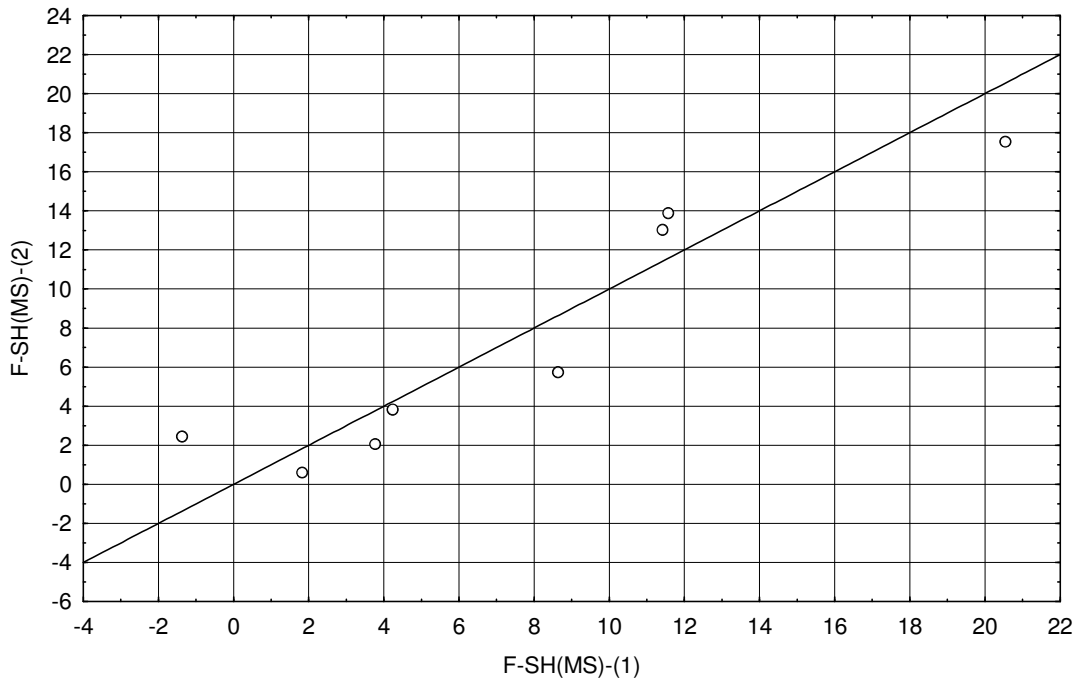
F LPT IC 1:F LPT IC 2: $r = 0.9824$, $p = 0.00001$
Spearman $r = 0.95$ $p=0.00$
ICC(agreement)=0.949(0.269;0.992) ICC(consistency)=0.981(0.908;0.996) SEM=0.995
x=y line



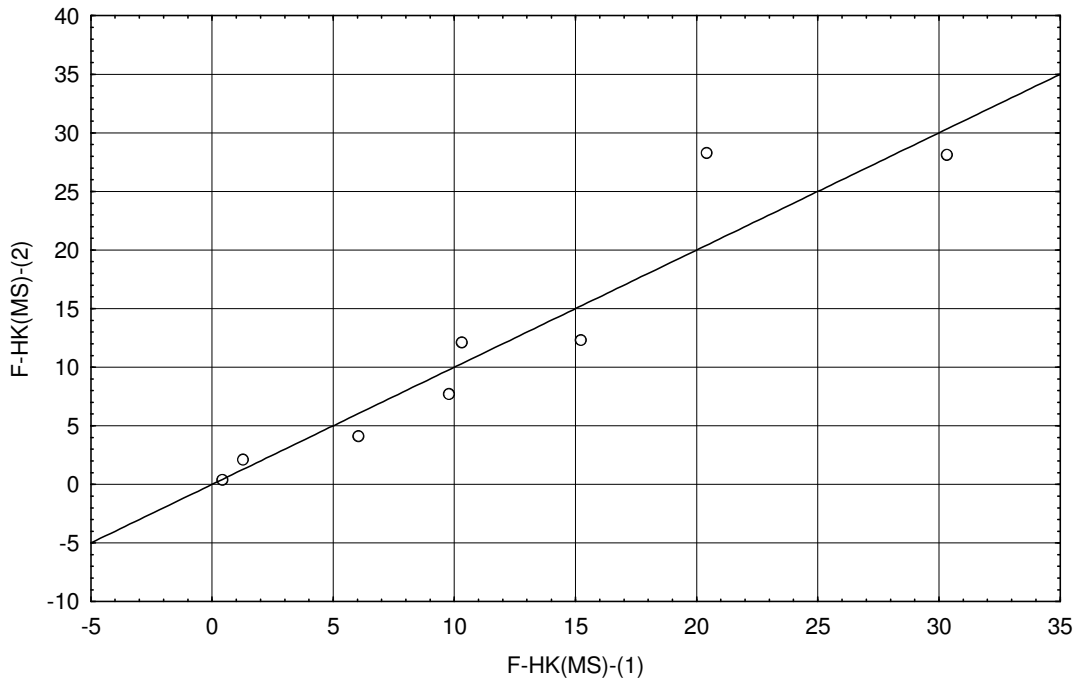
F-HH(MS)-(1):F-HH(MS)-(2): $r = 0.9173$, $p = 0.0013$
Spearman $r = 0.83$ $p=0.01$
ICC(agreement)=0.890(0.568;0.977) ICC(consistency)=0.883(0.525;0.975)
x=y line



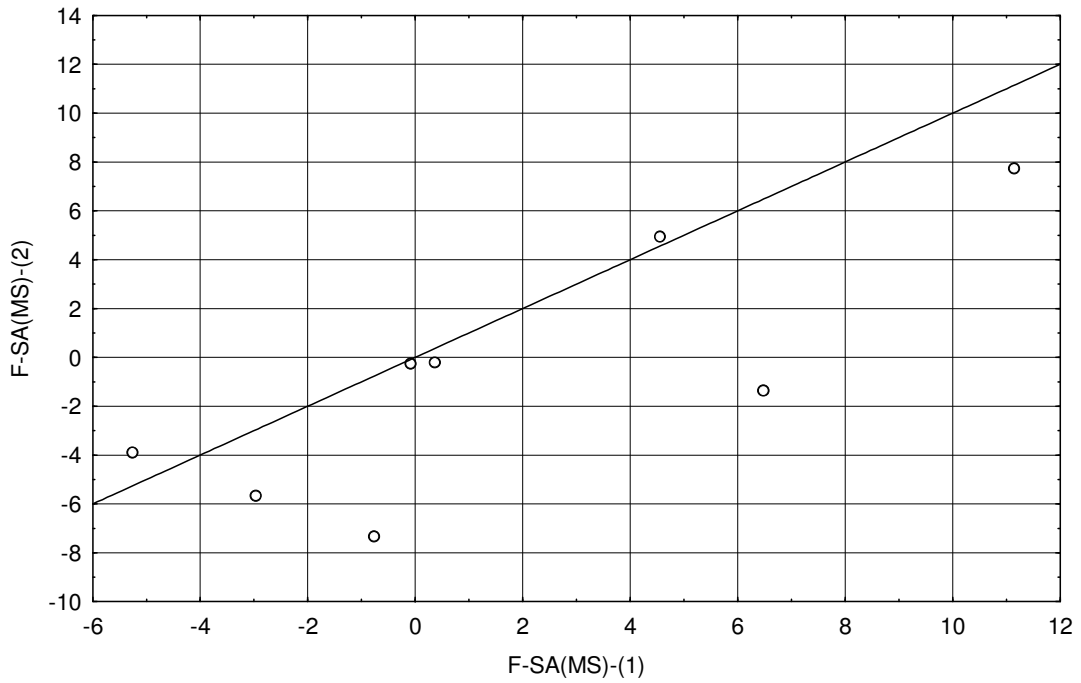
F-SH(MS)-(1):F-SH(MS)-(2): $r = 0.9326$, $p = 0.0007$
Spearman $r = 0.93$ $p=0.00$
ICC(agreement)=0.938(0.722;0.987) ICC(consistency)=0.930(0.693;0.986)
x=y line



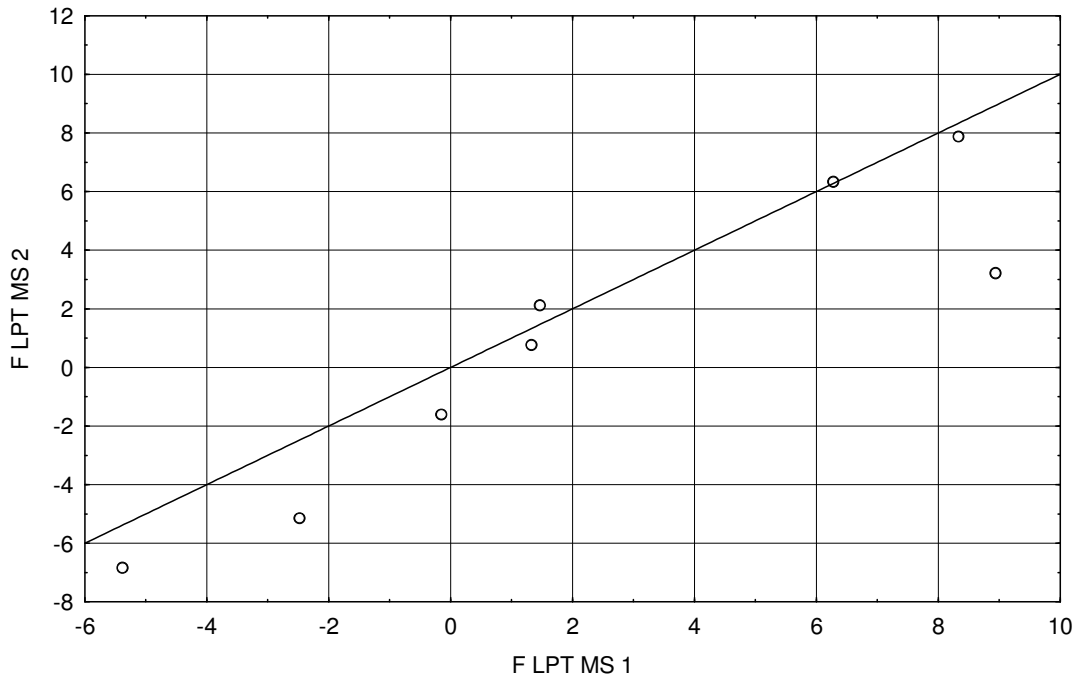
F-HK(MS)-(1):F-HK(MS)-(2): $r = 0.9472$, $p = 0.0004$
Spearman $r = 0.98$ $p=0.00$
ICC(agreement)=0.950(0.773;0.990) ICC(consistency)=0.944(0.748;0.989)
x=y line



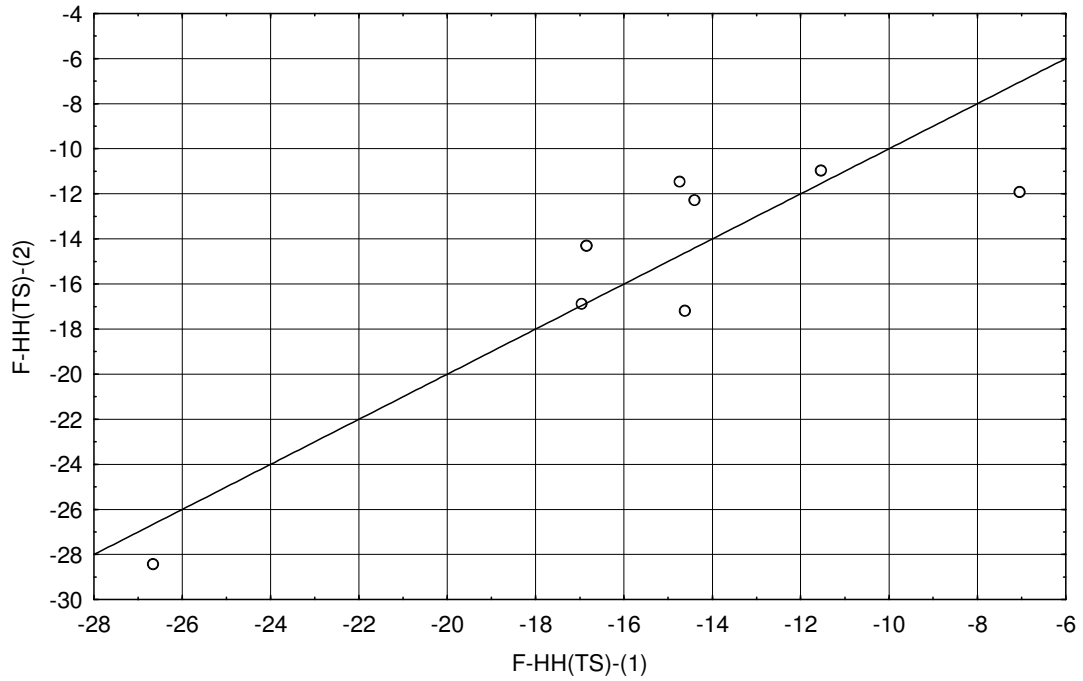
F-SA(MS)-(1):F-SA(MS)-(2): $r = 0.7972, p = 0.0178$
 Spearman $r = 0.76, p = 0.03$
 ICC(agreement)=0.736(0.146;0.941) ICC(consistency)=0.796(0.277;0.956)
 x=y line



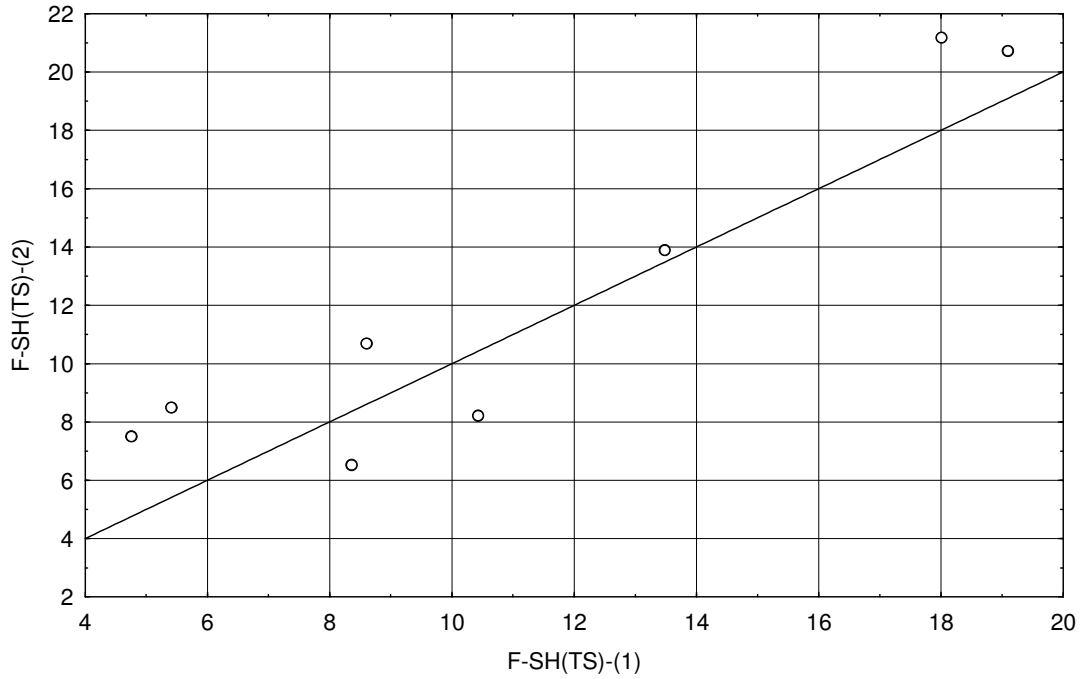
F LPT MS 1:F LPT MS 2: $r = 0.9245, p = 0.0010$
 Spearman $r = 0.93, p = 0.00$
 ICC(agreement)=0.898(0.518;0.979) ICC(consistency)=0.925(0.672;0.984) SEM=1.419
 x=y line



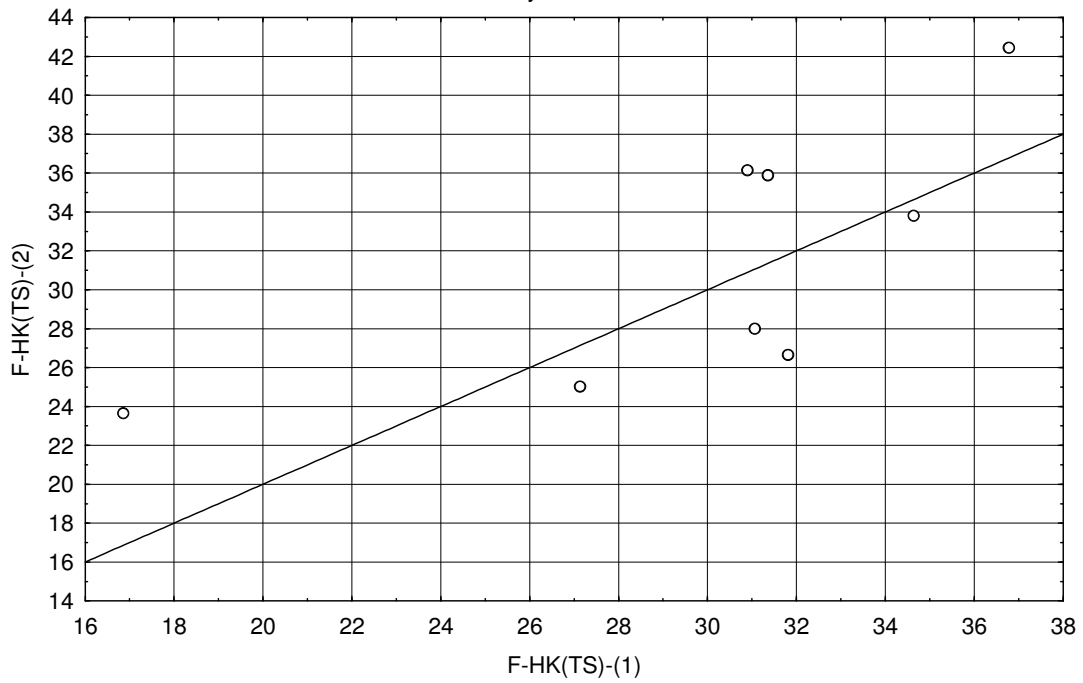
F-HH(TS)-(1):F-HH(TS)-(2): $r = 0.8776$, $p = 0.0042$
Spearman $r = 0.69$ $p=0.06$
ICC(agreement)=0.891(0.541;0.977) ICC(consistency)=0.877(0.507;0.974)
x=y line



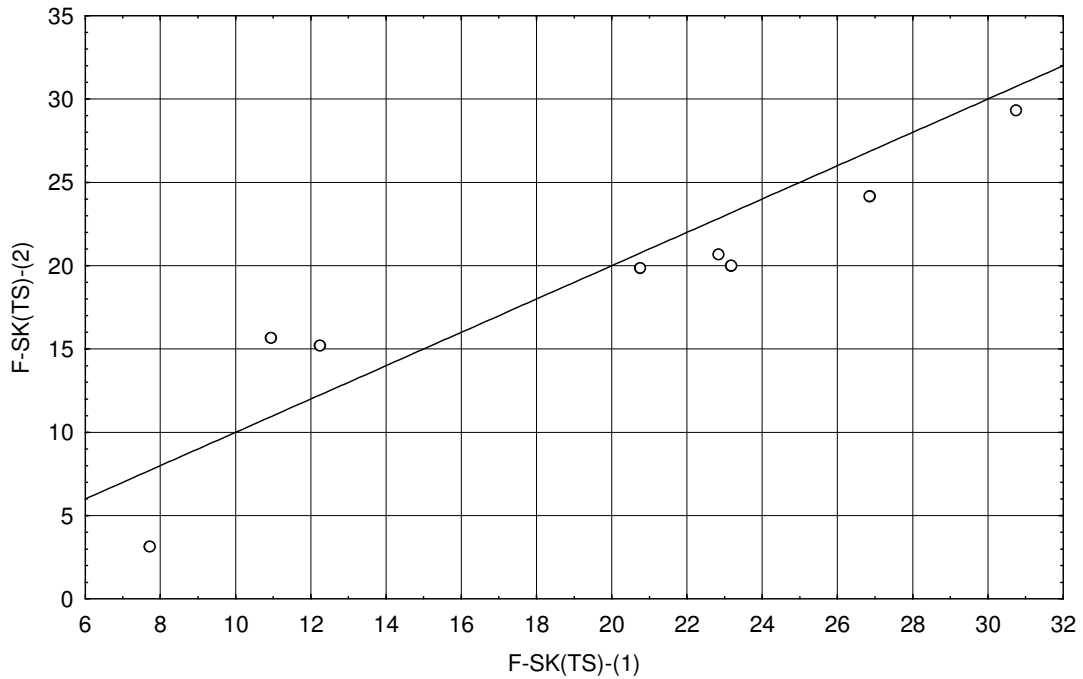
F-SH(TS)-(1):F-SH(TS)-(2): $r = 0.9310$, $p = 0.0008$
Spearman $r = 0.81$ $p=0.01$
ICC(agreement)=0.917(0.659;0.983) ICC(consistency)=0.928(0.684;0.985)
x=y line



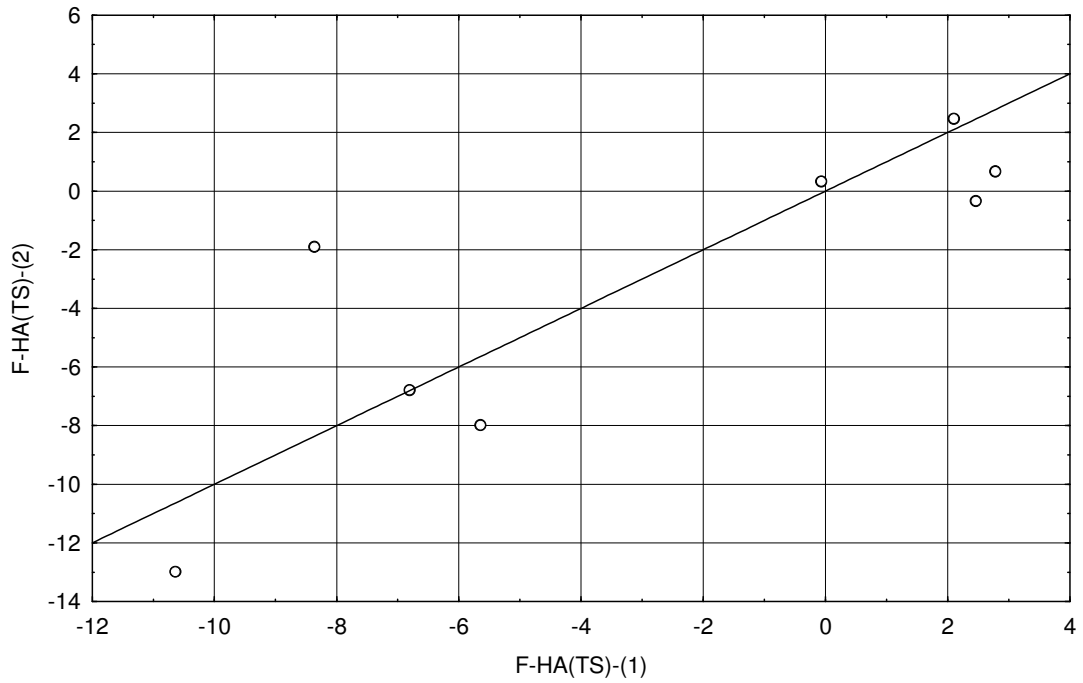
F-HK(TS)-(1):F-HK(TS)-(2): $r = 0.7313$, $p = 0.0393$
 Spearman $r = 0.64$ $p=0.09$
 ICC(agreement)=0.736(0.167;0.940) ICC(consistency)=0.728(0.120;0.939)
 x=y line



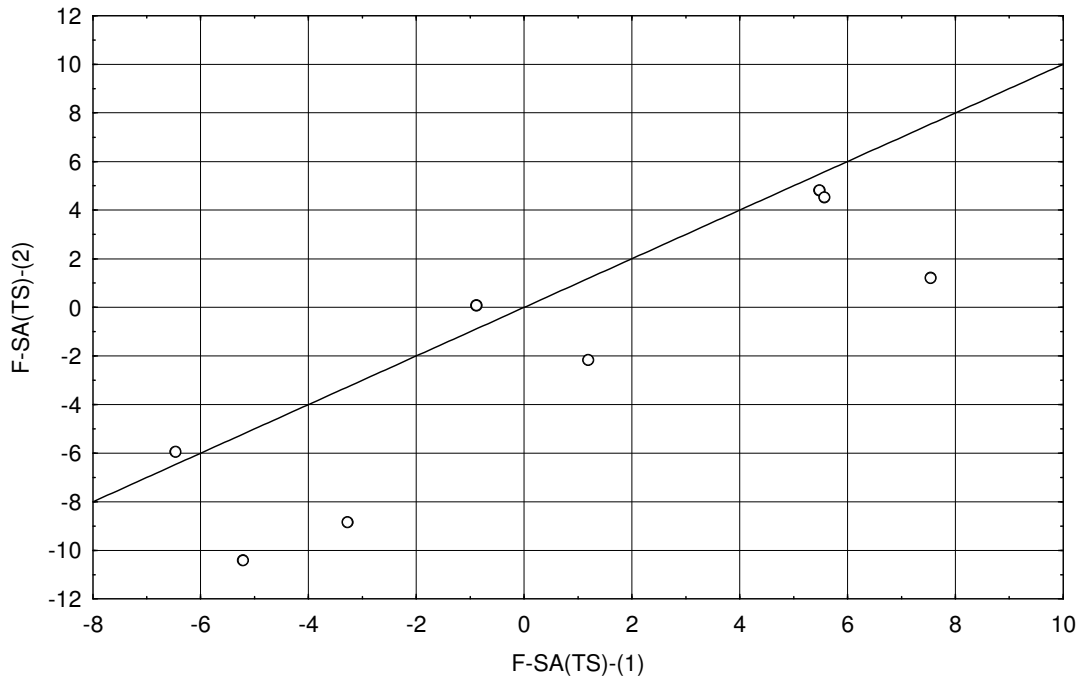
F-SK(TS)-(1):F-SK(TS)-(2): $r = 0.9225$, $p = 0.0011$
 Spearman $r = 0.95$ $p=0.00$
 ICC(agreement)=0.924(0.691;0.984) ICC(consistency)=0.920(0.657;0.984)
 x=y line



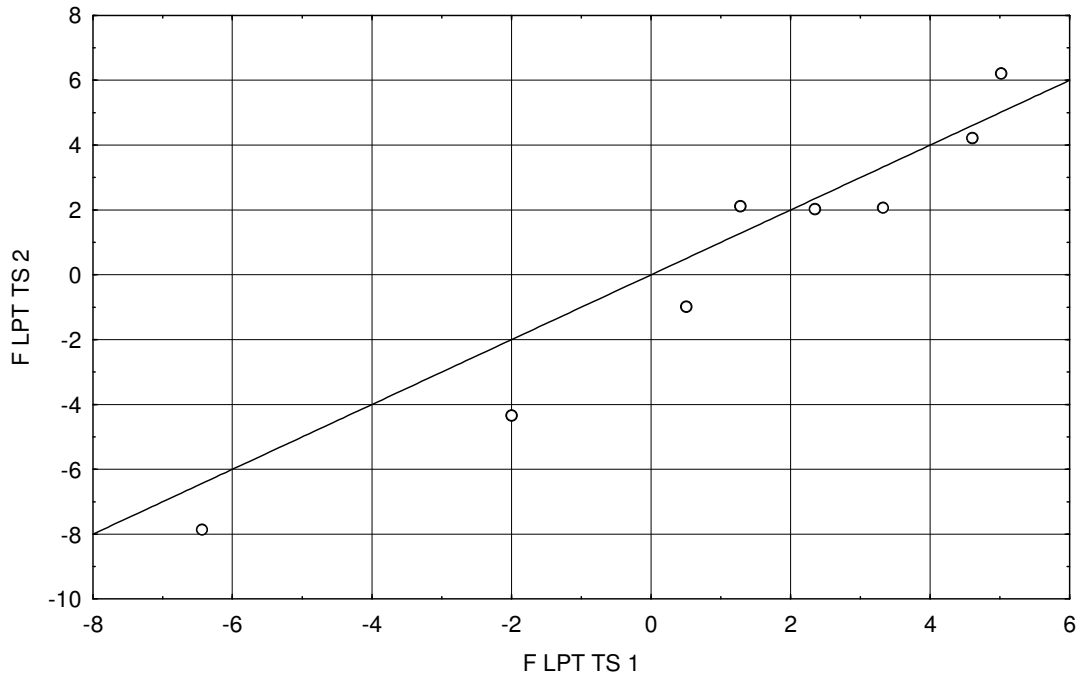
F-HA(TS)-(1):F-HA(TS)-(2): $r = 0.8414$, $p = 0.0088$
 Spearman $r = 0.79$ $p=0.02$
 ICC(agreement)=0.857(0.434;0.970) ICC(consistency)=0.841(0.398;0.966)
 x=y line



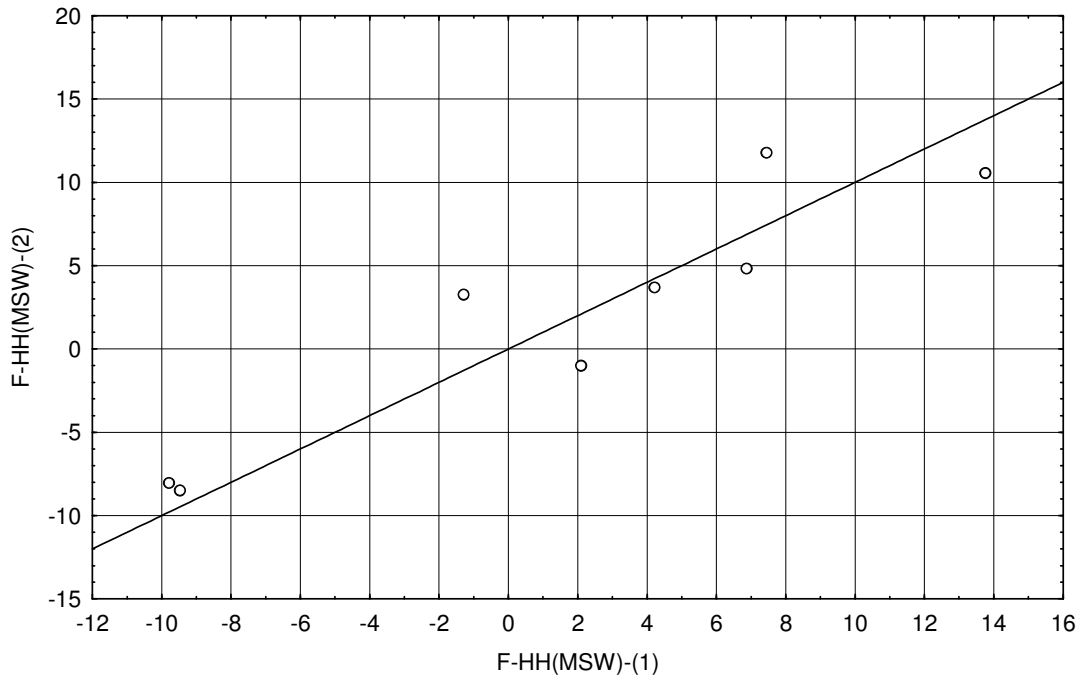
F-SA(TS)-(1):F-SA(TS)-(2): $r = 0.8687$, $p = 0.0051$
 Spearman $r = 0.81$ $p=0.01$
 ICC(agreement)=0.794(0.157;0.957) ICC(consistency)=0.865(0.469;0.971)
 x=y line



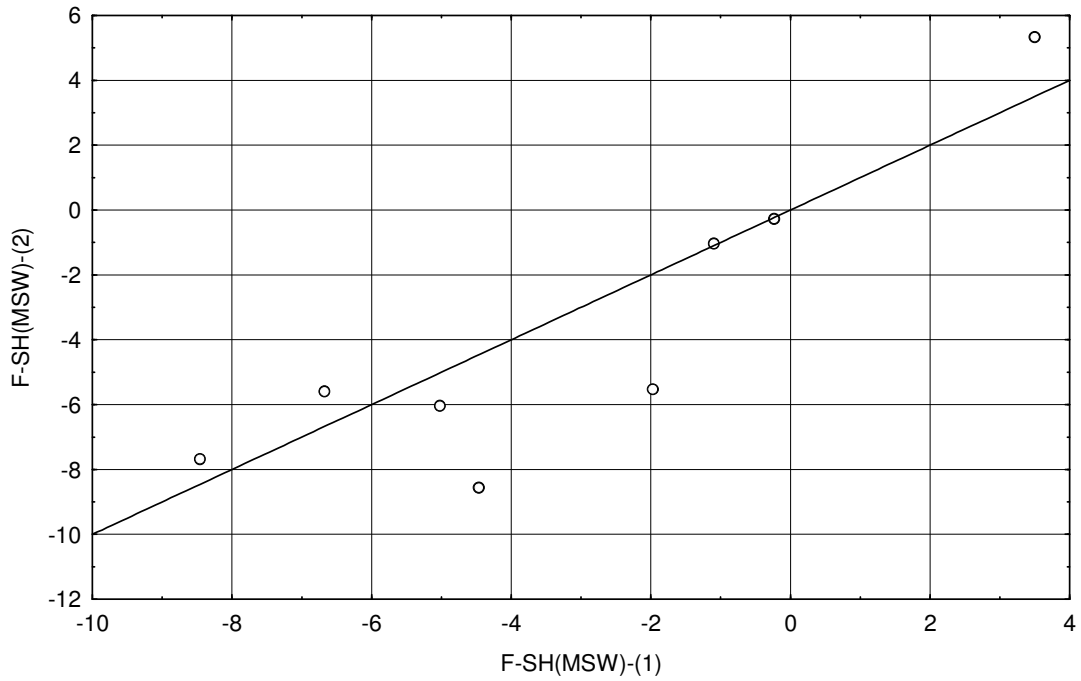
F LPT TS 1:F LPT TS 2: $r = 0.9772$, $p = 0.00003$
 Spearman $r = 0.93$ $p=0.00$
 ICC(agreement)=0.953(0.789;0.990) ICC(consistency)=0.959(0.810;0.992) SEM=0.857
 x=y line



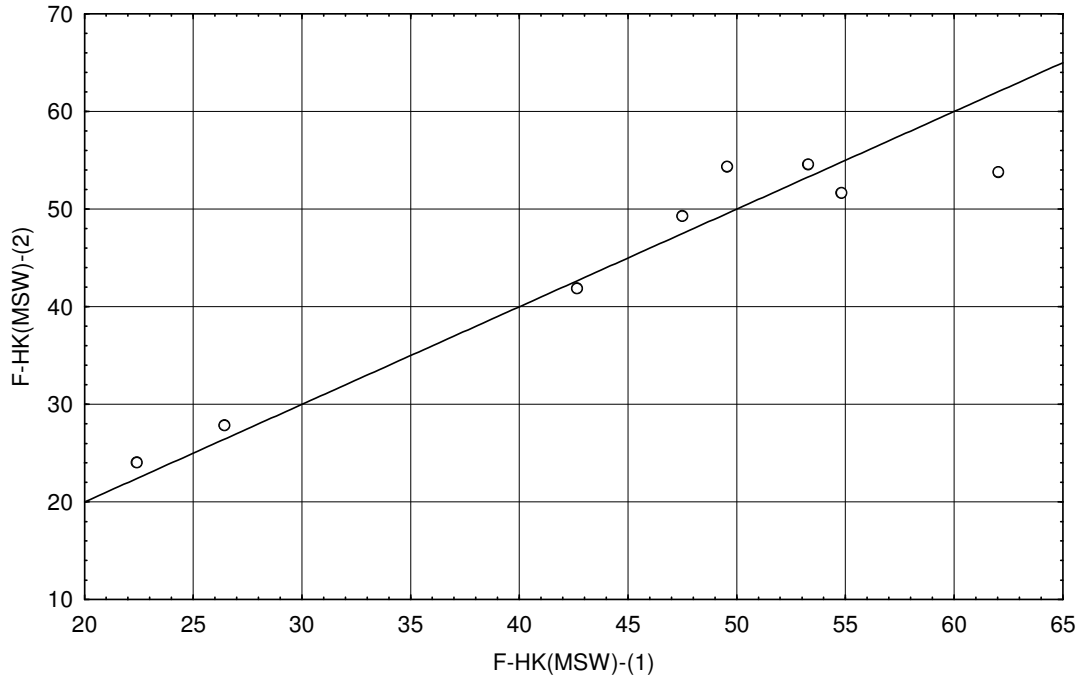
F-HH(MSW)-(1):F-HH(MSW)-(2): $r = 0.9275$, $p = 0.0009$
 Spearman $r = 0.93$ $p=0.00$
 ICC(agreement)=0.932(0.701;0.986) ICC(consistency)=0.924(0.670;0.984)
 x=y line



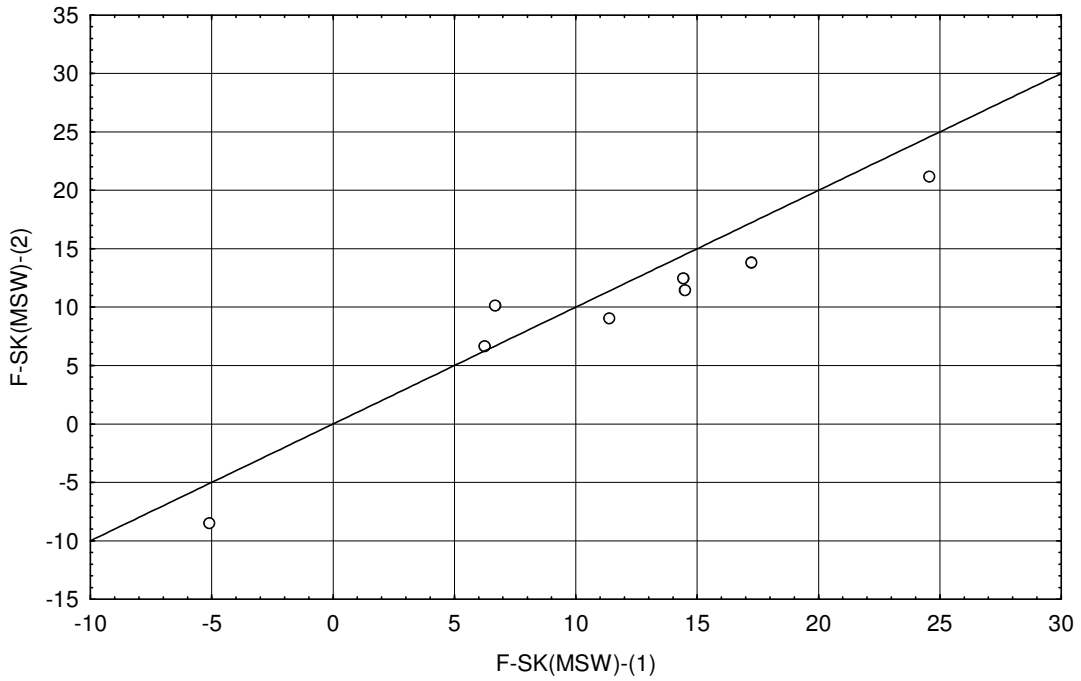
F-SH(MSW)-(1):F-SH(MSW)-(2): $r = 0.8889$, $p = 0.0032$
Spearman $r = 0.83$ $p=0.01$
ICC(agreement)=0.878(0.536;0.974) ICC(consistency)=0.873(0.494;0.973)
x=y line



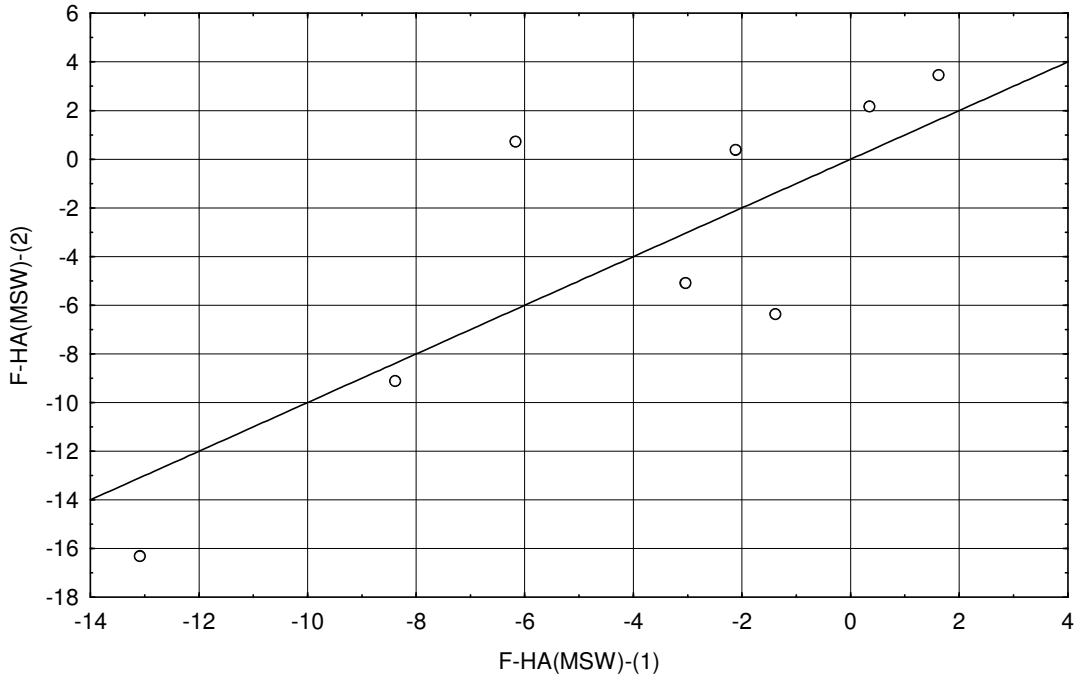
F-HK(MSW)-(1):F-HK(MSW)-(2): $r = 0.9606$, $p = 0.0001$
Spearman $r = 0.81$ $p=0.01$
ICC(agreement)=0.959(0.811;0.992) ICC(consistency)=0.954(0.790;0.991)
x=y line



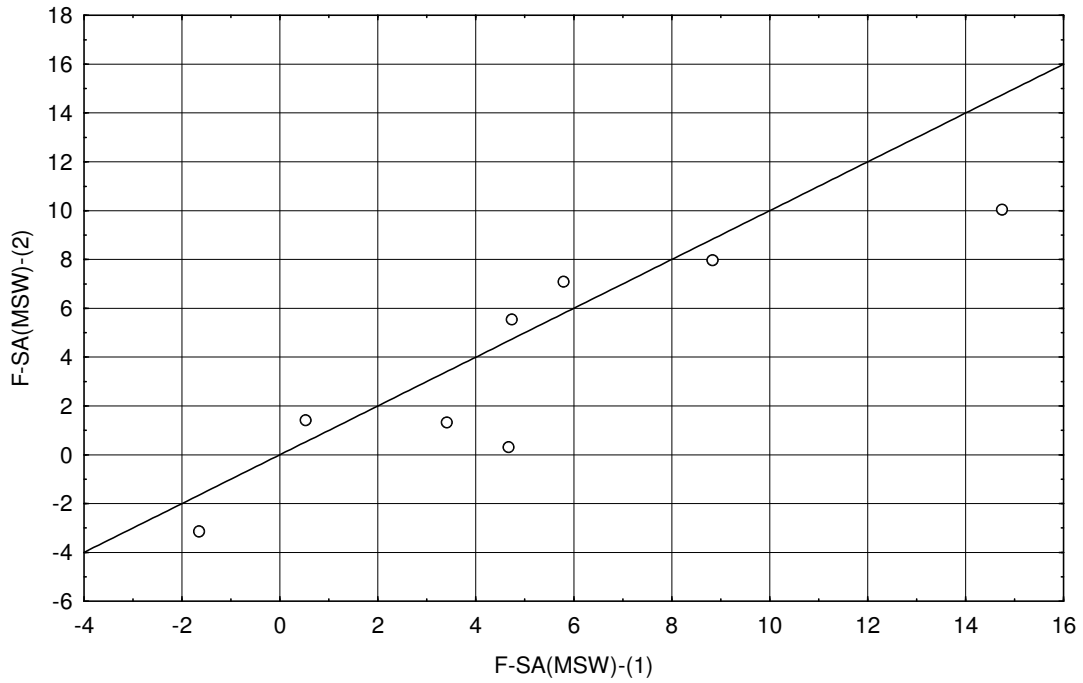
F-SK(MSW)-(1):F-SK(MSW)-(2): $r = 0.9607, p = 0.0001$
 Spearman $r = 0.95, p = 0.00$
 ICC(agreement)=0.946(0.717;0.989) ICC(consistency)=0.960(0.814;0.992)
 x=y line



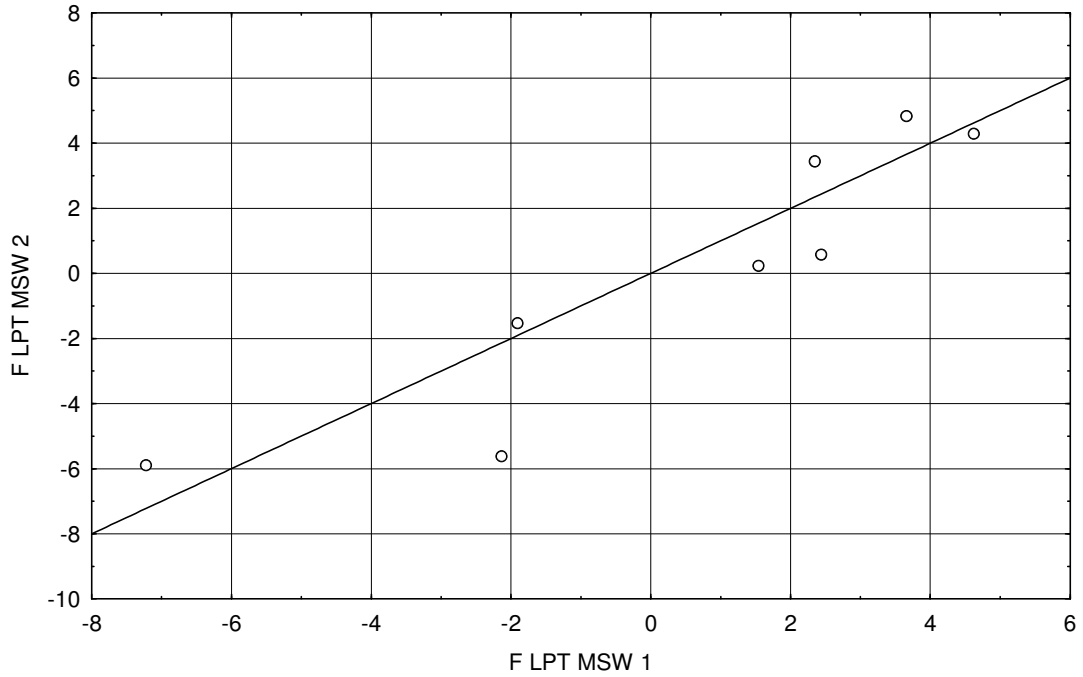
F-HA(MSW)-(1):F-HA(MSW)-(2): $r = 0.8361, p = 0.0097$
 Spearman $r = 0.79, p = 0.02$
 ICC(agreement)=0.815(0.303;0.960) ICC(consistency)=0.795(0.273;0.955)
 x=y line



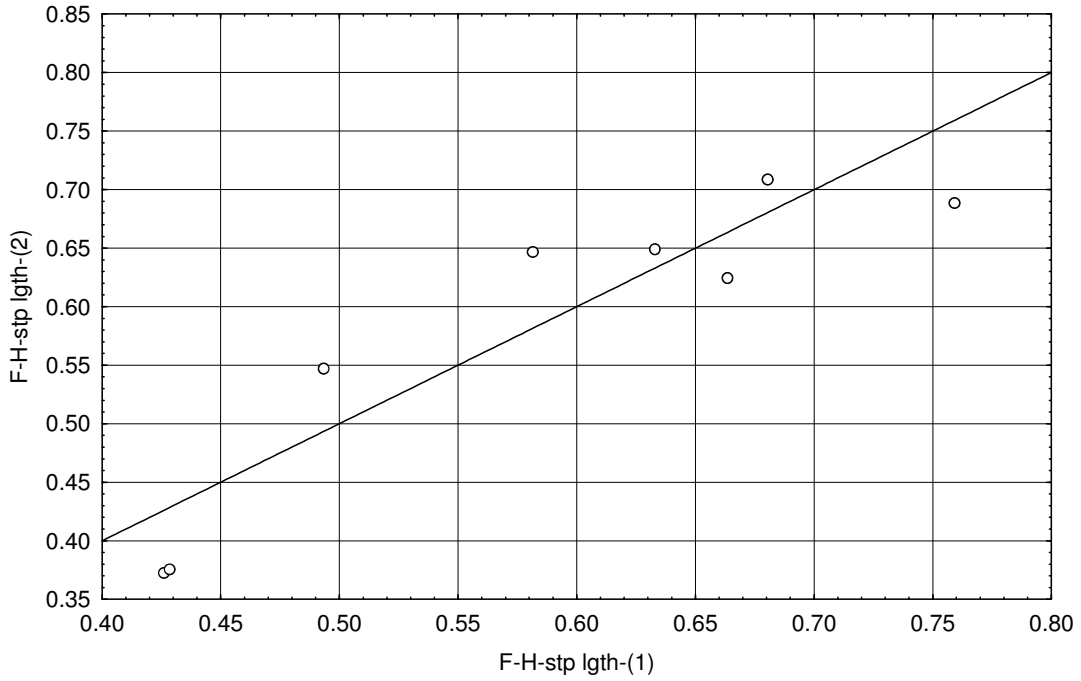
F-SA(MSW)-(1):F-SA(MSW)-(2): $r = 0.8871$, $p = 0.0033$
 Spearman $r = 0.90$ $p=0.00$
 ICC(agreement)=0.862(0.476;0.970) ICC(consistency)=0.882(0.523;0.975)
 x=y line



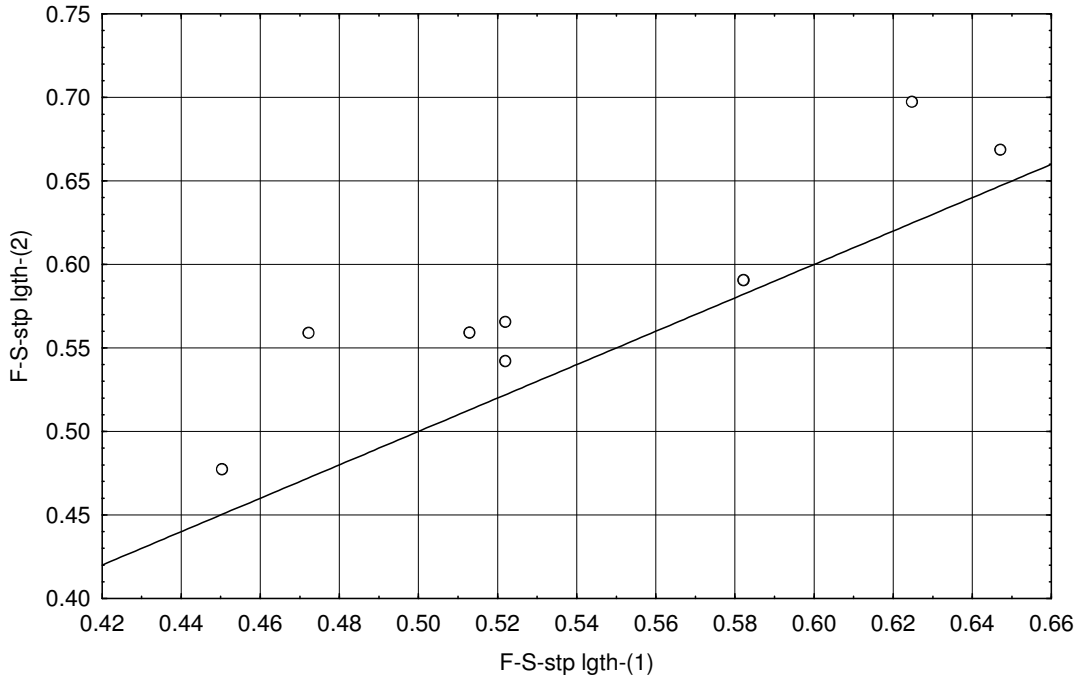
F LPT MSW 1:F LPT MSW 2: $r = 0.9116$, $p = 0.0016$
 Spearman $r = 0.95$ $p=0.00$
 ICC(agreement)=0.916(0.655;0.982) ICC(consistency)=0.910(0.618;0.981) SEM=1.219
 x=y line



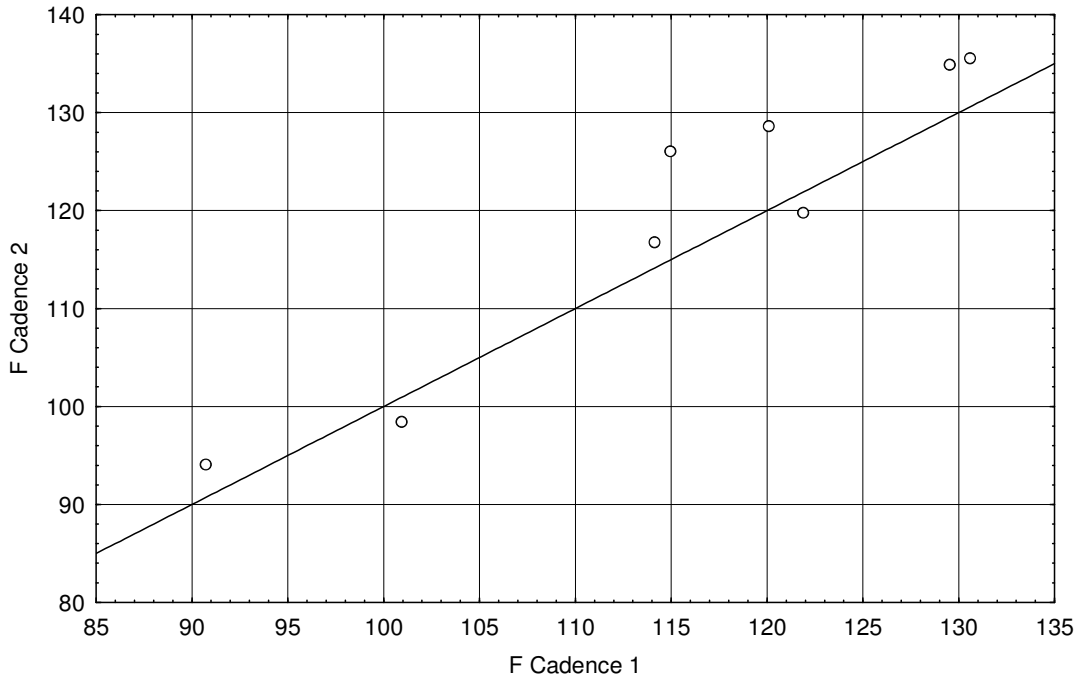
F-H-stp lgth-(1):F-H-stp lgth-(2): $r = 0.9167, p = 0.0014$
 Spearman $r = 0.90, p = 0.00$
 ICC(agreement)=0.922(0.665;0.984) ICC(consistency)=0.914(0.632;0.982)
 x=y line



F-S-stp lgth-(1):F-S-stp lgth-(2): $r = 0.9249, p = 0.0010$
 Spearman $r = 0.90, p = 0.00$
 ICC(agreement)=0.797(-0.054;0.964) ICC(consistency)=0.925(0.674;0.984)
 x=y line



F Cadence 1:F Cadence 2: $r = 0.9571$, $p = 0.0002$
 Spearman $r = 0.93$ $p=0.00$
 ICC(agreement)=0.922(0.536;0.985) ICC(consistency)=0.949(0.767;0.990) SEM=3.335
 x=y line



F Velocity 1:F Velocity 2: $r = 0.9784$, $p = 0.00002$
 Spearman $r = 1.00$ $p=-9999.00$
 ICC(agreement)=0.941(0.300;0.990) ICC(consistency)=0.975(0.882;0.995) SEM=0.044
 x=y line

