# SURFACE EMG OF ABDOMINAL MUSCLES AS A TOOL TO PREDICT THE AMBULATION OUTCOME IN T6-T12 MOTOR COMPLETE PARAPLEGICS – AN OBSERVATIONAL STUDY

Dissertation submitted to the Dr. M.G.R. Medical University, Chennai,

in partial fulfillment of the requirements for

the M.D. in Physical Medicine and Rehabilitation, March 2011

## CERTIFICATE

This is to certify that this thesis entitled **"Surface EMG of Abdominal Muscles as a Tool to Predict the Ambulation Outcome in T6-T12 Motor Complete Paraplegics – An Observational Study"** is the bona fide work of Dr. Linu Paulson and was conducted at the Department of Physical Medicine and Rehabilitation, Christian Medical College, Vellore.

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This is to certify that this thesis entitled **"Surface EMG of Abdominal Muscles as a Tool to Predict the Ambulation Outcome in T6-T12 Motor Complete Paraplegics – An Observational Study"** is the bonafide work of Dr. Linu Paulson and was conducted at the Department of Physical Medicine and Rehabilitation, Christian Medical College, Vellore, under my direct supervision and guidance.

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## DECLARATION BY THE CANDIDATE

I, Dr. Linu Paulson, declare that the materials and information for this thesis entitled '**Surface EMG of Abdominal Muscles as a Tool to Predict the Ambulation Outcome in T6-T12 Motor Complete Paraplegics – An Observational Study**' has been taken from the patients who have been admitted under the Department of Physical Medicine and Rehabilitation, Christian Medical College and Hospital, Vellore.

I also declare that this thesis was conducted under the guidance and supervision of Dr. Raji Thomas, Professor, Department, CMC, Vellore. This thesis is submitted in partial fulfillment of the rules & regulations for the requirements for the M.D. in Physical Medicine and Rehabilitation, March 2011

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LIST OF ABBREVIATIONS

| | |
|---|---|
| AIS | - ASIA impairment score |
| ASIA | - American Spinal Injury Association |
| FIM | - Functional Independence Measure |
| MUAP | - Motor Unit Action Potential |
| MU | - Motor Units |
| NLI | - Neurological Level of Injury |
| RTA | - Road Traffic Accident |
| SCI | - Spinal cord injury |
| SEMG | - Surface Electromyogram |
| WISCI | - Walking Index for Spinal Cord Injury |

# INTRODUCTION

# INTRODUCTION

The ancient Edwin Smith Papyrus (written by an Egyptian physician around 3,000 to 2,500 years B.C.), speaks of a spinal cord lesion as “an ailment not to be treated”(1) (2)

In the past, a spinal cord injury almost always meant certain death, or at best a lifetime of struggles to survive secondary complications.(3)

Such was the approach to this condition until World War I1, when new programs for medical treatment and rehabilitation reduced mortality rates following spinal cord injury from over 80 percent in World War I to below 10 percent by 1946. (4) We have come a long way from such times.

## Improved management Strategies

The decrease in the overall mortality due to spinal cord injury and the improved quality of life that has occurred over the years (5) (6) correlates with a better understanding of the sequelae of the condition and advances made in the field of spinal cord injury management. (7)

As there is no definite cure as yet for spinal cord injury, the focus of management is on optimal rehabilitation, capitalizing on the strengths, discovering new ability, and substituting for the lost functions.

Occurrence of spinal injury affects not only the individual but the entire family and the immediate community. As such, social integration and lifetime follow up are important goals of care.

Current management approaches include

- Strategies to minimize primary injury- this includes prevention of hypoxia and hypotension.
- Prevention of secondary injury- The secondary injury cascade is a series of events which will be described below.
- Attempts to prevent secondary complications- such as deep vein thrombosis, pressure ulcers, genitourinary infections and osteoporosis.
- Early competent multidisciplinary care and comprehensive rehabilitation programmes aimed at capitalizing on the residual potentials in order to maximize the functional outcome.(3) (8)
- Social integration and lifetime follow up.
- Peer interaction and involvement of the patient in goal setting according to their views and felt needs have also been recognized as contributory factors in successful rehabilitation.

Secondary Injury

In addition to the mechanical insult to the cord, the neural tissue is further damaged by a series of events collectively termed as the secondary injury cascade. (9) This involves oedema to the cord, microhaemorrhages, local vasoactive substances, high levels of excitatory aminoacids like glutamate, elevated intra cellular calcium, and free radicals toxic to the cells.

The damaged area of the cord is replaced eventually by a fluid filled central cavity surrounded by demyelinated axons.

Surgical Intervention:

When the integrity of the middle column and either the anterior or posterior column is affected, the spine is likely to be unstable. In such conditions, the spinal cord which it normally protects becomes vulnerable to damage.(9) Hence, surgical stabilization of the spine is sometimes required.

Non Traumatic Spinal Cord Lesions

In addition to trauma, demyelinating diseases, infections, radiation myelitis, arterio venous malformations or tumours may result in spinal cord damage. However, the principles of management and especially of rehabilitation remain similar to traumatic cord injuries, which is essentially to strive towards achieving goals of maximizing function and community reintegration. Iseli et al state that prognosis and recovery in the two groups seem to be comparable.(10)

## Newer Therapies and Strategies:

In addition to the above mentioned traditional approaches, there has been keen interest the world over in research to explore new rehabilitation strategies such as body weight supported treadmill training and the use of functional electrical stimulation (FES) to assist locomotion, as well as to evaluate therapies such as tissue engineering (e.g. stem cell therapy). (7)

## Implications of the Improved Survival Rate among the Spinal Cord Injured

As a result of this increased survival rate, the population of spinal cord injured is now greater than it used to be. It is hence a greater challenge to strive for the optimal care and quest for cure for these patients.

**Quality of Life after SCI- The Challenges**

The shift of interest nowadays is from this traditional goal of functional achievement to better quality of life (QOL) and life satisfaction as perceived by the spinal cord injured individual. It has justifiably become a key outcome in determining the effectiveness of rehabilitation programmes for people with SCI. However, it is difficult to quantify QOL owing to the fact that its perception varies from individual to individual. (11)

Multiple factors have been identified as being importantly related to the quality of life and one of them is the level of physical function achieved. Post et al have found that the levels of social and psychologic functioning are more important predictors of life satisfaction than the seriousness of the injury itself.(12)

Hicken et al have found that functional disability as measured by the Functional Impairment Measure [FIM] instrument is a predictor for life satisfaction.(13)

Higher Health Related Quality of Life (HRQoL) has been found by Jain et al, to be related with the ability to get around independently.(14) They found age, employment status, motor level and completeness of injury, and mobility as independent factors associated with HRQoL in SCI. (14)

Although comprehensive care and early rehabilitation has improved the mortality and to some extent, the quality of life of people following spinal cord injury, we are still far from meeting the expectations and answering the questions of a person with spinal cord lesion. This includes their questions about neurological recovery in terms of ambulation, bowel, bladder and autonomic functions. (15) (16)

## Mobility and Its Prediction- a Challenge

One of the commonest questions posed by an individual with a spinal cord lesion is whether he or she would ever walk.(17) (15) (16) However, for the health professional to be able to answer this is often both difficult and challenging owing to many reasons.

Secondly, prediction of outcome is also important for goal setting. Goal setting must be done as early as possible to decrease the costs associated with greater length of hospital stay.

There are very few methods to predict the ambulation outcome (18). This is especially so in the case of spinal cord injury occurring at the thoracic level because in this case it is difficult to precisely assess the motor function as opposed to cervical level lesions where motor function of upper limb can be assessed and lumbar or sacral levels where lower limb functions can be assessed.

In general, prediction of the mobility outcome of the patient with thoracic level spinal cord injury is based on the sensory level. i.e.T6 –T10 level paraplegics can often be trained to become therapeutic walkers with the help of knee ankle foot orthoses and walker while patients with sensory level T10 and below can become functional walkers with the help of KAFOs and elbow crutches. Patients with neurological level above T6 can be trained to be wheel chair independent.

In an ideal scenario, the above expectations are to be met. However, in many patients, the mobility outcome is not as expected or predicted.

It may be predicted that the patient will be able to attain functional walking based on the thoracic sensory level, but finally the patient may only become a therapeutic walker or be independent in a wheelchair. On the other hand, a patient for whom wheelchair training was planned due to his high neurological level may become a functional walker. Hence it is important to look at other factors that may determine the final mobility outcome of the paraplegic patient.

There is evidence that functional ambulation is a possibility among thoracic paraplegics (9) although there are differing opinions (19) (20). Predictors used for ambulation among thoracic level paraplegics are few and not well studied.

In this study we explore the use of surface electromyography (SEMG) of the abdominal muscles as a tool to predict the ambulation outcome in a paraplegic patient. This is an easy and noninvasive test which can be done with a portable machine that can be connected to a personal computer. To our knowledge, there is no study in current literature, to examine the Surface EMG of abdominal muscles as a predictor of SCI ambulation.

# AIM

# and

# OBJECTIVES

## AIM AND OBJECTIVES

**Aim**- To evaluate whether abdominal muscle Surface EMG activity can predict outcome of ambulatory capacity in patients with spinal cord lesions with NLI (Neurological Level of Injury) at T6-T12

**Objectives**

1. To prospectively examine whether abdominal muscle activity using surface EMG can independently predict ambulation outcome in paraplegics with NLI at T6 to T12.
2. To examine if the sensory level of a thoracic paraplegic correlates with presence of surface EMG activity in the muscle groups examined

## HYPOTHESIS

Presence of abdominal muscle activity as measured by surface EMG is a predictor of functional ambulation outcome among thoracic paraplegics

# BACKGROUND

# AND

# JUSTIFICATION

# OF THE STUDY

## BACKGROUND AND JUSTIFICATION OF THE STUDY

There is a definite need for prediction of ambulatory capacity among persons with spinal cord lesions. There is also a need for better predictors than those which are currently used for this prediction.

The above two arguments can be justified as follows:

### The Developing Country Scenario- Poor Wheelchair Accessibility

Rehabilitation of physical disabilities including SCI is not a high priority in the health care sector among the developing countries. Hence, the person with SCI and the family often have to struggle against many odds for survival especially among those with limited resources.

Walking among thoracic level complete paraplegics has been found to be inefficient according to some studies.

However, wheelchair accessibility is poor in India and other developing countries. Work places, countryside roads, footpaths and home environment are usually not suited for wheelchair use owing to non-availability of ramps or pavements and owing to the presence of uneven surfaces.

In such a challenging situation it is of paramount importance to target functional ambulation as a means to improve the paraplegic patient's mobility. This is necessary to improve their functional independence, employability (21) as well as community reintegration and quality of life.

MC Schonherr et al has stated that among patients with complete spinal cord lesions both the rehabilitation team as well as the patients often viewed functional walking as not a possible achievement. (22) This was stated irrespective of the neurological level of injury. This study grouped together the subjects as complete and incomplete paraplegics and tetraplegics.

Most studies state that irrespective of the neurological level of injury, if the spinal cord lesion is complete, it is a poor prognostic indicator for ambulation. (17) (23) (18)

As such, in developing countries, functional ambulation with Knee Ankle Foot Orthosis (KAFO) is being encouraged as the mode of primary mobility among thoracic level paraplegics (9) (24)

Grundy et al stated that in the context of rehabilitation of spinal cord injured persons in the developing country "care must be taken not to blindly apply the methodology used in the developed world, but to adapt the principles of treatment to take into account the specificity of the Third World, especially the limited financial means and cultural differences" (3)

The burden caused is enormous both in terms of economics and productivity as most of the persons are young at the time of injury. It causes permanent changes in the economical and social aspects of the person and has far reaching consequences on the quality of life. As there are limited options for complete cure, emphasis is mainly on capitalizing the strengths, discovering new abilities and substituting for the lost functions.

**Prediction of Mobility- Felt Need**

Ambulation is often expressed by paraplegics as an important felt need. (17), (25) (26). At times ambulation function has been prioritized by them even above bowel bladder and sexual function. (27) As pointed out earlier, involvement of the patients views and needs have significant implication on the rehabilitation outcome and quality of life.

**Prediction of Mobility-Importance in Goal Setting**

Often, the mobility outcome is not as expected; the mobility goal is set as ambulation and in the course of mobility training the patient cannot achieve functional ambulation, then wheelchair mobility training would have to be initiated.

Therefore in these cases, duration of hospital stay and their expenses would go up.

On the other hand, an occasional person for whom wheelchair mobility training was planned would be found to achieve functional ambulation.

Spinal cord injured individuals incur recurrent expenses throughout their lives beginning from initial hospitalization and acute rehabilitation to home modification, follow up evaluation and treatment of secondary complications as may develop. This is in addition to loss of wages and unemployment or underemployment.(28)

Hence, length of hospital stay requires careful consideration during the goal setting.

**Prediction of Mobility - Difficulties in Prediction**

The predictors available for functional ambulation among paraplegics are few and opinions are divided as to which group of patients should have functional ambulation as the goal for mobility.(25) This is especially so in the case of thoracic level paraplegics.

Currently clinical evaluation using the ASIA impairment score (AIS) is being used to predict the functional outcome. This scale requires the determination of Neurological Level of Injury (NLI). (29)

Motor outcomes are hence being correlated with the NLI. In the case of thoracic level paraplegic it is difficult to determine a definite motor level. As such, sensory level is used for the prognostication of motor function. This should lead us to consider that tools which evaluate the muscle function at these levels would be more accurate in the prognostication rather than the sensory level which is currently being used.

**Prediction of Mobility- realistic hopes.**

Realistic goals and the involvement of patients is indispensible for their rehabilitation. As a part of this process, providing information about the prognosis of functional outcome is vital. (22) (30)

# REVIEW

# OF

# LITERATURE

## REVIEW OF LITERATURE- Outline

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## Spinal Cord Injury- The Overwhelming Statistics

According to the National Spinal Cord Injury Statistical Center (NSCISC), it is estimated that the annual incidence of spinal cord injury is approximately 40 cases per million population in the United States. (2)

Though national statistics for SCI is not available for most of the developing countries, if we should extrapolate the above data to the Indian population of above 1000 million the burden would be colossal. (3) (9)

By estimate, approximately 200,000 individuals with spinal cord injury live in India, with 10,000 new individuals added to this number every year. (31)

## How Common is ASIA A and B Thoracic Level Spinal Cord Injury

Complete spinal cord lesions are far more common than the incomplete type.(32) The distribution of lesions by ASIA scale is as follows: ASIA A (45%), B (15%), C (10%), and D (30%). Hence ASIA A and B type injuries account for 60% of all spinal cord injuries. (32)

Approximately 55% of acute SCI occurs in the cervical region, with approximately 15% occurring in every other region. (32)

## Ambulation in Spinal Cord injury- Advantages

Ambulation training has many benefits besides improvement of walking ability. The ability to walk short distances and the ability to perform activities which require standing and walking are often the goals for people with spinal cord injuries.

Ambulation has been shown to be associated with various physiological and psychological and other clinical advantages

## 1. **Physiologic Benefits**

a) Prevention of Deep Vein Thrombosis (DVT) – DVT occurs around day 30 (33) after a spinal cord injury. Immobilization is well known as a cause for DVT and ambulation can prevent this potentially life threatening condition.

b) Metabolic Advantages - Walking helps to improve the overall activity level. Spinal injured patients are often classified as sedentary and are found to have an increased incidence of secondary complications like diabetes mellitus, hypertension and dyslipidemia. (34) (35)

An interesting study by Morse et al (36) suggested that CRP in chronic SCI is independently related to locomotive mode. CRP could be related to systemic inflammation and cardiovascular health (37)

c) Locomotor recovery – Locomotor training programmes may contribute to spinal cord recovery. This is the basis of the concept of retraining the spinal cord which has gained popularity in the field of Rehabilitation Medicine in the form of body weight supported treadmill training. (38) (39)

d) The development of pressure ulcers is associated with prolonged sitting (40) and hence may be prevented if ambulation is possible. Pressure ulcers in general are fewer in ambulant persons according to a study by Gupta et al. (31)

e) Pain Relief- Ambulators experienced less pain compared to nonambulators, though the frequency of shoulder pain was more among the ambulators due to the long-term use of walking aids.(31)

f) Spasticity- Severe spasticity that interferes with function might be less in persons who are ambulant (31)

g) Osteroporosis and fracture prevention- The weight bearing in the vertical position could possibly contribute to the prevention of osteoporosis and fractures. (41)

h) Prevention of rehospitalisation: It has been shown that persons with non-ambulatory high cervical or non-cervical SCI were more likely to be hospitalized.(42) Therefore if ambulation is facilitated, rehospitalisation may be prevented.

**2. <u>Psychological benefits-</u>**

Persons with spinal injury will have sustained profound psychological trauma and may continue to manifest fear and anxiety, wide variety of moods, and behaviour similar to the grieving process. (3)

In addition to psychotherapeutic interventions, goal directed activities such as ambulation training could be a part of their coping mechanism and adaptability.

Also, at discharge from the safe and supportive milieu of a rehabilitation facility, a person with SCI enters a new stage of adjustment—dealing with the reality and practical problems and challenges. In that situation, achieving ambulation will go a long way in facilitating autonomy of transportation to place of recreation, or to re-connect with friends etc.

Powered wheelchairs, Environmental Control Systems and other technology have been suggested to reduce the feeling of helplessness that contributes to psychological problems. However, in developing countries, these tools are not available or are expensive and hence not feasible. Hence, walking becomes important as a way of accessibility, and decreased dependence on the caregiver.

Hicks et al report that ambulation training has been associated with improved life satisfaction.(43) Literature indicates that for many people, physical activity itself is the main vehicle through which they redefined their lives. (44) (45)

## 3. Functional Achievement and Implications

Activity Level and Independence-

As mentioned above, autonomy of transportation would facilitate easier performance of ADL and I-ADL. Ambulation training has been associated with improved physical function. (43) Krause et al reported better participation among spinal cord injured persons who ambulated as opposed to those who used wheelchair (46) However, this study did not show consistently better results for subjective well being.

Negotiation of Barriers-

The perceived environmental accessibility is stated to be related to the quality of life of a paraplegic. (47) , (48) Richards et al have studied this and found that access to the environment is important in predicting satisfaction with life for persons with spinal cord injury (49)

**4. Community Reintegration**

Ambulation could go a long way in community reintegration of individuals with spinal cord injury for example going to the market or place of work, involving in social activities.

**5. Employment- return to work**

Many factors are found to correlate with return to work after SCI. Pflaum et al found that employment rates are lower for persons with tetraplegia than for persons with paraplegia and lower for those with complete compared to incomplete deficits.(50)

Ottomanelli et al have reviewed the critical factors related to return to work and have found that having greater functional ability has been shown to be related to the employability.(51) This should lead us to consider that, maximizing the performance at a particular level is of great importance.

Autonomy of transportation to the place of work is important as a predictor of return to work. (21) This finding may impart priority to achievement of walking function to negotiate non-wheelchair accessible areas as are common in developing countries.

In a study by Hess et al, the results support the value of employment in sustaining and improving psychological well-being. (52) Among persons with a spinal cord injury, even part-time employment provided significant psychological advantages over unemployment status.

**6. Life opportunities as a whole**

Reduced life satisfaction and quality of life (QOL) have been reported to correlate with reduced life opportunities, reduced social interaction and reduced mobility. (11) It has been stated that 'the primary goal [in rehabilitation] must be achieving the highest level of quality of life.

## Factors Affecting Ambulation

1. **Etiology:**

McKinley et al report that paraplegics with non-traumatic SC1 subjects have lower discharge motor FIM scores than those with traumatic SCI. (53) However, Iseli et al state that motor recovery as well as ambulatory capacity was comparable in the two groups. (54)

2. **Level of the spinal cord lesion-**

Higher the level and the more complete the injury, the more likely it is that there will be loss of muscle function and strength, and functional disability in SCI (14)

3. **ASIA Impairment Score (AIS)-** Kay et al state that more individuals with ASIA C or D walked compared to ASIA A or B (55) The study also indicated that level of injury did not significantly affect walking after AIS grade C or D injuries.

4. **Spasticity-** Spasticity has been reported to have the potential to inhibit effective walking. (56)

5. **Age-** Being 50 years or older had a significant negative affect on walking in subjects with AIS grade D but not AIS grade C injuries.(55)

6. **Gender-** Scivoletto et al report that no sex-related difference is seen in the outcome including ambulation outcome. (57)

Interestingly, taking quality of life (QOL) as an outcome, Middleton et al report that factors such as completeness of lesion, sex, age at time of injury, and time since injury were not associated with reduced QOL. (58)

## Is Functional Ambulation Possible After Spinal Injury? – A Literature Review

There are varied opinions about ambulation in persons with complete thoracic paraplegia

a) Walking is possible but not for function– Merati et al reported high energy expenditure among subjects who used different orthoses and walked. (19) They also suggest that subjects who achieved high wheelchair speeds were the right candidates for reciprocating gait orthosis, as was used in their study. Cerny et al also recommend that wheelchair training should rightly be prescribed for the same reason.(59)

b) Functional walking is possible- Follow up study in the community done on patients discharged from CMC Hospital, Vellore, has shown that thoracic level paraplegics continue to use orthosis for functional ambulation. (60).

WHO guidelines suggest that ambulation is possible in the thoracic level paraplegic (9) as follows:

T7 to T11 levels - Persons with these levels can be trained to ambulate functionally or therapeutically with bilateral KAFO and walker/elbow crutches. However the endurance, speed, energy efficiency and ease of outdoor mobility will be limited.

T12- L2 levels - Patient can be totally independent with bilateral KAFO and elbow crutches. (9)

c) The WHO manual for mid level workers (61) has classified paraplegics according to possibility of outcome of physical function based on the sitting balance achieved. The grades are as follows

Grade 1-4 are different grades of tetraplegia.

Grade 5 – high paraplegia: Can sit without support, can lift both hands up at the same time, requires physical assistance initially for activities in this position

Grade 6- Low Paraplegia: Can sit without support, can throw and catch a ball above the head and does not require physical assistance.

According to this, walking is possible only in Grade 5 and 6 paraplegics or incomplete paraplegics.(61)

d) According to Kirshblum et al, in patients with T1-T12, functional walking is not usually an inpatient goal (62)

e) Functional walking is not tried due to rehabilitation professionals preferences (63) Ditunno et al report that professional staff placed greater value in wheelchair independence than did acute SCI subjects who showed a greater preference for walking and this was based on their practical experience of having to discharge patients early due to restrictions on the number of rehabilitation days allowed for reimbursement by third party payers.

f) Conflicting results of follow up studies: Western literature indicates that around 90 % of persons used wheelchair for mobility at follow up. (64) However, a study done at CMC Hospital, Vellore, seems to indicate that 60% were ambulant with orthoses and walking aids, and besides were independent in activities of daily living. (65) .

Such a striking difference should lead us to consider that the developing countries have unique challenges. Pre-morbid experiences of such a population could contribute to such a finding.

## **Are there dangers of harmful over exercise in thoracic level paraplegics?**

The sympathetic innervation of the heart derives from the spinal cord segments between T1 and T4. A lesion above T1-4 could seriously compromise with an an increase in heart rate at the beginning of the exercise, as well as cardiac output, final diastolic volume, and stroke volume. (66)

Hence, thoracic paraplegics below this level (T4 level) could safely be prescribed an exercise program.

## **Ambulation in Spinal Cord Injury- Types**

### Swing to gait

This type is stated as the easiest type of gait to achieve. The disadvantage is that it is too slow for functional ambulation and is hence described to be used only as an exercise.

The patient puts the crutches a short distance in front of the feet and leans forward on to the crutches. He or she then pushes down with the shoulders, which lifts both legs together. The feet must land behind the crutches. It is a short, sharp lift. Prolonging the lift will make the feet go past the crutches and the patient will lose balance and fall

### Swing through gait

Swing through gait is advantageous because of the greater speed achieved. However, it does expend a lot of energy. Hence, if used for function, short distance ambulation may be possible.

The patient places the crutches about 18 inches in front of the feet and leans forward on to the crutches; he or she then pushes the shoulder down, which raises both feet off the floor together. The lift must be maintained so that the feet are placed the same distance in front of the crutches as they started behind.

As the feet touch the floor the patient must retract the shoulders to extend the hips and hence remain balanced.

### Four point gait

Four point gait is the most difficult and requires excellent balance and strong shoulders and trunk. It is the nearest equivalent to a normal gait, but is very slow.

The patient moves one crutch forward, transfers body weight on to the adjacent leg, and then moves the opposite leg forward by using latissimus dorsi to “hitch” the hip. The step must be short; if too large a step is taken the patient will fall, as he or she cannot recover balance.

**Methods and Orthotics Being Tried in Thoracic Level Paraplegia**

Various orthosis are being designed and tried out for use by thoracic level paraplegics.(67) Knee Ankle Foot Orthosis (KAFO), Hip Knee Ankle Foot Orthosis (HKAFO), Reciprocating Gait Orthosis (RGO) and Hip Guidance Orthosis (HGO). (68) Important patterns, aids and orthotics are described below:

**Ambulation Using Knee Ankle Foot Orthosis (KAFO)**

KAFOs are used when mechanical control of the knee joint is required in weight-bearing due to weak or absent muscle function or joint deformity. As the name implies, KAFOs physically encompass the foot, ankle, and knee, providing direct control of each of those joints. (67) KAFOs can be worn unilaterally or bilaterally as required.

Hip stability is not provided by the orthosis but can be augmented when necessary by shifting the trunk center of mass posteriorly so that the ground reaction force is oriented posterior to the hip joints, creating tension in the anterior Y ligament of the hip joint and internally stabilizing the hip joints. This posture allows for stable standing in adults. Heel raise on the shoe helps to maintain the hyperextension at the hip while the patient is using a KAFO. The toe wedge on the AFO reduces the spasticity.

**Advantages associated with Lofstrand crutches include the following:** (69)

Ambulation is safer and easier. This type of crutch is a good substitution for the cane, because the forearm support stabilizes the wrist during weight bearing. The patient's hands are free to perform various tasks while the individual's body weight is supported through the forearm by the forearm cuff pivots. The patient does not have to worry about dropping the crutches. These crutches are shorter than axillary crutches.

Measurement prescription – With the proper crutch length determined and the crutch then placed 3 inches lateral to the foot, the proper handpiece location can be measured. The patient's elbow should be flexed 20°, the wrist should be in maximal extension, and the fingers should be held in a fist.

**Ambulation in Spinal Cord Injury- Primary Muscles Used**

Upper Limb

Shoulder Depressors, Elbow extensors, Wrist extensors

Thorax - Intercostals

Anterior Abdominal wall

Paraspinal and Back Muscles:

Lattisimus dorsi, Quadratus Lumborum, Erector Spinae

Quadratus Lumborum extends from iliac crest to lateral thorax posteriorly. This is a powerful lateral flexor of the trunk and can elevate the pelvis. Latissimus Dorsi muscle extends from iliac crest to upper end of humerus. This is a powerful extensor and adductor of the shoulder and elevates the pelvis when the shoulder is stabilized.

The following muscles have been described in HGO walking (68) and their action is applicable to KAFO/EC walking also.

**Latissimus Dorsi:** this large muscle acts when the flexed arm is extended against resistance until the arm reaches the plane of the body; it also acts as a tie between the shoulder and the pelvis on the swing leg side.

**Pectoralis Major:** acting as a whole, the muscle adducts the humerus; the lower fibres act in conjunction with Latissimus Dorsi.

**Deltoid:** is also capable of acting in parts or as a whole; the rearmost fibres co-operate with the Latissimus Dorsi; it acts to steady the shoulder; it acts as an abductor of the shoulder joint.

**Trapezius:** assists in steadying the scapula and maintains the level and poise of the shoulder.

**Triceps:** the principal extensor muscle of the elbow.

## Steps in Progressive Ambulation

Steps for gait training for functional ambulation using knee ankle foot orthosis and Lofstrand's crutches have been described as follows (61) (9)

### Balance Training

Once the patient is ready to stand with KAFO, the first step is to attain standing balance. Usually the standing balance training is carried out within the parallel bars, in front of a mirror. Patient is taught to balance the upper trunk behind the line of gravity by hyper extending the hips. The shoulders should be aligned behind the waist.

The taut anterior iliofemoral ligaments (Y Ligament) of the hip maintain the stability of the hip joints. The mediolateral stability is achieved by hand support.

So, practically even high level patients can achieve therapeutic standing by using KAFO. Hence the HKAFO is rarely considered in our clinical practice. Standing balance may be enhanced by appropriate adjustments like lateral, medial or posterior wedges in the shoes. The aim is to achieve standing without support. Further, good standing balance improves performance of activities of daily living.

Gait Training

The next step in mobility training is to start hiking - strengthening of the hip hikers, mainly the quadratus lumborum and latissmus dorsi. Hiking can be started with forearm support within the parallel bar. This would facilitate balancing body weight on one leg to enable the opposite leg for hiking training. When the patients are not able to isolate the hip hiker muscles, a wooden plank can be given on the opposite foot to improve the ground clearance.

Next step will be to train hiking in standing position. In order to hike the right leg the left hand has to be placed forward on the parallel bars to gain better upper trunk control. The right hand is to be placed at the hip level to improve the hiking muscles work. Now, the person has to attempt lifting the right leg to initiate hiking.

If the person is able to perform hiking on both sides with good ground clearance, ambulation inside parallel bars is started. An endurance of 500 meters inside the parallel bars is achieved before progressing to a reciprocal walker.

The hikers can be strengthened by using weights and swinging the leg forward and back ward. Low level SCI persons may substitute hiking using trunk extensors which needs to be discouraged.

Standby assistance is needed in all the gait training phases to ensure safety. Waist belts/towel around the waist also will ensure greater safety and improves the patient's confidence during the earlier stages of mobility training.

Once the patient is ambulant with walker, then he is brought back to the parallel bars for crutch training. Initially standing balance with one elbow crutch is started, progressed to complete.

The person is taught to ambulate inside the parallel bars using one elbow crutch and one of the bars. After this he is trained to walk outside the parallel bars in the same way. The progression will be to bilateral crutches inside then outside the parallel bars, aiming a total of 500 meters without rest. This ambulation with the aid of elbow crutches can be either 4 point gait or swing through gait.

Training in Four Point Gait The patient is taught to place the right crutch forwards followed by the left leg and then the left side crutch followed by the right leg. This gait pattern resembles normal walking and the loads on the upper limbs are relatively less.

Advanced ambulation training: This includes step climbing, using ramps, uneven surfaces and safe fall to the floor. While walking on a ramp the patient has to balance by leaning forward when going upwards and by leaning backwards when moving downwards.

## **Prediction of Ambulation- Advantages in the Rehabilitation of SCI**

Knowing in advance whether a patient with spinal cord lesion is likely to be ambulant has many clinical advantages.

### ***1. Goal Setting***

Firstly, it would help specifically in goal setting at the initiation of a specific rehabilitation program for mobility training directed at either functional ambulation training or wheelchair use.

Goal setting involves a prediction of the possible functional outcome. The importance of having a well planned initial rehabilitation goal and programme cannot be overemphasized.

It is during this time that the paraplegic patient would conceptualize and actually learn the way he would carry on activities for the rest of his life.

The initial hospitalization is also a time when social support is usually maximal. Conditioning, and goal directed training are of paramount importance to equip the paraplegic for future adaptability and ability to cope with the challenges of a new kind of life. Hence, it is imperative to be able to predict what long term functional outcome might be achieved and to train him or her accordingly before discharge

## 2. Perception of illness

Secondly, it would help in the spinal cord injured person's perception of his or her illness and self-concept. Thus, predicting that a patient would be ambulant might help them allay their anxiety and help form a concept that braced ambulation and use of aids might be necessary.

Prediction that ambulation might not be possible is also beneficial in that the patient would better come to terms with the new adaptations necessary subsequent to the illness. In addition, it would help the family in responding to and planning for the situation and in their psychosocial adaptation.

### The expectation of gait according to the neurological level of injury

The expectation of gait according to the neurological level of injury has been stated as follows according to popular teaching: (7)

| | |
|---|---|
| T1–T8: | Swing to gait with calipers and rollator;<br>May use crutches if spasticity is controlled |
| T8–10 | Swing to and swing through gait with full length calipers and crutches;<br>Walking more likely to be an exercise rather than for function. |
| T10–L2 | Swing through and four point gait with calipers and crutches;<br>Requires wheelchair for part of the day— walking may be fully functional. |
| L2–L4 | Below knee calipers with crutches or sticks.<br>Wheelchair not required |
| L4–L5 | May or may not require calipers.<br>Wheelchair not required.<br>May require sticks or other walking aid. |

## A Critical Look at the Accepted Goal Setting Principles

1. Socioeconomic and environmental factors are not taken into account-

Wheelchair inaccessible areas are all too common in developing countries. Hence it is imperative to take this factor into account.

2. Preference of patient versus rehabilitation professional (63)

As mentioned before, professional staff placed greater value in wheelchair independence than did acute SCI subjects who showed a greater preference for walking.

3. Cost versus benefit:

Energy efficiency has been cited as a reason for wheelchair preference. (20)

4. Have paraplegics with thoracic level done well?

For patients with thoracic paraplegia where ambulation was the primary goal, the functional outcome has been followed up in the community among South Indian persons (60) in a study done at CMC Hospital. High levels of community reintegration in physical independence, social integration, and cognitive independence has been reported.

## Summary of Rationale of the Study Based on the Review of Literature:

In the context of an environment with poor wheelchair accessibility, such as in a developing country, ambulation training is an important option .Prognostication and goal-setting in the context of a spinal cord lesion pose many challenges to the physiatrist, more so in the case of thoracic paraplegia. This can be explained as follows.

In the case of persons with tetraplegic or low level paraplegics, motor examination of the upper and lower limbs respectively can serve as a guide to setting functional goals. However, in thoracic paraplegics precise determination of the motor level is difficult. Hence, sensory level has long been used as a guide to predict whether a paraplegic would achieve functional ambulation, such as in the ASIA scale.

At present, the Standard Neurological Classification of Spinal Cord Injury. given by the ASIA (American Spinal Injury Association) is widely used to predict the ambulation independence.

This scale defines the Neurological Level of Injury (NLI) using muscle testing of key muscles in upper and lower limbs. NLI is taken as the most caudal level with normal function. Among thoracic paraplegics, where an objective assessment of the myotomes involved is difficult, the sensory level is rather used to define the NLI according to the ASIA Impairment Scale.

According to available literature, paraplegics above T11 do not become functional walkers. However, it is our observation that some persons with high sensory level achieve functional ambulation whereas some with lower sensory level do not.

Therefore, in this study we try to see if the presence of abdominal muscle activity as picked up by surface EMG can be used as a predictor of walking performance.

**Predictors Being Explored**

Other than the Neurological Level of Injury as per the ASIA scale, other predictors are currently being explored.

**1. Electrophysiological testing:**

Somatosensory Evoked Potential (SSEP) has been found to be of supplemental value to the clinical examination in the prediction of functional outcome. (Iseli et al) Pudendal SSEP was significant for predicting ambulation among tetraplegics but not among paraplegics (54) Pudendal SSEP was significant for predicting ambulation among tetraplegics but not among paraplegics.

Iseli and Curt further studied ischemic and traumatic paraplegics and found that both the pudendal and tibial SSEP were of value in predicting functional recovery. (70) (54)

MJ Arun Kumar et al (71) have compared Motor and Somatosensory Evoked Potentials (MEP and SSEP) after experimental spinal cord injury in Bonnet monkeys (macaca radiata) and found it to be related to the motor function achieved. The study required invasive procedures both for causing the injury as well as for the measurement of outcome.

Most studies involving locomotion only include incomplete paraplegics. So also in clinical practice, trial of ambulation is offered preferentially to incomplete paraplegics. A study has shown this to be related to bias among persons in the rehabilitation team. (63) (16)

## **2. The Beevor's Sign**

The rectus abdominis muscle is one of the anterior abdominal wall muscles, which together act to keep the viscera in place. Contraction aids expiration as well as evacuation of the rectum, bladder and uterus. It is a sheet-like muscle that is supplied by the ventral rami of the lower six or seven thoracic nerves.

Normally the muscle contracts as one, with no independent control of the upper vs. the lower, or left vs. right, parts of the muscle. This is evident by the fact that the umbilicus remains in a central position during contraction. This is most easily demonstrated by having the subject lie supine, and then raise their head from the couch, or attempt a sit-up.

Beevor's sign describes the upward movement of the umbilicus when performing either of these manoeuvres due to weakness of the lower part of the rectus abdominis(72)

Beevor's sign is said to be characteristic of a cord lesion at the T 10 level (73)

## **Surface Electromyogram (SEMG)**

Electromyography is the study of muscle function through the inquiry of the electrical signal the muscle emanates. (74)

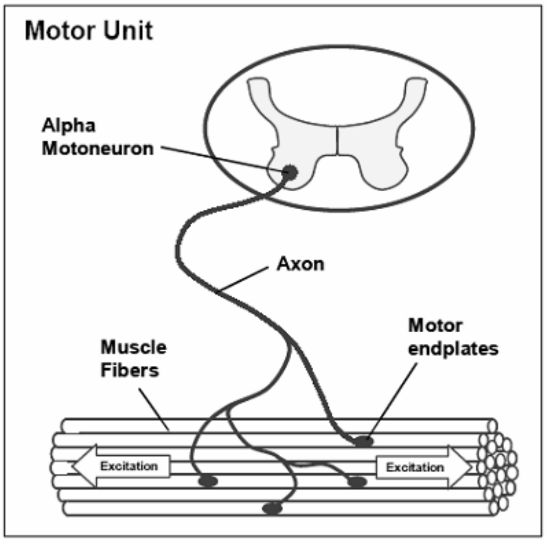
Electromyography can be a very useful analytical method for muscle activity if applied under proper conditions and interpreted in light of basic physiological, biomechanical, and recording principles.

For purposes of recording EMG, two types of electrodes are available; needle electrodes and surface electrodes. In general, surface EMG will represent the activity of individual muscles or muscle groups over which the electrodes are placed. Muscles that are smaller and of a deep location are difficult to record from with surface EMG, but the major interest is in the larger muscles or in muscle groups. The paradoxical problem with surface EMG is that it is one of the easiest electrophysiological signals to measure, but also one of the hardest to interpret quantitatively. De Luca mentions surface EMG as 'too easy to use and consequently too easy to abuse' (75)

The electromyographic (EMG) signal is composed of the action potentials from groups of muscle fibers organized into functional units called motor units (MUs) (75). This signal can be detected with sensors placed on the surface of the skin. The motor unit action potential, estimated from surface EMG, is a measure of muscle activation level. (76)

In the study of muscle physiology, neural control of excitable muscle fibres is explained on the basis of the action potential mechanism. The electrical model for the motor action potential reveals how EMG signals provide us with a quantitative, reliable, and objective means of accessing muscular information.

When an alpha motoneuron cell is activated (induced by the central nervous system or as a result of a reflex action), the conduction of this excitation travels along the motor nerve's axon and neurotransmitters are released at the motor endplates. An endplate potential is formed at the muscle fibres and innervates the motor unit (the smallest functional unit where neural control over muscular contraction occurs).




Muscle fibres are composed of muscle cells that are in constant ionic equilibrium and also ionic flux. The semi-permeable membrane of each muscle cell forms a physical barrier between intracellular (typically negatively charged compared to external surface) and extracellular fluids, over which an ionic equilibrium is maintained. These ionic equilibriums form a resting potential at the muscle fibre membrane (sarcolemma), typically -80 to -90mV (when not contracted). This potential difference is maintained by physiological processes found within the cell membrane and are called ion pumps. Ion pumps passively and actively regulate the flow of ions within the cell membrane.

When muscle fibres become innervated, the diffusion characteristics on the muscle fibre membrane are briefly modified, and Na+ flows into muscle cell membranes resulting in depolarization. Active ion pumps in the muscle cells immediately restore the ionic equilibrium through the repolarization process which lasts typically 2-3 milliseconds.

When a certain threshold level is exceeded by the influx of sodium (Na+) resulting in a depolarization of the cellular membrane, an action potential is developed and is characterized by a quick change from -80mV to +30mV. This monopolar electrical burst is restored in the repolarization phase and is followed by a hyperpolarization period.

Beginning from the motor end plates, the action potential spreads across the muscle fibres in both directions at a propagation speed of 2-6m/s. The action potential leads to a release of calcium ions in the intracellular fluid and produces a chemical response resulting in a shortening of the contractile elements of the muscle cells.

The depolarization-repolarization process described is a monopolar action potential that travels across the surface of the muscle fibre. Electrodes in contact with this wave front present a bipolar signal to the EMG differential amplifiers because the electrodes are measuring the difference between two points along the direction of propagation of the wave front.

EMG signals provide us with a viewing window into the electrical signals presented by multiple muscle fibres and are in fact a superposition of multiple action potentials.

Amplitude analysis looks at the activation levels during rest and contractions. The averaged contraction is the mean level of the muscle's electrical activity during a contraction period, and is considered to be a good indicator of the level of muscular strength and endurance. Variability in the activation levels indicates neuromuscular stability.

<u>The SENIAM (surface EMG for non-invasive assessment of muscles) project:</u> The SENIAM does not state electrode placements for abdominal SEMG. However, the principle used for SENIAM is relevant. The sensor placement sites are derived from the

following principle: with respect to the longitudinal (in fibre direction) location of the sensor on the muscle, it is recommended to place the sensor halfway between the most distal motor endplate zone and the distal tendon. With respect to the transverse location of the sensor on the muscle, it is recommended to locate the sensor at the surface away from the 'edge' with other subdivisions or other muscles so that the geometrical distance to other muscles is maximised.

## SEMG- Abdominal Electrode Placements

Surface electrodes placed on the skin over a muscle pick up the algebraic sum of the action potentials of all active motor units in the muscle, but the parts of the muscle more remote from the electrodes have a smaller effect than the adjacent parts. Thus, the electrical record is composite and represents the summated electrical activity of all the active motor units, with due regard to (i) their spatial distribution, relative to the recording electrodes, and (ii) the temporal dispersion of firing. (77)

Surface electrodes can usually be placed so that the action potentials are picked up from one muscle only, but for each particular muscle so studied it is essential to ensure that extraneous action potentials from adjacent muscles do not interfere with the record. With electrodes fixed over a given muscle, the electromyograms for different movements can be arranged in order of amount of activity, even though the force of contraction cannot be assessed quantitatively from the record. Increased force of contraction is reflected in the surface electro-myogram by increased frequency and amplitude of the potentials. When the same pattern and amount of electrical activity is found in a muscle for two different movements, we shall say that the muscle is involved to the same extent in the two movements. (77)

Floyd et al (77) compared different parts of the same rectus muscle. Four electrodes were placed over each rectus, in corresponding positions on each side of the mid-line, 6 cm. apart along the long axis of the muscle. Similar activity was found in the different segments for each movement studied. The 'rectus electrodes' pick up only from the rectus muscle. They do not pick up from the external or internal oblique, or from the transversus muscles. No muscle, apart from the rectus, underlies the electrodes.

Furthermore, they showed that the typical pattern of activity for straining involves the external and internal oblique and transversus muscles, but not the recti. This result could not have been obtained if there had been a large extraneous pick-up, at the rectus electrodes, from these other muscles.

For experimental purposes, Floyd et al have used the following electrode placements.(77)

Rectus:

Upper and lower rectus on each side, equidistant from the midline and taking care to avoid the tendinous insertions.

External oblique:

A pair of electrodes was placed 3.5 cm. apart on each side in the flank, above the anterior half of the iliac crest, in an oblique line parallel with the underlying external oblique muscle fibres. The electrodes do not record from the internal oblique on account of distance from that muscle and the low amplification used.

Internal oblique:

A pair of electrodes was placed on each side over the triangle bounded by the lateral edge of the rectus sheath, the inguinal ligament and the line joining the anterior superior spine to the umbilicus. In this area the fibres of the internal oblique are separated from the skin only by the external oblique aponeurosis, and hence are accessible for study with surface electrodes.

The electrodes were placed in a line parallel with the inguinal ligament, i.e. over those fibres which arch over the inguinal canal and are inserted into the conjoint tendon. The limitation of electrode placement in this retro-aponeurotic triangle is that the behaviour of these fibres might not be representative of the behaviour of the rest of the muscle.

It is possible that the internal oblique electrodes may pick up from the lowest fibres of the transversus abdominis. These fibres also arch over the inguinal canal and are conjoined with the internal oblique fibres. The similarity of origin, course, and insertion between these two sets of transversus and internal oblique fibres makes it likely that their function is also similar. For this reason no attempt is made to differentiate between them. The cremaster and psoas muscles activity recorded from the internal oblique electrodes was found to be of insignificant contribution.

In their experiment, the amplitude of recording from these electrodes was found to be slightly diminished by the proximity of the electrodes to each other, 2.5 cm. compared with

3.5-10 cm. used elsewhere. This was done to keep both electrodes as far away as possible from the rectus and external oblique fibres.

As the same amplification has been used in all six channels at any one time, the relative amount of activity in the internal oblique fibres is slightly greater than appears from the record. When the activity from the corresponding muscles of both sides is compared, a small difference is commonly seen. This difference may be due to functional asymmetry: for example, the left rectus may predominate in one movement, and the right rectus in another. The electrodes are placed in corresponding areas of skin, measurements being made from the umbilicus, the mid-line and the anterior superior spine.

**Ambulation in paraplegics - which is the outcome measure**

From the patient's perspective, improvements in the ability to function in everyday activities will be the most meaningful determinant of treatment efficacy.(78)

1. Walking Endurance - The maximum distance covered without any break/rest.

2. Speed of walking: the distance covered in one minute with or without rest.

3. There are many outcome measures used in clinical trials, such as 10 minute walk test (10 MWT), and 6 minute walk test 6MWT.(78)

4. WISCI- (27) (79) i.e., Walking Index for Spinal Cord Injury. This will be described later

5. FAS- Functional Achievement Score was developed for the purpose of the present study. This will be described later

# STUDY DESIGN, MATERIALS AND METHODS

## Study Design, Materials and methods

### Study Design

The present study is an observational study to evaluate the use of surface EMG (SEMG) of the anterior abdominal musculature as an independent predictor of ambulation outcome in thoracic level paraplegics.

As per current standards, neurological level of injury (NLI) at the thoracic level is determined by clinical examination of the sensory level and this is used as a guide for goal setting and prognostication of ambulation. We also examined Beevor's Sign as a predictor of ambulation outcome.

Beevor's sign was recorded positive if there was an upward shift of the umbilicus when a supine lying patient raised his head voluntarily. Positive Beevor's Sign indicates abdominal muscle weakness is present.

The Negative Beevor's Sign occurred in the following situations

- Weak/Poor upper and lower abdominal muscle strength
- Fair upper and lower abdominal muscle strength
- Good upper and lower abdominal muscle strength

i.e., upper and lower abdominal muscle groups had similar strength.

The Positive Beevor's Sign occurred in the following situations

- Upper abdominals good, lower abdominals fair/poor
- Upper abdominal fair, lower abdominals poor

As such the abdominal muscle strength was also documented.

## Subjects

Institutional Review Board approval was obtained before initiating the study.

A recording of abdominal muscle activity using surface EMG was initially done on a volunteer (normal subject) at the Movement Analysis Laboratory, CMC, Bagayam.

Twenty patients who were undergoing in-patient rehabilitation in the department of PMR and who fulfilled the inclusion criteria were recruited for the study. They were recruited into the study once they progressed to parallel bar ambulation with bilateral KAFO, they were recruited. Signed Informed Consent Form stating that the patient is being voluntarily recruited was initially obtained from the patient.

## Criteria for selection of Subjects

### Inclusion Criteria

1. Paraplegics with ASIA Impairment Scale A and B and NLI T6 to 12
2. Subjects recruited must be within the age group15-60 years

### Exclusion Criteria

1. Patients with spinal cord injury with spinal instability
2. Patients with progressive pathology of spinal cord such as tumours
3. Patients with complications such as acute deep vein thrombosis, persistant pulmonary problems, pressure sores, contractures of lower limb
4. Patients with motor incomplete paraplegia i.e., ASIA Impairment Scale C, D and E and NLI above D6 and below D12
5. Age <15 years and > 60 years

**Equipment:**

Surface EMG recording machine and the CMC-DAQ software were both designed at the Department of Bioengineering.

**Description of the machine:**

A Multi channel EMG recording machine, CMCdaq, was used to pick up the surface EMG from the anterior abdominal muscles using manoeuvres described later.

A pair of bipolar electrodes was placed on the skin over the muscle, oriented parallel to the muscle fibres.

A ground electrode was placed nearby over an electrically inactive part of the body. The signal from the electrodes was amplified, digitized and sent to a personal computer (PC) over a USB link.

**Software:**

The EMG recording machine used CMC Data Acquisition Software (CMC DAQ) to obtain the surface EMG. The EMG data was stored on a PC. The stored data was processed later for further evaluation. During the recording the EMG was monitored on-screen to ensure that the quality of recording was good.

After the recording, the software was used to calculate the average (rectified Mean) using a sliding window of 0.4s. The average or rectified-mean EMG is proportional to the net electrical activity of the muscle as it is the cumulative value of all the underlying action potentials. Therefore, the average EMG is proportional to the total number of active motor units and their firing rates.

The mean-rectified or average EMG contains the same information as the alternative measure of RMS (root-mean square) value. The average EMG was displayed as a function of time on the screen, and measurements of the amplitude could be made using a cursor.

**Recording and reference electrodes:**

Two circular silver (AgCl) discs of diameter 10mm and inter-electrode spacing of 15mm were used as the pair of bipolar recording electrodes and a single carbon gel adhesive electrode was used as the reference electrode.

The spacing between the recording electrodes was maintained constant with the help of a polypropylene back support.

**Methodology**

Skin Preparation and Electrode Placement

Skin preparation was done by shaving the skin surface at which the electrodes had to be placed. The next step was to clean the skin with surgical alcohol and allow the alcohol to vaporize so that the skin will be dry before the electrodes were placed.

A thin layer of electrode gel was put on the recording electrodes to lower the electrode-skin impedance before placing them on the skin over the muscle of interest.

The reference electrode was placed on the forearm. The electrodes were fixed onto the skin with adhesive tapes onto points described in earlier studies, in the direction of the muscle fibres.

**Patient position and maneuvers used:**

All recordings were taken with the patient in supine position. After placing the recording electrodes they were connected to the surface EMG machine and recordings were obtained during manoeuvres described below to obtain a recording of the maximal voluntary isometric contraction of each muscle.

Three of the four muscles of the anterior abdominal wall can be evaluated using surface EMG (SEMG) recording techniques, namely rectus abdominis and external oblique and internal oblique muscles. Due to its deep position, Transversus Abdominis (TA) can only be investigated using intramuscular needle electrodes and hence was not studied.

We estimated the maximum voluntary contraction level by asking each subject to perform each maneuver (which will be described below) for 3 sec with maximum force. This was repeated thrice and the highest EMG amplitude among the 3 trials was defined as the maximum voluntary contraction level. The subject was preinformed that this would be to check his abdominal muscle strength.

## Surface EMG recording

**Fig. 1. AgCl electrode with fixed interelectrode distance**

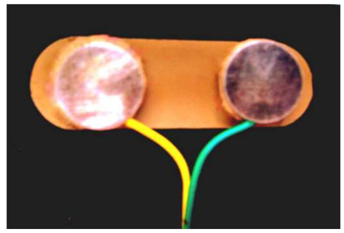


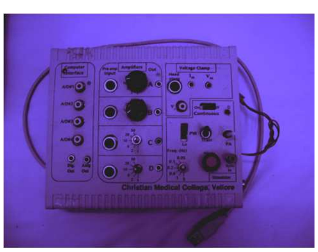
**Fig 2 Application of Jelly**

**Fig 3 Skin Preparation with Alcohol swab; shaving if necessary**

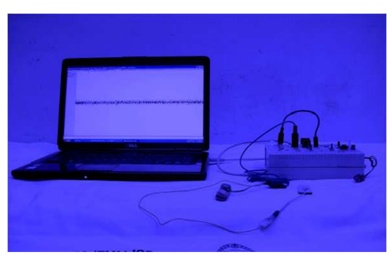
**Fig 5 Surface electrodes for left upper rectus; Ground electrode over forearm**

**Isometric Trunk Flexion to check Left upper rectus abdominis**

**Fig 6 SEMG Machine**

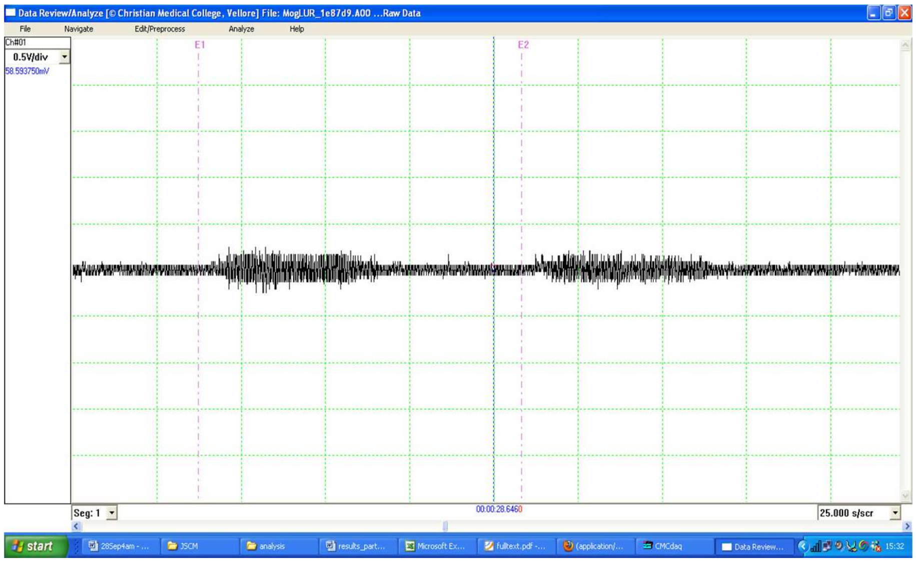


**The Entire setup connected to a personal computer**

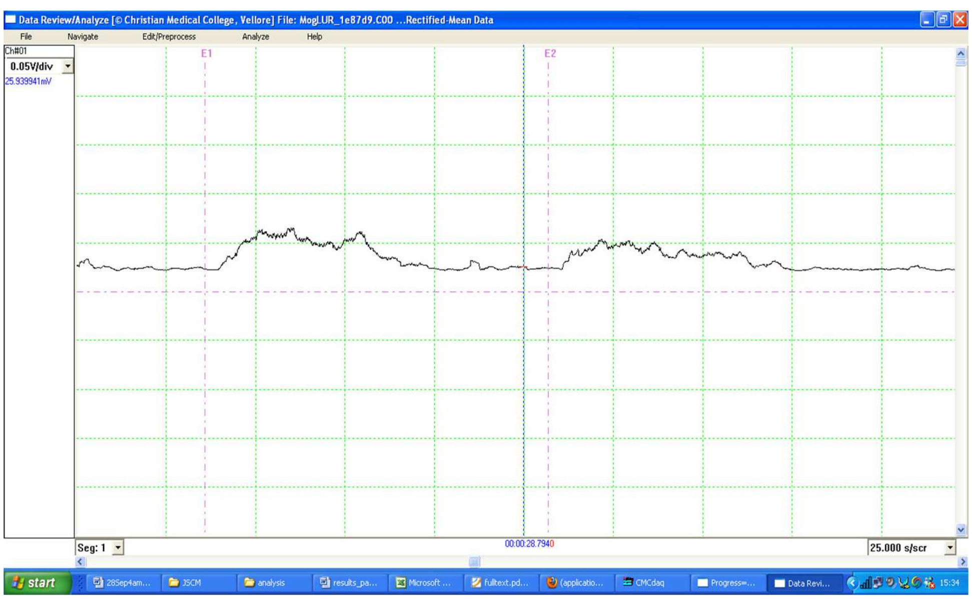


**Screenshots of a typical reading :-**

**Raw data acquisition (Left upper rectus)**




**Rectified Mean using CMC DAQ software (for the same reading)**



**Electrode Positions:**

Surface EMG electrodes were placed as described in earlier studies (80)

(1) Upper rectus abdominis

Electrodes positioned vertically and centered on the muscle belly (not on the tendinous intersection) near the midpoint between the umbilicus and the xiphoid process and 3 cm lateral from the midline;

(2) Lower rectus abdominis

Electrodes positioned 8 degrees from vertical in the inferomedial direction and centered on the muscle belly near the midpoint between the umbilicus and the pubic symphysis and 3 cm lateral from the midline;

(3) External oblique

Electrodes positioned obliquely approximately 45 degrees (parallel to a line connecting the most inferior point of the costal margin of the ribs and the contralateral pubic tubercle) above the anterior superior iliac spine (ASIS) at the level of the umbilicus;

(4) Internal oblique

Electrodes positioned horizontally 2 cm inferomedial to the ASIS within a triangle outlined by the inguinal ligament, the lateral border of the rectus sheath, and a line connecting the ASISs.

**Maneuvres used to elicit EMG activity**

SEMG of external and internal oblique muscles has been studied during postural and respiratory manoeuvres (81) and the same manoeuvres were used for the present study with some modification as explained below.

The following table is from Goldman et el (81)

| Muscle activated | Movement |
|---|---|
| External oblique | Lift left shoulder and point it towards right hip |
| Internal oblique | Lift right shoulder and point it towards left hip |
| Transversus abdominis | Pull "belly" in |
| Rectus abdominis | Lift both legs. (This movement is not specific, but activates rectus abdominis to ensure the wire is in place. The electrode is in a visibly different position from the other three electrodes) |

In our study, the following maneouvres were used:

For the Rectus abdominis muscle, the subject was asked to raise the head against resistance at the forehead. Leg lift as described above was not possible as they were complete paraplegic.

External oblique muscle was tested by ipsilateral trunk flexion. Subjects were asked to lift same side shoulder (i.e., same side of electrode placement.) and point it towards opposite hip

Internal oblique muscle was tested by trunk rotation to the contralateral side. Subjects were asked to lift opposite shoulder and point it towards hip on the same side as electrode placement.

**Setting**

Surface EMG was done at the Movement Analysis Laboratory, Rehabilitation Institute, Christian Medical College, Vellore. A recording of abdominal muscle activity using surface EMG was initially done on a volunteer (normal subject) at the Movement Analysis Laboratory, CMC, Bagayam.

## Measures of Outcome

**Walking distance & speed:** Walking distance & speed was recorded by the experimenter with the help of measuring scale & stop-watch respectively. Data for this particular variable was collected just before the discharge, to know the maximum functionality achieved by the patient during the rehabilitation program and exercise training.

**WISCI- (The Walking Index of Spinal Cord Injury):** (27)

This assessment index ranks ambulation outcome, from the level of most severe impairment (0) to least severe impairment (20) based on the use of devices, braces and physical assistance of one or more persons.

The order of the levels suggests each successive level is a less impaired level than the former. The ranking of severity is based on the severity or the impairment and not on functional independence in the environment.

The specific WISCI descriptors are detailed in the section "appendices". WISCI categories into which the study populations fell were:

| WISCI Score | |
|---|---|
| 1 | Ambulation not achieved |
| 5 | Ambulation in Parallel bars, legs braced, >10m |
| 9 | Ambulation with walker, legs braced, >10m |
| 12 | Ambulation with elbow crutches, legs braced >10m |

**FAS- (Functional Achievement Score)**

The WISCII score uses a 10m cut off. However, some studies have used 250m which might correlate more with the use of ambulation as the primary mode of mobility. As such a new scoring system was made.

Patient ambulation outcome was classified and scored as follows:

| FAS Score | Description |
|---|---|
| 6 | Independent with bilateral elbow crutch and KAFO with endurance >/= 250m |
| 5 | Independent with bilateral elbow crutch and KAFO with endurance < 250m |
| 4 | Independent with walker and bilateral KAFO with endurance >/= 250m |
| 3 | Independent with walker and bilateral KAFO with endurance < 250m |

| | |
|---|---|
| 2 | Wheelchair for mobility- Achieved walking within parallel bars |
| 1 | Wheelchair for mobility- Achieved self supported standing within parallel bars |
| 0 | Wheelchair for mobility- stands with support within parallel bars |

**Statistics**

Statistical evaluations were performed using SSPE software package.

The Kruskal-Wallis test was employed for multivariate analysis of samples. Spearman's rank correlation coefficients were computed for paired comparisons involving ordinal data.

The median values and the differences between upper and lower quartiles were used to describe values that were not normally distributed and skewed.

# RESULTS

# AND

# ANALYSIS

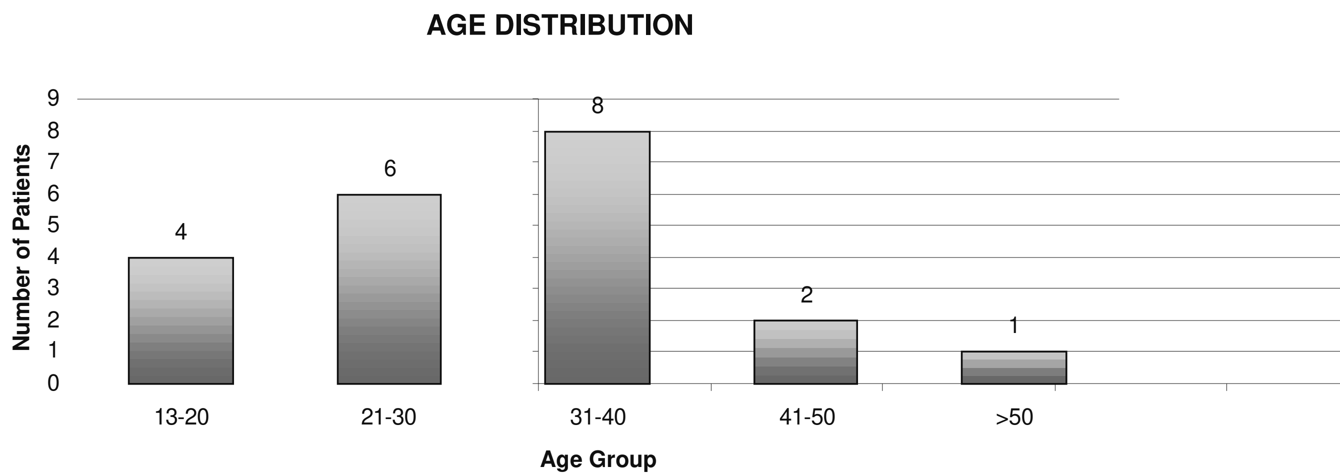
# Results

**Demographic Data**

21 male patients were included in the study

## 1. Age distribution and Gender

The mean age of the patients was 30.9 years (range from 13 to 55 years).




The maximum numbers of subjects were in the category of “31-40 years” followed by age group “21 to 30 years”.

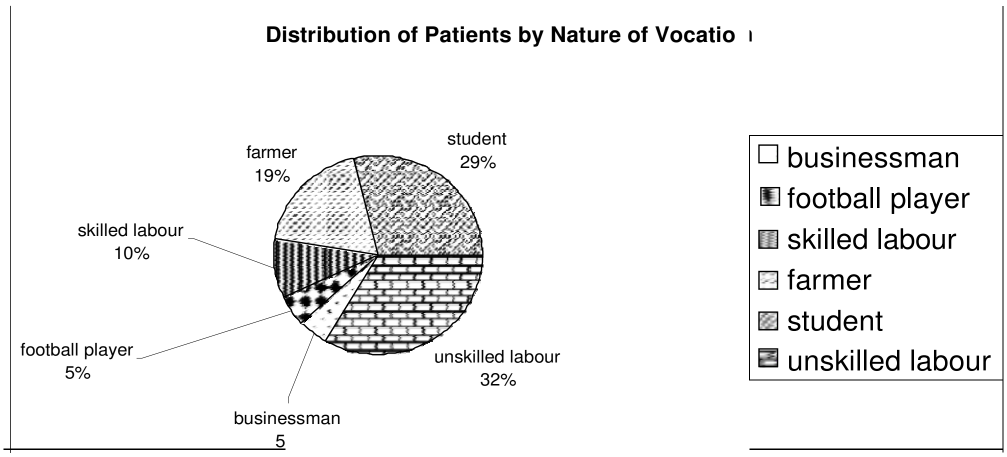
The least common age group was the “Above 50” year group and 41-50 years.

Spinal Cord Injury occurs more frequently in the younger population.

**Gender:**

All subjects who participated in the study were males.

**2. Vocation**

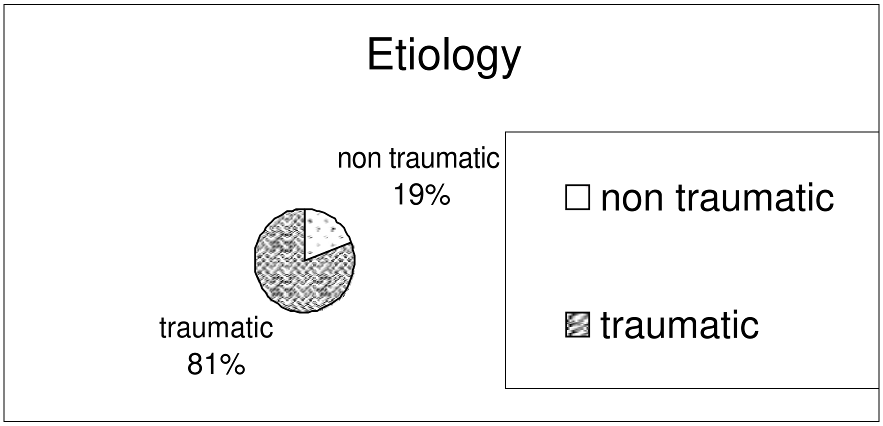



Unskilled labourers formed the largest category.

This included building construction workers and daily wage labourers who were not skilled in any particular job.

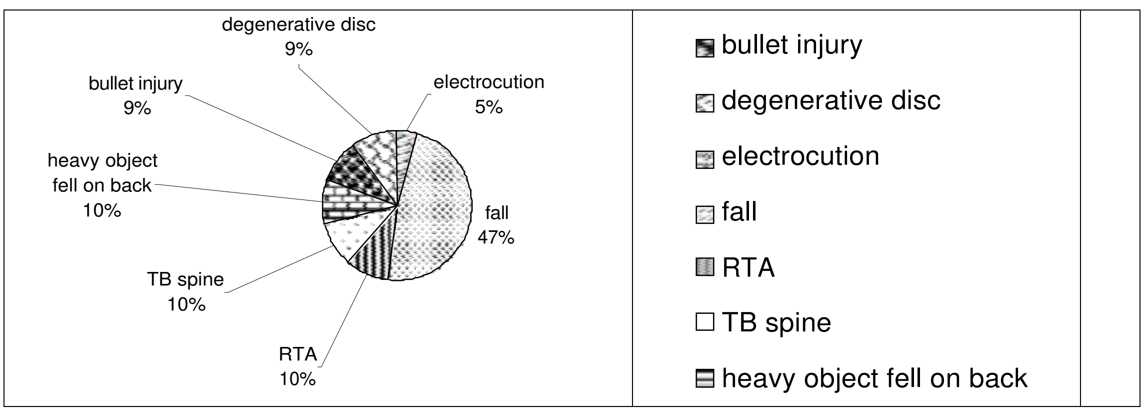
This was followed by the student population and farmers.

## Etiology




In our study population, traumatic etiology (81%) exceeded the non traumatic category by far. The non-traumatic category only had 19%.

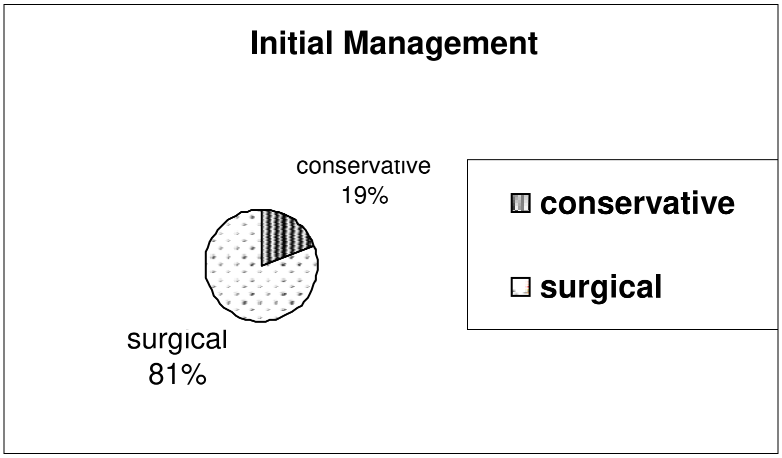
## Etiology- Subcategories were as follows:




The commonest category was fall from a height. The next common etiology was shared by three groups: heavy object fell over back, road traffic accident (RTA) and TB spine.

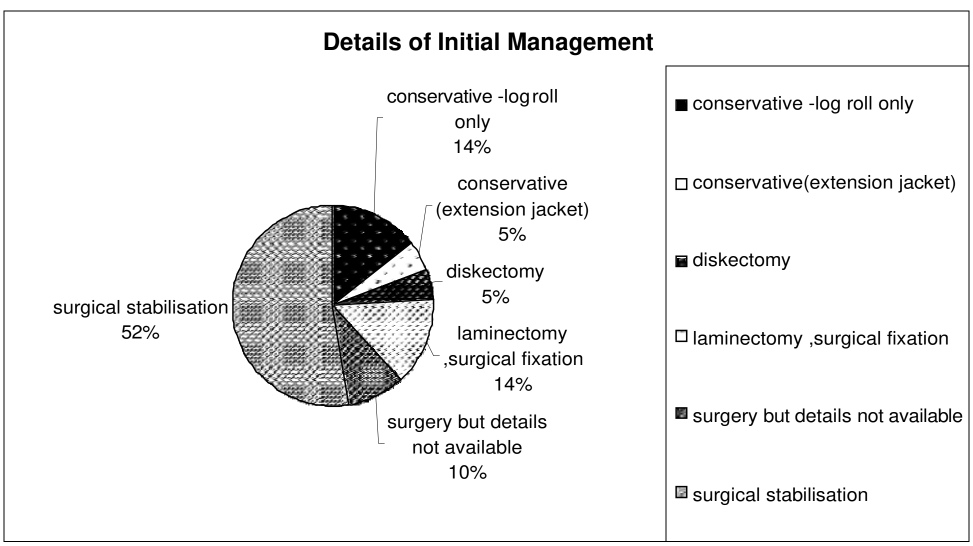
Etiologies classified under the non traumatic category included tuberculosis (TB) spine and Degenerative Disc.

# Initial Management




Majority of patients received surgical management (81%) as opposed to 19% who were managed conservatively.

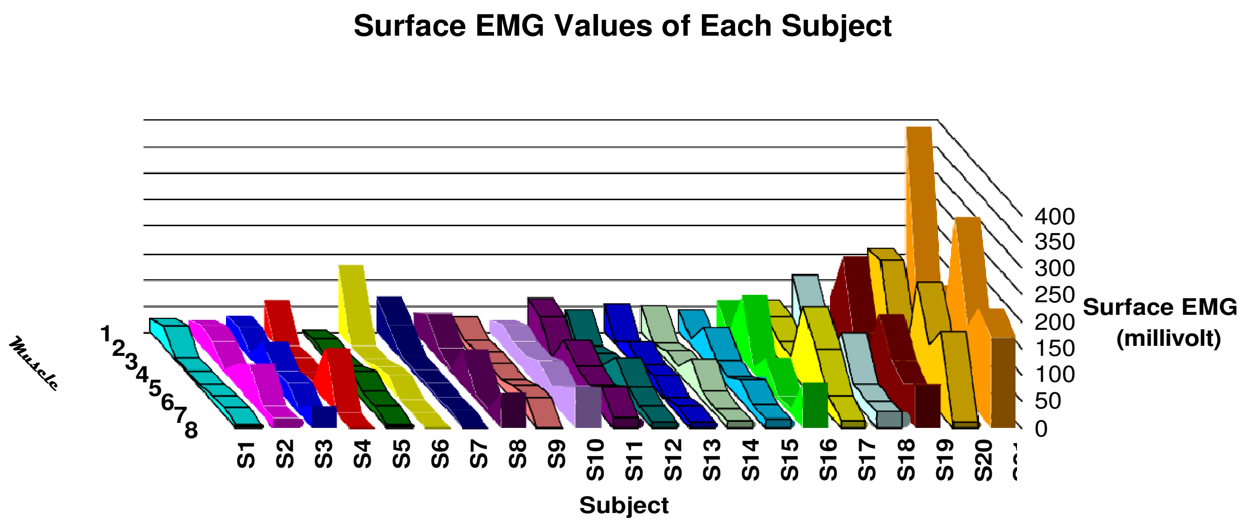
# Details of Initial Management




Conservative management included immobilization and position change by log roll only. One person was managed with an extension jacket.

## DISTRIBUTION OF PATIENTS BY PREDICTORS

### 1. Surface EMG Amplitudes (millivolts) of each subject (S1 to S21) in each of the eight muscle groups



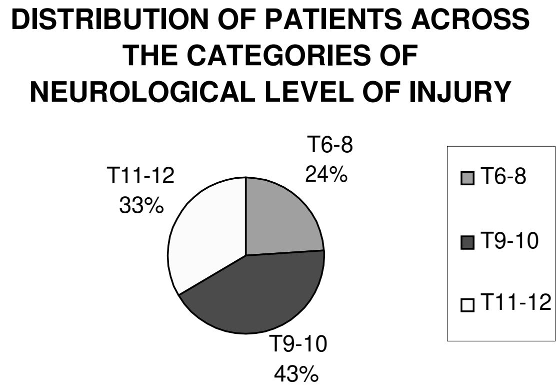

Key

| | |
|---|---|
| 1. Right upper rectus | 5. Left upper rectus |
| 2. Right lower rectus | 6. Left lower rectus |
| 3. Right internal oblique | 7. Left internal oblique |
| 4. Right external oblique | 8. Left external oblique |

x- Individual subjects y- surface EMG z- Individual Muscles as given in the above tables

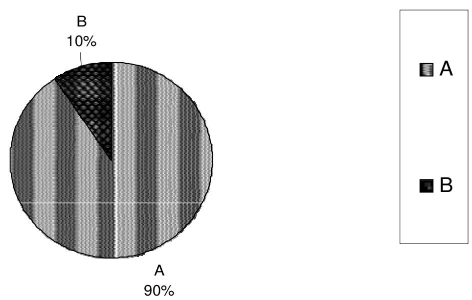
From this graph, it is possible to see that there were occasional extreme values of EMG amplitudes.

## 2. Classification of Subjects by the NLI (Neurological Level of Injury)




Maximum number of patients fell in the category T9-10 category. This was followed by T11-12 and lastly T6-8 categories.

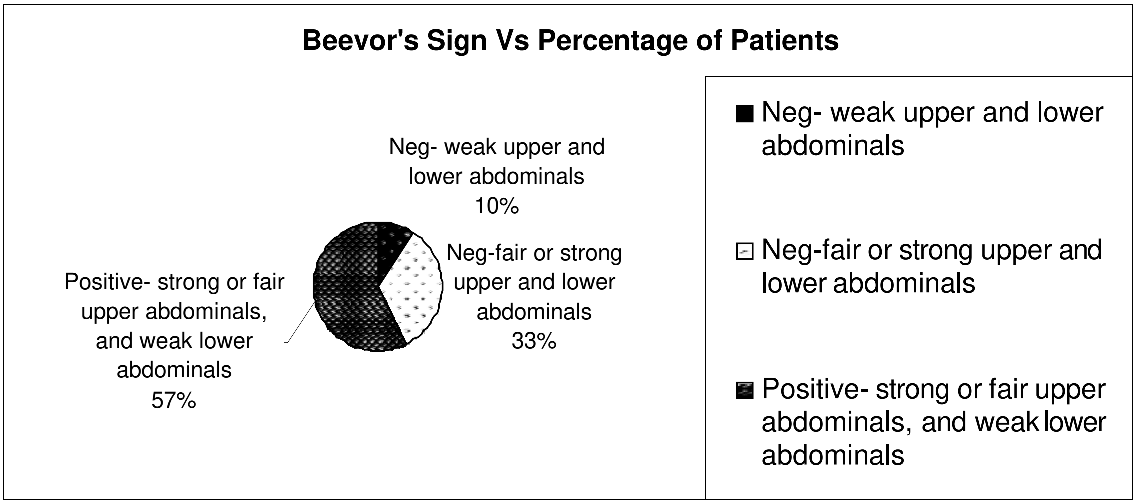
## Distribution of Patients by the ASIA Scale




Majority of persons (90%) fell in the ASIA A group.

Only two persons (10%) fell in the ASIA B category.

## 3. Distribution of Patients by Beevor's Sign

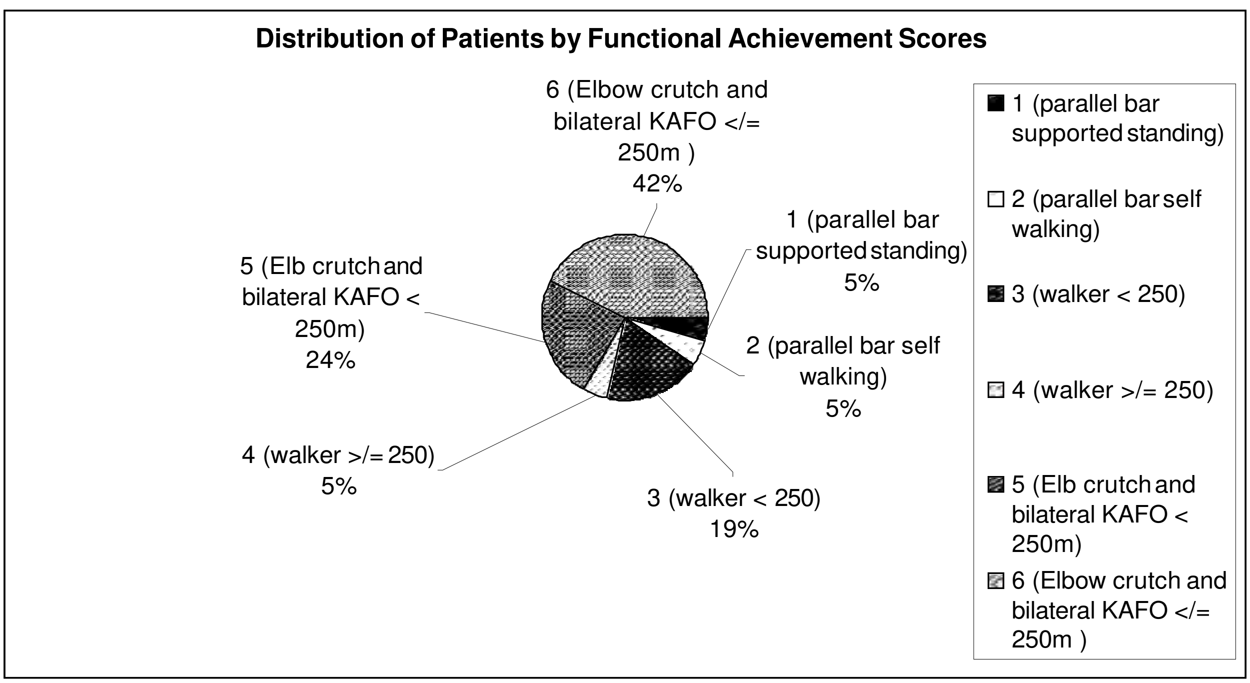



Majority (57%) had positive Beevor's sign.

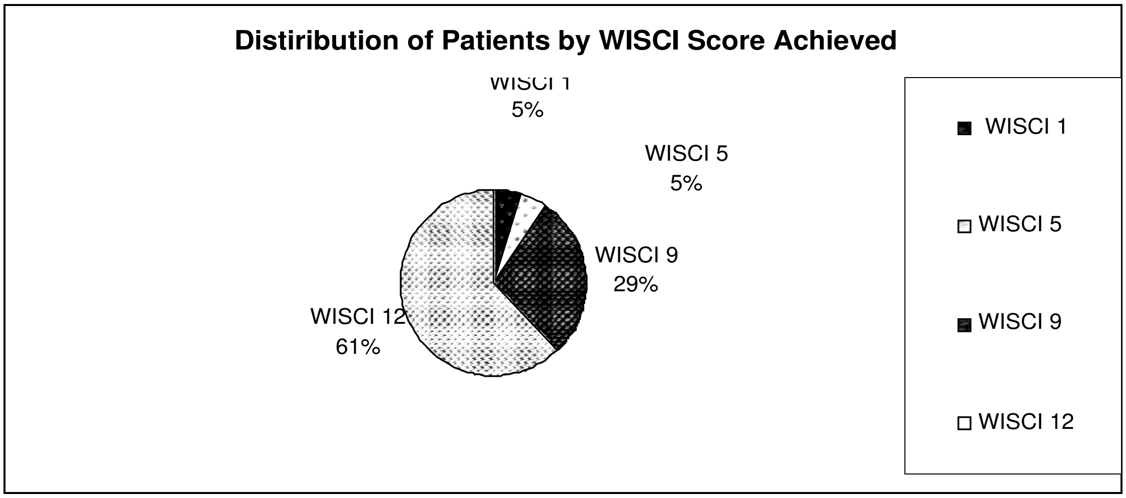
Among the patients with negative Beevor's sign, few subjects had abdominal muscle weakness (10% of all subjects).

## DISTRIBUTION OF PATIENTS BY OUTCOME

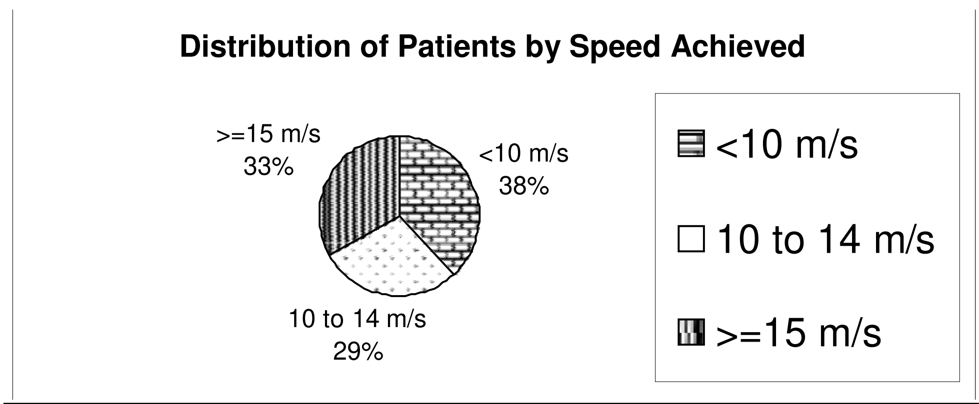
## 1. Distribution of Patients by the FAS(Functional Achievement Score)



**2. Distribution of Patients by WISCI score achieved**




**3. Distribution of Patients by Speed Achieved**



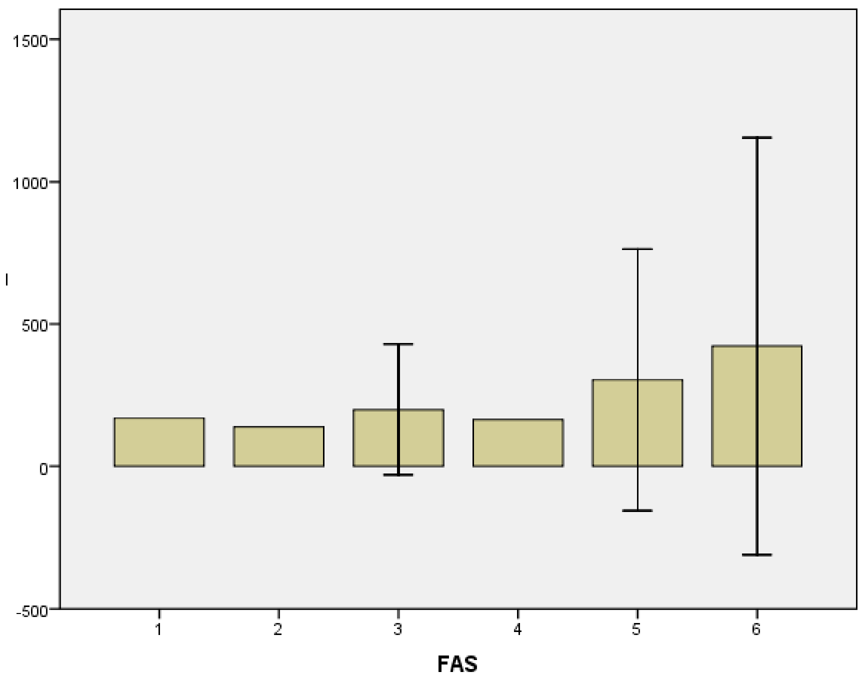

**Scheme of analysis used:**

1. Correlation Between Predictors (i.e., NLI, SEMG and Beevor's sign) and Outcome Measures (FAS, Speed achieved and WISCII)
2. Correlation Between the Individual Predictors
3. Examination of various other patient characteristics (age, occupation) versus predictors and outcome measures

## PREDICTORS VS OUTCOME

### 1. Surface EMG as a Predictor

### Total EMG vs FAS




X axis- FAS scores

Y axis- Surface EMG amplitude (in millivolts)

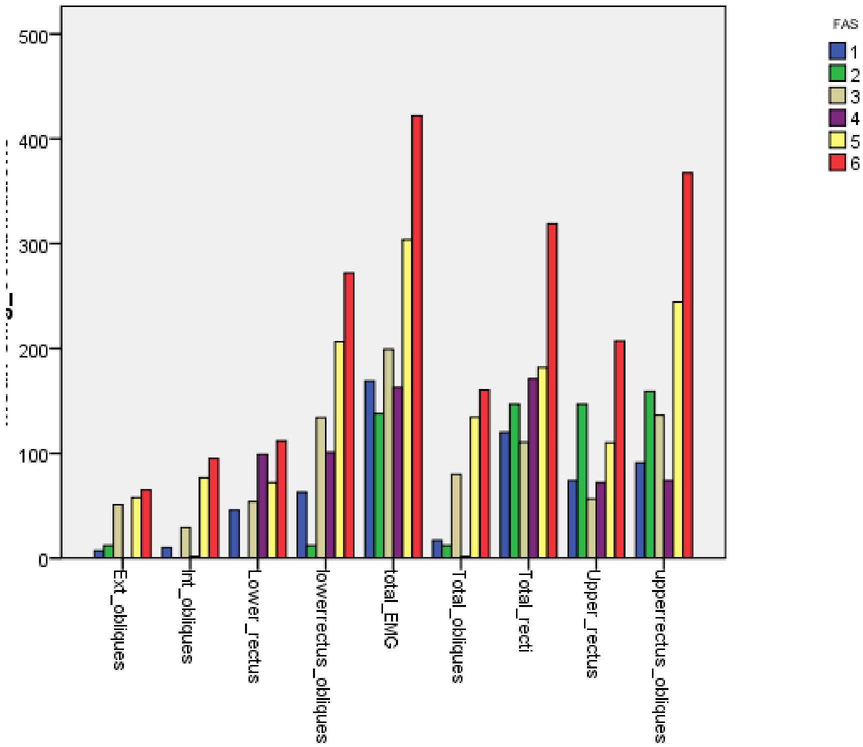
N=21

- Mean - green rectangle
- Interquartile range- blunt ended lines

With increasing EMG values, better FAS scores are seen to be achieved. However, the correlation was not significant (p=0.15)

As evident from the graph, interquartile range is more than twice the mean. This indicates the possibility of skewed values in these groups.

**Individual EMG vs FAS**




For each muscle group, better EMG amplitudes were seen associated with better Functional Achievement Scores.

Subjects were classified as who achieved at least elbow crutch walking as functional outcome (i.e., FAS 5,6) , versus those who did not achieve elbow crutch walking.

**Individual EMG of FAS 5 and 6 versus FAS <5**

| Upper_rectus | Lower_rectus | Total_recti | Ext_obliques | Int_ obliques | Total obliques | upper rectus plus obliques | lower rectus obliqu es | total EM G |
|---|---|---|---|---|---|---|---|---|
| .073 | .412 | .179 | .044 | .003 | .021 | .021 | .030 | .109 |

The EMG amplitude of the following muscle groups was seen to be significantly related to achievement of crutch walking

FAS vs external obliques ($p= 0.044$ )

FAS vs internal obliques – highly significant ($p= 0.003$ )

FAS vs total obliques –significant- ($p= 0.021$)

FAS vs upper rectus plus obliques ($p=0.03$ )

Subjects were classified as who achieved at least 250m of walking endurance with walker as functional outcome (i.e., FAS 4, 5,6) versus those who did not achieve the same.

**Individual EMG of FAS 4, 5 and 6 versus FAS <4**

| Upper_rectus | Lower_rectus | Total_recti | Ext_obliques | Int_ obliques | Total obliques | upper rectus plus obliques | lower rectus obliques | total EMG |
|---|---|---|---|---|---|---|---|---|
| 0.119 | 0.213 | 0.119 | 0.185 | 0.014 | 0.102 | 0.073 | 0.035 | 0.15 |

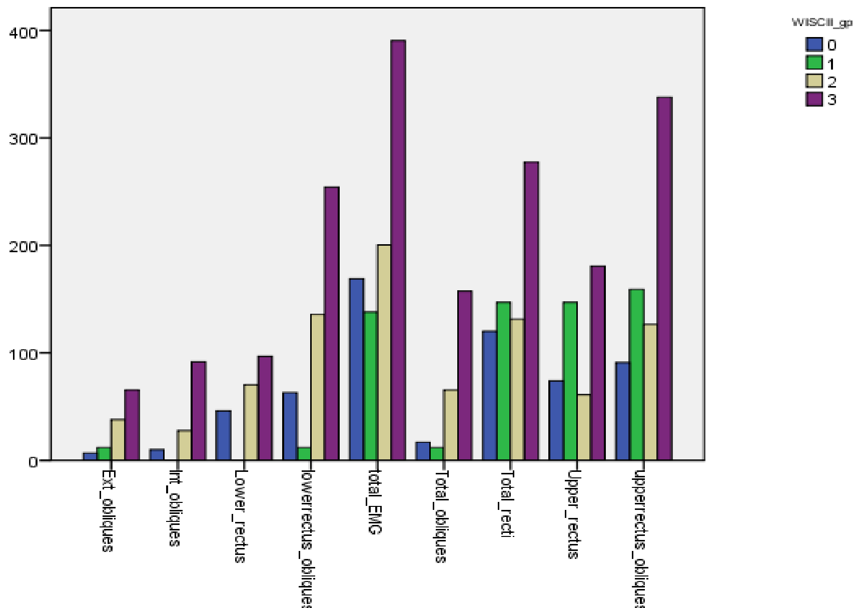
In all muscle as the amplitude of EMG increased, the FAS score was better. This relationship was statistically significant in the following:

EMG vs Achievement of FAS at least 4 (i.e.,4/5/6, i.e, at least walker >250m) vs

Internal obliques ($p= 0.014$ )

Lower rectus plus obliques ($p=0.035$ )

## Surface EMG vs WISCI

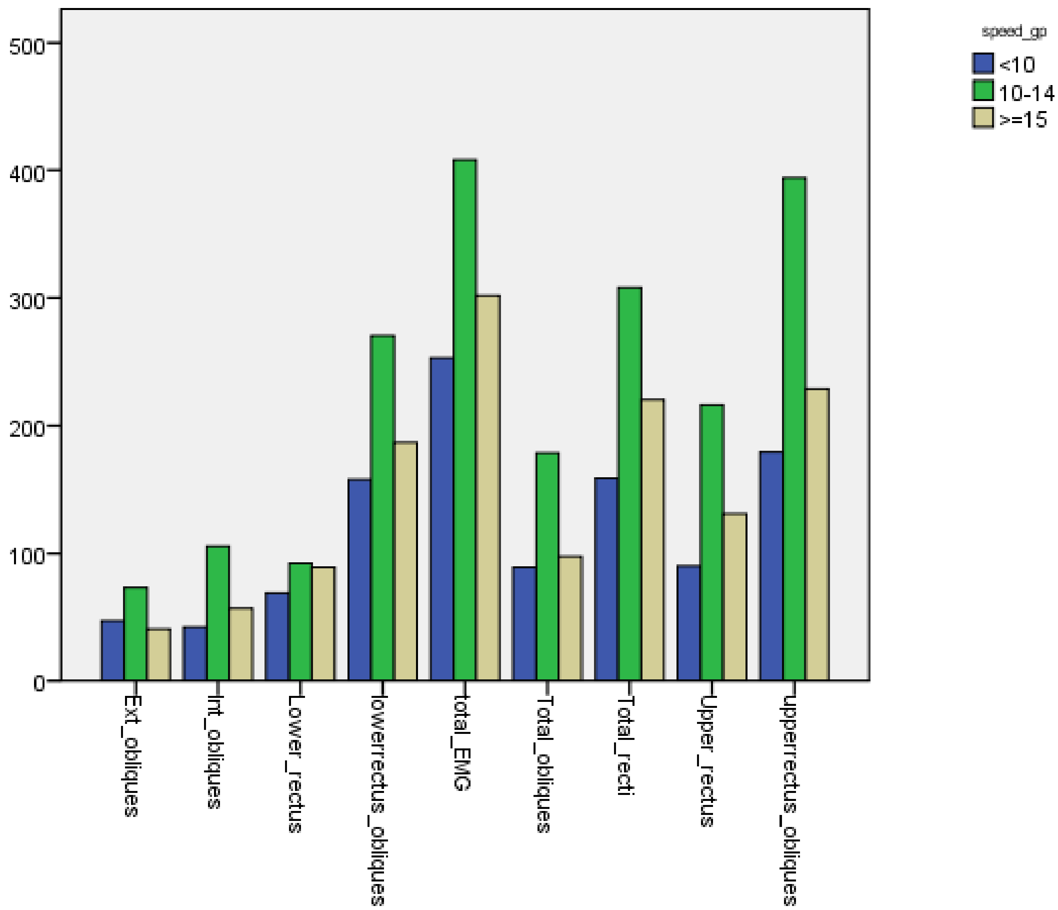



For each muscle group, better EMG amplitudes were seen associated with better WISCI Scores. Statistical significant correlation was seen between the starred (*) muscle groups/ combination of muscle groups and WISCII Score achieved

| | | | | |
|---|---|---|---|---|
| | Upper_rectus | Correlation Coefficient | | .403 |
| | | Sig. | | .070 |
| | Lower_rectus | Correlation Coefficient | | .138 |
| | | Sig. | | .551 |
| | Total_recti | Correlation Coefficient | | .235 |
| | | Sig. | | .304 |
| | Ext_obliques (*) | Correlation Coefficient | | .543* |
| | | Sig. | | .011 |
| | Int_obliques (*) | Correlation Coefficient | | .659** |
| | | Sig. | | .001 |
| | Total_obliques (*) | Correlation Coefficient | | .575** |
| | | Sig. | | .006 |
| | upperrectus_obliques (*) | Correlation Coefficient | | .569** |
| | | Sig. | | .007 |

| | | |
|---|---|---|
| lowerrectus_obliques (*) | Correlation Coefficient | .501* |
| | Sig. | .021 |
| total_EMG | Correlation Coefficient | .351 |
| | Sig. | .119 |

**Surface EMG vs Speed**




For each muscle group, better EMG amplitudes were seen associated with better speed.

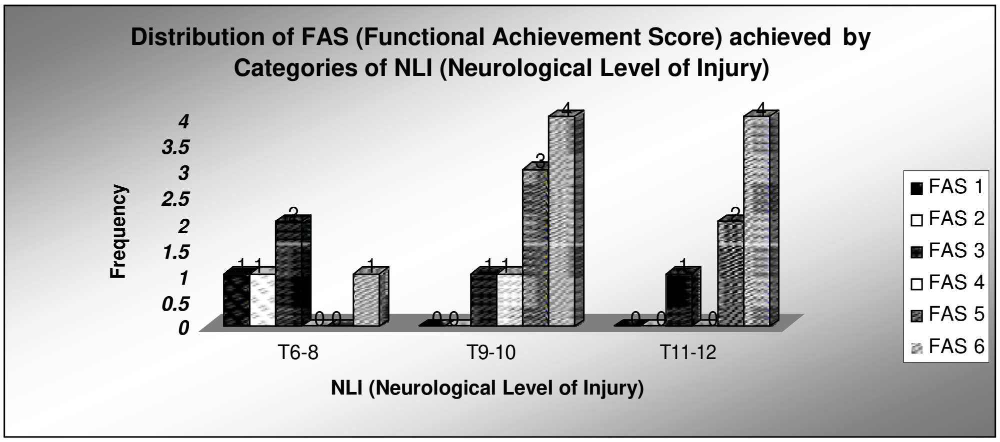
The correlation was not statistically significant for any muscle group.

## 2. NLI as per ASIA as a Predictor

NLI did not significantly correlate with the outcomes FAS (p=0.298) or with WISCI (p=0.195) or speed (p=0.351)

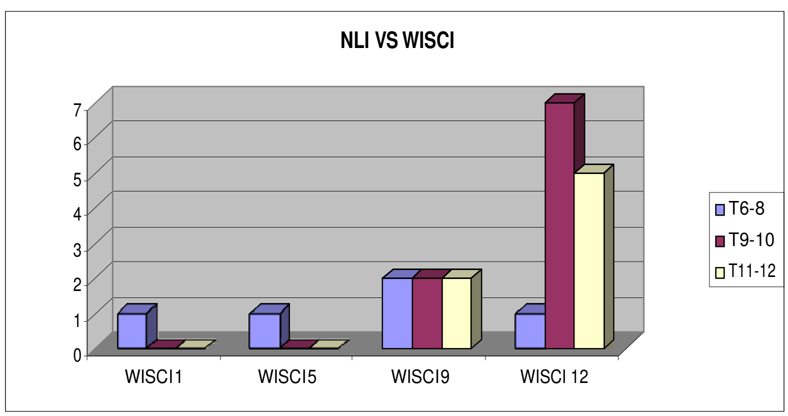
It is interesting to note that although the results were not statistically significant, from the graph it is evident that better outcomes were seen in lower NLI.

**<u>Neurological Level of Injury (NLI) as per ASIA vs FAS</u>**



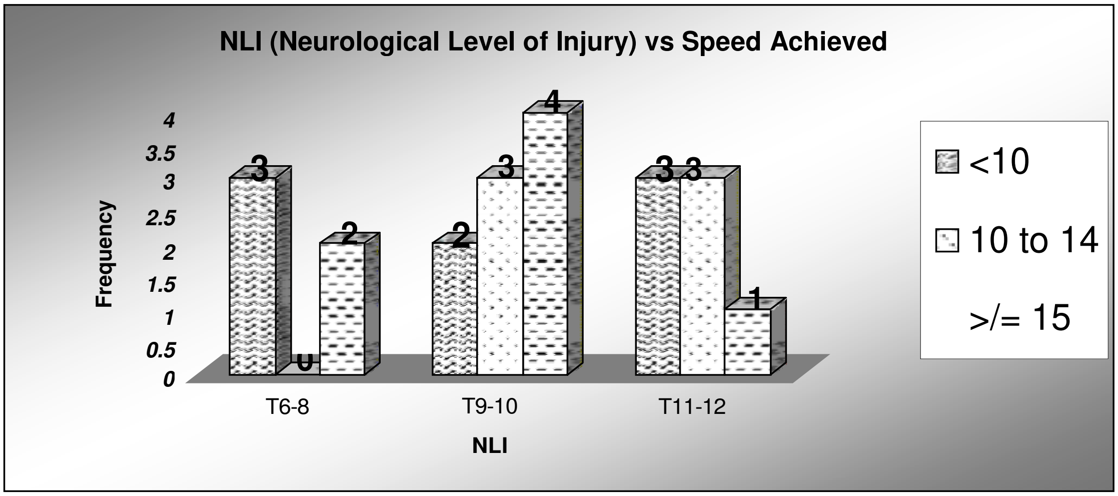

The correlation was not statistically significant. (p=0.298)

**<u>Neurological Level of Injury (NLI) as per ASIA vs WISCI</u>**




The correlation was not statistically significant (p=0.195)

**Neurological Level of Injury (NLI) as per ASIA vs Speed**



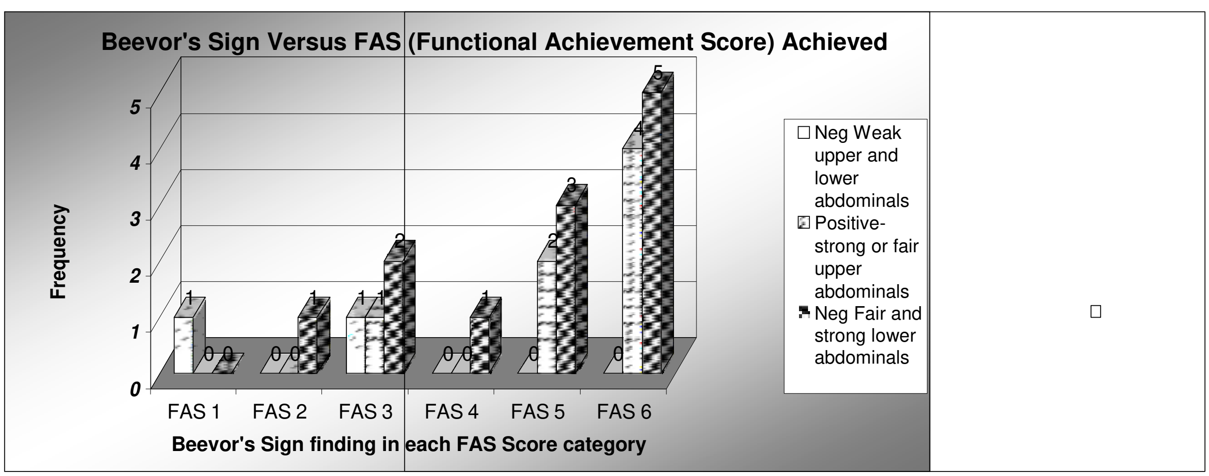

The correlation was not statistically significant (p=0.351)

**3.** **Beevor's Sign as a Predictor**

Beevor's sign did not significantly correlate with the outcomes FAS ( P= 0.179) ,

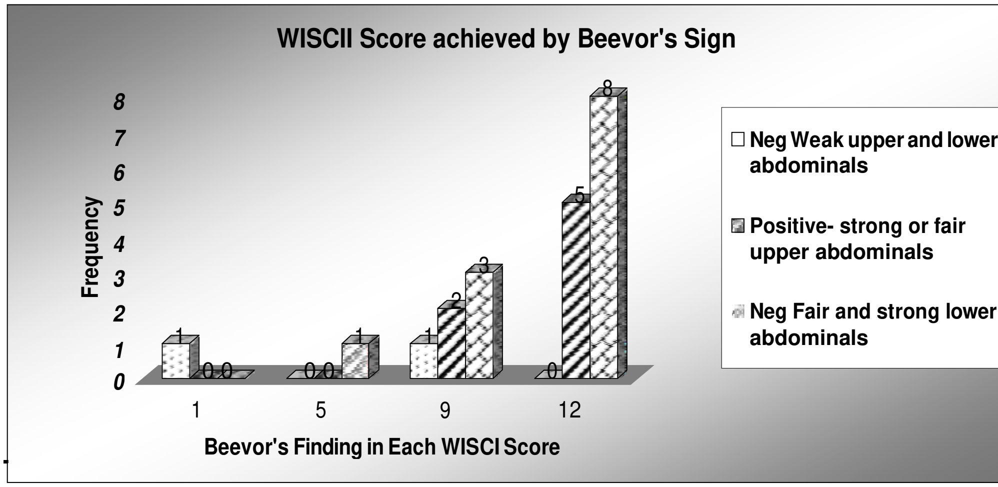
WISCI (P=0.062), or Speed (p= 0.646 )

**Beevor's Sign vs FAS**



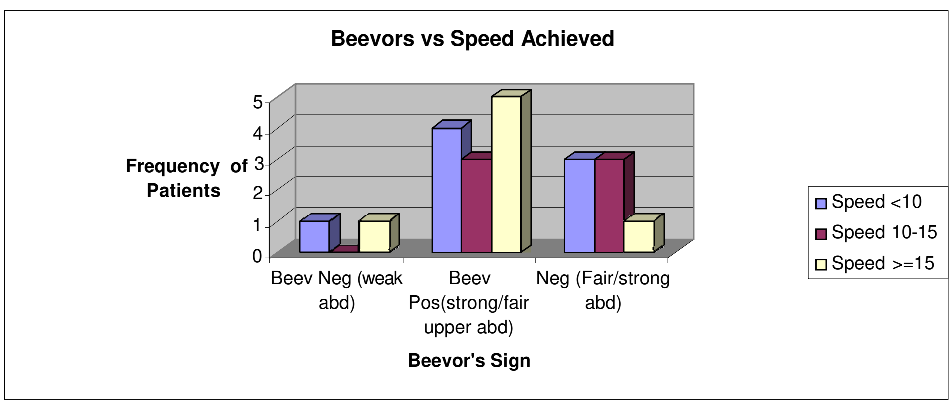

( p= 0.179)

## Beevor's Sign Vs WISCI




(p=0.062)

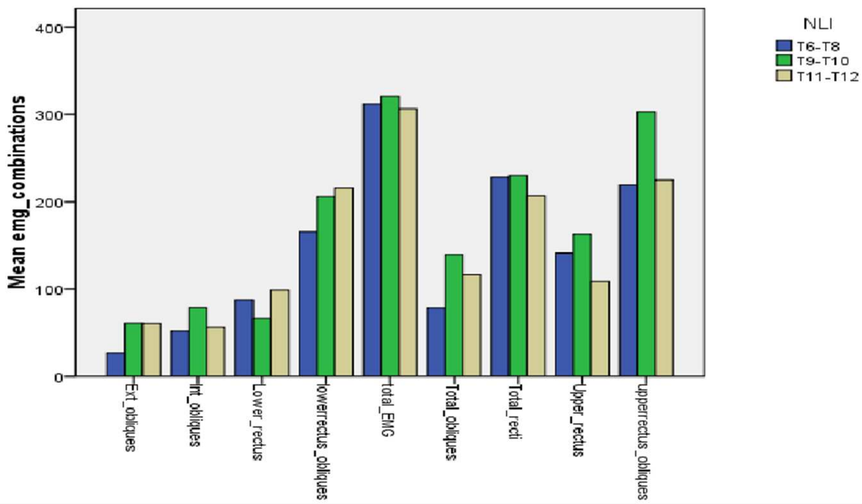
## Beevor's Sign vs Speed




(p= 0.646)

## Correlation Between Predictors

### 1. NLI vs EMG




For most muscle groups, smaller EMG amplitudes were seen associated with high level paraplegics. The correlation was not significant for any muscle group. P values were as follows:

| Upper rectus | Lower rectus | Totl recti | Ext obl | Int obl | Total obl | Upper rectus plus obl | Lower rectus plus obl | Total EMG |
|---|---|---|---|---|---|---|---|---|
| .865 | .592 | .947 | .262 | .521 | .568 | .852 | .358 | .877 |

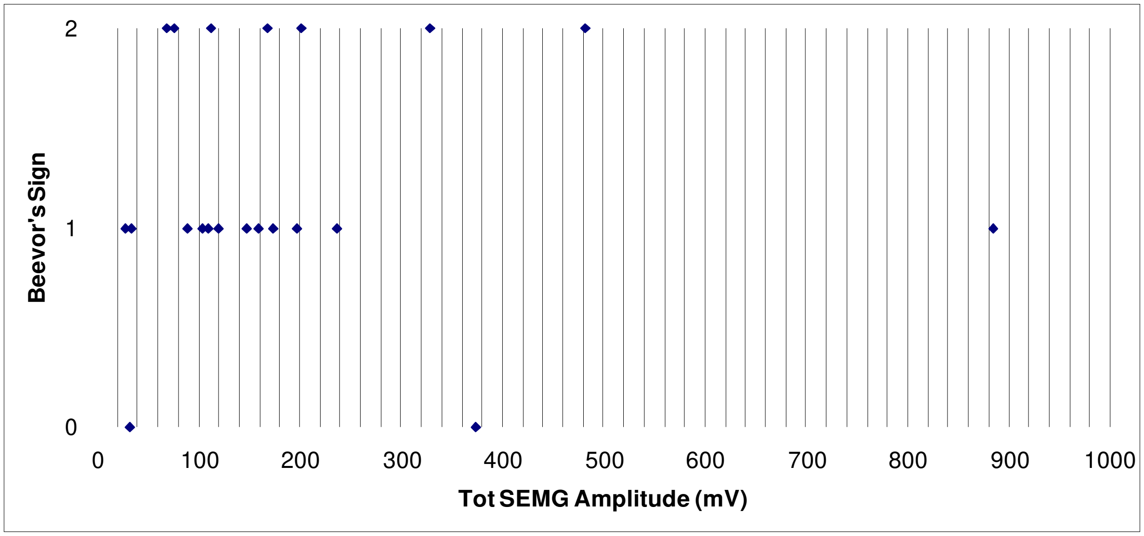
## 2. Beevor's Sign vs EMG

Beevors Sign was classified as follows

0= Beevors negative with weak upper and lower abdominals

1= Beevors positive owing to weak lower abdominals and strong or fair upper abdominals

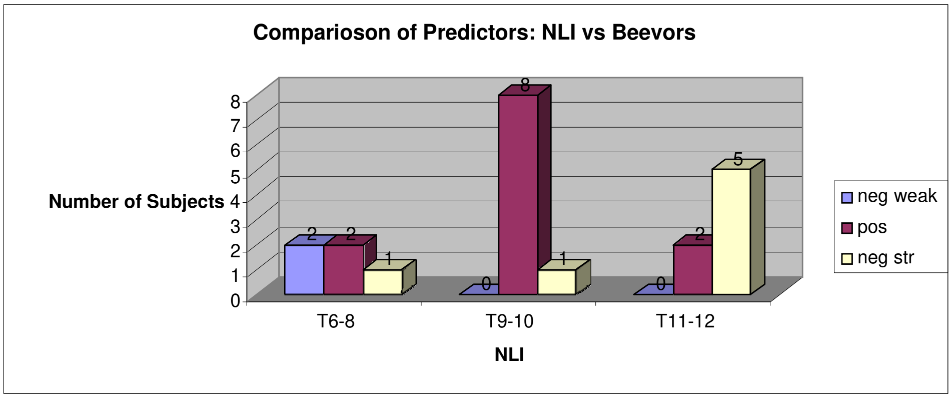
2= Beevors neg with fair or strong upper and lower abdominals




Weak abdominals as interpreted using the Beevor's sign was associated with lower values of total SEMG amplitude. Howevr, the correlation was not significant. For this correlation, the p values for total and individual muscle groups were as follows.

| Upper rectus | Lower rectus | Totl recti | Ext obl | Int obl | Total obl | Uppe rectus plus obl | Lower rectus plus obl | Total EMG |
|---|---|---|---|---|---|---|---|---|
| **0.243** | **0.836** | **0.273** | **0.124** | **0.19** | **0.199** | **0.105** | **0.142** | **0.445** |

**3.** **NLI and Beevor's Sign**




Abdominal muscle weakness as indicated by positive Beevor's sign did not show a trend of increasing occurrence in high level paraplegics.

However, negative Beevor's Sign with strong abdominal muscles was seen in increasing frequency among low level paraplegics.

Also, negative Beevor's Sign with weak abdominal muscles was seen in increasing frequency among high level paraplegics.

**Age versus Outcome**

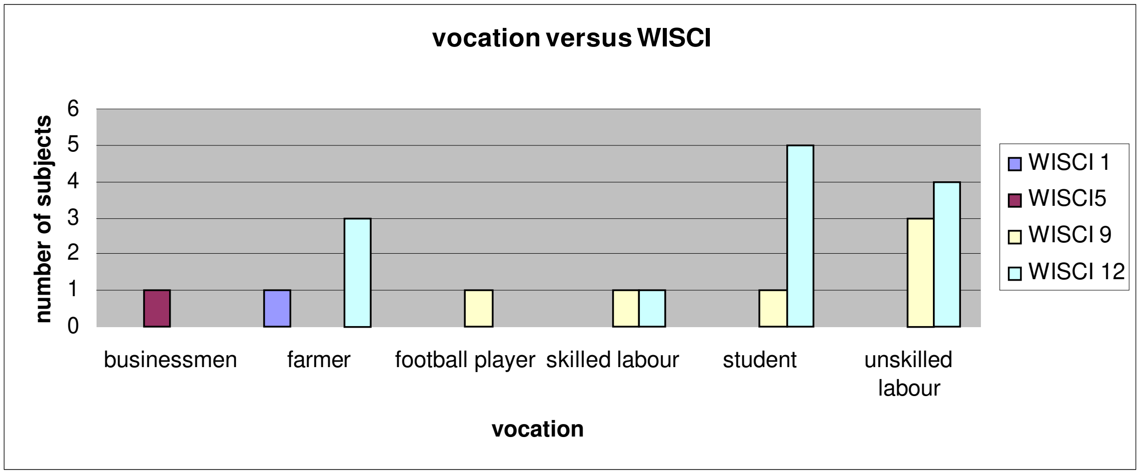
Being in a particular age group did not correlate significantly with the outcome measures (FAS / WISCI/ Speed)

**Etiology versus Outcome**

It did not correlate significantly with the outcome measures (FAS / WISCI/ Speed) FAS (p= 0.074) , WISCI (p= 0.202) , Speed (p= 0.571).

**Occupation**- correlated with WISCI

Students, farmers and unskilled labourers achieved better WISCI scores



# Discussion

# Discussion

Prediction of ambulation outcome in a thoracic level paraplegic is extremely important for reasons of prognostication as well as for rehabilitation planning and goal setting. (9)

However, unlike other cervical or lumbosacral levels of spinal cord injury, where the upper and lower limb muscles respectively are available for clinical testing of motor function, such direct testing is not possible in the case of thoracic level. As such, the sensory level is used to prognosticate outcome. Beevor's Sign is a rough indicator of the abdominal muscle strength- it only indicates a differential weakness between upper and lower abdominal muscles. (72) It indicates a T10 level spinal injury. (73)

Hence there is a disadvantage in the thoracic level when it comes to predicting ambulatory outcome. There is a need for a better predictor which could be more related to the motor innervation of trunk muscles than the dermatomal nerve supply.

This is especially relevant in a developing country scenario where wheelchair accessibility is poor and many thoracic level ASIA complete paraplegics have been trained to walk successfully using KAFOs. (60)

Surface electromyogram (SEMG) of abdominal muscles has not been studied as a predictor for ambulation outcome in thoracic level paraplegics. It is however more directly related to the motor function than the sensory level as used by ASIA.

Hence, we hypothesized that SEMG could be a predictor of the ambulatory outcome. We also examined the currently used predictors (NLI and Beevor's Sign) and compared the results.

21 patients with thoracic level paraplegia and no lower limb motor function (ASIA A and B) were recruited into the study. Maximum number of patients fell in the category 31-40 years, followed by 21- 30 years. The least number was found in the groups > 50 years and 41-50 years. Spinal cord lesions seem to be commoner among the younger population. This is comparable to studies which report that people in the productive age group are most commonly affected by spinal cord injury. (82)

All the subjects were males. National statistics indicates higher incidence of spinal cord injury among males. (83) Both traumatic and non traumatic etiologies were included in the study. Fall from a height comprised the largest group. This is comparable to data from developing countries. (84) , (85)

Unskilled labourers (Manual labourers, construction workers excluding masons, daily wage labourers) comprised the largest category, followed by the student group. Majority of patients received surgical management (81%) as opposed to 19% who were managed conservatively

Maximum number of patients fell in the T9-10 group and least number in T6-T8. Most walkers achieved speeds in the category < 10m/s, followed by >/=15m/s, and lastly the 10 to 14 m/s category.

The predictors and outcome measures for ambulation were examined for correlation.

## **Surface EMG as a Predictor**

The correlation of SEMG amplitude (in millivolts) with each outcome measure (FAS, WISCI and speed) was examined. For total EMG, positive correlation was seen but this was not statistically significant (p=0.15).

For individual EMG the following findings are noteworthy:-

The EMG amplitude of the following muscle groups was seen to be significantly related to achievement of crutch walking (i.e., FAS 5 and 6)

External obliques (p= 0.044 )

Internal obliques – highly significant (p= 0.003 )

Total obliques –significant- (p= 0.021)

Upper rectus plus obliques (p=0.03 )

EMG values significantly correlated with the achievement of ambulation with at least a walker > 250m i.e., FAS at least 4 for internal obliques (p= 0.014 ), lower rectus plus obliques (p=0.035 )

We also examined the correlation of the currently used predictors like NLI and Beevor's Sign with the ambulation outcome.

**<u>NLI as per ASIA as a Predictor</u>**

NLI did not significantly correlate with the outcomes FAS P=0.298 or with WISCI P=0.195 or speed (p=0.351)

It is interesting to note that although the results were not statistically significant, from the graph it is evident that better outcome was seen in lower NLI.

**<u>Beevor's Sign as a Predictor</u>**

Higher FAS score was achieved by persons with better abdominal strength as deduced from the Beevor's Sign. Also, higher WISCI score was achieved by persons with better abdominal strength as deduced from the Beevor's Sign. The results were not statistically significant.

Some individuals with 2nd best Beevor's (Beevor's Positive , lower abdominals fair or weak) achieved the greatest speed. However, Beevor's Negative with weak abdominals was found in persons with least speed. Beevor's sign could possibly predict negative outcomes.

The above results show that all three predictors (SEMG, NLI and Beevor;s Sign) correlated with the ambulation outcome. However, among the three predictors, only surface EMG showed statistically significant correlation with the outcome measures (FAS, WISCI). This suggests that surface EMG of abdominal muscles is a better predictor of ambulation outcome than the currently used predictors.

Another interesting finding is that the NLI showed a positive correlation with the EMG amplitudes obtained but it was not statistically significant.

Surface EMG is a non invasive test. It can even be done in an OPD setting. Hence it can be of supplemental value to the prediction using clinical findings of the NLI and Beevor's Sign.

Based on the findings in our study we can say that before progressive ambulation training is initiated for a patient, one might predict whether crutch walking would be possible by using Surface EMG activity picked up from external obliques, internal obliques, total obliques, upper rectus plus obliques

Similarly, we can say that before progressive ambulation training is initiated for a patient, one might predict whether ambulation with at least a walker > 250m i.e., FAS at least 4 would be possible by using Surface EMG activity picked up from for internal obliques and lower rectus plus obliques.

# CONCLUSIONS

## Conclusions:

1. There was a statistically significant correlation of surface EMG amplitudes of of external obliques, internal obliques, total obliques as well as upper rectus plus obliques with crutch walking.

There was a statistically significant correlation of surface EMG amplitude of internal obliques and lower rectus plus obliques with walker ambulation to at least 250m (i.e., FAS at least 4)

This can be of significance in prediciting the ambulatory capacity in patients with T6-T12 spinal cord lesions.

2. Correlation between surface EMG and Neurological Level of Injury was not statistically significant. Neurological Level of Injury as determined by the ASIA scale may not be sufficient to predict ambulatory outcome in thoracic level paraplegics.

3. Statistically significant correlation was not present between NLI or Beevor's sign with the ambulatory capacity using any of the outcome measures studied. Hence, SEMG may be a better predictor of ambulatory outcome than the existing predictors (NLI and Beevor's Sign) among T6-T12 spinal cord injured patients.

# LIMITATIONS

**Limitations of the study**

•Small sample size

•Swing through gait - in one patient, although functional ambulation was achieved, it was due to swing through gait. All other patients used four-point gait. Swing through gait uses upper limb musculature, and as such SEMG cannot be used as a predictor of function. However this is a rare scenario as it is even more energy consuming than the four-point gait and functional ambulation is usually not achieved.

•Deeper muscles could not be studied which could be more relevant to ambulation than the anterior muscles.

•SEMG amplitudes were studied. Onset of activation was not considered.

•Cardiac and respiratory activity not corrected for during the collection of data

•Outcome: maximum achieved functional walking in this study included patients who achieved stairs, ramps and rough terrains. This was not quantified separately.

•Spasticity could interfere with ambulation outcome as well as surface EMG recording. The presence of spasticity was not taken into account.

# Recommendations

**Recommendations**

1. The study must be repeated with a larger sample size owing to the following reasons:

A) The total of lower rectus and oblique SEMG amplitudes showed a statistically significant correlation with the functional ambulation score.

Positive correlation was seen between the total individual surface EMG amplitudes and outcomes even though it was not statistically significant in all muscle groups.

B) The present data had a few extreme values of surface EMG amplitudes (positively skewed).

2. Better outcome measure could be used to correlate with surface EMG values.

a. Outcome measures of Function (E.g., FIM Instrument)

b. Outcome measures to include negotiation of barriers.

c.Physiological cost index

3. Patient expectations could be included in the prediction of outcome.

4.Within the limits of the study, the EMG values correlated better with the FAS than WISCI which is widely accepted. FAS as an outcome measure could be studied.

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# APPENDICES

## PROFORMA

Serial Number: ____ Date: _________

---

Name:
Age: ____years
Sex: Male / Female
Occupation/ vocation: skilled labour/ unskilled labour / business / student / misc.
Details __________
Address:

---

Etiology:
Trauma / Nontraumatic
Details: _________

Initial Management
Surgical management / Conservative
Details:

Neurological Level of Injury (NLI):
T 6 / 7 / 8 / 9 / 10 / 11 / 12
ASIA A / B

Beevor's Sign:
Positive / Negative
Upper Abdominal Muscle Strength –
Lower Abdominal Muscle Strength –

Surface EMG Amplitude (milli volt) – best of 3 trials
Total:

| | Right | Left |
|---|---|---|
| Upper Rectus | | |
| Lower Rectus | | |
| External Oblique | | |
| Internal Oblique | | |

Speed at discharge = ____m/minute
WISCI at discharge = ____
Functional Ambulation Scale (FAS) at discharge = ____

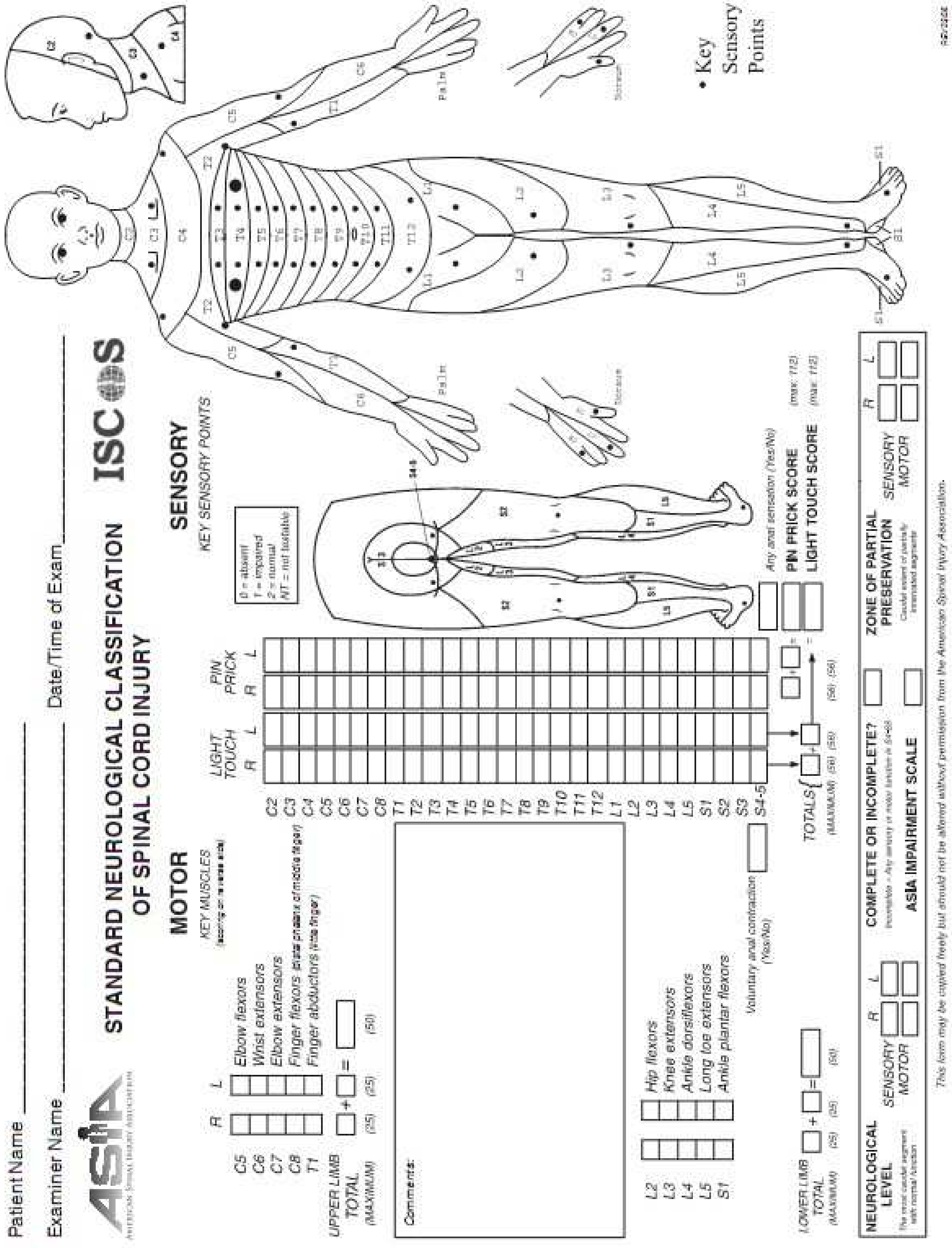
---

# DATA SHEET

| Ser. No. | Occ | etiol | etiol – detail | surgery | Age | NLI | ASIA | Beevor's | RUR | RLR | RIO | REO | LUR | LLR | LIO | LEO | total SEMG | Speed - m/min | WISCI | FAS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | skill lab. | trau | bullet | surg | 55 | 11 | A | 1 | 32 | 34 | 13 | 58 | 30 | 32 | 13 | 40 | 252 | 7 | 9 | 3 |
| 2 | Un skill Lab | non trau | TB spin | cons | 33 | 9 | B | 1 | 62 | 0 | 2 | 0 | 10 | 99 | 0 | 0 | 173 | 15 | 9 | 4 |
| 3 | Businesman | non trau | degen disc | surg | 37 | 8 | A | 1 | 126 | 0 | 0 | 12 | 21 | 0 | 0 | 0 | 159 | 0 | 5 | 2 |
| 4 | Un skill lab | trau | Fall | surg | 25 | 11 | A | 2 | 64 | 169 | 48 | 28 | 137 | 73 | 56 | 78 | 653 | 7 | 12 | 5 |
| 5 | stud | trau | Fall | surg | 20 | 10 | A | 1 | 36 | 58 | 23 | 5 | 70 | 11 | 9 | 64 | 276 | 17 | 12 | 6 |
| 6 | Farmer | trau | Fall | cons | 26 | 10 | A | 1 | 388 | 78 | 139 | 57 | 319 | 140 | 198 | 168 | 1487 | 13 | 12 | 6 |
| 7 | football er | trau | bullet injur | surg | 31 | 12 | A | 2 | 24 | 41 | 34 | 6 | 44 | 66 | 14 | 17 | 246 | 11 | 9 | 6 |
| 8 | unskill lab | trau | Wt on bac | surg | 34 | 11 | A | 2 | 24 | 40 | 34 | 32 | 49 | 28 | 50 | 75 | 332 | 15 | 12 | 6 |
| 9 | farmer | trau | Fall | surg | 23 | 6 | A | 0 | 66 | 40 | 5 | 7 | 8 | 6 | 5 | 0 | 137 | 0 | 1 | 1 |
| 10 | unskille labo | Non trau | deg. Disc | surg | 46 | 9 | B | 1 | 60 | 25 | 121 | 9 | 54 | 9 | 9 | 85 | 372 | 11 | 12 | 5 |
| 11 | Skilled Lab | trau | fall | surg | 33 | 11 | A | 1 | 61 | 54 | 32 | 32 | 150 | 96 | 35 | 14 | 474 | 13 | 12 | 6 |
| 12 | Stu | trau | RTA | surg | 19 | 6 | A | 0 | 26 | 36 | 4 | 3 | 5 | 7 | 11 | 5 | 97 | 18 | 9 | 3 |
| 13 | unskill lab | trau | Electroc | ext. jacket | 25 | 8 | A | 2 | 64 | 53 | 3 | 62 | 37 | 27 | 51 | 18 | 315 | 6 | 9 | 3 |
| 14 | Farmer | trau | Fall | surg | 38 | 12 | A | 2 | 29 | 11 | 13 | 16 | 14 | 27 | 31 | 0 | 141 | 7 | 12 | 6 |
| 15 | Stu | Non trau | TB spin | surg | 18 | 10 | A | 2 | 42 | 0 | 11 | 15 | 54 | 24 | 15 | 10 | 171 | 10 | 12 | 6 |
| 16 | Farmer | trau | Fall | cons | 47 | 10 | A | 1 | 53 | 7 | 32 | 15 | 22 | 6 | 15 | 10 | 160 | 15 | 12 | 5 |
| 17 | Stu | trau | Fall | surg | 24 | 9 | A | 1 | 43 | 13 | 60 | 24 | 17 | 38 | 18 | 15 | 228 | 6 | 12 | 5 |
| 18 | Stu | trau | Fall | surg | 21 | 10 | A | 1 | 109 | 36 | 16 | 20 | 100 | 29 | 22 | 29 | 361 | 20 | 12 | 6 |
| 19 | Un skill labo | trau | RTA | surg | 40 | 11 | A | 2 | 49 | 4 | 15 | 11 | 51 | 16 | 9 | 14 | 169 | 12 | 12 | 5 |
| 20 | Stu | trau | Fall | surg | 13 | 6 | A | 1 | 156 | 162 | 27 | 15 | 196 | 105 | 154 | 11 | 826 | 15 | 12 | 6 |
| 21 | Un skill lab | trau | wt on bac | surg | 40 | 10 | A | 1 | 4 | 12 | 7 | 13 | 28 | 15 | 14 | 5 | 98 | 6 | 9 | 3 |

stu = student, unskill. lab. = unskilled labour, , trau =traumatic , wt on bac= heavy object fell on back, degen=degenerative disc disease, electroc=electrocution, RTA=Road Traffic Accident, surg = surgery, cons.=conservative management, ext. jacket= extension jacket, RUR & LUR= Right & Left Upper Rectus, RLR & LLR= right & left lower rectus, REO and LEO= right and left external oblique, RIO and LIO= right and left internal oblique

# ASIA



Patient Name ____________________

Examiner Name ____________________ Date/Time of Exam ____________________

ASIA AMERICAN SPINAL INJURY ASSOCIATION

**STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY**

ISCoS

**MOTOR**

KEY MUSCLES (scoring on reverse side)

R L

C5 Elbow flexors
C6 Wrist extensors
C7 Elbow extensors
C8 Finger flexors (distal phalanx of middle finger)
T1 Finger abductors (little finger)

UPPER LIMB TOTAL (MAXIMUM) + = (25) (25) (50)

Comments:

L2 Hip flexors
L3 Knee extensors
L4 Ankle dorsiflexors
L5 Long toe extensors
S1 Ankle plantar flexors

Voluntary anal contraction (Yes/No)

LOWER LIMB TOTAL (MAXIMUM) + = (25) (25) (50)

**SENSORY**

KEY SENSORY POINTS

LIGHT TOUCH R L — PIN PRICK R L

C2, C3, C4, C5, C6, C7, C8, T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, L1, L2, L3, L4, L5, S1, S2, S3, S4-5

TOTALS (MAXIMUM) (56) (56) (56) (56)

0 = absent
1 = impaired
2 = normal
NT = not testable

Any anal sensation (Yes/No)

PIN PRICK SCORE (max: 112)

LIGHT TOUCH SCORE (max: 112)

• Key Sensory Points

NEUROLOGICAL LEVEL — The most caudal segment with normal function — SENSORY R L, MOTOR R L

COMPLETE OR INCOMPLETE? — Incomplete = Any sensory or motor function in S4-S5

ASIA IMPAIRMENT SCALE

ZONE OF PARTIAL PRESERVATION — Caudal extent of partially innervated segments — SENSORY R L, MOTOR R L

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# ASIA cont'd

### MUSCLE GRADING

0 total paralysis

1 palpable or visible contraction

2 active movement, full range of motion, gravity eliminated

3 active movement, full range of motion, against gravity

4 active movement, full range of motion, against gravity and provides some resistance

5 active movement, full range of motion, against gravity and provides normal resistance

5* muscle able to exert, in examiner's judgement, sufficient resistance to be considered normal if identifiable inhibiting factors were not present

NT not testable. Patient unable to reliably exert effort or muscle unavailable for testing due to factors such as immobilization, pain on effort or contracture.

### ASIA IMPAIRMENT SCALE

☐ **A = Complete:** No motor or sensory function is preserved in the sacral segments S4-S5.

☐ **B = Incomplete:** Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-S5.

☐ **C = Incomplete:** Motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade less than 3.

☐ **D = Incomplete:** Motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade of 3 or more.

☐ **E = Normal:** Motor and sensory function are normal.

### CLINICAL SYNDROMES (OPTIONAL)

☐ Central Cord
☐ Brown-Sequard
☐ Anterior Cord
☐ Conus Medullaris
☐ Cauda Equina

### STEPS IN CLASSIFICATION

The following order is recommended in determining the classification of individuals with SCI.

1. Determine sensory levels for right and left sides.
2. Determine motor levels for right and left sides.
   *Note: in regions where there is no myotome to test, the motor level is presumed to be the same as the sensory level.*
3. Determine the single neurological level.
   *This is the lowest segment where motor and sensory function is normal on both sides, and is the most cephalad of the sensory and motor levels determined in steps 1 and 2.*
4. Determine whether the injury is Complete or Incomplete (sacral sparing).
   *If voluntary anal contraction =* **No** *AND all S4-5 sensory scores =* **0** *AND any anal sensation =* **No***, then injury is COMPLETE. Otherwise injury is incomplete.*
5. Determine ASIA Impairment Scale (AIS) Grade:

**Is injury <u>Complete</u>?** If **YES**, AIS=A Record ZPP
(For ZPP record lowest dermatome or myotome on each side with some (non-zero score) preservation)

NO ↓

**Is injury motor <u>incomplete</u>?** If **NO**, AIS=B
(Yes=voluntary anal contraction OR motor function more than three levels below the motor level on a given side.)

YES ↓

**Are <u>at least</u> half of the key muscles below the (single) <u>neurological</u> level graded 3 or better?**

NO ↓ AIS=C

YES ↓ AIS=D

**If sensation and motor function is normal in all segments, AIS=E**
*Note: AIS E is used in follow up testing when an individual with a documented SCI has recovered normal function. If at initial testing no deficits are found, the individual is neurologically intact; the ASIA Impairment Scale does not apply.*

## Walking Index for Spinal Cord Injury (WISCI II) Descriptors

Physical Limitation for walking secondary to impairment is defined at the person level and indicates the ability of a person to walk after spinal cord injury. The development of this assessment index required a rank ordering along a dimension of impairment, from the level of most severe impairment (0) to least severe impairment (20) based on the use of devices, braces and physical assistance of one or more persons. The order of the levels suggests each successive level is a less impaired level than the former. The ranking of severity is based on the severity or the impairment and not on functional independence in the environment. The following definitions standardize the terms used in each item:

**Physical assistance**: 'Physical assistance of two persons' is moderate to maximum assistance. 'Physical assistance of one person' is minimal to moderate assistance.

**Braces**: 'Braces' means one or two braces, either short or long leg. (Splinting of lower extremities for standing is considered long leg bracing). 'No braces' means no braces on either leg.

**Walker**: 'Walker' is a conventional rigid walker without wheels.

**Crutches**: 'Crutches' can be Lofstrand (Canadian) or axillary.

**Cane**: 'Cane' is a conventional straight cane.

| **Level** | **Description** |
|---|---|
| 0 | Client is unable to stand and/or participate in assisted walking. |
| 1 | Ambulates in parallel bars, with braces and physical assistance of two persons, less than 10 meters |
| 2 | Ambulates in parallel bars, with braces and physical assistance of two persons, 10 meters. |
| 3 | Ambulates in parallel bars, with braces and physical assistance of one person, 10 meters. |
| 4 | Ambulates in parallel bars, no braces and physical assistance of one person, 10 meters |
| 5 | Ambulates in parallel bars, with no braces and no physical assistance, 10 meters. |
| 6 | Ambulates with walker, with braces and physical assistance of one person, 10 meters. |
| 7 | Ambulates with two crutches, with braces and physical assistance of one person, 10 meters. |
| 8 | Ambulates with walker, no braces and physical assistance of one person, 10 meters. |
| 9 | Ambulates with walker, with braces and no physical assistance, 10 meters. |
| 10 | Ambulates with one cane/crutch, with braces and physical assistance of one person, 10 meters. |
| 11 | Ambulates with two crutches, no braces and physical assistance of one person, 10 meters. |
| 12 | Ambulates with two crutches, with braces and no physical assistance, 10 meters. |
| 13 | Ambulates with walker, no braces and no physical assistance, 10 meters. |
| 14 | Ambulates with one cane/crutch, no braces and physical assistance of one person, 10 meters. |
| 15 | Ambulates with one cane/crutch, with braces and no physical assistance, 10 meters. |
| 16 | Ambulates with two crutches, no braces and no physical assistance, 10 meters. |
| 17 | Ambulates with on devices, no braces and physical assistance of one person, 10 meters. |
| 18 | Ambulates with on devices, with braces and no physical assistance, 10 meters. |
| 19 | Ambulates with one cane/crutch, no braces and no physical assistance, 10 meters. |
| 20 | Ambulates with no devices, no braces and no physical assistance, 10 meters. |

## Scoring Sheet for the Walking Index for Spinal Cord Injury (WISCI II)

Name____________________________________ Date_____________________

*Check descriptors that apply to current walking performance, and then assign the highest level of walking performance. (In scoring a level, one should choose the level at which the patient is safe as judged by the therapist, with patient's comfort level described. If devices other than those stated in the standard definitions are used, they should be documented as descriptors. If there is a discrepancy between two observers, the higher level should be chosen.)*

Gait: reciprocal ________; swing through ________

**Descriptors**

| Devices | | Braces | | Assistance | Patient reported Comfort level |
|---|---|---|---|---|---|
| //bars < 10 meters | | Long Leg Braces- Uses 2<br>Uses 1 | | Max Assist x 2 people | Very comfortable |
| //bars 10 meters | | Short Leg Braces- Uses 2<br>Uses 1 | | Min/Mod assist x 2 people | Slightly comfortable |
| Walker- Standard<br>Rolling<br>Platform | | Locked at knee _____<br>Unlocked at knee _____ | | Min/mod assist x 1 person | Neither comfortable nor uncomfortable |
| Crutches- Uses 2<br>Uses 1 | | Other: _______________ | | | Slightly uncomfortable |
| Canes- Quad<br>Uses 2<br>Uses 1 | | | | | Very uncomfortable |
| No devices | | No braces | | No assistance | |

**WISCI Levels**

| Level | Devices | Braces | Assistance | Distance |
|---|---|---|---|---|
| 0 | | | | Unable |
| 1 | Parallel bars | Braces | 2 persons | Less than 10 meters |
| 2 | Parallel bars | Braces | 2 persons | 10 meters |
| 3 | Parallel bars | Braces | 1 person | 10 meters |
| 4 | Parallel bars | No braces | 1 person | 10 meters |
| 5 | Parallel bars | Braces | No assistance | 10 meters |
| 6 | Walker | Braces | 1 person | 10 meters |
| 7 | Two crutches | Braces | 1 person | 10 meters |
| 8 | Walker | No braces | 1 person | 10 meters |
| 9 | Walker | Braces | No assistance | 10 meters |
| 10 | One cane/crutch | Braces | 1 person | 10 meters |
| 11 | Two crutches | No braces | 1 person | 10 meters |
| 12 | Two crutches | Braces | No assistance | 10 meters |
| 13 | Walker | No braces | No assistance | 10 meters |
| 14 | One cane/crutch | No braces | 1 person | 10 meters |
| 15 | One cane/crutch | Braces | No assistance | 10 meters |
| 16 | Two crutches | No braces | No assistance | 10 meters |
| 17 | No devices | No braces | 1 person | 10 meters |
| 18 | No devices | Braces | No assistance | 10 meters |
| 19 | One cane/crutch | No braces | No assistance | 10 meters |
| 20 | No devices | No braces | No assistance | 10 meters |

Level assigned____________

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