



GLOBAL JOURNAL OF MEDICAL RESEARCH: K
INTERDISCIPLINARY

Volume 16 Issue 1 Version 1.0 Year 2016

Type: Double Blind Peer Reviewed International Research Journal

Publisher: Global Journals Inc. (USA)

Online ISSN: 2249-4618 & Print ISSN: 0975-5888

Effect of Gravitational Stress and Exercises on Bone Demineralization & Renal Complication in Paraplegics & Quadriplegics

By Verma CV, Khadkikar A, Bellare B & Krishnan V

Seth GS Medical College & KEM Municipal Hospital, India

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Methodology: 48 subjects (36 patients+12 controls) participated in this study. The patients were divided into groups A, B & C and the controls were in Group D. Basal parameters (BP, PR, RR) were recorded and Urine samples were sent for analysis. Group A was treated with only limb exercises & Group B was given limb exercises & tilt table standing. Group C had chronic patients to visualize the longterm effect of physical rehabilitation & body's attempt at bone mineral homeostasis on urinary parameters.

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GJMR-K Classification: NLMC Code: WE 200, WJ 378



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Gravitational Stress & Exercises for Spinal Cord Injury

Verma CV ^α, Khadkikar A ^ο, Bellare B ^ρ & Krishnan V ^ω

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Results: Significant changes were noted in the values of urine calcium, inorganic phosphate, hydroxyproline & serum enzyme alkaline phosphatase among groups A, B & C when compare with D.

Conclusion: Tilt-table standing along with limb exercises were more effective in decreasing demineralization & renal complications. Also, active wheelchair bound life style can replace the need for verticalisation in chronic stages.

Keywords: spinal cord injury, gravitational stress, renal complication, bone demineralization, active/passive exercises, verticalisation.

1. INTRODUCTION

A spinal cord injury (SCI) is a multi-system damage with life-threatening complications. It can result in autonomic, neuromuscular and physiologic impairment of the legs, arms or trunk with the severity of the symptoms dependent upon the level and magnitude of the injury to the spinal column. A SCI to the cervical segments of the spinal column (C1-C8) down to the most proximal thoracic segment (T-1) often causes quadriplegia and results in impairment of the arms,

Author α: Professor, Department of physiotherapy, Seth GS medical college & KEM municipal hospital, parel, Mumbai.
e-mail: cvwkresearch@gmail.com

Author ο: B.P.Th, Lokmanya tilak municipal medical college & general hospital, sion, Mumbai.

Author ρ: Professor & HOD, department of physiotherapy, Lokmanya tilak municipal medical college & general hospital, sion, Mumbai.

Author ω: M.P.Th, Lokmanya tilak municipal medical college & general hospital, sion, Mumbai. e-mail: victoryv2@yahoo.co.in

trunk, legs, bladder, bowels and sexual organs. Any SCI occurring at the level of the 2nd thoracic vertebrae (T-2) or distally can result in paraplegia, with accompanying impairments of the trunk, legs and pelvic organs, with a decreasing severity of deficiencies the more distal incursion of the SCI¹. Persons with SCI have a reduced health status, decreased quality of life and increased rates of mortality compared to able-bodied population. The most common medical complications observed in SCI are muscular atrophy, bone metabolism disorders, cardiovascular disease & autonomic dysregulation due to removal of neural drive to the impaired muscles resulting in subsequent reduced metabolic demand accompanied by rapid & chronic deconditioning².

Osteoporosis: a well-known complication of SCI, is characterized by low bone mass & deterioration of the skeletal microarchitecture³. The mechanism of bone loss in SCI is not completely understood; however, a significant amount of bone loss occurs during the first 4–6 months after injury and stabilizes between months 12 and 16. Bone demineralization reaches almost 50% by the end of the first year following SCI. However, bone mineral loss continues to a lesser degree in the pelvis and lower extremities over the next 10 years^{4, 5}.

The pathophysiology of SCI-induced osteoporosis is complex and differs from that observed after prolonged bed rest in patients without SCI and in those with other neurologic deficits⁶. SCI can cause immediate and, in some regions, permanent gravitational unloading, leading to disuse structural change. It triggers significant increase in osteoclastic activity peaking at 10 weeks following SCI at values 10 times the upper limit of normal⁷. Hypercalciuria is 2–4 times that of persons without SCI who undergo bed rest and reaches a peak 1–6 months post injury; this marked increase in urinary calcium is the direct result of an imbalance between bone formation and resorption^{8, 9}. A reduction of bone mineral content during the first year after the injury of 4% per month in regions rich in cancellous bone, and 2% per month on sites containing mainly cortical bone is reported¹⁰.

SCI- mediated hormonal changes also lead to osteoporosis by⁵-

- Increased renal elimination
- Reduced intestinal calcium absorption resulting in negative calcium balance
- Vitamin D deficiency
- Inhibits osteoanabolic action of sex steroids
- Hyperleptinaemia
- Pituitary suppression of TSH
- Insulin resistance & IGF

Renal complications: Neurogenic bladder dysfunction due to SCI poses a significant threat to patient well-being. This can result from detrusor hypocompliance, detrusor-sphincter dyssynergia & neurogenic detrusor overactivity. Some of the complications observed are Incontinence, Renal impairment, Urinary tract infection, Stones etc^{11, 12}. In the absence of adequate treatment, calculi can lead to sepsis & renal failure. The major risk factors found are¹³.

- Hypercaliuria
- Increased susceptibility to Urinary tract infection.
- Immobilization
- Stasis of urine
- Altered urine pH

The chemical composition of SCI-related urinary stones is predominantly nonoxalate calcium (carbonate apatite) during the early years and consists of a higher proportion of magnesium (struvite) in the later years¹⁴.

It is hypothesized that verticalization, early mobilization & exercising of paralysed muscles may lower blood & urine concentration of catabolic products from collagen & bone and thus reduce the skeletal & renal complications¹⁵. Donaldson et al found that quiet standing for 2 hrs a day appears to reverse the changes in mineral metabolism induced by immobilization, whereas vigorous supine exercises for as long as 4 hrs daily is ineffective¹⁶.

Therefore, this study was undertaken to compare the effects of tilt-table standing & limb exercises against limb exercises alone in paraplegics & quadriplegics with a treatment regimen of 15 days. Also a comparison was made to assess the levels of urinary parameters between chronic patients & normal ambulatory control group.

II. METHODOLOGY

Post an institutional ethics committee approval, an informed consent was obtained from all the subjects prior to commencement of the study.

A total of 36 patients with a spinal cord injury, level of lesion ranging from C3-4 to T12 vertebrae were included in this study. Their age groups ranged between 18-55 yrs. The cause of lesion varied from trauma, myelopathy, transverse myelitis, and extra medullary tumor to Koch's spine. Participants were recruited from the outpatient & inpatient department of a tertiary care

public hospital & a renowned paraplegic foundation for the study conducted for a period of 15 days.

The inclusion criteria were as follows-

- Absence of cardiovascular, pulmonary or metabolic disorder
- Naturally free from spasticity or spasticity controlled pharmacologically
- Subjects willing to participate in the study

Exclusion criteria consisted of-

- Unstable or poor surgical fixation
- Presence of debilitating pressure sores

24 of these patients with acute injury were divided randomly by coin toss method into Groups A & B. 12 patients with chronic injury formed Group C & 12 normal subjects shaped the control Group D to assess the effect of this regimen in long-term management of these patients.

Basal parameters of PR, RR & BP were measured and recorded prior & post the study. 24hour urine sample & fasting blood sample was collected on day1, day7 & day15 for analyses in the biochemistry lab. The parameters analyzed were

- Urine calcium
- Urine inorganic phosphate
- Urine hydroxyproline
- Serum enzyme alkaline phosphatase

Exercise Protocol:

- Upper body active or active assisted exercises
- Passive lower limb movements with 10 repetitions for each joint
- Log rolling
- Deep breathing exercises with effective coughing techniques.

Tilt table standing:

- The patient was mounted on the tilt table with the help of 2 ward boys.
- Slings were tied across the patient's chest & knee to ensure maximum stability
- The table was then tilted with the degree of tilt maintained according to the patient's tolerance & pulse rate, volume to prevent postural hypotension
- Post tilt vitals were recorded
- Within 3-4 days the duration of tilt was increased to an 85-90 degree upright position for a period of 30 mins without much discomfort.

Procedure:

Group A: included 2 females & 10 males with 4 quadriplegics & 8 paraplegic patients. Their mean age was 35.08 yrs & mean injury duration was 4.25 weeks. This group followed the exercise protocol twice a day.

Group B: incorporated 5 females & 7 males, 6 quadriplegics & 6 paraplegics, mean age 29.49 & mean

injury duration of 7.98 weeks. They were subjected to tilt table standing along with limb exercises.

Group A & B both patients had an indwelling urine catheter.

Group C: consisted of 2 females & 10 males, 3 quadriplegics & 9 paraplegics with a mean age of 30.25 yrs & injury duration of 16.08 yrs. These patients were actively moving in wheel chairs, independent in ADL & some even participating in wheel chair sports. None of them were subjected to tilt table standing during their early paralysis phase.

This group was studied to see the long-term effect of physical rehabilitation & body's attempt at bone mineral homeostasis on urinary parameters.

Group D: comprised of normal ambulatory subjects with 5 females & 7 males and a mean age of 32.7 yrs. Their urine parameters were considered as normal values for comparison.

III. RESULTS

Comparison was made between the 3 study groups with the control group. All statistical analysis were done by using bivariate methods. Comparison of parameters between Groups A & B was done using unpaired student's t test & paired t test was used to analyze difference within a group.

Table 1 : Comparison of urine calcium between group A & B

URINE CALCIUM		
DAYS	GROUP A	GROUP B
1	12.38 + 5.23	13.75 + 6.19
7	10.53 + 3.12	10.45 + 2.48
15	10.60 + 3.48	8.38 + 1.56
t value	2.58	5.65
p value	< 0.05	< 0.001

Inference: A significant fall in the urine calcium levels were observed in both the groups with group B greater than group A from day 1 to 15

Table 2 : Comparison of urine phosphatase between group A & B

URINE INORGANIC PHOSPHATE		
DAYS	GROUP A	GROUP B
1	46.27 + 17.42	50.33 + 14.91
7	45.66 + 12.97	50.43 + 11.11
15	46.98 + 13.31	43.93 + 10.43
t value	1.36	4.51
p value	> 0.05	< 0.001

Inference: Levels of phosphate showed significant difference in group B while it was non-significant in group A.

Table 3 : Comparison of urine hydroxy proline between group A & B

URINE HYDROXY PROLINE		
DAYS	GROUP A	GROUP B
1	2.93 + 0.43	2.98 + 0.78
7	2.83 + 0.29	2.64 + 0.48
15	2.78 + 0.29	2.29 + 0.48
t value	2.45	4.54
p value	< 0.05	< 0.001

Inference: Levels of hydroxy proline showed significant difference in group B

Table 4 : Comparison of serum enzyme alkaline phosphatase between group A & B

SERUM ENZYME ALKALINE PHOSPHATASE		
DAYS	GROUP A	GROUP B
1	12.39 + 2.09	14.13 + 2.98
7	11.60 + 1.17	11.25 + 1.74
15	11.14 + 1.23	10.01 + 2.41
t value	2.91	7.1
p value	< 0.05	< 0.001

Inference: Serum enzyme alkaline phosphatase was significantly reduced in group B after 15 days of treatment

Table 5 : Comparison of urine parameters between group C & D

URINARY PARAMETERS		
PARAMETER	GROUP C	GROUP D
CALCIUM	6.79 + 1.39	6.91 + 0.95
PHOSPHATASE	65.65 + 6.61	64.02 + 5.84
HYDROXY PROLINE	2.55 + 0.48	2.19 + 0.49
SR. A. P	12.03 + 2.89	11.60 + 1.09

Inference: Urine parameters & serum enzyme alkaline phosphatase were near normal between groups C & D

IV. DISCUSSION

The recent progress in the management of SCI has prolonged the survival of patients. The incidence of secondary bone & joint disorders has also increased considerably¹⁷. Bearing in mind the evaluation and particularities of the osteoporosis occurring in SCI patients, one should pay special attention to the time of injury. Intervention must ideally be introduced early as a large portion of bone loss occurs within 6 months, stabilizing at 12 to 24 months after SCI at values 60% to 70% of normal in the femoral neck and 40% to 50% in the proximal tibia^{10, 18}.

The physiological changes in various systems occur as a result of¹⁹-

- Change from partially upright-partially horizontal body position to a completely horizontal one
- Reduction in energy expenditure due to relative confinement in bed
- Almost complete reduction of stress on muscles & bones

Muscular loading of bones has been thought to play a role in the maintenance of bone density. Exercise increases site-specific osteogenesis in able-bodied individuals²⁰. A study demonstrated that standing might reduce the loss of trabecular bone after SCI. In this prospective study of 19 acute SCI patients, the patients involved in early loading intervention exercise lost almost no bone mineral, whereas the immobilization patients lost 6.9 to 9.4% of trabecular bone²¹.

A study done by Schoutens et al. has shown that exercises without weight bearing cannot counteract the loss of bone mass provoked by bed rest. Also, Kaplan et al, observed reduction in hypercalcemia in quadriplegics after weight bearing & strengthening exercises. Our findings, depicted in tables 1, 2, 3 & 4 correlate well the above studies. Mild significant fall in urine calcium is observed in group A too due to the fact that muscle loading & contraction in the form of active & active assisted exercises, promote maturation of newly formed collagen & calcification of bone matrix^{8, 21}.

Hydroxy proline also, returned to baseline as found in our study, supported by conclusion by Bergmann et al & Chantraine A^{22, 23}.

The abnormality in bone mineral metabolism is directly proportional to the amount of bone tissue immobilized. Thus, SCI patients develop hypercalciuria & mild hypercalcemia. With time, the bones become severely osteoporotic, mobilization of calcium reduces & eventually normalizes¹⁵. This was confirmed by our study in table 5. Since the patients in group C had a mean duration of paralysis of 16 yrs, the urinary levels had come back to their normal limits. This could be because of the body's adaptive strategy to control bone mineral loss over a prolonged period. During this period changes in hormonal factors such as growth hormone or a decrease in IGF-1 may result in a reduced bone turn over²⁴. Also, the independent & active lifestyle that the patients were leading played a crucial role.

a) Limitations

- Male to female ratio could not be maintained equally
- The level of lesion varied amongst patients recruited
- Cause of the lesion was different in amid patients
- Duration of paralysis was also different between patients
- The study had to be restricted to 15 days because of early discharge of patients.

V. CONCLUSION

Thus in our study we conclude that-

- Tilt-table standing which includes a positive gravitational stress & weight bearing was definitely more effective than limb exercises alone in decreasing bone mineral loss & breakdown products of collagen metabolites. This could be crucial for preventing skeletal deconditioning & renal complications in SCI patients
- In chronic patients, an active wheelchair bound lifestyle replaced the need for verticalisation when compared to the normal control group.

VI. ACKNOWLEDGEMENTS

The authors would like to thank all the patients for participating in this study. We also like to express our gratitude to Dr. (Mrs.) Kavita Dipnaik, department of biochemistry & dean of LTMMC & LTMGH Dr. Shirhatti without whose invaluable support this study would not have been possible.

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