

## REDUCTION OF HYPERCALCIURIA IN TETRAPLEGIA AFTER WEIGHT-BEARING AND STRENGTHENING EXERCISES

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**Abstract.** Both weight-bearing and strengthening exercises have been thought to reduce the hypercalciuria associated with tetraplegia. In patients with incomplete spinal cord injuries and tetraplegia, tilt table exercises reduced hypercalciuria and made the calcium balance more positive particularly in the early group of patients. Strengthening exercises did not have nearly as great an effect.

**Key words:** Tetraplegia; Exercise therapy; Calcium, urine; Spinal cord injuries, rehabilitation.

### Introduction

TETRAPLEGIA has been the clearest example of the effects of immobilisation of large masses of muscle, bone, and joint upon calcium metabolism. Increased urinary levels of calcium and hydroxyproline have been noted in subjects with spinal cord injuries and tetraplegia (Claus-Walker *et al.*, 1972; Chantraine, 1970-71). The effects of exercise and weight bearing have been observed to lessen the decrease in bone mass (Guttmann, 1953, 1971). Although kinetic studies on calcium metabolism were conducted in this group of subjects, calcium balance studies were not performed. The object of this study was to determine the effect of weight bearing across long bones on calcium metabolism in tetraplegia subjects.

### Methods and Materials

The study group consisted of eight men and two women from 19 to 56 years of age who had spinal cord injuries. The level of injury was determined by a complete neurological examination and was ascertained to be incomplete and between C5 and C7. Six of the subjects were studied within 6 months of the spinal cord injury (early group). Five of the subjects were studied between 12 and 18 months after the spinal cord injury (late group). None of the subjects had a history of diabetes, kidney disease, or heart disease prior to the spinal cord injury. One of the subjects in the early group had a history of hypertension prior to the spinal cord injury. However, in that subject, the hypertension was not in evidence during the study and required no treatment.

Calcium balances were determined according to the method of Kaplan *et al.* (1978). In brief, the study consisted of a 3 to 6 day dietary equilibrium period followed by a 3 to 6 day collection period. The diet, supervised by a dietician, contained 100 g protein and 1600 mg calcium daily. Calcium balance studies were performed before and after the start of tilt table exercises (normal urine Calcium = 250 mg/24-hours) for each subject. Each tilt table exercise lasted at least 20 minutes at least once a day, and the tilt table angle attained was 45° or greater. The

exercises were coordinated with the second equilibrium and collection periods. In the early group, calcium balances were determined a third time 1 week after tilt table exercises had been terminated. Calcium balance values were evaluated using Student's *t*-test or one-way analysis of variance followed by *t*-test. Significance at the 1 per cent level was chosen (marked with an asterisk\*).

All of the subjects had manual muscle test serially during the study period and had upper and lower extremity strengthening exercises during the study period. However, none of the subjects was ambulatory.

### Results

Neither sex nor age of the subjects nor protein intake contributed significantly to the results of the calcium metabolic balance studies of this group of subjects. All of the serum calcium, phosphorus, total protein, and albumin values remained within the normal range in both the early and late groups before and after tilt table exercises. All values are expressed as mean and standard error of the mean value.

In all cases, the mean 24-hour urinary calcium output decreased. However, in all but two cases, hypercalciuria persisted. During the initial period of evaluation, prior to tilt table exercises in the early group, the mean faecal calcium excretion was  $1221 \pm 4$  mg. The mean urinary calcium output was  $464 \pm 10$  mg and mean calcium balance was  $-85 \pm 11$  mg. The mean faecal excretion for the late group, prior to tilt table exercises, was  $1221 \pm 2$  mg, the mean urinary calcium output  $353 \pm 16$  mg, and the mean calcium balance  $27 \pm 10$  mg. The total group, prior to tilt table exercises, showed a mean faecal calcium excretion of  $1221 \pm 2$  mg, a mean urinary calcium value of  $410 \pm 28$  mg, and a mean calcium balance of  $58 \pm 10$  mg.

Following tilt table exercises, the early group's mean faecal calcium excretion was  $1211 \pm 4$  mg, the mean urinary calcium output was  $404 \pm 5$  mg\*, and the calcium balance was  $-15 \pm 4$  mg\*. The mean faecal calcium excretion for the late group was  $1212 \pm 2$  mg, the mean urinary calcium output was  $323 \pm 28$  mg\*, and the mean calcium balance was  $55 \pm 10$  mg\*. The total group following tilt table exercises showed mean faecal calcium excretion of  $1211 \pm 3$  mg, mean urinary calcium output of  $366 \pm 27$  mg, and a mean calcium balance of  $34 \pm 9$  mg.

In the early group, the urinary calcium output decreased after tilt table exercises by 60 mg while the calcium metabolic balance increased by 70 mg\*. In the late group, the urinary calcium output decreased after tilt table exercises by 30 mg while the calcium metabolic balance increased by 28 mg.

For the early, late, and early plus late combined groups, there were significant differences between urinary calcium output and calcium metabolic balance before and after tilt table exercises. Prior to tilt table exercises, the difference between the early and late group of urinary calcium output was 111 mg\* and of calcium metabolic balance was 112 mg\*. After tilt table exercises, the difference of urinary calcium output was 81 mg\* and of calcium metabolic balance was 70 mg\*.

For the early group, 1 week after termination of tilt table exercises, the mean faecal calcium excretion was  $1219 \pm 4$  mg. The mean urinary calcium output was  $460 \pm 15$  mg, and the mean calcium balance was  $79 \pm 10$  mg.

All of the patients in the early group advanced at least one full grade of muscular strength in the upper and lower extremities during the study period. None of the patients of the late group had that amount of augmentation of muscular strength during the study period.

### Discussion

Change in urinary calcium excretion was noted when duration of the injury was considered. This 111 mg difference between the early group (1-6 months) and the late group (12-18 months) was consistent with past studies of tetraplegic patients (Claus-Walker *et al.*, 1975, 1977-78). All of the patients in this study had the same level of injury. Associated with the recumbency and the high calcium urinary excretion of the early group was increased bone remodelling and resorption (Heany, 1962). The hypercalciuria was reflected in the composition of urinary tract calculi (Burr, 1972, 1978-79).

Following tilt table exercises, the values for calcium balance and urinary calcium output demonstrated the anticipated changes. In both groups, urinary calcium output decreased. The calcium balance became less negative in the early group and augmented the already positive balance in the late group. In addition, the early group showed a significantly greater response than the late group. The calcium balances in the early group reverted to pre-tilt table levels after the termination of tilt table exercises. Tilt table exercises were a major cause of alteration of the urinary calcium output and calcium balances towards a positive calcium balance and lead to results similar to those noted in paraplegics before and after ambulation (Kaplan *et al.*, 1978).

The lack of hypotension during tilt table exercises would indicate significant residual muscular activity. Certainly, the increased muscular strength seemed to parallel the increased response to tilt table exercises of the early group when compared to the late group. However, the fact that muscular exercise alone has relatively little influence over calciuria was demonstrated by the increase of urinary calcium excretion after the termination of tilt table exercises. Past studies of tetraplegic patients have not differentiated between muscular strengthening and weight bearing exercises with regard to urinary calcium excretion (Claus-Walker *et al.*, 1972, 1977-78). On one hand, voluntary muscle activity inhibited local osteoporosis in hemiplegic patients (Panin *et al.*, 1971) and in animals (Geiser & Trueta, 1958). On the other hand, hypercalciuria has been observed in recumbent patients immobilised by plaster casts (Birge & Whedon, 1968; Issekutz *et al.*, 1966), after multiple fractures (Scheller & Crothers, 1979), and by poliomyelitic tetraplegia (Whedon & Shorr, 1957). However, this new investigation demonstrated that the influence of strengthening exercises was probably less important than that of weight bearing when urinary calcium excretion was considered.

That the calcium excretion increased after the termination of tilt table exercises also indicated that time alone was not a major factor in the decrease of calcium excretion after tilt table exercises. Chantraine (1970-71) has noted the decrease of calcium excretion with time. However, time minimally influenced the response of the early group of patients to tilt table exercises.

These results are also consistent with the decreased bone density demonstrated in astronauts during the Gemini spaceflights (Hattner & McMillan, 1968). Weight bearing and axial compression seemed to be factors in decreasing the rate at which bone mass was lost. As a result, the National Aeronautics and Space Administration adopted an axial compression exercise programme. This programme led to a reduction in the rate of loss of bone mass in later spaceflights (Birge & Whedon, 1968; Hattner & McMillan, 1968). These results confirm the importance of axial compression. Moore and Burr (1973) have observed that recumbency removed circadian rhythm of calcium excretion, and the circadian rhythm of parathyroid hormones has been demonstrated (Jubiz *et al.*, 1972). Therefore, the mechanisms

of the effect of weight bearing upon calcium metabolism was probably hormonal in nature and related to the turnover of parathyroid hormone.

A low calcium diet may also result in a diet low in protein (Talbot, 1968). Mobilisation (Birkhead *et al.*, 1966) and tilt table exercises are effective methods of reducing hypercalciuria in the first six months after spinal cord injuries and tetraplegia. The effect of weight-bearing exercises upon calcium metabolism in tetraplegic patients is that of retention and conservation of calcium.

#### SUMMARY

The influence of tilt table exercises on the calcium balances of patients with incomplete spinal cord injuries and tetraplegia was examined. Weight bearing across long bones decreased the hypercalciuria. The gain of muscular strength was greater in the early group. The early group had a sharper decrease of hypercalciuria than the late group.

#### RÉSUMÉ

L'influence des exercices de la table d'inclinaison sur la balance du calcium des malades souffrant de lésions incomplètes de l'épine cervicale fut examinée. La force du poids à travers les os longs a fait décroître l'excès du calcium dans l'urine. Le gain de la force musculaire était plus grand dans le groupe tôt. Le groupe tôt ont un décroissement plus tranchant de la hypercalciurie que le groupe tard.

#### ZUSAMMENFASSUNG

Der Einfluß von Neigungtischübungen über die Calciumwaagschale von Patienten mit unvollständigen Wirbelsäulenverletzungen und Tetraplegikern werden gebrüchen. Die Draht von Gewicht über Langknochen der Übercalcurin war abnehmte. Der Vorteil von Muskelkraft war in die Zeitiggruppe vermehrt. Die Zeitiggruppe hat em scharfer Verringerung von Übercalcurin als die Spätgruppe gehabt.

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