

UNCLASSIFIED

AD **407 016**

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION, ALEXANDRIA, VIRGINIA



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

⑤ 70 900 63-4-1
① scale = 2

ALASKAN AIR COMMAND
ARCTIC AEROMEDICAL LABORATORY
FORT WAINWRIGHT

CARDIOVASCULAR EFFECTS OF REFEEDING STRESS
FOLLOWING STARVATION. PART XI.

⑩ by G. S. Smith and B. Connor Johnson,

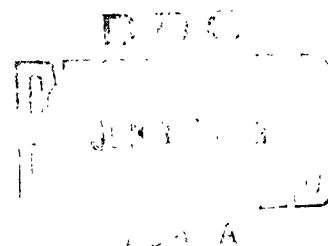
- ⑥ Serp. 1.
- ⑦ NA
- ⑧ NA
- ⑨ NA
- ⑫ 104
- ⑬ NA
- ⑭ NA
- ⑮ NA
- ⑯ NA
- ⑰ NA
- ⑱ U
- ⑳ NA

L.C.

TECHNICAL NOTE

⑧ AAL-TN-611

⑨



⑪ SEPTEMBER 1961

④
* 1.60

AD No. 407016

DDC FILE COPY

407016

⑥ **CARDIOVASCULAR EFFECTS OF REFEEDING STRESS
FOLLOWING STARVATION. PART XI***

G. S. Smith and B. Connor Johnson
University of Illinois
Urbana, Illinois

The research project was undertaken to determine what, if any, are the principal factors in the diet which may induce and/or aggravate cardiovascular stress during refeeding following starvation. This report is concerned with the responses of young adult swine to a second long-term starvation episode and refeeding, initially with either pure glucose or pure corn oil and subsequently with diets high in content of either glucose or corn oil.

EXPERIMENTAL

In a planned series of long-term starvation-refeeding episodes, the four young swine described in a previous report (Smith and Johnson, 1960) were subjected to the second episode. The various phases of experimentation which have been undergone by the animals to date are summarized as follows:

- 1) preliminary adjustment and training period (30 days);
- 2) initial "control" period, Diet 160 at maintenance level (20 days);
- 3) Diet 160 at maintenance (2 pigs) versus 2 x maintenance (2 pigs), (10 days);
- 4) Diet 160 at 3 x maintenance, all animals (5 days);
- 5) Starvation (28 days);
- 6) refeeding with pure glucose (3 kg) versus pure starch (3 kg) (1 day);
- 7) refeeding with diets high in glucose versus starch (1 kg Diet 160 + 1 kg glucose or starch) (28 days);
- 8) Diet 160 at approximately 2 x maintenance (2.3 kg) (30 days);
- 9) Starvation (40 days);
- 10) refeeding with pure glucose (3 kg) versus corn oil (1.5 kg + 1.5 kg cellulose) (1 day);
- 11) refeeding with diets high in glucose versus corn oil (1.5 kg Diet 160 + 1 kg glucose or 0.75 kg corn oil) (28 days);

* Effects of long-term starvation-refeeding episodes.

- 12) Diet 160 at level slightly above maintenance (30 days);
- 13) Diet 160 at 2 x maintenance (10 days).

RESULTS AND DISCUSSION

Responses observed during phases 1 through 7 were reported in the previous report (Smith and Johnson, 1960); however they are considered generally in the present report as a means of preserving continuity in discussion of this study and in order to facilitate interpretation of the data. It should be noted that phases 3 and 4 were described erroneously in this report, although the results and the inferences drawn were in no way handicapped by the error. The heart rate and blood pressure data for individual animals in phases 2 through 13 are summarized in Tables I - IV. The values reported are means and standard deviations of responses during increments (usually 10 days each) of each phase. A summary of the averages and standard deviations of responses by all animals is shown in Figure 1. A summary of body weight data is shown in Table V.

During the 30-day period in which Diet 160 was fed following the first episode (i. e., phase 8) the animals gained approximately 50 pounds. This gain of approximately 1.6 pounds per day, though high for growing pigs of the age (8 months) and size (175 pounds) involved, was apparently a reflection primarily of "growth" rather than "fattening," since the general appearance of the animals indicated no appreciable degree of "fattening." As indicated in Table I, the heart rates were reduced below the level previously encountered in phase 6, but remained above the initial control level as seen in phases 2, 3 and 4. The abrupt decrease in heart rates which occurred as the result of feeding Diet 160 in phase 8 is unexplained at the present time, since the caloric intake level was not greatly changed. In phase 7 the daily ration was 1 kg of Diet 160 plus 1 kg of either glucose or starch, whereas in phase 8 the ration was 2.3 to 2.5 kg of Diet 160. A notable influence of diet upon the blood pressure is also revealed (Fig. 1) in the blood pressure changes which occurred from phase 7 to phase 8. The response in phase 8 was similar in all pigs, indicating no differences as the result of glucose versus starch in phase 7. During phase 8 blood pressures increased steadily, reaching hypertensive (i. e., above 160 mm Hg) levels in the case of pig 1 and bordering on hypertension in the cases of pigs 2 and 4 (see Table II). Electrocardiographic observations during the "control" period (phase 8) revealed no notable pattern changes.

In the starvation phase of episode 2 (phase 9) heart rates returned promptly to the level observed during the latter part of the first starvation

period. In two of the pigs which had exhibited sinus arrhythmia previously, the arrhythmia became more pronounced during starvation; however, no electrocardiographic evidence of heart block (such as had been observed in one pig studied previously) was seen. Non-specific T-wave inversions and alterations, similar to those previously reported in conjunction with starvation, were observed in all pigs. Blood pressures, both systolic and diastolic, continued to rise throughout the starvation period, a result in contrast to the findings in the first starvation period (see Fig. 1). A similar increase in diastolic pressures during starvation was seen previously; however, the rise was of lesser magnitude and was not compensated by systolic elevation. At the end of the second starvation period all four pigs were hypertensive (systolic pressures in excess of 160 mm Hg). Body weights decreased during the 40-day starvation period from approximately 220 pounds to approximately 175 pounds, a loss of about 19 to 20%.

Following starvation, pigs 1 and 3 received 3 kg of pure glucose in a single meal, whereas pigs 2 and 4 received 1.5 kg corn oil mixed with 1.5 kg purified cellulose. In the previous episode pigs 1 and 2 had received glucose, while 3 and 4 received starch. Distress symptoms, as described in previous reports, were seen in pigs 1 and 3 within two to three hours after consumption of the glucose. Pig 4 also exhibited symptoms of mild distress, with some diarrhea and subsequent tremors. Pig 1, which had registered "heart failure" in the previous episode, consumed the meal very slowly, yet exhibited some evidence of distress in the form of tremors. Pig 3, which consumed the glucose meal most readily, exhibited a pattern of bradycardia (as contrasted to tachycardia, which is generally encountered in glucose refeeding) and marked arrhythmia (rates 55 to 85 beats per minute) seven hours following consumption of the meal. Heart rates during the first ten days of refeeding (see Table I) were increased by the glucose diet more than by the corn oil diet. The difference in diet effects upon heart rate had disappeared by the third 10-day refeeding period, and rates were elevated in all animals. Blood pressures were lowered slightly from starvation levels during the first ten days of refeeding, but remained within hypertensive ranges and gradually returned to the level reached at the end of starvation. It was observed that, although the actual ranges of systolic and diastolic pressures were not greatly changed during refeeding, the "strength of the heart sounds" was greatly increased. Both pig 1 and pig 3 (on the glucose diet) exhibited flushing of the skin and slight edema, similar to the symptoms seen in the first episode. In the case of pig 1 a heart "murmur" developed which has persisted to date, being more noticeable when the systolic pressure is high.

In phase 12, Diet 160 was fed at the rate of 1.6 kg per day (slightly in excess of the requirement for weight maintenance), replacing the experimental diets of Diet 160 (1.5 kg) plus glucose (1.5 kg) or corn oil (0.75 kg). Heart rates were decreased, but blood pressures were not greatly affected

except for increased variation in systolic pressure during the first ten days of the phase. Electrocardiograms showed no striking pattern changes; however, pig 2 (which had previously registered "heart failure") exhibited short intervals of mild tachycardia following the first meal of Diet 160 plus corn oil. In these instances the heart rate increased from 80 to 110 beats per minute in a matter of a few seconds, continued at the increased rate for 30 to 40 seconds, and then returned to the range of 80 beats per minute.

When the daily intake of Diet 160 was doubled (phase 13), heart rates were promptly elevated. This response is in contrast to the response elicited (phase 4) by increased feed intake prior to the first starvation episode. The blood pressure response resembled that observed in phase 4 (see Fig. 1) but was much more pronounced, resulting not only in extremely high systolic pressures but in very high pulse pressures as well (see also Table IV, especially pig 3). Electrocardiographic patterns during this phase revealed only T-wave inversions and slight changes in the depth of the S-wave, which are not considered of significance. Heart "murmurs" were heard in the cases of pigs 1, 3 and 4 during this period.

These observations tend to confirm earlier findings which suggested that starvation-refeeding stresses result in irreversible changes in the cardiovascular system. These changes become evident in the responses to subsequent starvation-refeeding episodes. Although "stress" was elicited by both glucose and corn oil in the second episode, the stress which accompanied refeeding with the corn oil diet was of considerably less severity and may possibly have been due to the components of Diet 160 which were included.

REFERENCES

1. Smith, G. S., and B. C. Johnson. Cardiovascular effects of refeeding stress following starvation. X. Ad libitum refeeding of glucose or starch. Technical Note 60-29, Arctic Aeromedical Laboratory, Fort Wainwright, Alaska, 1960.

TABLE I

Summary of Heart Rate Data

Treatment	Phase	No. of days	Animal Number				Average
			1	2	3	4	
Initial Control Period:	2)	1-10	77±6	74±5	80±3	75±5	77±3
" " "	2)	11-20	81±2	76±1	79±2	79±3	79±1
" " "	3)	21-30	81±2	75±2	76±2	79±3	78±3
" " "	4)	31-35	78±3	77±3	80±3	77±2	78±3
Starvation:	5)	1-10	74±1	71±1	73±0	73±0	72±1
"	5)	11-20	69±2	66±3	69±3	67±1	68±2
"	5)	21-28	61±6	60±6	56±10	58±7	59±6
			glucose		starch		
Refeeding, Exp. Diets:	6-7)	1-10	92±15	142±20	110±23	87±12	108±17
" " "	7)	11-20	113±13	137±6	129±13	91±11	118±11
" " "	7)	21-30	114±8	136±6	100±14	88±9	109±9
Refeeding: Diet 160	8)	1-10	96±8	94±21	84±5	86±5	90±6
" " "	8)	11-20	(not recorded)				
" " "	8)	21-30	108±15	88±7	93±6	92±4	95±8
" " "	8)	31-37	97±5	91±9	90±4	91±4	92±6
Starvation:	9)	1-10	62±5	62±6	62±2	65±2	64±4
"	9)	11-20	60±2	60±3	60±1	62±2	60±2
"	9)	21-30	69±11	66±5	61±3	60±6	64±6
"	9)	31-40	63±5	57±4	56±3	52±6	57±4
			glucose	corn oil	glucose	corn oil	
Refeeding, Exp. Diets:	10-11)	1-10	96±27	79±14	94±22	78±9	87±9
" " "	11)	11-20	107±17	98±10	102±10	84±6	98±13
" " "	11)	21-30	94±3	114±4	124±7	102±11	108±7
Refeeding: Diet 160	12)	1-10	75±4	75±5	83±7	74±9	77±6
" " "	12)	11-20	69±6	74±4	74±4	75±6	73±4
" " "	12)	21-30	66±2	69±5	68±2	68±5	68±3
Diet 160 at (2 x M)	13)	1-10	95±13	101±21	99±15	110±14	101±16

TABLE II

Summary of Systolic Pressure Data

Treatment	Phase	No. of days	Animal Number				Average
			1	2	3	4	
Initial Control Period:	2)	1-10	149±6	141±4	128±7	149±6	142±5
" " "	2)	11-20	146±3	139±5	130±13	139±4	138±3
" " "	3)	21-30	144±6	131±5	122±8	137±7	133±3
" " "	4)	31-35	142±9	134±6	130±15	137±9	136±9
Starvation:	5)	1-10	121±10	113±10	115±10	117±9	116±5
"	5)	11-20	114±4	105±5	110±5	107±5	109±5
"	5)	21-30	105±2	102±1	104±3	104±2	104±2
			glucose		starch		
Refeeding, Exp. Diets:	6-7)	1-10	127±12	129±12	137±11	131±16	131±12
" " "	7)	11-20	131±8	145±5	134±13	127±9	135±7
" " "	7)	21-30	135±9	143±8	127±10	133±12	135±9
Refeeding: Diet 160	8)	1-10	142±11	136±9	139±9	144±6	140±8
" " "	8)	11-20	150±11	145±11	134±11	138±7	142±10
" " "	8)	21-30	161±15	144±9	126±5	143±10	144±10
" " "	8)	31-37	173±16	149±7	129±5	151±7	150±10
Starvation:	9)	1-10	158±5	151±14	148±10	157±10	154±10
"	9)	11-20	170±8	176±8	164±9	167±9	169±8
"	9)	21-30	190±14	168±12	168±12	157±8	171±11
"	9)	31-40	182±13	172±10	168±12	154±5	169±9
			glucose corn oil		glucose corn oil		
Refeeding, Exp. Diets:	10-11)	1-10	178±13	170±6	147±13	153±12	162±11
" " "	11)	11-20	181±11	174±8	150±6	166±11	168±10
" " "	11)	21-30	185±14	172±10	164±13	165±15	172±12
Refeeding Diet 160	12)	1-10	172±15	176±24	172±20	168±10	172±19
" " "	12)	11-20	175±9	172±5	165±10	167±5	170±7
" " "	12)	21-30	188±9	161±4	156±4	168±4	168±13
Diet 160 at (2xM)	13)	1-10	180±18	166±16	203±28	172±9	180±23

TABLE III

Summary of Diastolic Pressure Data

Treatment	Phase	No. of days	Animal Number				Average
			1	2	3	4	
Initial Control Period:	2)	1-10	115±4	110±5	89±7	112±10	106±5
" " "	2)	11-20	113±6	110±13	99±16	100±5	103±4
" " "	3)	21-30	113±6	108±6	93±10	100±12	103±6
" " "	4)	31-35	111±8	101±6	98±16	92±1	100±9
Starvation:	5)	1-10	95±10	85±4	84±4	86±5	88±3
"	5)	11-20	86±5	85±4	88±4	84±2	86±4
"	5)	21-30	85±5	84±2	83±3	82±1	83±3
			glucose		starch		
Refeeding, Exp. Diets:	6-7)	1-10	73±5	72±8	74±12	66±10	71±7
" " "	7)	11-20	73±7	76±4	76±6	72±7	74±6
" " "	7)	21-30	74±6	77±7	70±8	75±4	74±6
Refeeding: Diet 160							
" " "	8)	1-10	99±8	94±12	90±13	99±17	95±12
" " "	8)	11-20	114±10	112±12	101±9	104±10	108±10
" " "	8)	21-30	124±11	112±8	95±6	108±8	110±8
" " "	8)	31-37	131±14	113±6	94±6	115±8	113±9
Starvation:	9)	1-10	129±3	122±13	117±10	127±13	124±11
"	9)	11-20	137±8	145±8	134±9	134±10	138±9
"	9)	21-30	157±12	138±10	137±10	125±7	139±9
"	9)	31-40	155±7	148±11	143±19	132±10	144±13
			glucose	corn oil	glucose	corn oil	
Refeeding, Exp. Diets:	10-11)	1-10	139±8	137±7	113±11	117±7	127±9
" " "	11)	11-20	141±10	139±7	117±10	132±13	132±10
" " "	11)	21-30	144±13	135±13	128±18	128±22	134±16
Refeeding: Diet 160	12)	1-10	133±13	127±16	126±10	129±6	129±12
" " "	12)	11-20	135±8	134±8	129±8	129±7	132±8
" " "	12)	21-30	148±9	125±5	119±5	130±5	131±13
Diet 160 at (2 x M)	13)	1-10	144±16	112±23	109±26	116±15	115±8

TABLE IV

Summary of Pulse Pressure Data

Treatment	Phase	No. of days	Animal Number				Average
			1	2	3	4	
Initial Control Period:	2)	1-10	38±4	31±1	39±1	38±1	37±3
" " "	2)	11-20	33±5	39±11	31±12	39±5	35±2
" " "	3)	21-30	31±7	24±6	29±7	37±3	31±5
" " "	4)	31-35	31±5	33±7	32±6	45±6	36±5
Starvation:	5)	1-10	26±4	28±9	31±13	31±12	29±5
"	5)	11-20	28±6	21±5	23±6	24±6	24±5
"	5)	21-30	20±4	19±2	21±3	22±3	21±3
			glucose		starch		
Refeeding, Exp. Diets:	6-7)	1-10	54±12	57±15	63±15	65±25	60±17
" " "	7)	11-20	58±10	70±5	58±12	58±15	61±10
" " "	7)	21-30	64±14	66±8	55±12	59±14	61±11
Refeeding: Diet 160	8)	1-10	43±	42±16	51±14	44±15	45±15
" " "	8)	11-20	37±4	33±4	33±5	34±6	34±5
" " "	8)	21-30	37±7	32±3	30±2	34±4	33±4
" " "	8)	31-37	42±3	36±2	35±3	38±6	38±4
Starvation:	9)	1-10	29±1	30±2	30±1	33±1	30±1
"	9)	11-20	33±2	30±3	30±2	33±2	32±2
"	9)	21-30	33±3	30±2	31±3	32±2	32±3
"	9)	31-40	27±3	28±3	29±2	26±3	28±3
			glucose	corn oil	glucose	corn oil	
Refeeding, Exp. Diets	10-11)	1-10	40±7	34±4	34±5	36±6	36±6
" " "	11)	11-20	40±4	35±5	36±3	38±2	37±3
" " "	11)	21-30	40±7	42±7	40±4	42±5	41±5
Refeeding: Diet 160	12)	1-10	39±5	49±13	44±16	40±4	43±3
" " "	12)	11-20	41±4	38±3	37±2	37±3	38±3
" " "	12)	21-30	39±3	37±1	37±1	37±1	37±1
Diet 160 at (2 x M)	13)	1-10	56±19	54±11	95±39	56±12	65±28

TABLE V

Summary of Animal Weights Data

Date	Treatment Phase	Average Body Weight ¹
5/9/60	Start training period	109 ± 9
6/13/60	Start initial control period	145 ± 7
7/8/60	End initial control period	143 ± 1
7/14/60	2nd day starvation	150 ± 8
8/9/60	28th day starvation	127 ± 5 (-15%)
8/16/60	Refeeding, 7th day (Exp. diet)	143 ± 3
9/12/60	" 34th day (start Diet 160)	174 ± 10
10/10/60	" 62nd day (Diet 160)	220 ± 10
10/17/60	Starvation, 2nd day	221 ± 10
11/21/60	" 37th day	177 ± 8 (-19%)
11/28/60	Refeeding, 4th day (Exp. diet)	178 ± 7
12/21/60	" 27th day (Exp. diet)	234 ± 7
1/23/61	Refeeding, 59th day (Diet 160)	251 ± 5
2/1/61	" 68th day (Diet 160)	266 ± 8

HEART RATE AND BLOOD PRESSURE DATA

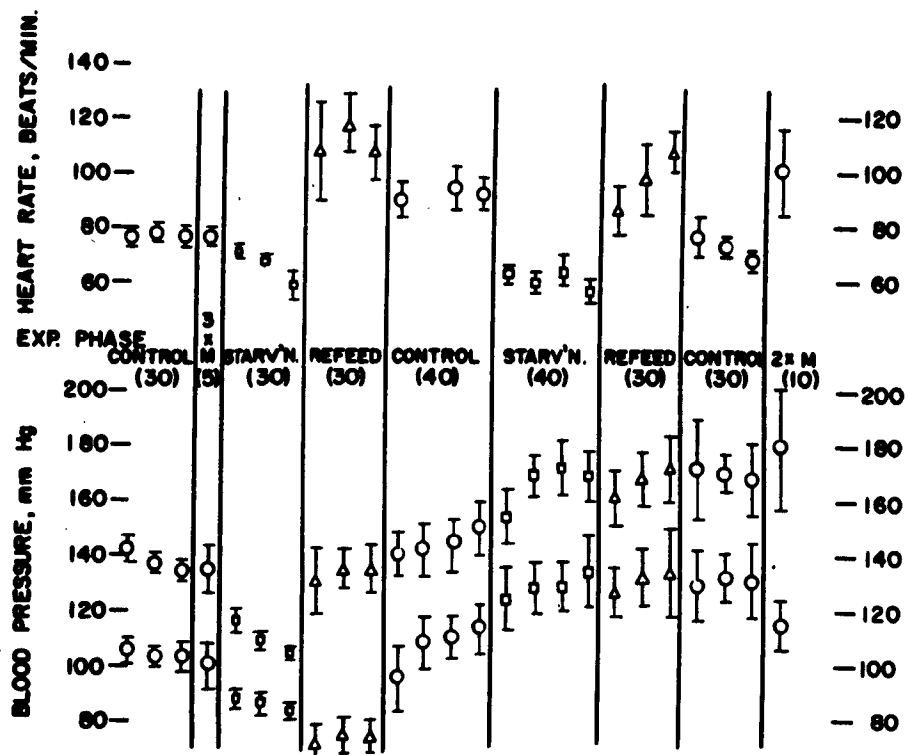


FIGURE 1