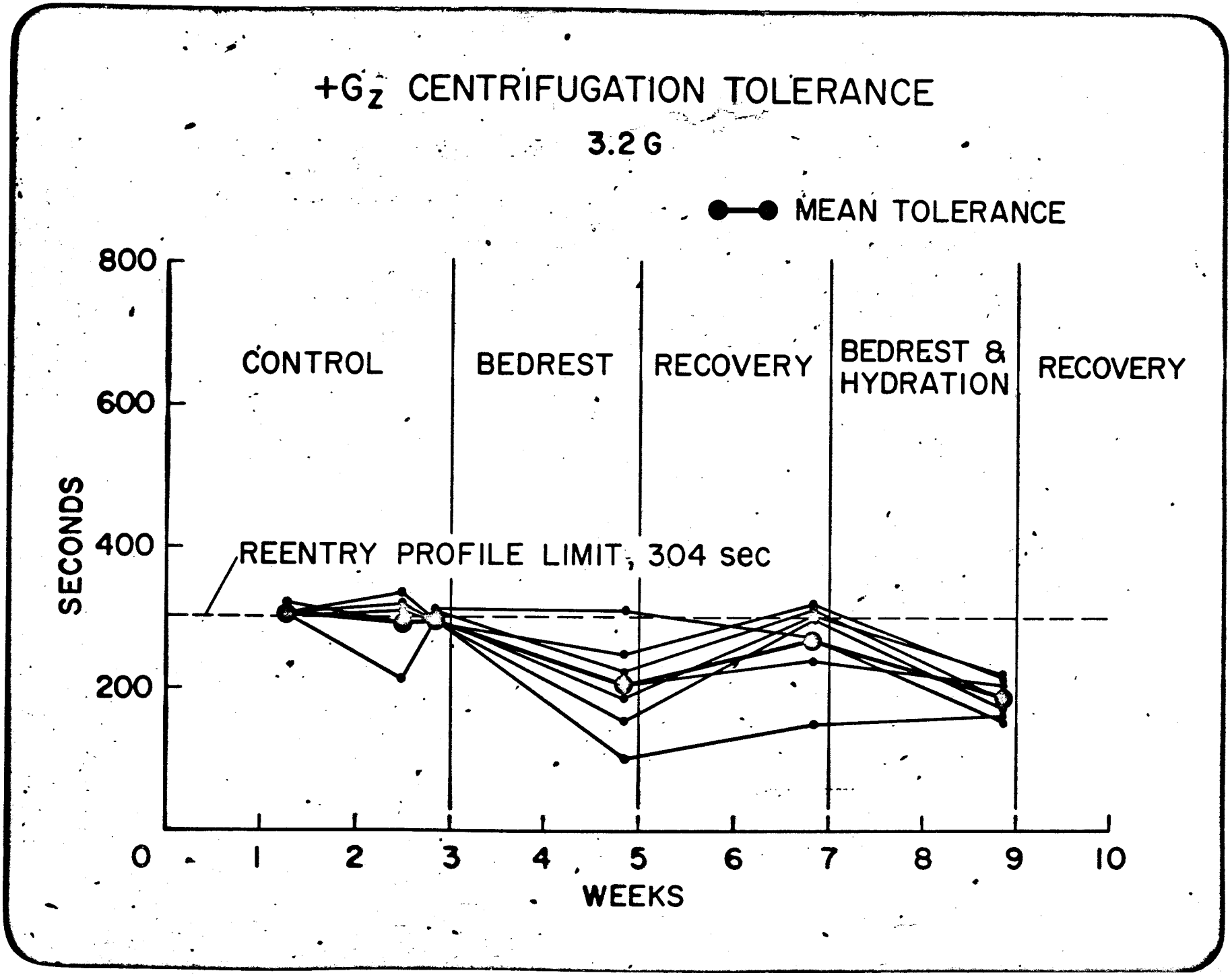
CENTRIFUGATION SUMMARY

(TOLERANCE TIMES, SYSTOLIC AND DIASTOLIC PRESSURES, HEART RATES)

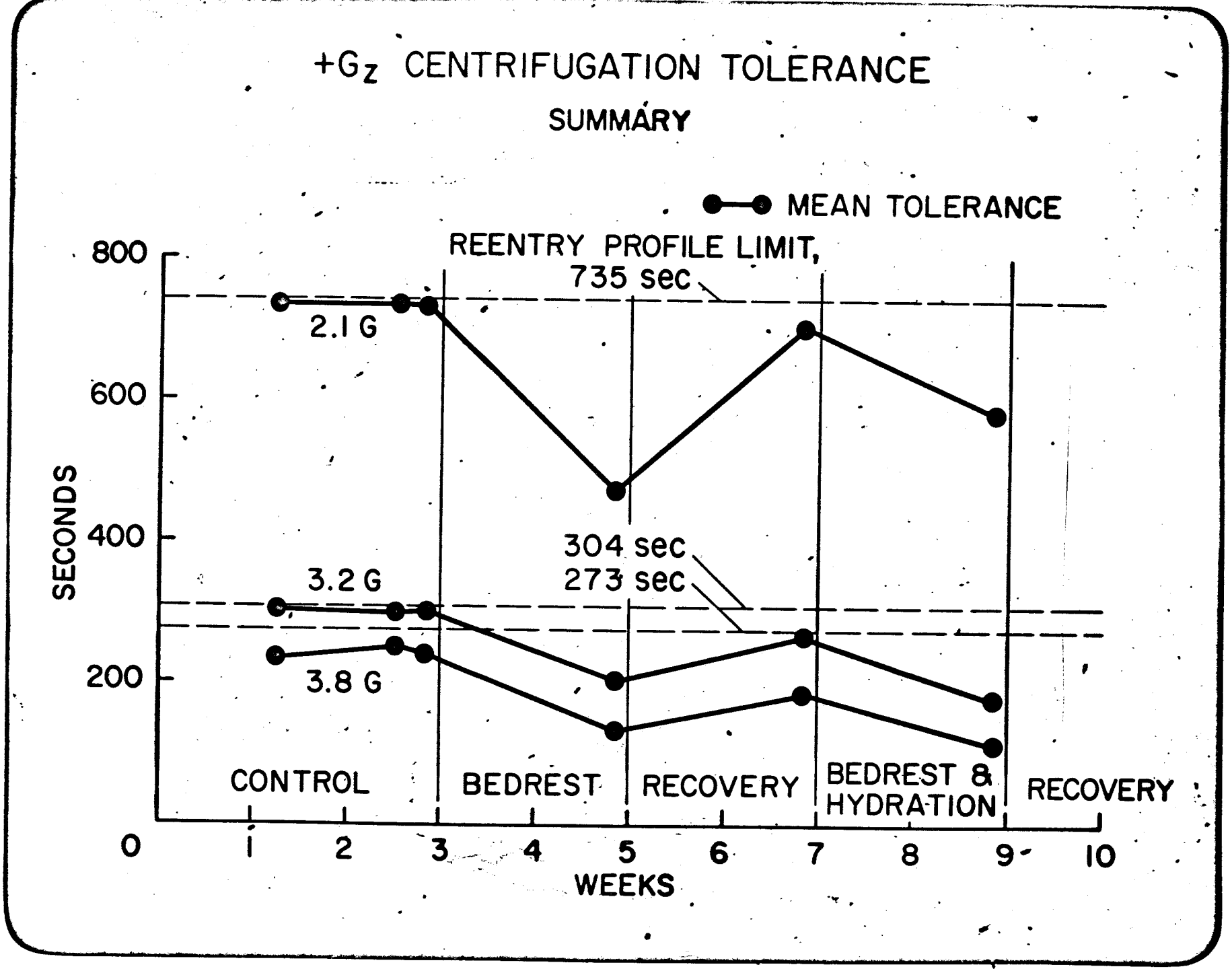
		CONTROL	BED REST	RECOVERY	BED REST + HYDRATION
2.1 G	TIME (SEC)	736	468	701	592
	SBP (mm Hg)	144	142	151	137
	DBP (mm Hg)	114	94	116	100
	HR	124	158	136	141
3.2 G	TIME (SEC)	299	205	265	185
	SBP (mm Hg)	173	158	164	152
	DBP (mm Hg)	125	107	121	115
	HR	150	156	154	142
3.8 G	TIME (SEC)	246	133	188	114
	SBP (mm Hg)	197	160	176	159
	DBP (mm Hg)	153	108	121	146
	HR	164	156	176	140

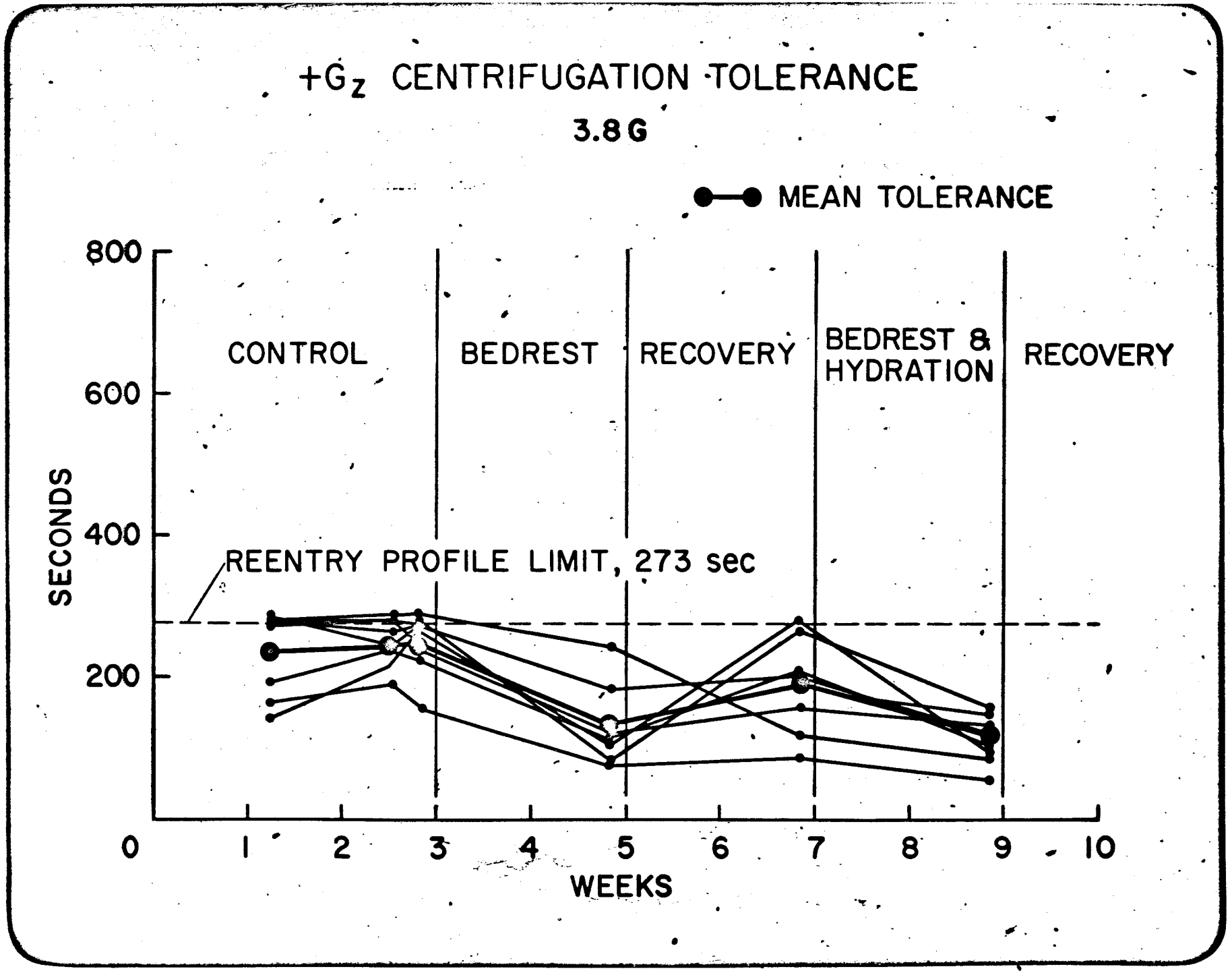
CONCLUSIONS:

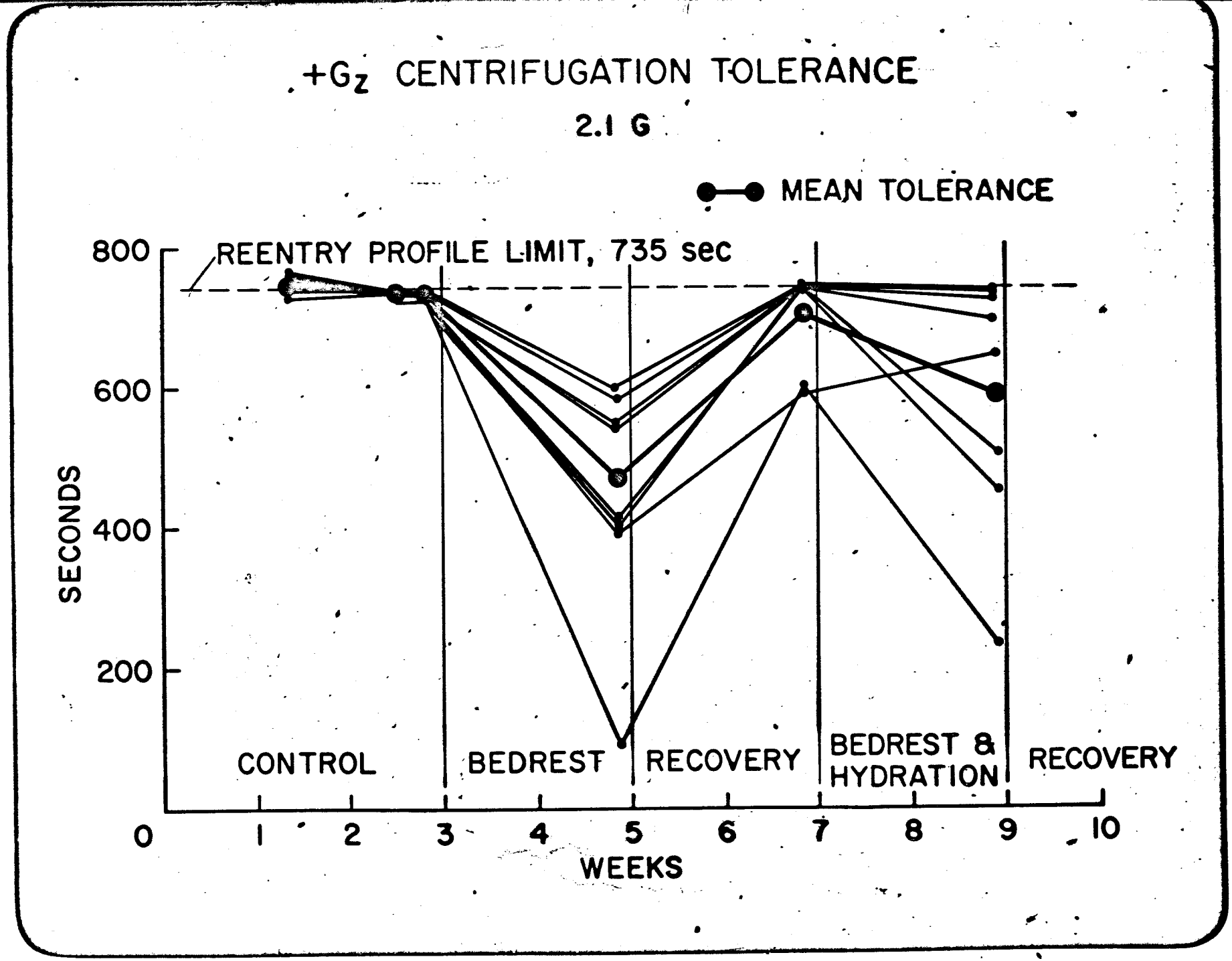
1. TWO WEEKS OF RECOVERY BETWEEN BED-REST TESTS DID NOT PERMIT FULL RESTORATION OF 3.8 G TOLERANCE. COMPARE CONTROL #1 WITH CONTROL #2 VALUES.
2. IN POST BED-REST RUNS, THE TERMINAL HEART RATES ARE EXTREMELY CONSTANT COMPARING THE THREE G PROFILES.
3. FLUID REPLACEMENT INCREASED TOLERANCE IN THE 2.1 G RUNS: 3.2 AND 3.8 G TOLERANCES WERE UNAFFECTED.



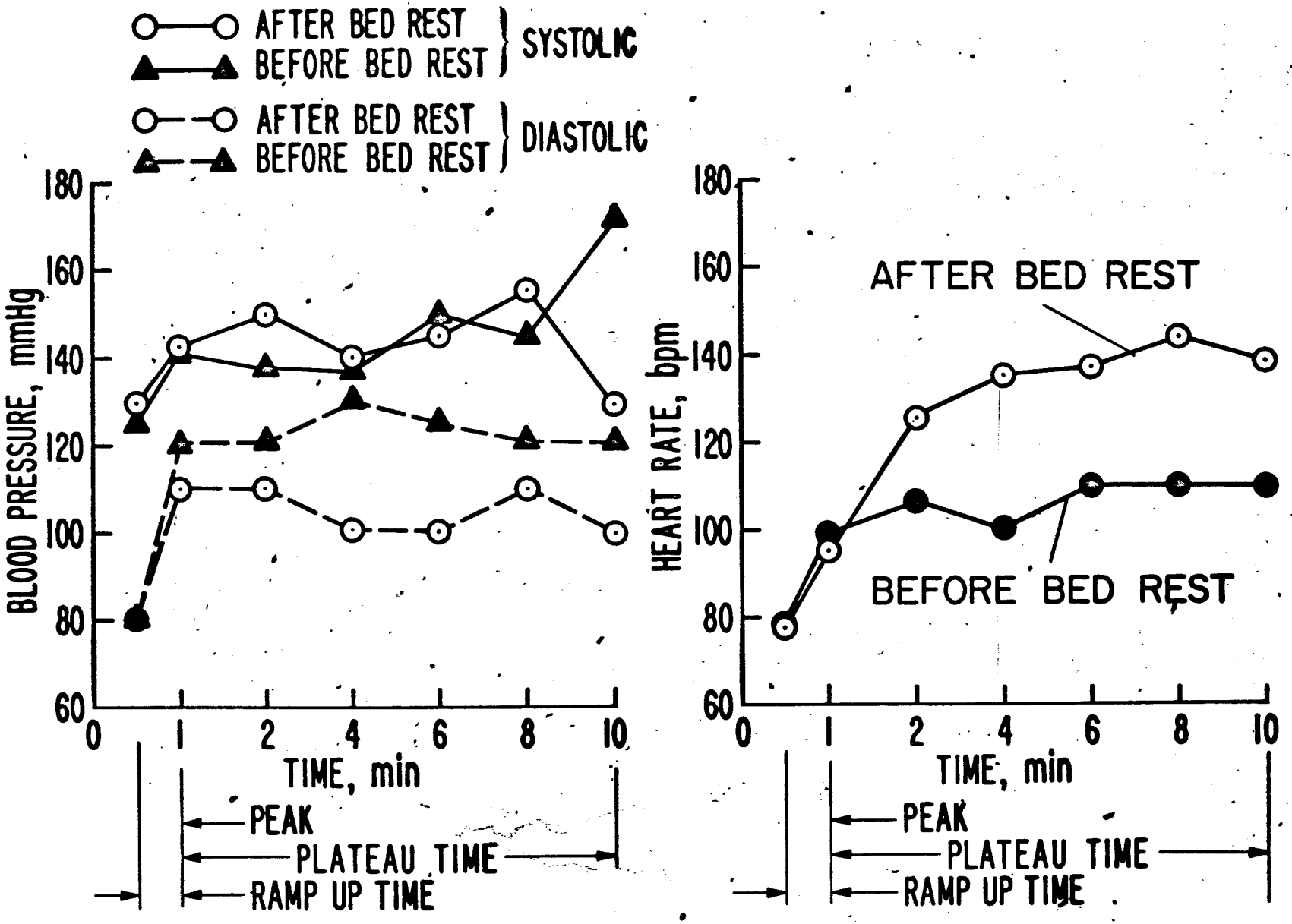
TOP VERTICAL


+Gz CENTRIFUGATION TOLERANCE
SUMMARY
MEAN TOLERANCE
REENTRY PROFILE LIMIT,
735 sec
2.1 G
304 sec
273 sec
3.2 G
3.8 G
SECONDS
800
600
400
200
0
CONTROL
BEDREST
RECOVERY
BEDREST & HYDRATION
RECOVERY
1
2
3
4
5
6
7
8
9
10
WEEKS

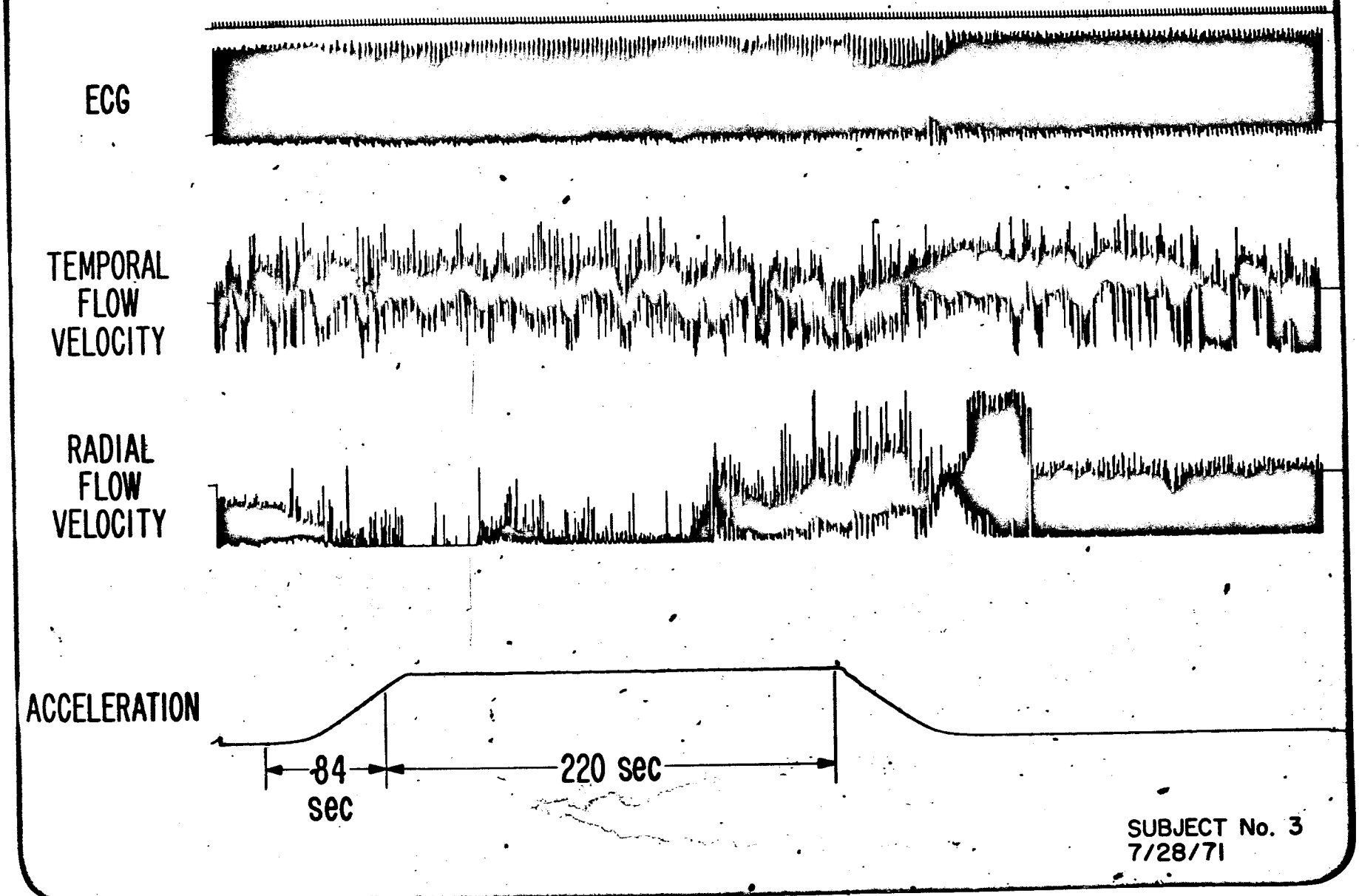

+Gz CENTRIFUGATION TOLERANCE
3.8 G
MEAN TOLERANCE
800
600
400
200
SECONDS
CONTROL
BEDREST
RECOVERY
BEDREST & HYDRATION
RECOVERY
REENTRY PROFILE LIMIT, 273 sec
0
1
2
3
4
5
6
7
8
9
10
WEEKS

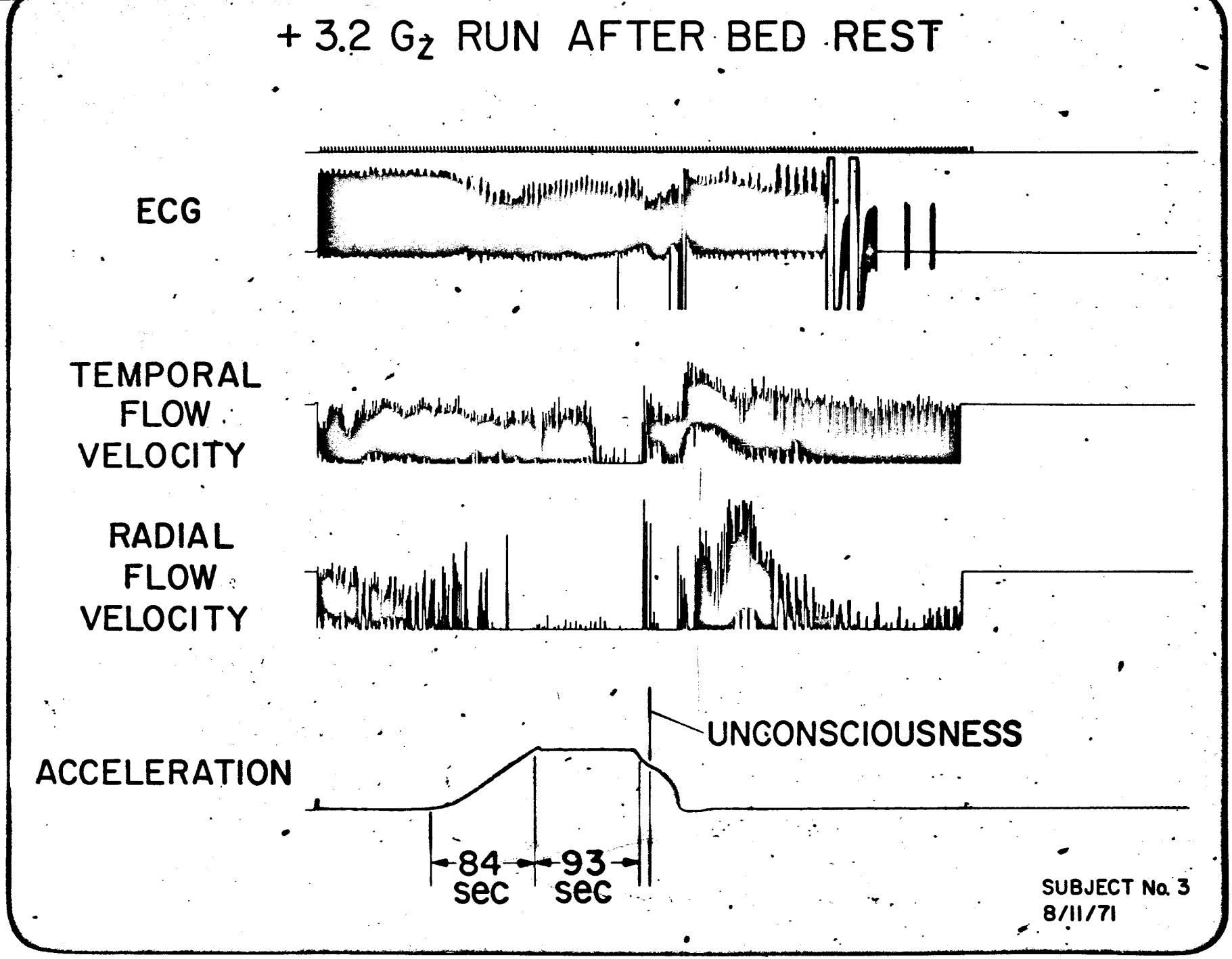

+Gz CENTRIFUGATION TOLERANCE
2.1 G
MEAN TOLERANCE
REENTRY PROFILE LIMIT, 735 sec
800
600
400
200
SECONDS
CONTROL
BEDREST
RECOVERY
BEDREST & HYDRATION
RECOVERY
0
1
2
3
4
5
6
7
8
9
10
WEEKS

CARDIOVASCULAR RESPONSE +2.08 G_z BEFORE AND AFTER BED REST

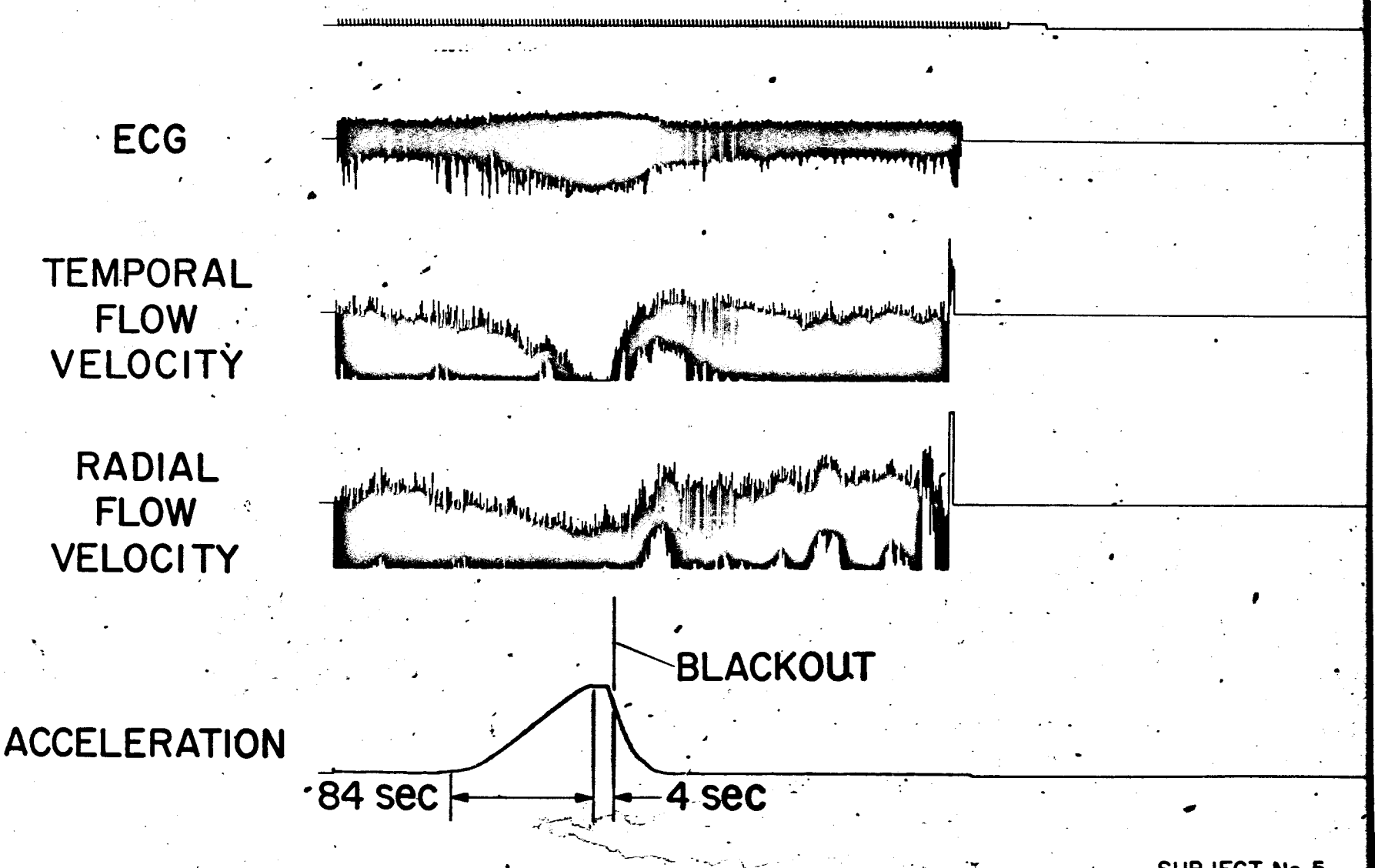


NORMAL + 3.2 G_z RUN

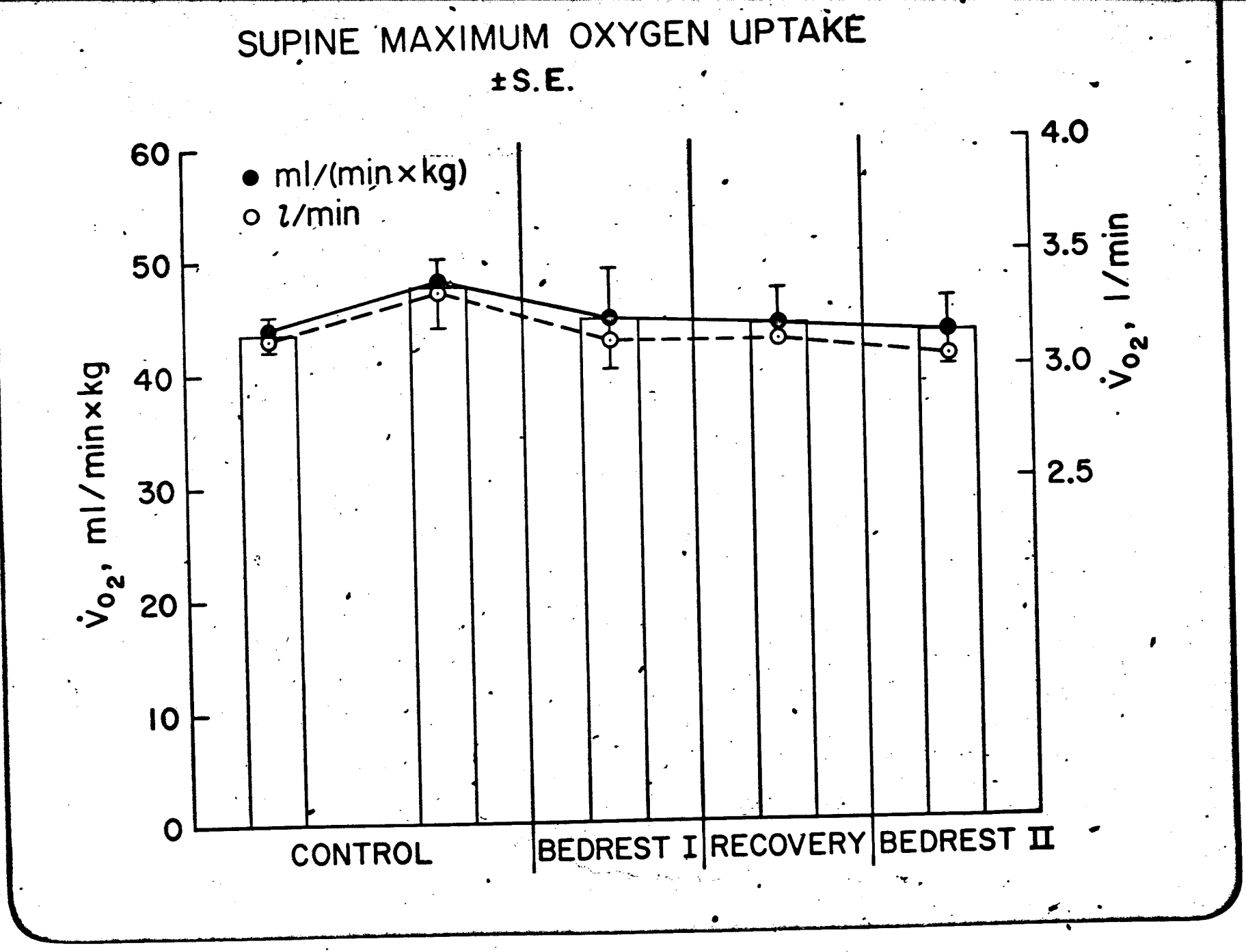



+ 3.2 G_z RUN AFTER BED REST
ECG
TEMPORAL FLOW VELOCITY
RADIAL FLOW VELOCITY
ACCELERATION
UNCONSCIOUSNESS
84 sec
93 sec
SUBJECT No. 3
8/11/71

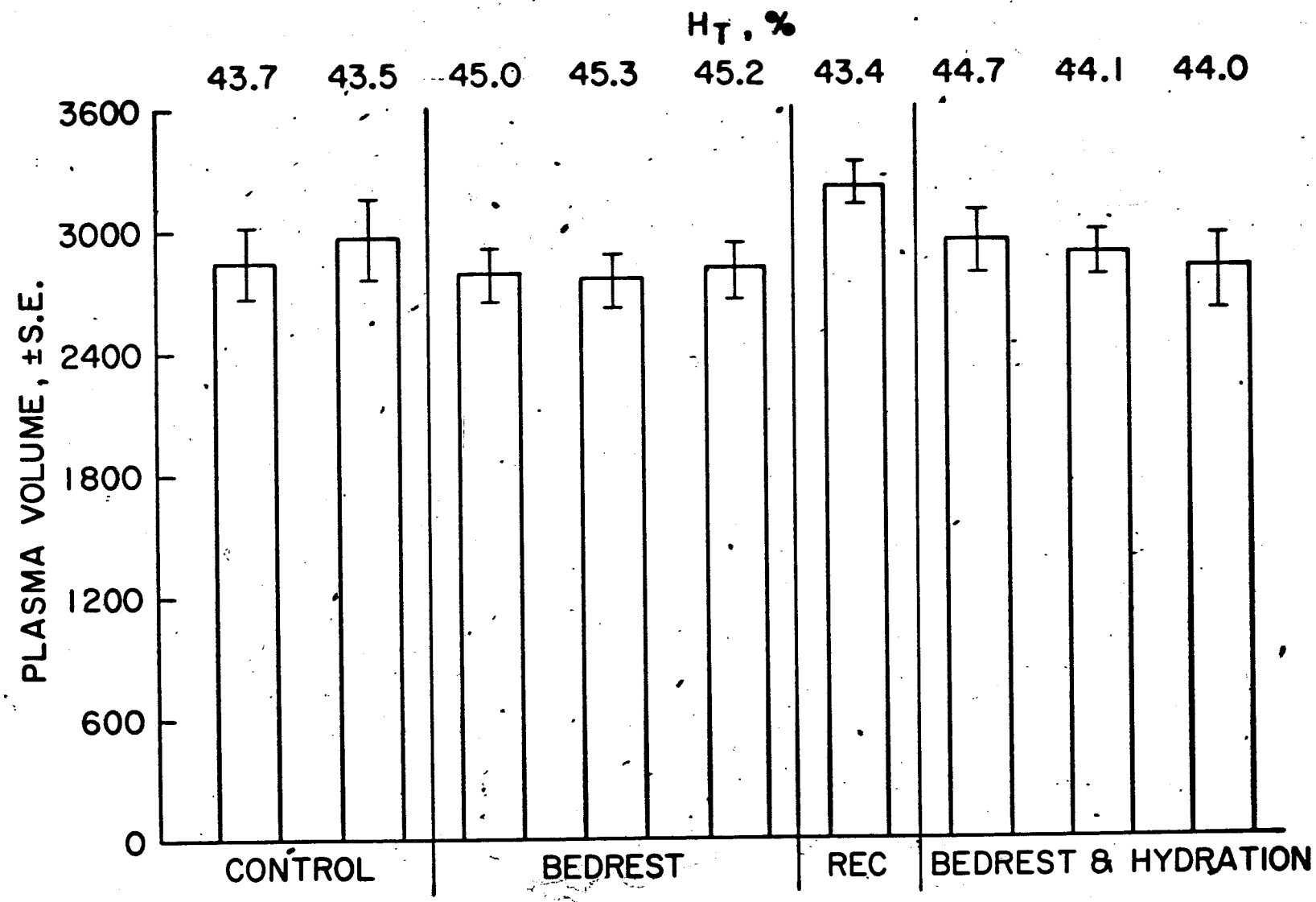
+ 3.8 G_z RUN AFTER BED REST

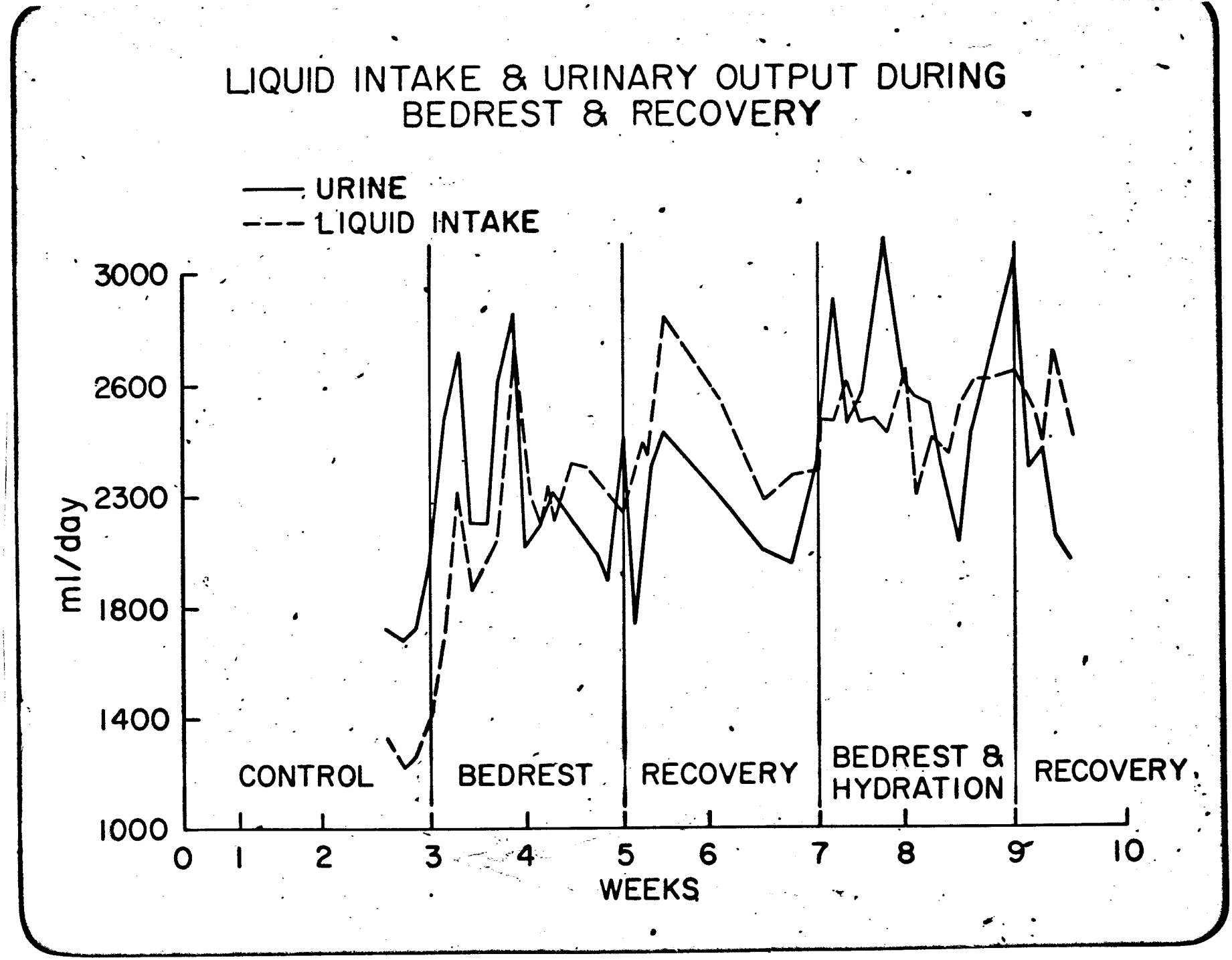


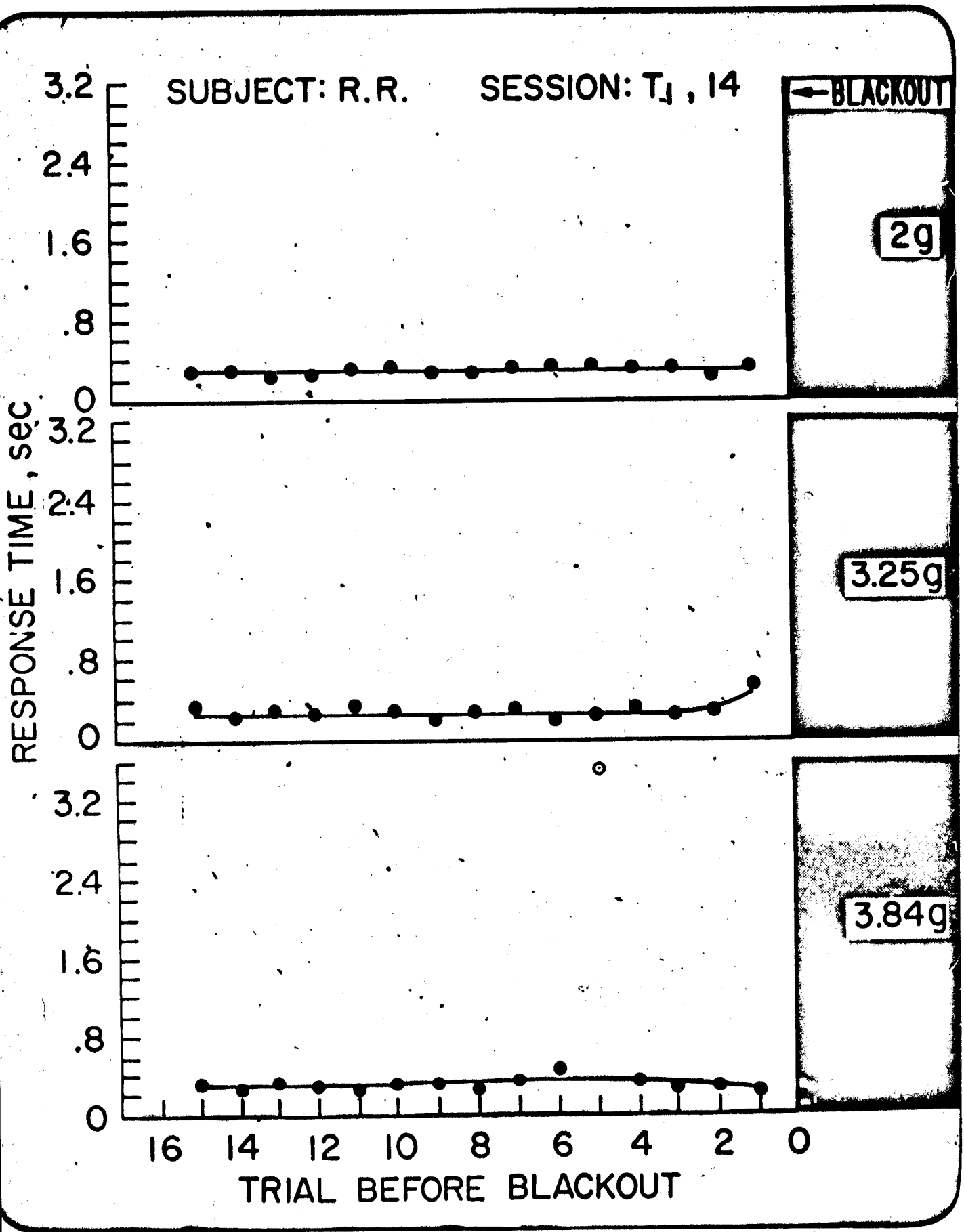
SUBJECT No. 5
8/12/71

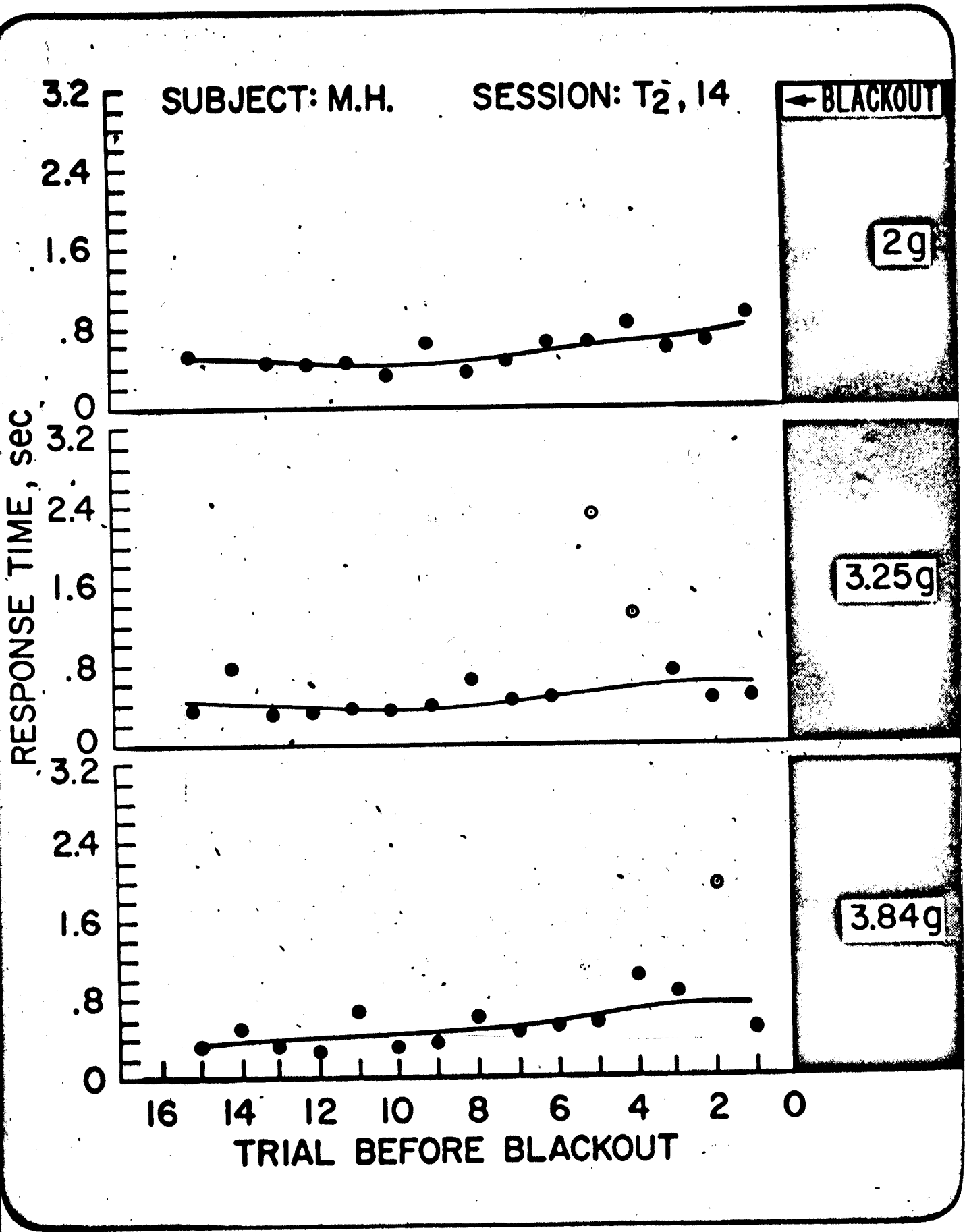

SUPINE MAXIMUM OXYGEN UPTAKE
±S.E.
● ml/(min×kg)
○ l/min
$\dot{V}_{O_2}$, ml/min×kg
$\dot{V}_{O_2}$, l/min
60
50
40
30
20
10
0
4.0
3.5
3.0
2.5
CONTROL
BEDREST I
RECOVERY
BEDREST II

PLASMA VOLUME AND HEMATOCRIT DURING BEDREST AND RECOVERY

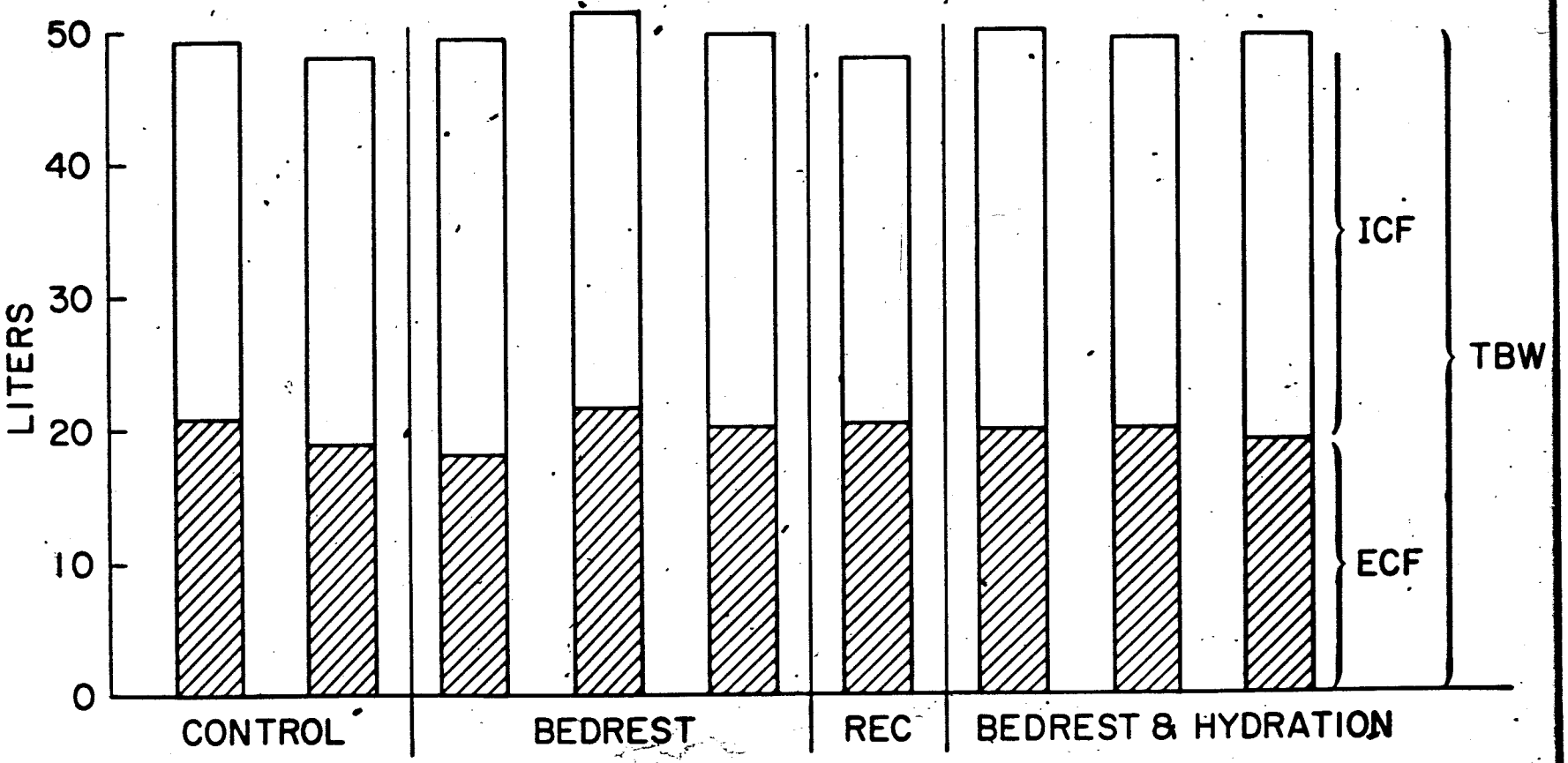



LIQUID INTAKE & URINARY OUTPUT DURING
BEDREST & RECOVERY
URINE
LIQUID INTAKE
3000
2600
2300
1800
1400
1000
ml/day
CONTROL
BEDREST
RECOVERY
BEDREST & HYDRATION
RECOVERY
0
1
2
3
4
5
6
7
8
9
10
WEEKS


SUBJECT: R.R.
SESSION: T1 , 14
BLACKOUT
2g
3.25g
3.84g
RESPONSE TIME, sec
3.2
2.4
1.6
.8
0
16 14 12 10 8 6 4 2 0
TRIAL BEFORE BLACKOUT

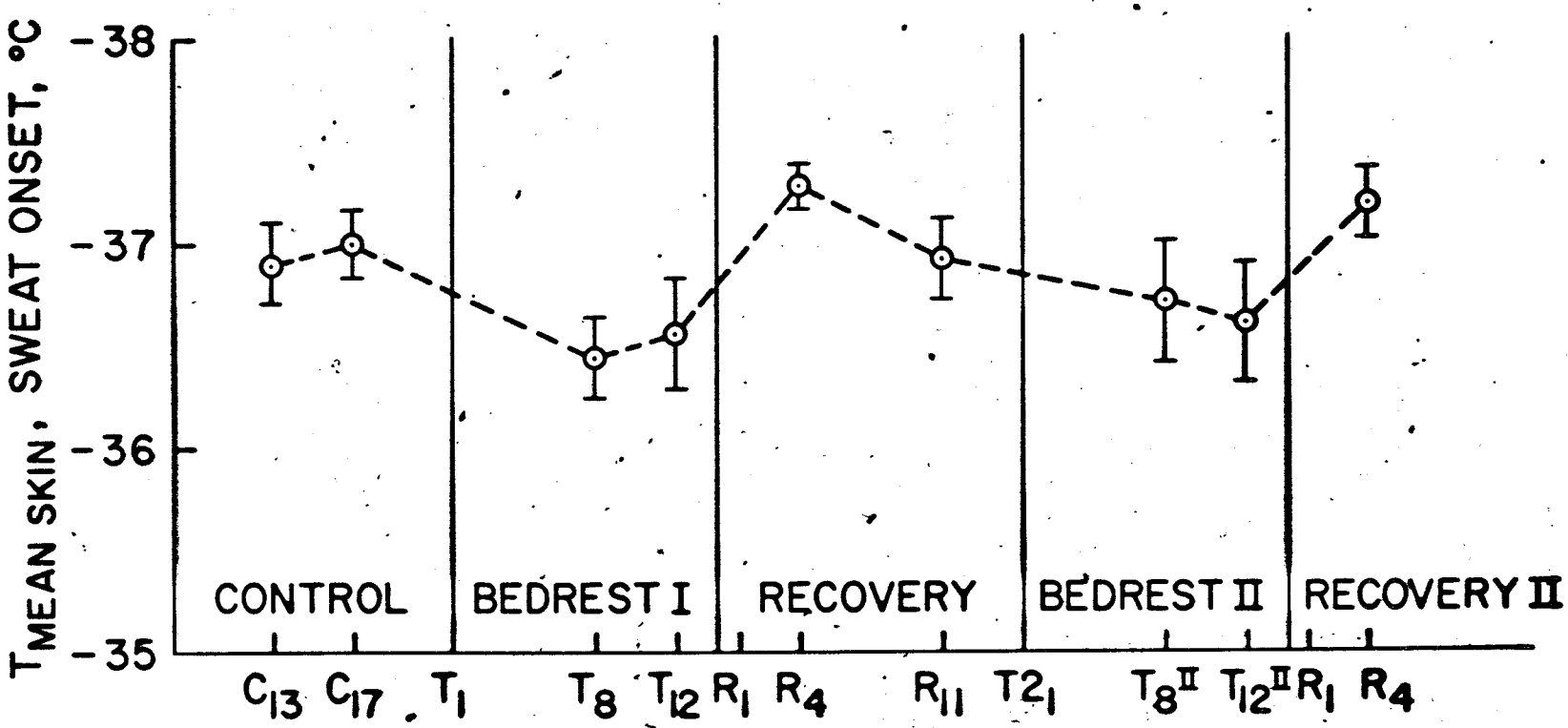

SUBJECT: M.H.
SESSION: T2, 14
BLACKOUT
2g
3.25g
3.84g
RESPONSE TIME, sec
3.2
2.4
1.6
.8
0
16 14 12 10 8 6 4 2 0
TRIAL BEFORE BLACKOUT

TOTAL BODY WATER (TBW), INTRACELLULAR FLUID VOLUME (ICF) AND EXTRACELLULAR FLUID VOLUME (ECF) DURING BEDREST AND RECOVERY



MEAN SKIN TEMPERATURE AT THE ONSET OF SWEATING

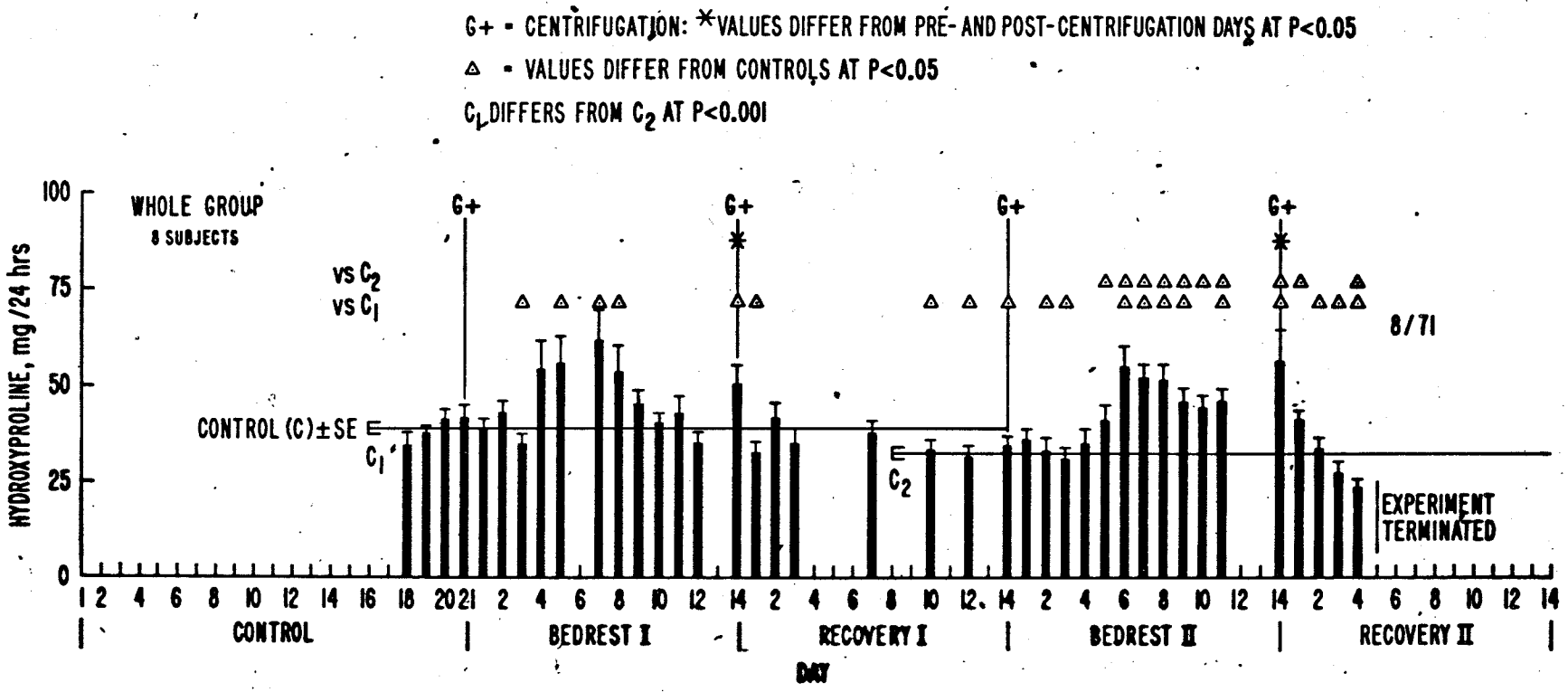
$\bar{X} \pm$ S.E.



TOP VERTICAL

24 hr URINARY HYDROXYPROLINE EXCRETION

EFFECT OF BEDREST AND CENTRIFUGATION ON CONNECTIVE TISSUE



PLASMA HORMONE AND GLUCOSE LEVELS DURING BED REST AND CONTROL PERIODS

Samples Obtained at 8:00 A.M.

Mean Values With Standard Error

	Control Period	Bed Rest I	Recovery	Bed Rest II
Number of Samples	4	36	20	4
GROWTH HORMONE μμg/ml	1.12 ± 0.03	1.08 ± 0.17	1.66 ± 0.75	1.16 ± 0.22
CORTISOL μg/100 ml	45.0 ± 3.1	45.8 ± 3.5	48.7 ± 4.1	37.3 ± 7.6
GLUCOSE mgs/100 ml	78.5 ± 2.4	78.2 ± 2.1	83.2 ± 2.7	92.5 ± 4.1

CONCLUSIONS: Growth hormone, cortisol, and glucose levels did not differ significantly between bed rest, control, and recovery periods ($p > 0.05$).

July, 1971

EFFECT OF CENTRIFUGATION ON PLASMA HORMONE AND GLUCOSE LEVELS

Change from Precentrifugation Level

	Subject			
GROWTH HORMONE		mμg/ml	%	P
	1	0.2	13	(paired t)
	2	4.1	442	
	3	8.6	572	
	4	0.5	59	
	Mean + S.E.	3.3 ± 1.2	288	< 0.02
CORTISOL		μg/100 ml		
	Mean + S.E.	16.4 ± 3.2	39	< 0.02
GLUCOSE		mgs/100 ml		
	Mean + S.E.	9.9 ± 4.1	12	< 0.05

CONCLUSIONS:

1. Growth hormone, cortisol and glucose were all elevated by centrifugation. The rises did not differ between bed rest, control and recovery centrifuge runs.

2. Two subjects (#2,#3) with poor centrifuge tolerances showed marked rises in growth hormone; whereas two subjects (#1,#4) with high G tolerances showed virtually no change in growth hormone.

July, 1971

EFFECT OF BED REST ON PLASMA ALDOSTERONE AND RENIN

Period	Plasma Aldosterone* mμg/100 ml ± S.E.	P	Renin* mμg I/100 ml/hr ± S.E.	% Increase	P
Control 1-21	10.2 ± 1.1 (12)		45 ± 6.6 (8)		
Bed Rest I 1-14	13.1 ± 0.93 (20)	> .05	118 ± 27.0 (20)	162	< .05
Recovery 1-14	11.3 ± 0.92 (20)	> .05	137 ± 19.0 (20)	204	< .01
Bed Rest II 1-14	12.2 ± 0.84 (20)	> .05	181 ± 38.3 (20)	300	< .02

*Mean of four subjects; post-G samples not included.

CONCLUSIONS: Plasma renin increased significantly during BR-I, Recovery, and BR-II.
Plasma aldo not changed significantly during BR-I, BR-II, and Recovery.

Normal Levels:	Recumbent:	Renin 30-140 mμg/100 ml/hr	Aldo	7.1 (3-16) mμg/100 ml
	Upright:	70-250 mμg/100 ml/hr		13.4 (4-30) mμg/100 ml

July, 1971

TOP VERTICAL

MEAN PLASMA RENIN AND ALDOSTERONE CONCENTRATIONS

EFFECT OF BED REST AND CENTRIFUGATION

Period	No. Days Sampled	Subject #5 Renin	#5 Aldo	#6 Renin	#6 Aldo	#7 Renin	#7 Aldo	#8 Renin	#8 Aldo
Control	2	42	10.6	29	7.5	28	12.3	48	10.5
C-1	1	119	12.9 (>.05)	89	13.6 (<.01)	51	9.3 (>.05)	75	23.5 (<.02)
Bed Rest I	5	149	15.0	143	9.2	184	17.4	37	10.5
C-2	1	38 (<.05)	27.7 (<.02)	489 (<.001)	21.0 (<.01)	212 (>.05)	26.2 (=.02)	584 (<.001)	26.0
Recovery	5	165	12.9	120	8.5	172	13.4	92	10.4
C-3	1	102 (>.05)	10.4	182 (>.05)	14.3	104 (>.05)	11.3	118 (>.05)	17.8
Bed Rest II	5	159	11.1	266	9.8	213	14.7	87	13.2
C-4	1	66 (>.05)	13.0	65 (>.05)	10.5	67 (>.05)	12.1	370 (<.001)	36.0

Normal Levels:

Renin	Recumbent:	30-140 mμg/100 ml/hr
	Upright:	70-250 mμg/100 ml/hr
Aldo		7.1 (3-16) mμg/100 ml
		13.4 (4-30) mμg/100 ml

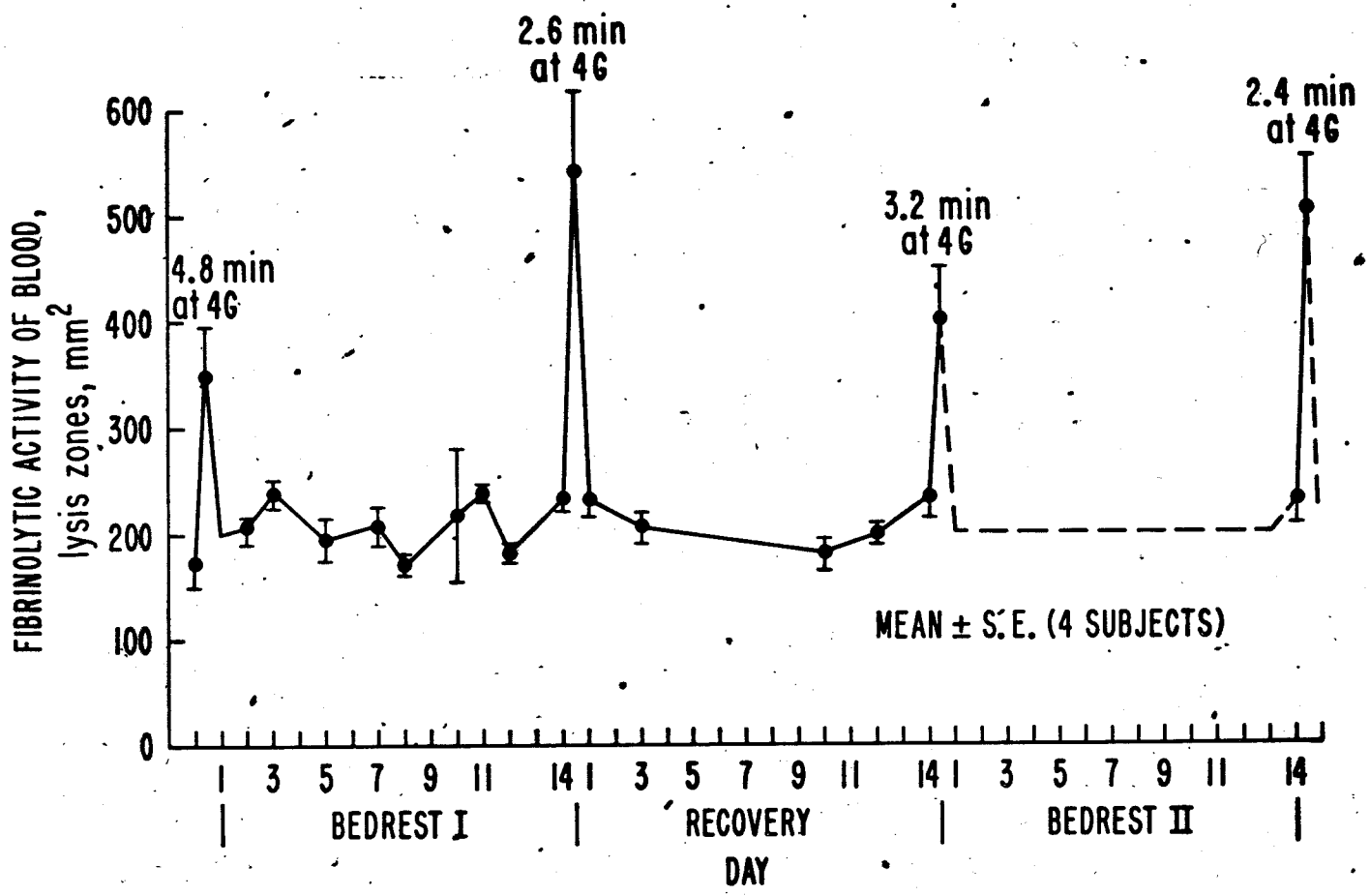
Values in parenthesis are "p" values; difference from pre-centrifugation significant at p>.05.

CONCLUSIONS:

1. After Bed Rest I, centrifugation produced in all four subjects a significant increase in plasma aldo; plasma renin response highly variable.
2. After recovery, centrifugation did not change plasma renin or aldo significantly.
3. After Bed Rest II, centrifugation produced an increase in plasma renin and aldo only in one subject (#8).

July, 1971

FIBRINOLYTIC ACTIVITY OF THE BLOOD IN HUMANS EXPOSED TO CENTRIFUGATION BEFORE AND AFTER 14-DAY PERIODS OF BEDREST



CONCLUSIONS:

1. CENTRIFUGATION INDUCES A FIBRINOLYTIC RESPONSE IN HUMANS.
2. THE FIBRINOLYTIC RESPONSE IS SIGNIFICANTLY GREATER ($p<0.01$) AFTER A 14 DAY PERIOD OF BEDREST.
3. REMEDIAL MEASURES (HYDRATION AFTER 2nd BEDREST PERIOD) DID NOT LESSEN THE ENHANCED FIBRINOLYTIC RESPONSE THAT OCCURS AFTER BEDREST.

CENTRIFUGATION PROCEDURE

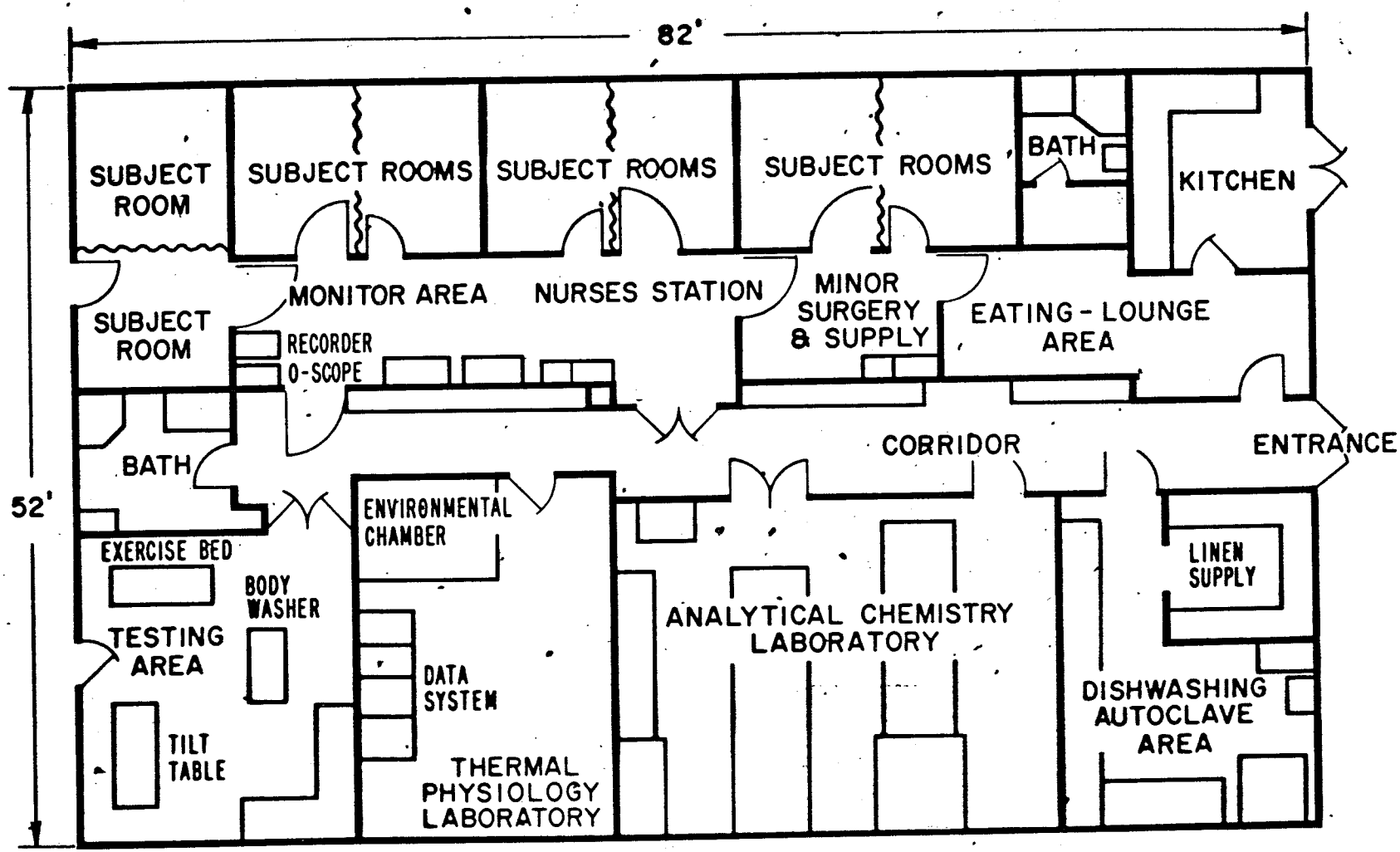
$+G_z$ LEVEL (±SD)	SEAT ANGLE	CENTRIFUGE TIME (SEC) RAMP	PLATEAU	TOTAL
(A) 2.1 ± 0.1	30.0°	65	670	735
(B) 3.2 ± 0.2	19.5°	84	220	304
(C) 3.8 ± 0.4	16.6°	98	185	273

- RAMP ACCELERATION IS 1.8 G/MIN
- THE VARIOUS ACCELERATION LEVELS WERE PRESENTED TO THE SUBJECTS IN A SELECTED RANDOM ORDER; E.G., SUBJECT 1 WAS (A), (B), (C); SUBJECT 2 WAS (B), (C), (A); SUBJECT 3 WAS (C), (A), (B); ETC. EACH SUBJECT ALWAYS FOLLOWED HIS RAMP SEQUENCE DURING ALL CENTRIFUGATIONS.
- DURING BED REST, THE SUBJECTS WERE TRANSPORTED TO AND WERE PLACED IN THE CENTRIFUGE IN THE SUPINE POSITION.
- CENTRIFUGE RUNS WERE TERMINATED WHEN THE SUBJECTS LOST EITHER PERIPHERAL VISION (GRAYOUT) OR CENTRAL VISION (BLACKOUT).
- THE SUBJECTS WERE INSTRUCTED TO RIDE THE CENTRIFUGE PASSIVELY (WITHOUT MUSCULAR CONTRACTION).
- THERE WERE 5 TO 10 MINUTE REST PERIODS BETWEEN RAMPS.
- MEASUREMENTS TAKEN DURING CENTRIFUGATION WERE HEART RATE, SYSTOLIC AND DIASTOTIC BLOOD PRESSURES AND VISUAL REACTION TIME TO THE PERIPHERAL LIGHTS.

TOP VERTICAL

HUMAN RESEARCH FACILITY

LIFE SCIENCES DIRECTORATE



▲ MEASUREMENTS

● BIOCHEMICAL (BLOOD)

TOTAL BODY WATER (DEUTERIUM OXIDE), EXTRACELLULAR FLUID VOLUME (BROMINE), PLASMA VOLUME (EVANS BLUE), HEMATOCRIT, HEMOGLOBIN, RED CELL COUNT, WHITE CELL COUNT, RETICULOCYTES, LYMPHOCYTES, NEUTROPHILS, BANDS, MONOCYTES, EOSINOPHILS, BASOPHILS, GLUCOSE, URIC ACID, UREA NITROGEN CREATININE, TOTAL PROTEIN (PLUS ALBUMIN, $\alpha 1$, $\alpha 2$, β AND γ GLOBULINS), OSMOLALITY, CHLORIDE, SODIUM, POTASSIUM, CALCIUM AND PHOSPHORUS.

— ENZYMES: CREATINE PHOSPHOKINASE, GLUTAMIC-OXALOACETIC TRANSAMINASE, LACTATE DEHYDROGENASE (PLUS THE 5 LDH ISOENZYMES) AND GLUTAMIC-PYRUVIC TRANSAMINASE.

— HORMONES: RENIN-ANGIOTENSIN, ALDOSTERONE, INSULIN, FIBRINOLYSIN, GROWTH HORMONE, CORTISOL.

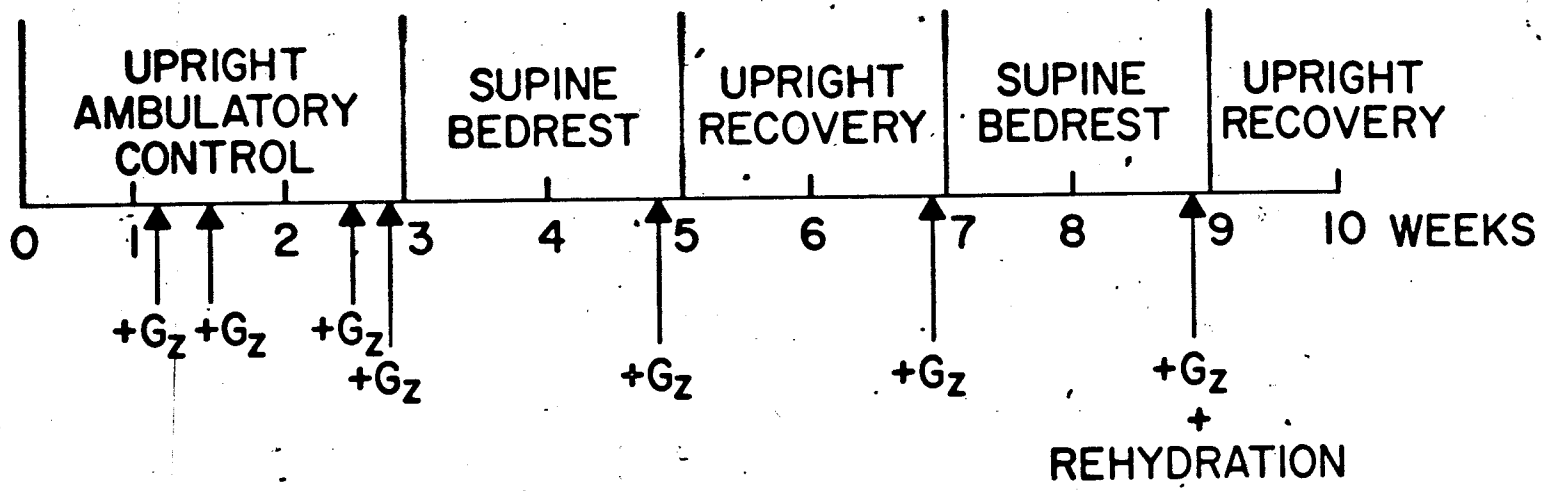
● BIOCHEMICAL (URINE)

SODIUM, POTASSIUM, CHLORIDE, OSMOLALITY, CALCIUM, PHOSPHORUS, UREA NITROGEN, CREATININE, HYDROXYPROLINE.

● PERFORMANCE

VISUAL REACTION TIME, AUDITORY ACUITY, PERSONALITY INVENTORY, ORTHOSTATIC TOLERANCE, BODY BALANCE, MAXIMAL OXYGEN UPTAKE, CENTRIFUGATION TOLERANCE, TEMPERATURE SENSITIVITY, EXERCISE TEMPERATURE REGULATION, BASAL METABOLISM, BODY DENSITY, RESIDUAL VOLUME, VITAL CAPACITY, TIMED VENTILATORY CAPACITY.

▲ EXPERIMENTAL DESIGN



- 8 MALE SUBJECTS
- CONTROLLED DIETARY INTAKE (2,500 kcal/day)
- LEG EXERCISE AT 1/2 MAXIMAL OXYGEN UPTAKE FOR 1/2 hr/day (450 kcal/day)

EFFECT OF 14 DAYS BED REST UPON $+G_z$ ACCELERATION TOLERANCE

▲ PURPOSE

- TO DETERMINE THE EFFECT OF BED REST UPON $+G_z$ TOLERANCE
- TO DETERMINE THE REMEDIAL EFFECT OF REHYDRATION UPON $+G_z$ TOLERANCE.
- TQ INVESTIGATE VARIOUS BRIOCHEMICAL CONSTITUENTS AND PERFORMANCE MEASURES AS PREDICTORS OF PHYSICAL AND MENTAL DETERIORATION.