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Effect of Hydration on Nitrogen Washout in Human Subjects

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ABS: Five subjects were tested to assess the influence of drinking hypotonic water (distilled water) on whole body tissue nitrogen washout. During the test, the subjects breathed aviators' oxygen for three hours. Each subject performed two baseline nitrogen washouts in a two-week period. The third washout, in the third week, was done under a transient hydrated condition. This was accomplished by having the subjects drink 1.5 liters of hypotonic water 30 minutes before the washout. Five-minute plots of tissue nitrogen removal from the three separate washouts were analyzed to ascertain if the hydration technique had any effect. Our results clearly indicate that the hydration technique did not alter the tissue nitrogen washout characteristics to any degree over three hours. An increase in tissue nitrogen washout under a transient hydrated condition using hypotonic
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EFFECT OF HYDRATION ON NITROGEN WASHOUT IN HUMAN SUBJECTS

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ABSTRACT

Five subjects were tested to assess the influence of drinking hypotonic water (distilled water) on whole body tissue nitrogen washout. During the test, the subjects breathed aviators oxygen for three hours. Previous reports stated that such hydration techniques reduced the incidence of reported and measured decompression sickness in man and in animals. Additionally, they hypothesized that this protection resulted from more tissue nitrogen washout resulting from the transient hydrated condition.

To check this, each subject performed two baseline nitrogen washouts in a two-week period. The third washout, in the third week, was done under a transient hydrated condition. This was accomplished by having the subjects drink 1.5 liters of hypotonic water 30 minutes before the washout. Five-minute plots of tissue nitrogen removal from the three separate washouts were analyzed to ascertain if the hydration technique had any effect.

Our results clearly indicate that the hydration technique did not alter the tissue nitrogen washout characteristics to any degree over three hours. An increase in tissue nitrogen washout under a transient hydrated condition using hypotonic fluid was not demonstrated to be the mechanism responsible for the reported benefit of this technique in preventing Type I altitude decompression pain in man.

INTRODUCTION

References 25, 26, 20, 16, and 24 provide data which suggest that under specific conditions the over consumption of fluids, especially isotonic fluids, before decompression moderates the development of altitude (Type I) decompression pain in man. One possible explanation could be that nitrogen removal from tissues and fluids is increased during a transient hydrated state.

Many factors can influence the characteristics of nitrogen washout over an extended period. Behnke (refs. 6, 7, 8) showed how body composition and exercise can influence a washout. More recent sudies by Balldin, et. al. (refs. 4, 3, 5, 2) showed how temperature and body position and immersion can influence whole body nitrogen washout and inert gas removal from adipose and from muscle tissue. Theis, et. al. (ref. 21) confirmed and supplemented this data by examining whole body nitrogen washout during supine body position. Also, changes in carbon dioxide concentration of inhaled breathing gases increased the volume of nitrogen removed from men, Margaria and Sendroy (ref. 18).

The majority of the explanations for the altered behavior of tissue nitrogen washout under experimental condition involves changes in cardiovascular and pulmonary dynamics. Additional mechanisms have been proposed to explain the positive results that come from hydration techniques before decompression.

stress. Such factors as changing the diffusion and solubility coefficients of inert gases in body fluids (ref. 11), altering cardiovascular dynamics and increasing the surface tension of body fluids (refs. 23, 24) have been implicated as plausible mechanisms which could improve inert gas transport within the hydrated body or inhibit bubble formation.

This study was initiated to examine if hypotonic oral hydration before a three-hour nitrogen washout would significantly influence the characteristics of that washout. Thus, explaining why hydration has been reported to offer some degree of resistance to altitude decompression sickness in man.

METHOD

Five males between 22 and 35 years old breathed dry aviators oxygen for three hours on three different occasions to achieve the desired nitrogen washouts. Each washout was separated by one week. The third washout was performed exactly as the two baseline washouts except the subject was instructed to drink 1.5 liters of tap water within 30 minutes of the test.

All subjects, having fasted for 12 hours, submitted a first morning's urine sample. Each sat in a recliner either reading or watching television, while breathing aviators oxygen through a modified Sierra Fire Fighters Mask equipped with a Robert Shaw Mini demand oxygen regulator. All washouts were done at room termparature (21-23 degrees C) and atmospheric pressure.

Saturated exhaled gas volume was measured by a mechanical spirometer on a breath-by-breath basis while dry nitrogen, oxygen, and carbon dioxide concentrations were integrated with the volume data in a LSI-11 microcomputer. A calibrated MGA 1100 Perkin-Elmer Mass Spectrometer measured these gas concentrations. It contained a range setting that allowed nitrogen concentration to 0.005 % to be resolved. All gas volumes were converted to a standard temperature, pressure, and dry gas volume. Details of the Nitrogen Washout Measuring System are described (Levitan, 1981).

A ten-second oxygen purge removed the nitrogen from the dead air space of the mask (820 ml). The subjects then breathed normally during the remainder of the washout. Tissue nitrogen volumes were plotted at 5-minute intervals. They were corrected for pulmonary nitrogen by subtracting the value of nitrogen removed in the first 40 liters of ventilated oxygen. To prevent nitrogen inhalation should a mask leak, the subjects' heads were in an oxygen tent. The ventilation within the tent (15 liters/minute) kept the nitrogen concentration below 5%. The remainder of the body was exposed to room air.

During each non-hydrated washout subjects were required to void urine after 165 minutes of washout, while during their hydrated run they voided 30, 60, 90, 120, and 150 minutes into the washout. Urine samples were measured for volume and specific gravity and were used as an indicator of hydration.

RESULTS

Hydrating five men orally with 1.5 liters of hypotonic water 30 minutes before a 3-hour washout had no measureable effect on the amount of tissue nitrogen removed or the charcteristics of the washout over a three hour period. The hydration procedure increased urine output in all subjects. The first urine sample was collected 30 minutes into the washout. Peak urine production occurred approximately 90 minutes into the test. Throughout the test, the collected urine was diluted.

Tables 1 and 2 show basic subject characteristics and the washout results. Since no significant differences were observed in total tissue nitrogen washout under hydrated conditions, all nitrogen data from the three washouts were averaged. Subject 4 completed only one non-hydrated and one hydrated washout.

Figures 1 through 5 display the characteristic washout of each subject under hydrated and normal conditions. They clearly indicate that any variability in the results of hydration washouts were within the measured variability of washouts under non-hydrated conditions. The results also demonstrate that individuals have unique tissue nitrogen washouts that are specific to their particular anatomy and physiology.

Figures 1 through 5 deserve detailed inspection. To account for pulmonary nitrogen, the lungs were ventilated with 40 liters of oxygen. Then that nitrogen volume was subtracted from the next 5-minute tissue values. This technique provided reproducible starting points except in Subject 1 (see figure 1). Even though the characteristic shape of all curves are the same in this

TABLE 1-SUBJECT CHARACTERISTICS

Subject	Age	Wt. (Kg)	Ht. (cm)	Body fat (%)	Body density	Estimated tissue* N_2 (ml)	Average tissue N_2 removed (ml)	Washout*** efficency (%)
1	33	66.5	176	10	1.078	1024	607	59
2	35	72.3	180	17	1.060	1483	778	52
3	28	77.5	178	14	1.066	1444	903	62
4	22	68.0	175	7	1.084	937	606 **	65
5	26	81.0	185	18	1.058	1714	1500	87

* N_2 estimate based on two tissue model of fat and lean tissue content of body.

** All values from Subject 4 come from one hydrated and one non-hydrated washout.

*** Washout efficency calculated as: $\frac{\text{average tissue } N_2 \text{ removed}}{\text{estimated tissue } N_2} \times 100$

TABLE 2-SUBJECT CHARACTERISTICS

Subject	Respiration Rate	Tidal volume (ml)	# of Breaths in 3 hours	Total exhaled O_2 volume (l)	N_2 removal after 3 hours (ml/min)	N_2 concentration after 3 hours (%)
1	13	610	2358	1438	1.00	.015
2	17	646	2986	1928	1.10	.009
3	7	1270	1200	1523	1.90	.027
4	14	704	2515	1769	0.65	.008
5	7	2146	1280	2748	4.15	.025

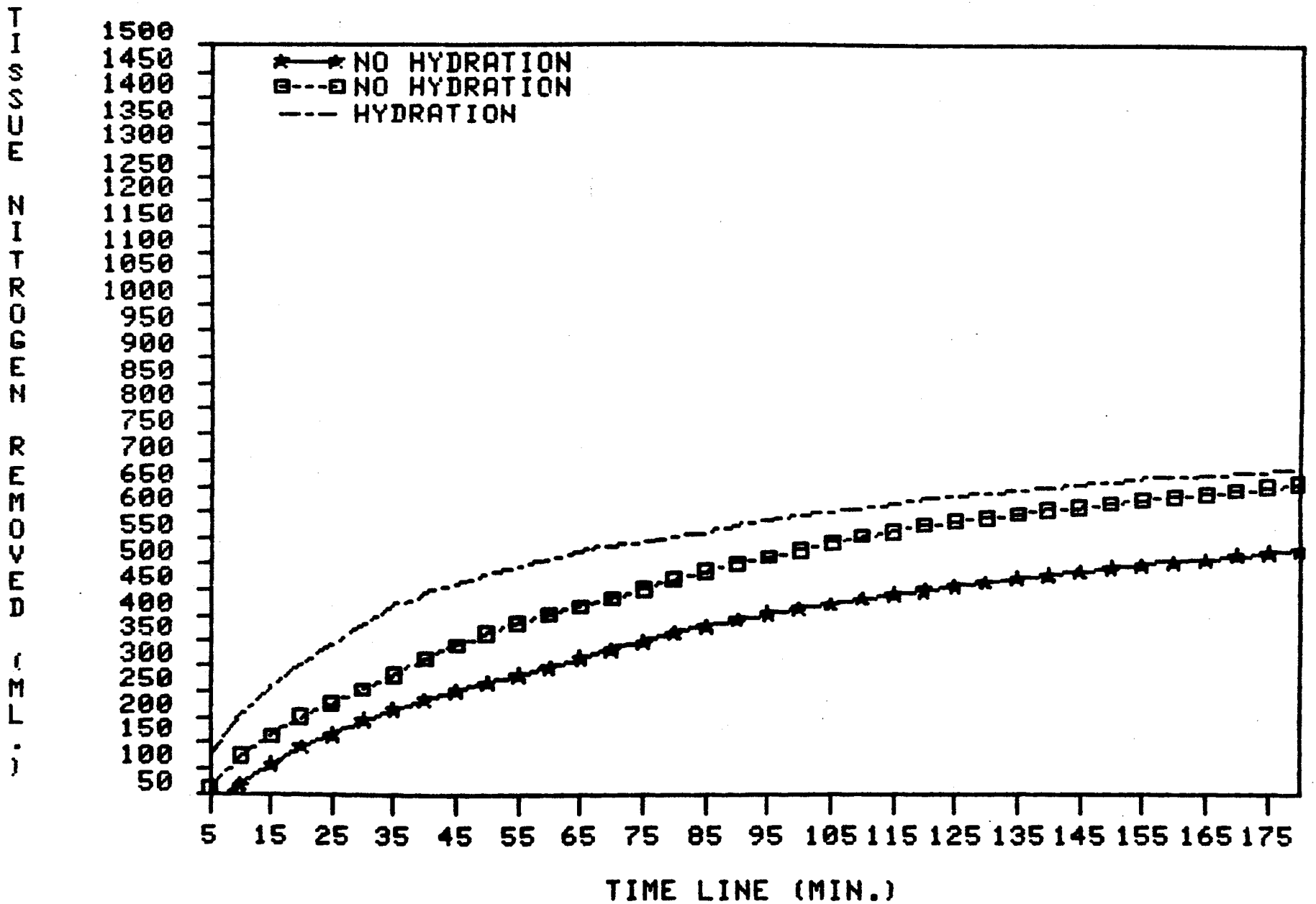

Figure 1.- Subject 1 tissue nitrogen washout.

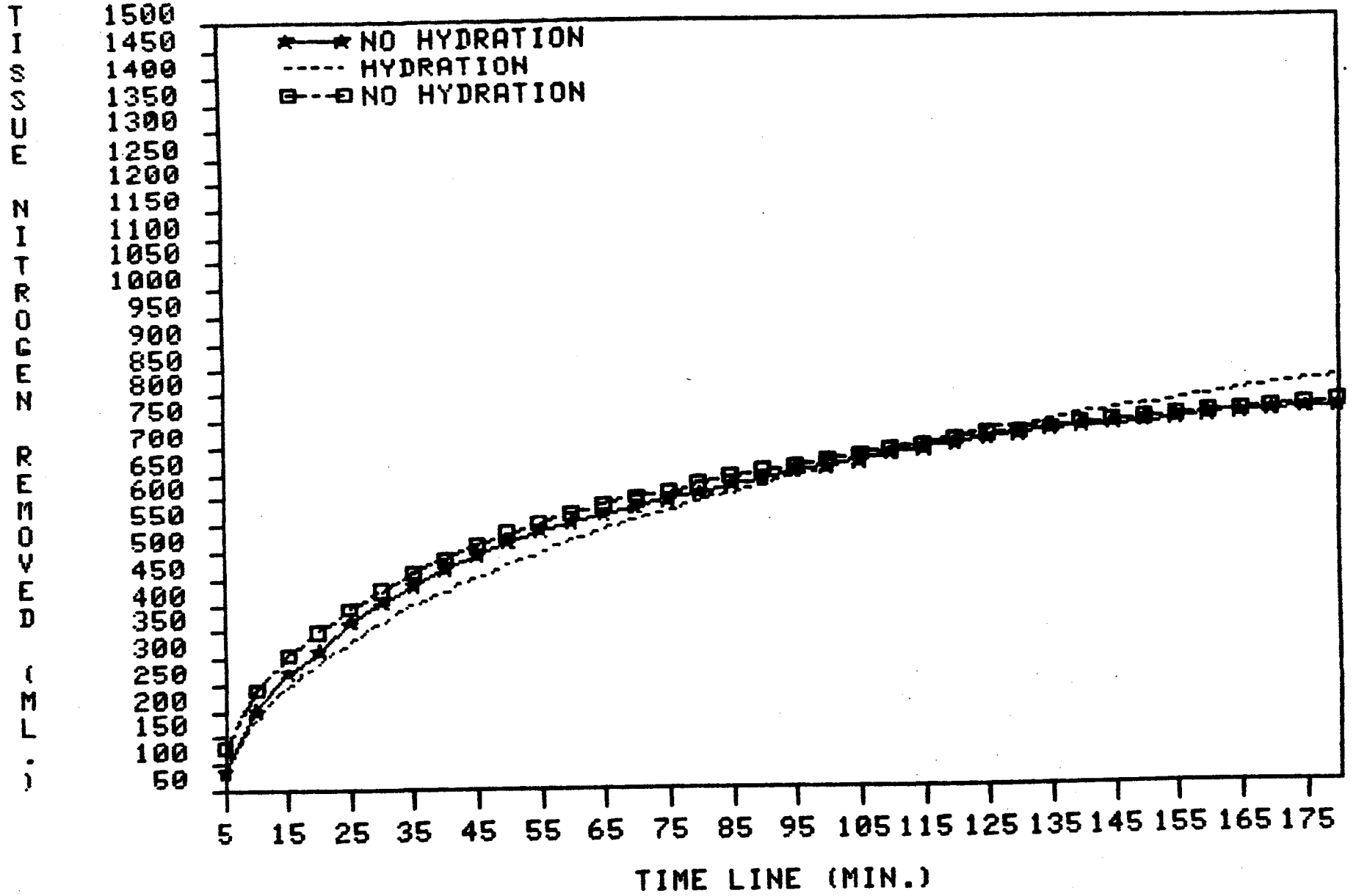

Figure 2.- Subject 2 tissue nitrogen washout.

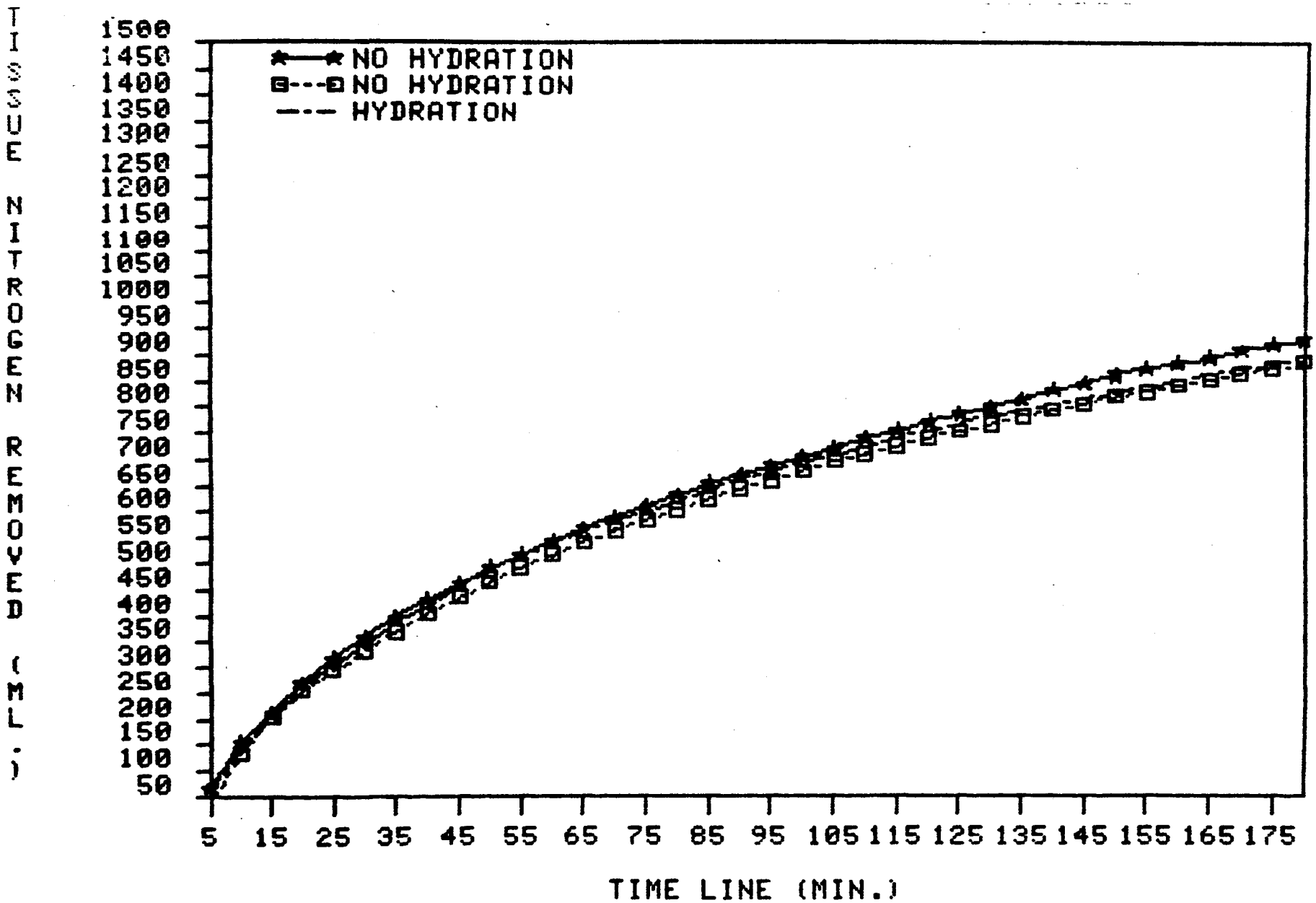

Figure 3.- Subject 3 tissue nitrogen washout.

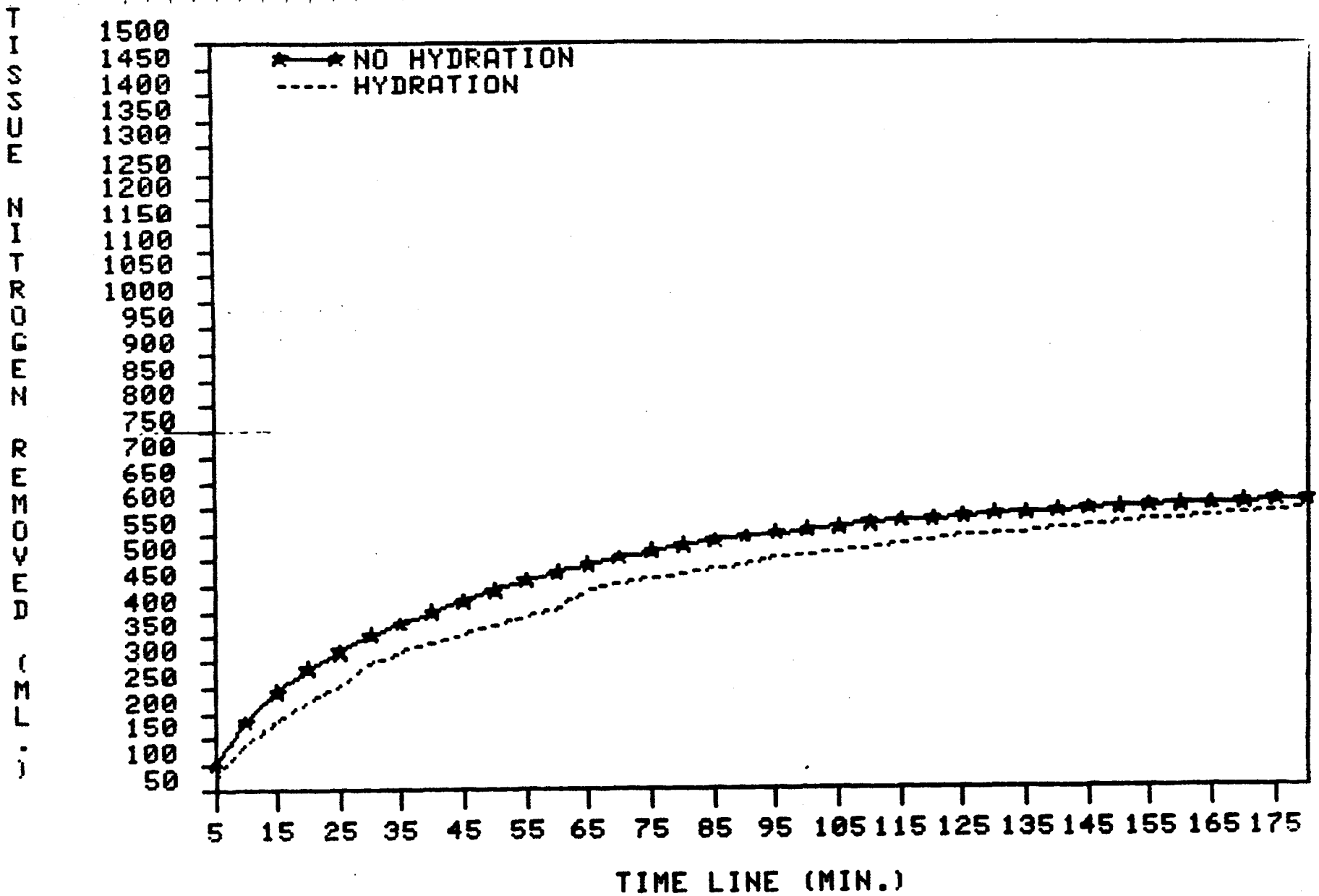

Figure 4.- Subject 4 tissue nitrogen washout.

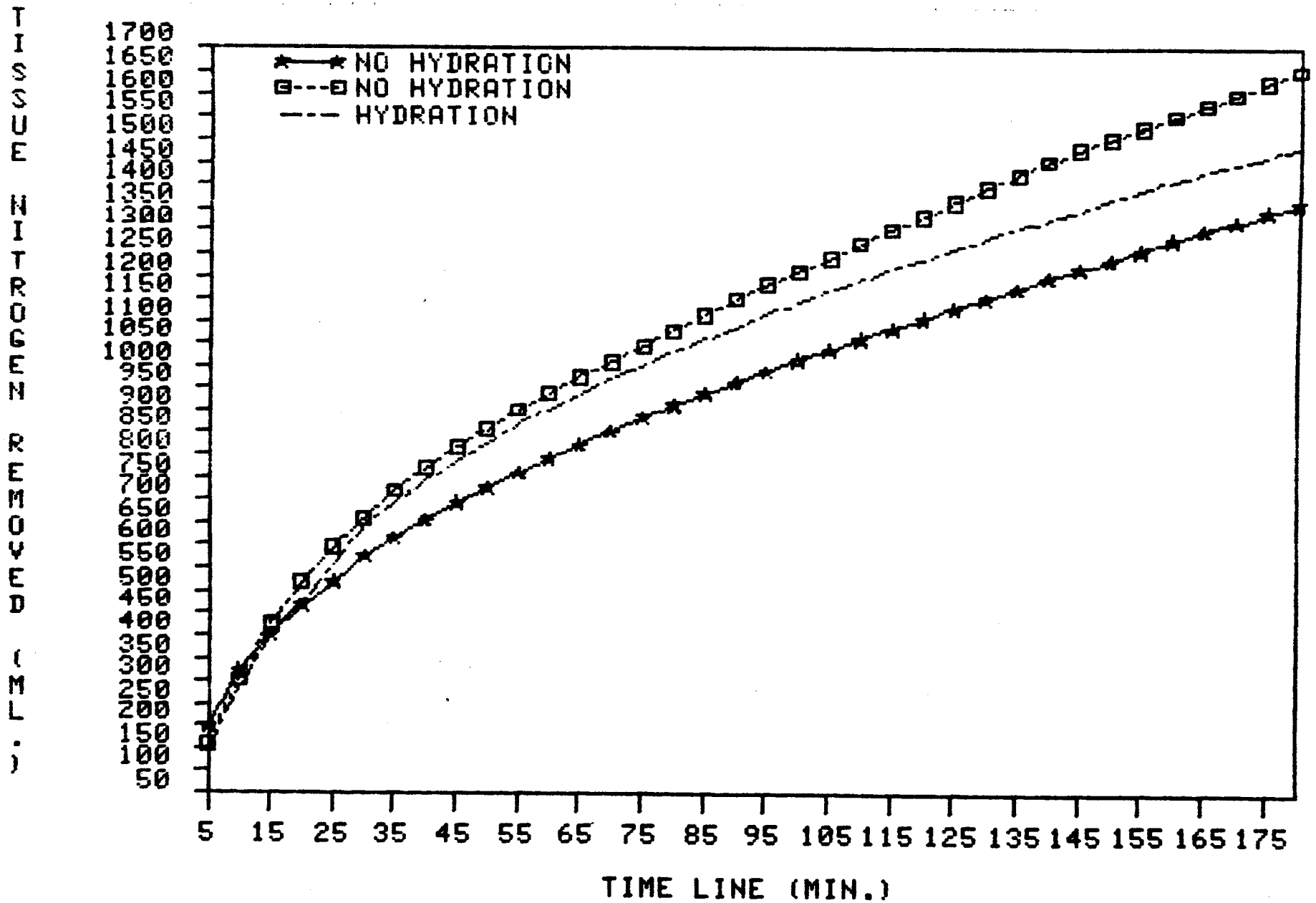

Figure 5.- Subject 5 tissue nitrogen washout.

individual, the starting points were different. This suggests that pulmonary nitrogen was not accounted for equally in the three runs by our technique.

Subject 5 had a large tidal volume and was the largest in overall weight and fat content of the subjects. Initial starting points were close and were attributed to his effective lung ventilation. Tissue washout after five minutes was approximately 170 ml/minute. The slope of the curves approaching three hours showed no indication of changing and it is likely that the initial estimate of whole body nitrogen content was conservative. After three hours of oxygen breathing Subject 4 had an average tissue washout of 4.15 ml/minute while the remaining subjects were in the 1.0 ml/minute range (see table 2).

Subject 5 also revealed three distinct washout patterns unlike the washouts the other four subjects. The maxium difference in the ending tissue nitrogen volumes was 289 milliliters while the maxium difference in the initial tissue nitrogen volumes was 49 milliliters. Physiological changes of the subjects with larger tissue nitrogen reservoirs may account for his difference.

Each subject had a subject-specific washout. Subjects 1 and 4 had essentially identical tissue nitrogen washouts. The anatomical data in tables 1 and 2 show that both had similar body types and breathing patterns. However, Subject 1 had a much higher average exhaled nitrogen concentration after three hours which indicated he had more nitrogen to offer. This agreed with estimate of tissue nitrogen which shows Subject 1 contained slightly more nitrogen than Subject 4.

Our results also indicated that increased alveolar ventilation does not necessarily increase or quicken tissue washout. Other factors are rate limiting. Subjects 1 and 4 had similar tissue nitrogen volumes after three hours, but Subject 4 actually ventilated his lungs with 331 liters more oxygen in the same time as Subject 1. Also, Subject 3 had a greater nitrogen production than 1 or 4, but had an intermediate volume for lung ventilation (see table 2).

All subjects except 4 displayed unique, reproducible nitrogen washout patterns irrespective of when they participated in the test or if they were challenged with a hypotonic fluid load before their washout. It is concluded that loading an individual with 1.5 liters of hypotonic fluid 30 minutes before a three-hour nitrogen washout does not increase or promote the overall removal of nitrogen from the body. Thus, it is unlikely that the beneficial effect of transient hydration that has been reported to offer a degree of resistance to altitude decompression sickness in man can be attributed to an increased removal of tissue nitrogen during oxygen prebreathing.

CONCLUSION

The results from this study suggest that the protective effect of hydration before decompression recorded in some animals (refs. 9,19,12,27) and human decompression studies (Refs. 25,26) was not due to the increased removal of tissue nitrogen during the hydration phase.

Earlier investigators suggest that hydration would enhance the movement of nitrogen from tissues, fluids, or from formed gas bubbles, and would enhance

the ability of the fluids to retain more nitrogen in solution. The washout results under hydrated conditions did not confirm earlier suggestions. Review articles by (refs. 13,22,10,1,14,15) suggest that no firm concensus yet exists concerning how alterations in body fluid balance, composition, or distribution may influence the development of decompression sickness in man.

It is possible that hydration reduces decompression sickness by increasing the surface tension of blood so that bubble formation in that tissue is somewhat hindered (refs. 23,24). Whether this would influence bubble formation in joints is not readily apparent. However, a hydrated condition may also serve to increase microcirculation otherwise compromised by the presence of gas emboli.

The issue is still unresolved concerning what mechanism would explain the positive results observed in some decompression studies where an aspect of hydration was a factor. It appears that increasing whole body nitrogen washout is not the mechanism since hypotonic hydration had no influence.

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15. Supplementary Notes

16. Abstract

Five subjects were tested to assess the influence of drinking hypotonic water (distilled water) on whole body tissue nitrogen washout. During the test, the subjects breathed aviators oxygen for three hours. Previous reports stated that such hydration techniques reduced the incidence of reported and measured decompression sickness in man and in animals. To check this, each subject perfored two baseline nitrogen washouts in a two-week period. The third washout, in the third week, was done under a transient hydrated condition. This was accomplished by having the subjects drink 1.5 liters of hypotonic water 30 minutes before the washout. Five-minute plots of tissue nitrogen removal from the three separate washouts were analyzed to ascertain if the hydration technique had any effect.

Our results clearly indicate that the hydration technique did not alter the tissue nitrogen washout characteristics to any degree over three hours. An increase in tissue nitrogen washout under a transient hydrated condition using hypotonic fluid was not demonstrated to be the mechanism responsible for the reported benefit of this technique in preventing Type I altitude decompression pain in man.

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