A STUDY OF THE HUMAN URINARY EXCRETION OF CHRONICALLY INGESTED URANIUM - INSIGHTS ON THE GASTROINTESTINAL ABSORPTION FACTOR

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ABSTRACT

A study was conducted in two Canadian towns to determine the feasibility of using urinalysis data to estimate uranium uptake where exposure is through the chronic ingestion of soluble natural uranium in drinking water. Forty-three subjects participated in the study. Uranium levels in drinking water varied from 5 to 376 μg/L, and intakes ranged from 3 to 628 μg/day. Urinary excretion varied from 1 to 10 μg/day. Variation of the gut absorption factor (f_1) correlated poorly with gender, years of residence, and age, while significant negative correlation was obtained with intakes greater than 9.5 μg/day.

INTRODUCTION

Despite numerous studies on the metabolism of uranium, there is still considerable uncertainty regarding the most appropriate value of the f_1 factor to use in the calculation of doses from uranium exposures. Values reported in the literature [1,2] have varied from less than 1% to as much as 32%. A number of human studies have been undertaken to estimate its value, but most have been conducted under conditions of acute exposure. Except when accidents occur, most exposures are chronic in nature. This is particularly true of environmental exposures.

This investigation was undertaken to determine how closely urinary uranium reflects uptake in the gut following chronic uranium ingestion, and to arrive at a "best estimate" of the f_1 factor to use in dose assessments.

METHODS

The subjects for the study were selected according to age, gender, health status, and years of residence in the towns that were studied. Twenty-two male and twenty-one female residents of the two towns with as good a spread in age between 20 and 70 years, and who had lived in the area from a minimum of 17 months to a maximum of 43 years, participated in the study. All were in good health, and were not subject to kidney problems or other complicating pathology. Two couples in one community requested that their three children - ranging in age from 5 to 14 years - be included in the study. Participants were asked to submit 24-hour urine specimens and samples of tap water collected at home and at work. Questionnaires were used to estimate total water intake, including water-based beverages, over a 7-day period. Laser-induced phosphorimetry was used to

measure the uranium content of samples.

Two assumptions were made in the design of the study and the interpretation of the results obtained. Subjects were assumed to be in a state of equilibrium insofar as their uranium excretion vis à vis their intake was concerned. Food was assumed to make a minor or even negligible contribution to uranium intake, compared to water. This was considered reasonable, based on the reported [3] factor of 10^{-3} for the bio-concentration of uranium by staples and garden vegetables grown in contaminated soil.

RESULTS AND DISCUSSION

The wide variability reported in the literature [1,2] for the value of the f_1 factor was also observed in this study, with values ranging from 0.2% to 61% of intake. Uptake data, separately or pooled between locations, were found to be gender-insensitive ($p < .60$). There appeared to be poor correlation between f_1 values and years of residence. This observation supports the assumption that the subjects were in a state of equilibrium with respect to uranium intake and excretion.

The variation of the f_1 values with intake expressed as μg/day was examined. For intakes ranging from 3.0 to 9.5 μg/day, the correlation with the f_1 factor was poor ($p < .40$). For intakes greater than 9.5 μg/day and up to 628 μg/day the best fit was obtained with a power function, with negative correlation being significant at the 99% confidence level (Fig.1). One possible explanation for these observations may be that for f_1 values that correspond to lower daily intakes, food uranium may represent more than a minor fraction of the total amount ingested, contrary to what was originally assumed in this study. A second and more intriguing explanation may be that above a certain level of daily intake (9.5 μg in this study), uptake in the GI tract decreases to a minimum, because some "mechanism" for gut uranium absorption becomes saturated when challenged with increasing uranium intakes.

Statistical tests for correlation also demonstrated that the f_1 values were age-independent. However, an examination of Figure 2 suggests that the f_1 factor may not be altogether age-insensitive. The higher concentration of elevated values at ages greater than 54 years might suggest some release of uranium from bone deposits in these individuals; that is, that these individuals may be in negative uranium metabolism, a phenomenon that has been reported, in older humans, for calcium which is also a bone-seeking element. In contrast, the low values (.004 to .025) for the minors (ages 5 to 14 years), might suggest deposition. The assumption that following prolonged exposure, all individuals are in equilibrium and that therefore, their daily urinary uranium output should be approximately equal to their daily uranium uptake, may have to be reexamined. Excretion in urine may indeed be less than the uptake, if in growing children, uranium deposition is actively taking place during bone development.

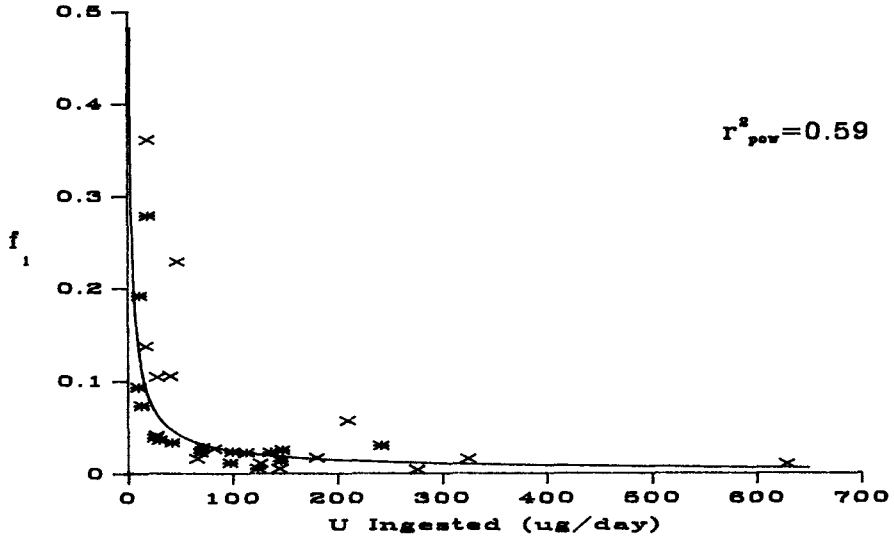

Fig. 1. Fractional gastrointestinal absorption of uranium as a function of intake (ug U/day). Data from a study of two towns were pooled and include uranium intakes ranging from 10 to 628 ug per day.

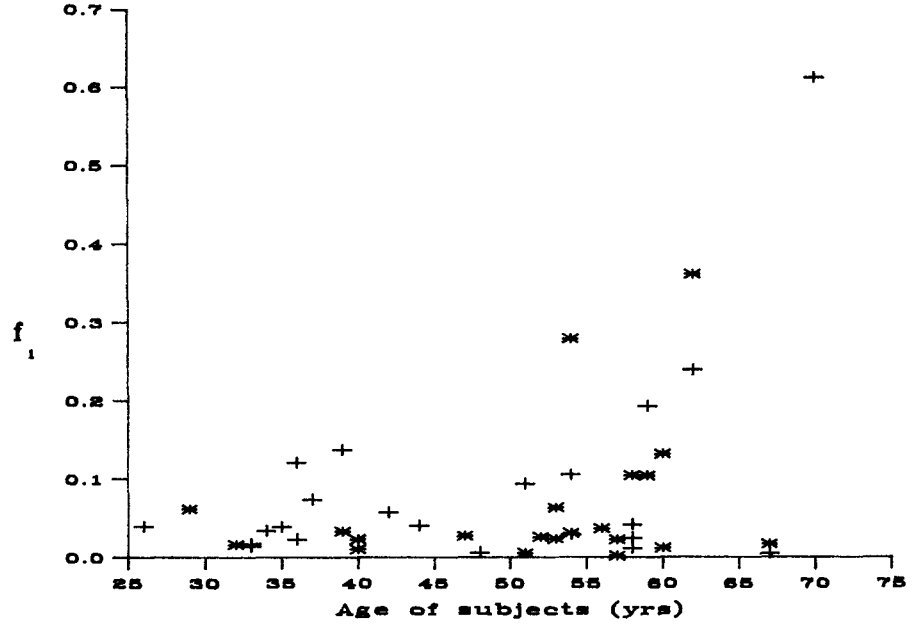

Fig. 2. Scatter plot of f1 values versus the age of male (+) and female (*) subjects.

FURTHER STUDY

The above insights suggest certain areas that require further investigation. A mass balance study of total intake (water plus food) versus total excretion (urinary and faecal elimination) is proposed. This should provide answers regarding the role of food in uranium ingestion, as well as the possible existence of a saturable GI absorption mechanism. It is also proposed that a greater number of minors and subjects fifty years of age or older be included in the study in order to reevaluate whether or not the f_1 factor is age-dependent.

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