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INFLUENCE OF EXERCISE ON PERFORMANCE AND CARCASS PARAMETERS OF CONFINEMENT REARED SWINE[1]

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Summary

Fifty-six crossbred growing and finishing swine were used to determine the effect of treadmill exercise on several performance and carcass parameters when housed in confinement on 100% slatted floors. The exercised swine were subjected to walking 1.6 km/hr for 1 hr 5 days per week. The mean experimental duration was 71 days. Jugular vein blood samples and *gracilus* muscle biopsy samples were obtained prior and following completion of exercise. Exercise had no major influence on average daily gain, daily feed intake or gain/feed ratio. Bone breaking strength of the left fourth metatarsal was significantly ($P < .01$) greater for exercised pigs than non exercised. However, right third and fourth metatarsal and left third metatarsal bone breaking strengths were not influenced by exercise. Similarly exercise did not affect *longissimus* muscle color or marbling scores, myoglobin concentration, water holding capacity, penetrometer or shear values, proximate analysis or cooking loss. Growth and advance in maturity resulted or were associated with a significant ($P < .05$) decline in serum glucose, ($P < .01$) lactate concentration, and ($P < .01$) blood cholesterol concentrations. Exercise had no influence on glucose, lactate, blood cholesterol or liver cholesterol. A significant ($P < .01$) increase in sarcoplasmic and myofibrillar protein was found as a result of growth, but exercise had no influence on protein extractability. Exercise did not significantly affect RNA-DNA ratio.

Introduction

Confinement rearing of swine encompasses various facility and management conditions and when combined with high pig density, intensified selection for performance and carcass meatiness has resulted in new challenges to the swine population.

Svajgr *et al.* (1968, 1969) observed that pigs on pasture appeared to have fewer leg problems and stronger bones than those reared on solid or slatted concrete floors. The influence of exercise on bone strength and physiological development is not well defined. This investigation was designed to determine the effect of 60 min of treadmill exercise 5 days per week on live animal performance and various carcass parameters.

Materials and Methods

Five trials involving 12 crossbred growing and finishing swine per trial were housed individually on slatted floor pens in an environmentally controlled experimental facility at the University of Nebraska. Fifty-six swine were involved in the study, four pigs were eliminated as a result of inability to adjust to exercise conditions. The swine were provided

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with automatic waterers and were self fed a 14% corn-milo-soybean meal diet. Daily gain, feed intake and feed conversion were determined on an individual pig basis.

At the initiation of each experiment the swine were randomly allotted to treadmill exercise or the control treatment. Treadmill exercise involved walking on a continuous belt for 60 min/day at the rate of 1.6 km/hr 5 days per week. The swine were on test for an average of 71 days of exercise.

Each pig was bled via jugular puncture to obtain blood for cholesterol determinations by the procedure of (Pearson *et al.*, 1953). Initial serum lactate was determined by the procedure of Marbach and Weil (1967) and glucose by the method of Raabo and Terkildsen (1960) on 12 exercised and 11 control swine. A biopsy of the left *gracilus* muscle (Moser *et al.*, 1972) was also obtained for RNA-DNA analysis (Schnieder, 1945) at initiation of two of the five trials. A portion of the muscle biopsy was used for sarcoplasmic and myofibrillar protein extraction and NPN content with a modified procedure of Helendar (1957) and Lawrie (1961) as described by Topel and Merkel (1967). Total nitrogen content was determined by Kjeldahl analysis (A.O.A.C., 1965). In addition, a portion of the right *gracilus* was removed for RNA-DNA analysis and protein extractability 12 min following exsanguination on the swine biopsied prior to initiation of the respective two trials. Twenty-five minutes post exsanguination a liver sample was obtained in four of the five trials for liver cholesterol analysis (Stromer *et al.*, 1966). Blood samples were taken by jugular puncture and provided complementary cholesterol, lactate and glucose data.

Carcass measurements included length and backfat (A.M.S.A., 1967); and subjective muscle score (U.S.D.A., 1969). Following a 24-hr chill at 2 C the carcasses were separated into wholesale cuts and percent ham, ham and loin, lean cuts and primal cuts were determined (A.M.S.A., 1967). Area of the *longissimus* muscle was determined on the cross section loin at the 9th and 10th rib (A.M.S.A., 1967).

Marbling score and *longissimus* muscle color score were subjectively determined (Annonymous, 1963) on the cross sectioned loins at the 9th and 10th rib. Two 2.54 cm thick pork chops were obtained at the cross sectioned location for chemical and physical analyses. Proximate analyses were conducted according to methods described in A.O.A.C., 1965. Myoglobin concentration was determined by the procedure adapted by Topel (1966). Firmness was measured to the nearest .01 mm by use of a penetrometer equipped with a 19 mm round stainless steel ball; measurements were taken at the proximal and distal positions on the cut surface of the *longissimus* muscle. Water holding capacity determinations were carried out by methods described by Wierbicki *et al.* (1957). One pork chop from each carcass was weighed and then cooked at 177 C in an electric rotary hearth oven to an internal temperature of 70 C. The chop was blotted dry and reweighed to determine cooking loss. Warner-Bratzler shear values were obtained on proximal and distal 2.54 cm diameter cores removed from the cooked samples.

The hams were processed according to conventional procedures used in the industry. Following a 24-hr chill at 2 C each ham was separated into shank, butt and center portions and acetate tracings were made of the lean, fat and bone. Percentage tissue area was then determined for each cross-section.

The right and left rear legs were removed below the hock to obtain the third and fourth metatarsal bones for bone breaking strength (BKS) determinations. Preparation of the bones and determination of BKS were according to the method of Svajgr *et al.* (1969).

The data were analyzed using analysis of variance procedures appropriate for data with unequal subclass numbers (Harvey, 1960). Final weight was included as a covariable in the analysis of variance for BKS, carcass measurements and chemical determinations (Steel and Torrie, 1960). The covariable was used to adjust all means to the same off-test weight.

Results and Discussion

The effect of minimal exercise associated with confinement rearing of swine has only recently been the subject of scientific investigation. Peo *et al.* (1970) conducted a study involving six barrows and six gilts and three time durations of treadmill exercise, varying from 15 min to 1 hour. They found no influence of treadmill exercise for 1 hr on average daily gain or feed conversion. Mandigo

TABLE 1. LEAST SQUARES MEANS AND STANDARD ERRORS FOR PERFORMANCE TRAITS AND BONE BREAKING STRENGTH

Source	No.	Non-exercise		Exercise[b]		Coefficient of variation
Avg daily gain[a] kg	56	.89	± .014	.85	± .013	—
Avg daily feed intake[a] kg	56	3.13	± .07	3.04	± .07	—
Gain/feed ratio[a]	56	.29	± .01	.28	± .01	—
Right third metatarsal[a] kg force	56	236	± 10	262	± 9	39
Right fourth metatarsal[a] kg force	56	200	± 10	224	± 10	39
Left third metatarsal[a] kg force	56	239	± 12	252	± 11	40
Left fourth metatarsal[a] kg force	56	192**	± 11	239**	± 11	39
Avg bone breaking strength[a] kg force	112	217	± 11	244	± 10	39

[a]Significant P < .01 trial difference.
[b]Sixty-minute treadmill exercise 5 days/week.
**Significant P < .01.

et al. (1971) reported no influence of treadmill exercise on average daily gain or feed consumption of growing and finishing swine. They did find a significantly (P < .05) greater gain per pound of feed for the exercised pigs. Data in table 1 indicate no significant (P < .05) influence of exercise on performance traits for the swine used in this study.

Exercised swine possessed significantly (P < .01) greater left fourth metatarsal BKS than non-exercised pigs table 1. No major differences were found for right and left third metatarsal or right fourth metatarsal BKS. Irrespective of the associated coefficients of variation, the general tendency for exercised pigs was to exhibit greater BKS than non-exercised pigs.

The results shown in table 1 are in direct contrast to those of Peo *et al.* (1970) in which non-exercised pigs possessed greater BKS. Svajgr *et al.* (1968) and Svajgr *et al.* (1969) reported greater BKS in swine raised on pasture than from those raised in confinement.

Svajgr *et al.* (1968) reported no difference for backfat, *longissimus* area, percent ham and loin, or carcass length on pigs reared in confinement *vs* dry lot with an exercise area. Peo *et al.* (1970) reported that treadmill exercise altered significantly the percent lean cuts but none of the other measured carcass traits. Mandigo *et al.* (1971) indicated no significant (P < .05) influence of exercise on percent lean cuts, primal cuts, ham and loin, ham or *longissimus* area. Significantly (P < .05) greater backfat was found for exercised pigs. Data in table 2 shows no major influence of exercise on length, backfat, muscle score, respective percent wholesale cuts or *longissimus* area. Significant differences in carcass measurements were noted among trials.

TABLE 2. LEAST SQUARES MEANS AND STANDARD ERRORS FOR CARCASS MEASUREMENTS

Source	No.	Non-exercise	Exercise[c]
Length[b] cm	56	76.60 ± .37	76.57 ± .36
Backfat[a] cm	56	3.72 ± .08	3.63 ± .08
Muscle score	56	3.04 ± .13	3.26 ± .13
% ham[b]	56	20.13 ± .29	20.40 ± .28
% ham and loin[b]	56	37.62 ± .38	37.85 ± .37
% lean cuts[a]	56	55.06 ± .50	55.47 ± .48
% primal cuts[a]	56	69.37 ± .40	69.73 ± .38
Loin eye area[b] cm^2	56	28.51 ± .58	29.02 ± .58

[a]Significant P < .01 trial difference.
[b]Significant P < .05 trial difference.
[c]Sixty minute treadmill exercise 5 days/week.

TABLE 3. LEAST SQUARES MEANS AND STANDARD ERRORS FOR CARCASS QUALITATIVE, CHEMICAL AND PHYSICAL MEASUREMENTS

Source	No.	Non-exercise	Exercise[c]
Longissimus muscle color[a]	56	2.53 ± .13	2.49 ± .12
Longissimus muscle marbling[b]	56	2.68 ± .22	2.48 ± .22
Myoglobin mg/g	56	.428 ± .047	.444 ± .045
Water-holding capacity[a] ml of juice	56	6.19 ± .15	6.28 ± .14
Penetrometer[b] mm	56	4.65 ± .22	4.57 ± .21
Warner-Bratzler shear[a]	56	14.22 ± .53	13.90 ± .51
Moisture %[a]	56	71.22 ± .23	71.42 ± .22
Ether extract %[a]	56	5.00 ± .34	4.58 ± .33
Protein %	56	21.96 ± .18	21.85 ± .17
Ash %	44	1.12 ± .02	1.11 ± .03
Cooking loss %[a]	56	21.35 ± .50	21.98 ± .49

[a]Significant P < .01 trial difference.
[b]Significant P < .05 trial difference.
[c]Sixty-minute treadmill exercise 5 days/week.

No major influence of treadmill exercise was found for the various carcass qualitative, chemical or physical measurements (table 3). This agrees with the earlier report of Mandigo *et al.* (1971) in which treadmill exercised swine were not significantly different (P < .05) from non-exercised swine for marbling score, *longissimus* muscle color, cooking loss, firmness, shear force values, proximate analysis, myoglobin concentration or water holding capacity. A significant trial difference for the various measurements again indicating the variability between experimental groups (table 3).

The physiological impact of exercise has been studied extensively in man, mice and rats. Analysis of serum glucose and lactate as well as blood cholesterol were studied to evaluate energy metabolism. Serum glucose decreased significantly (P < .05) during the course of the study (table 4). This would appear to be the result of physiological changes manifested during growth (Weiss *et al.*, 1971). No influence of exercise was observed upon glucose concentration. Weiss *et al.* (1974) reported increased circulatory glucose levels as the result of severe short term exercise of swine. This was more likely the result of an induced stressed status rather than a conditioned exercise response as shown in table 4.

Serum lactate data in table 4 show a significant (P < .01) concentration decline from the first bleeding to the second. In a growth and development study involving swine (Weiss *et al.*, 1971) indicated no influence of growth on serum lactate. Physical exercise greatly influences blood lactate and the degree of exercise must be considered in the discussion of

TABLE 4. LEAST SQUARES MEANS AND STANDARD ERRORS FOR SEVERAL PHYSIOLOGICAL PARAMETERS

Source	No.	Non-exercise	Exercise[b]
Serum glucose I mg%	23	113.70* ± 4.20	110.38* ± 4.40
Serum glucose II mg%	23	101.54* ± 9.90	97.42* ± 9.44
Serum lactate I mg%	23	66.07** ± 8.97	81.88** ± 8.56
Serum lactate II mg%	23	48.98** ± 10.36	52.60** ± 9.88
Blood cholesterol I[a] mg%	56	172** ± 6	163** ± 6
Blood cholesterol II[a] mg%	46	136** ± 5	129** ± 4
Liver cholesterol mg/g	45	3.00 ± .09	2.97 ± .09

[a]Significant P < .01 trial difference.
[b]Sixty-minute treadmill exercise 5 days/week.
**Significant P < .01.
*Significant P < .05.

TABLE 5. LEAST SQUARES MEANS AND STANDARD ERRORS FOR GRACILUS PROTEIN EXTRACTABILITY AND RNA:DNA

Source	No.	Non-exercise	Exercise[b]
Myofibrillar I mg/g	23	41.47** ± 1.87	35.54** ± 1.78
Myofibrillar II[a]	23	47.81** ± 1.51	44.59** ± 1.44
Sarcoplasmic I	23	57.82** ± 2.48	55.09** ± 2.37
Sarcoplasmic II[a]	23	86.17** ± 1.98	81.74** ± 1.89
NPN I	23	6.16 ± .62	5.35 ± .59
NPN II	23	6.52 ± .20	6.58 ± .19
RNA-DNA I	23	4.21 ± .48	4.53 ± .46
RNA-DNA II[a]	23	4.66 ± .40	4.65 ± .38

[a]Significant $P < .01$ trial difference.
[b]Sixty-minute treadmill exercise 5 days/week.
**Significant $P < .01$.

lactate values (Marple *et al.*, 1969). Weiss *et al.* (1974) reported substantial increases in serum lactate as a result of short term severe exercise. No exercise influence on serum lactate was revealed by the data in table 4 and was probably the result of the conditioned exercise.

Blood cholesterol levels declined from on-test to off-test blood samples (table 4) but were not influenced by exercise. Similarly, liver cholesterol concentrations were not influenced by exercise. The apparent conditioning effect of daily exercise is revealed by the physiological data shown in table 4.

The possibility that induced exercise may influence muscle protein composition was evaluated. In table 5 are presented *gracilus* RNA-DNA and protein extractability data. In earlier studies Moser (1972) and Moser *et al.* (1972) did not observe significant differences in RNA-DNA among genetic lines of swine, sex

TABLE 6. LEAST SQUARES MEANS AND STANDARD ERRORS FOR PERCENT LEAN, FAT AND BONE OF HAM CROSS SECTIONS

Source	No.	Non-exercise	Exercise[c]	Coefficient of variation
Rt. butt portion lean[b] %	56	79.14 ± .87	79.47 ± .84	6.01
Rt. butt portion fat[a] %	56	18.24 ± .83	17.18 ± .80	27.17
Rt. butt portion bone[a] %	56	2.82 ± .25	3.36 ± .24	46.84
Lt. butt portion lean[a] %	56	78.29 ± .69	79.17 ± .66	7.60
Lt. butt portion fat[a] %	56	18.21 ± .64	17.14 ± .62	31.61
Lt. butt portion bone[a] %	56	3.51 ± .24	3.70 ± .23	55.13
Rt. center portion lean[a] %	56	74.84 ± 1.06	74.45 ± 1.02	8.78
Rt. center portion fat[a] %	56	22.31 ± 1.02	22.85 ± .98	27.24
Rt. center portion bone[a] %	56	2.84 ± .18	2.70 ± .18	52.74
Lt. center portion lean[a] %	56	74.42 ± 1.19	76.21 ± 1.15	11.28
Lt. center portion fat[a] %	56	22.85 ± 1.19	21.20 ± 1.15	38.14
Lt. center portion bone[a] %	56	2.73 ± .18	2.60 ± .18	50.43
Rt. shank portion lean[a] %	56	50.24 ± 1.30	53.22 ± 1.25	19.06
Rt. shank portion fat[a] %	56	37.51 ± 1.27	34.18 ± 1.22	30.67
Rt. shank portion bone[a] %	56	12.26 ± .57	12.56 ± .55	26.52
Lt. shank portion lean[a] %	56	50.41 ± .43	53.76 ± 1.38	22.13
Lt. shank portion fat[a] %	56	34.43 ± .98	36.10 ± 1.41	35.34
Lt. shank portion bone[a] %	56	13.53 ± .41	13.54 ± .59	21.71

[a]Significant $P < .01$ trial difference.
[b]Significant $P < .05$ trial difference.
[c]60 min. treadmill exercise 5 days/week.

and different dietary levels of protein. Data in table 5 indicate no major differences due to exercise or sampling time.

Weiss *et al* (1971) reported that concentrations of sarcoplasmic and myofibrillar protein increased significantly ($P < .01$) in a swine growth and development study. A significant ($P < .01$) increase in myofibrillar and sacroplasmic protein is shown for both non-exercised and exercised swine between on-test and off-test determinations. No significant ($P < .05$) influence of treadmill exercise was observed for the protein extractability values (table 5).

In table 6 are presented percent lean, fat and bone of ham cross sections. Exercise had no significant influence on these traits. The coefficients of variation, particularly for the fat and bone components, and the significant trial differences would suggest that considerable variability exists in this form of measurement.

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