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Effect of Corticosterone and Protein Malnutrition on Muscle Protein Breakdown *in vivo* in Rats as Measured by the Urinary Excretion of 3-Methylhistidine

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The role of corticosterone in regulating the rate of muscle protein breakdown was evaluated by measuring the urinary excretion of 3-methylhistidine (3-Mehis) during the administration of 0.0 (vehicle), 0.8 (physiological dose) and 10 (pharmacological dose) mg of the glucocorticoid/100 g body weight/day to adrenalectomized rats (AdX, AdX 0.8 and AdX 10 respectively). A fourth group of intact rats receiving only vehicle (In) was included as control. Rats were fed on either adequate protein and energy (Co) or low-protein (l-P) diets, for eight consecutive days. No differences were found between AdX and AdX 0.8 groups as compared to the In group in regard to body and liver weights. The AdX 10 group exhibited a significant reduction in body weight and a considerable increase in liver weight; these results were found in rats fed on the Co and l-P diets, although rats on the l-P diet showed a proportional decrease in those parameters as compared to the rats fed on the Co diet.

Gastrocnemius, tibialis and E. D. L. muscle weights were significantly reduced in AdX 10 group, approximately at the same extent in the two dietary groups. Soleus muscle weight increased in the AdX 10 group, at the same extent in the two dietary groups, as compared to the In group. Plasma corticosterone levels were significantly greater in the AdX 10 group in both dietary treatments, though restriction of protein in the diet induced a higher plasma hormone level than that of the Co group. Urea-N and creatinine outputs were significantly higher in the AdX 10 group. 3-Mehis excretion underwent an immediate and significant rise in the AdX 10 group, although rats fed on l-P diet showed a more persistent rise than those fed on the Co diet. No differences were found among the other groups. It is concluded that high plasma corticosterone levels can accelerate muscle protein breakdown and that this action is not seriously affected by the protein content of the diet.

The marked catabolic effect of glucocorticoids in skeletal muscle is well documented (35, 37). In large doses, glucocorticoids lead to a net loss of body weight and a deep distribution of body mass. While the size of the liver is increased, the mass of the skeletal muscle is decreased, as for example is evident

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in Cushing's syndrome (10, 26). Besides, the administration of large doses of glucocorticoids causes an overall negative nitrogen balance in the organism (21, 27). These effects are explained on the basis that adrenocortical hormones cause an increase in the mobilization of body proteins and in the rate of hepatic gluconeogenesis at the expenses of peripheral tissue proteins (15).

In regard to the rate of muscle protein turnover in rats, increases in the rate of breakdown (14) and decreases in the rate of synthesis (18) as a consequence of administering high doses of glucocorticoids have been reported (37). However, SHOJI and PENNINGTON (31) and MILLWARD *et al.* (25), could not detect any change on the rate of muscle protein breakdown in animals treated with high doses of corticosterone, using different *in vivo* and *in vitro* techniques. In a recent paper from our laboratory (35) using the *in vivo* 3-methylhistidine technique, it was found that elevated plasma corticosterone levels exerted an effect on muscle protein turnover by increasing the average rate of muscle protein degradation.

Since both corticosterone treatment and deprivation of protein in the diet cause a decrease in the rate of muscle protein synthesis in rats (19, 20), it was felt that feeding rats on a low-protein diet and giving them a corticosterone treatment, could somehow, modify the action of the hormone on the rate of muscle protein turnover. It has been used the urinary excretion of 3-methylhistidine as an index *in vivo* of muscle protein breakdown. It was previously reported that this amino acid is released on breakdown of the myofibrillar proteins myosin and actin, and excreted quantitatively (19, 20, 38, 39). This approach thus provides an integrated assessment of the rate of protein breakdown in the myofibrillar proteins and is an elegant means of measuring changes in the rate of protein breakdown *in vivo* in muscle itself under the influence of various treatments. In the present paper, the effects of corticosterone administration to rats fed on adequate protein and energy and protein-depleted diets on the rate of muscle protein breakdown as measured by the urinary excretion of 3-methylhistidine, are reported. It is concluded that high plasma corticosterone levels and lack of protein in the diet cause a lower but more persistent rate of muscle protein breakdown than that of rats fed on an adequate diet.

Materials and Methods

Animals and treatments. Adrenalectomized male Sprague-Dawley rats about 120 g body weight (Charles River Breeding Laboratories, Wilmington, Mas. USA) were housed into individual metabolic cages. For a week after surgery, they were fed *ad libitum* on a purified diet containing 18 % (w/v) lactalbumin (19). They were given 1 % NaCl to drink. They were then randomized in three hormone-treated groups of 10 rats each; the treatment consisted in a daily subcutaneous injection of a vehicle, 0.8 or 10 mg of corticosterone/100 g body weight/day. A fourth group of 10 intact rats (120 g body weight), receiving vehicle injection was included as a control. Injections were administered between 10:00 and 12:00 h; the hormone was injected in 0.5 ml of vehicle, consisting of NaCl (0.8 %), polysorbate 80 (Fisher Scientific, Pittsburgh, Pa., USA), sodium CM-cellulose (0.5 %) and benzyl alcohol (0.9 %). Within these groups, two dietary groups of 5 rats each were made: control (18 % lactalbumin diet) and low-protein (1 % lactalbumin diet) which were given to the rats *ad libitum*. Composition of the diets is shown in table I. Intact-control and hormone-treated rats were pair-fed with the average food intake of the adrenalectomized group receiving vehicle injection in the two dietary groups. Body weight and food intake were recorded every day in all rats. Dur-

Table I. *Diet constituents: entries are g % dry diet.*

Both Control and Low-Protein diets were provided *ad libitum*. The mineral mix was purchased from General Biochemicals, Chagrin Fall, Ohio, USA. Composition of mineral and vitamin mixtures is as described by ROGERS and HARPER (29). Choline was added to the diet as an aqueous solution containing 1 g of choline hydrocloride/5 ml. The Corn oil was obtained from Wesson Oil Sales Co., Fullerton, Calif., USA.

Component	Control diet	Low-Protein diet
Dextrine	44.2	55.5
Sucrose	22.1	27.8
Lactalbumin	18.0	1.0
Mineral Mix	5.0	5.0
Vitamin Mix	0.5	0.5
Choline	0.2	0.2
Corn Oil	10.0	10.0
Agar	4.0	4.0
Water	100.0	100.0

ing the first three days of the experimental period, rats were given neither glucocorticoid nor dietary treatment. The third day, both treatments started and were continuated for 8 days.

Complete 24 h urine collection was obtained from each rat; 0.1 ml of toluene was added as preservative. At the completion of the experiment, all rats were killed by decapitation. Immediately, a blood sample was taken for a further plasma corticosterone assay; the livers were excised and weighed and the gastrocnemius, soleus, tibialis anterior and extensor digitorum longus muscles were removed by careful disection and weighed (3, 13).

Determination of urine constituents. Samples of the daily urine collections were pooled within each group for urea-nitrogen (11), creatinine (28) and 3-methylhistidine (4, 19, 20). Concentrations of this derivative aminoacid were determined as follows: after hydrolisis of the N-acetyl derivative with 2 M HCl in a boiling-water bath for 2 h. a subsequent desalting on a cation exchange column (Dowex AG50-X8, 6 cm × 1 cm) followed by stepwise elution with HCl of the acidic, neutral (2.0-2.5 N HCl) and basic (4.0-5.0 N HCl) amino acids, was performed. The acidic eluate containing the basic amino acids was dried in a rotatory evaporator, and the sample was reconstituted with citrate buffer (0.2 M adjusted to pH 2.2 with HCl) before application to a Beckman 121 automatic aminoacid analyzer.

Plasma hormone assay. Plasma corticosterone levels were determined by direct radioimmunoassay method. The hormone (both the unlabeled and labeled, 1, 3 [^{3}H] corticosterone) was extracted from the plasma with dichloromethane; the organic phase was separated from the aqueous by centrifugation and evaporated to dryness in a vacuum oven at room temperature; the antibody was then added and the mixture was incubated for 2 h at room temperature. At the completion of the incubation period, proteins were precipitated with $(NH_4)_2SO_4$, and separated by centrifugation. The supernatant was transferred to scintillation vials and counted. The radioimmunoassay kit was provided by Inter Science Institute (Los Angeles, Calif. USA).

Statistics procedures. Statistical evaluations were carried out by conventional one- and two-way analysis of the variance (7).

Results

Changes in body and organ weights. Figure 1 shows changes in body weight of the different hormone —and dietary— treated groups. As was expected (19), rats fed on low-protein diet exhibited a significant ($p < 0.01$) decrease in body weight as compared to the animals fed on the control diet, in the intact (—0.7 g/day),

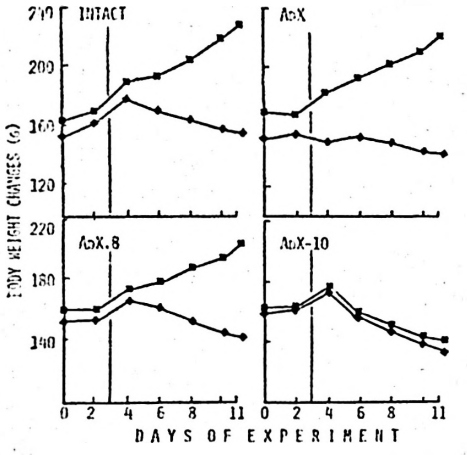

Fig. 1. *Daily body weight changes of rats under different corticosterone and dietary treatments.*
Values are means for five rats in each of the following hormone-treated groups: INTACT (normal animals, receiving vehicle injection), AdX, AdX-8 and AdX-10, adrenalectomized rats receiving vehicle, 0.8 and 10 mg of corticosterone/100 g body wt./day. Injections are given subcutaneosly, during 8 days. Within these hormone-treated groups, two dietary groups are made: rats fed on adequate control diet (18 % lactalbumin) (■), and rats fed on protein-depleted diet (1 % lactalbumin) (◆). Both diets are provided *ad libitum*. Hormonal and dietary treatments started on the third day of the experimental period (indicated by the vertical line).

adrenalectomized (—0.9 g/day) and adrenalectomized receiving physiological replacement (—1.8 g/day) groups. Animals treated with the high dose of the steroid, showed a continuous loss in body weight (—2.4 g/day), in both dietary treatments. No differences in body weight gain between the intact and adrenalectomized receiving 0.8 mg of corticosterone groups were found when the animals were fed on the control diet. The food intake was approximately 15 and 12 g of agar diet/day in the rats fed on the control and low-protein diets respectively.

The weights of the livers and of the four skeletal muscle excised are shown in table II. The livers of the rats fed on the low-protein diet exhibited a reduction in weight ($p < 0.05$) as compared to those fed on the control diet; but, in both dietary regimes, the administration of the high dose of the steroid produced a significant ($p < 0.01$) increase in liver weight, compared to any of the other hormone treated-groups. The four muscles disected, representing predominantly red (soleus), white (extensor digitorum longus) and mixed (gastroctemius and tibialis anterior) fibers, showed different responses: gastroctemius and tibialis anterior muscle weights (expressed by 100 g body weight) were significantly lower ($p < 0.01$) in the rats receiving 10 mg of corticosterone in both dietary groups. No differences appeared among the other groups. The extensor digitorum longus muscle weight (expressed by 100 g body weight) was also reduced in the animals receiving the high dose of the glucocorticoid, both in rats fed on the control diet ($p < 0.02$) and in those fed on the low-protein diet ($p < 0.01$). Soleus muscle weight (expressed by 100 g body weight) was relatively higher ($p < 0.05$) in the rats receiving 10 mg of corticosterone in the two dietary regimes; no significant differences were noted in this muscle weight among the other experimental groups.

Plasma corticosterone levels. Table II shows the corticosterone concentrations of plasma taken from the tail of the rats just 24 h after the last steroid injection. Values obtained are in agreement to those reported by GÓMEZ-SÁNCHEZ *et al.* (16) and TOMAS *et al.* (35). In both dietary groups, the hormone concentration in the adrenalectomized rats that did not receive corticosterone replacement, still showed some amounts of the hormone. This was probably due to the non-specific binding of the labeled hormone which could not be removed completely in the radioimmuno-

Table II. *Liver, muscle weights and plasma corticosterone levels of intact and adrenalectomized (AdX) rats, receiving vehicle (veh.) or corticosterone injections (0.8 and 10 mg of corticosterone/100 g body wt./day) subcutaneously, during 8 days, and fed* ad libitum *on adequate (18 % lactalbumin) and low-protein (1 % lactalbumin) diets.*

All entries are mean values for five rats ± S.E.M. E.D.L. means extensor digitorum longus muscle. All muscles were removed from both of the rear legs. Rats were killed by decapitation 24 h after the last injection of either vehicle or hormone. Blood was collected directly from the decapitation wound, and the plasma was assayed for corticosterone subsequent to separation. Vehicle consisted of NaCl (0.8 %), polysorbate 80 (0.4 %), sodium CM-cellulose (0.5 %) and benzyl alcohol (0.9 %).

Diet	Corticosterone treatment	Liver (g/100 g weight)	Gastrocnemius (mg/100 g weight)	Soleus (mg/100 g weight)	Tibialis (mg/100 g weight)	E.D.L (mg/100 g weight)	Plasma corticosterone (μg/100 ml)
Control	Intact + veh.	4.2 ± 0.3	1,000 ± 20	67 ± 4	363 ± 15	82 ± 5	30 ± 3
	AdX + veh.	4.2 ± 0.3	1,050 ± 35	68 ± 5	354 ± 12	87 ± 6	12 ± 2
	AdX-0.8	4.1 ± 0.2	1,004 ± 33	73 ± 2	353 ± 5	88 ± 1	25 ± 3
	AdX-10	6.4 ± 0.2	860 ± 48	81 ± 4	286 ± 18	74 ± 5	50 ± 1
Low-Protein	Intact + veh.	3.2 ± 0.1	1,060 ± 30	69 ± 4	359 ± 4	88 ± 6	40 ± 2
	AdX + veh.	3.1 ± 0.2	1,080 ± 30	79 ± 2	339 ± 3	90 ± 2	10 ± 3
	AdX-0.8	3.2 ± 0.3	1,130 ± 40	74 ± 13	363 ± 10	93 ± 1	30 ± 2
	AdX-10	4.6 ± 0.4	870 ± 50	82 ± 4	274 ± 6	76 ± 2	60 ± 1

assay method. Rats receiving the physiological replacement did not show significant differences in plasma corticosterone levels as compared to the values observed in the intact animals. However, the groups receiving the high dose of the glucocorticoid exhibited, within both dietary treatments, a significant increase ($p < 0.01$) as compared to the intact group. This rise in plasma corticosterone level was higher in the group fed on the low-protein diet.

Excretion of urinary urea-N and creatinine. Figure 2 shows the daily urinary urea-N excretion monitored in the different experimental groups. Only rats fed on the control diet and receiving the 10 mg of corticosterone had a significant ($p < 0.01$) increase in urea-N as compared to the intact animals. No significant differences were noted among the other groups. Creatinine excretion was also significantly elevated ($p < 0.01$) in rats treated with the high dose of the steroid (fig. 3) in the two dietary treatments. A little increase in creatinine excretion ($p < 0.05$) was observed in the adrenalectomized group without receiving corticosterone replacement, in the two dietary regimes. No differences were detected between the intact and adrenalectomized group receiving 0.8 mg of corticosterone.

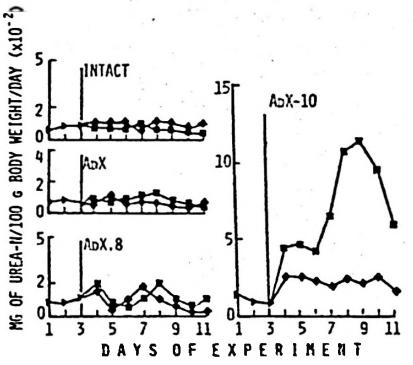

Fig. 2. *Urea-nitrogen excretion during the corticosterone and dietary treatment.* Each point is the value from a pooled sample of five rats. The symbol (▶) corresponds to the outputs monitored before the beginning of the hormonal and dietary treatment. Explanation of the other symbols and other details are as described in legend to figure 1.

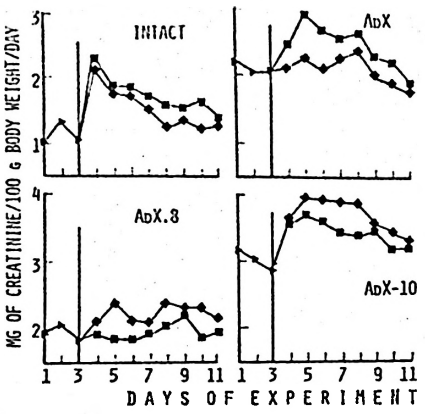

Fig. 3. *Creatinine excretion during the corticosterone and dietary treatments.*
Each point is the value from a pooled sample of five rats. Explanation of the symbols and other details are as described in legends to figures 1 and 2.

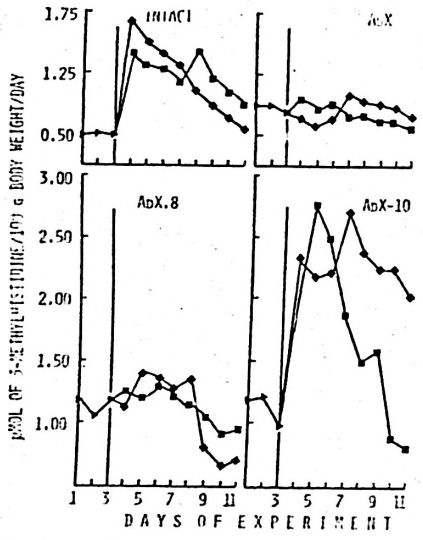

Fig. 4. *3-Methylhistidine excretion during the corticosterone and dietary treatment.*
Each point is the value from a pooled sample of five rats. Explanation of the symbols and other details are as described in legends to figures 1 and 2.

Excretion of 3-methylhistidine. Figure 4 shows the daily excretion of 3-methylhistidine. A decrease in the output of this metabolite was noted in rats fed on low-protein diet (in agreement with the results reported by HAVERBERG *et al.* (20), within the intact and adrenalectomized group receiving 0.8 mg of corticosterone, as compared to the output monitored in rats fed on the control diet ($p < 0.05$) since the 5th day of the experimental period. No differences were noted in the adrenalectomized group not receiving hormonal replacement. High corticosterone dose produced a distinct and significant increase ($p < 0.01$) in the 3-methylhistidine output, in the two dietary treatments, as compared to the values showed by the intact group. This increase was more distinct in the rats fed on the control diet than in those fed on the protein-depleted diet, and it was followed by a decrease in the excretion of this metabolite; in the case of rats fed on the control diet, this decrease continued at a constant rate throughout the experimental period, reaching the values of the intact animals; whereas, in the case of rats fed on protein-depleted diet, the decrease was evident only for two days, and then a new increased was displayed.

Discussion

A major action of adrenal glucocorticoids is to induce protein catabolism in peripheral tissues. As it has been shown in this paper, elevated corticosterone doses result in a reduction in body weight in rats fed on either control or protein-depleted diets and in increased nitrogen excretion due to the loss of protein from the carcass, whereas the protein content of the liver and other viscera increases (6). Adrenalectomized rats not receiving hormonal replacement and fed on the control diet gained more body weight than those receiving the 0.8 mg of corticosterone, and their gain in body weight almost reached

the values of the intact group. In this sense, it has been shown (9) that muscle protein formation as measured by the incorporation of labeled amino acids is increased soon after adrenalectomy, contributing to increased body mass, and, it is reduced when animals are treated with glucocorticoids. It seems likely that the 0.8 mg of corticosterone/100 g body weight dose administered daily does not induce a physiological plasma corticosterone levels, although it is close to it. Lack of protein in the diet, as was expected (19) caused a decrease in food intake and body weight which was essentially the same in all hormone-treated groups.

The hepatic hypertrophy found in rats receiving the high dose of corticosterone is a classical response to glucocorticoids administration (9); amino acids liberated in the periphery as a result in protein breakdown are transported to the liver where they are utilized in synthesis of new protein. Not only is there protein synthesis, but the total nucleic acid content of the liver also increases, which is due primarily to a rise in RNA content. It is interesting to point out that the response to glucocorticoids and to protein feeding are similar in that both lead to increased liver protein and RNA (26). Deprivation of protein from the diet brings about a reduction in both body and liver weight (12) but even in this dietary situation, the pharmacological dose of the steroid is able to induce liver enlargement.

The studies carried out by several workers on single muscles are contradictory and difficult to resolve owing to the differences in the type of steroid, the way of injection, the amount and period of dosage, the age and the sex of the rats and the hormone-resposiveness of the individual muscles. Our data, and those of others (13, 15, 32) confirm that changes caused by corticosteroid administration differ among muscle types. As it was noted by GOLDBERG and GOODMAN (15), the catabolic effect of glucocorticoids are more pronounced in the less active muscles that precisely are the pale ones (13), like extensor digitarum longus muscle (white fibers) and gastrocnemius and tibialis (mixed fibers). HANNEMAN and OLSON (17), suggested that in mobilizing body protein from these muscles for other purpose (like gluconeogenesis) the hormone spares those physiologically more active muscles, such as soleus (red fibers).

Plasma corticosterone levels were increased in the group of rats receiving the 10 mg of corticosterone, compared to the other groups in both dietary treatments. This increase was higher in the protein-depleted group. It is generally agreed that plasma cortisol is increased in all types of severe malnutrition; the high plasma cortisol levels found in malnourished children did not indicate hypersecretion. since the production rates of the steroid were similar in both the sick and recovered children. It was rather due to a decrease in cortisol degradation in those children (2). Similary, starvation or protein deprivation elevates plasma corticosterone in rats due to a prolonged half life of the hormone (33).

The decrease in body weight and in 3-methylhistidine output found in rats fed on protein-deficient diet are in agreement with the results of HAVERBERG *et al.* (20). although the decrease detected in this experiment is less significant than the one reported by later workers; this is probably due to the fact that they used a 0.5 % lactalbumin diet rather the 1 % used by us; besides (24), measuring the rate of synthesis and the change in total muscle protein, concluded that muscle protein breakdown must have diminished, at least, after day 10 of feeding with a protein-free diet. The catabolic action of the steroid on muscle protein is clearly manifested through the rapid increase in the excretion of 3-methylhistidine in rats fed on either control or protein-depleted diets and receiving the high dose of corticosterone, although rats fed on the low-

protein diet showed a less significant increase in the excretion of this metabolite; in addition, the animals exhibited a reduction in body weight and high plasma corticosterone levels, as stated above, which confirm a catabolic state. This 3-methylhistidine rise is similar to that reported in a recent paper from our laboratory (35), in which several doses of corticosterone were given to adrenalectomized rats fed on an adequate diet. The decline in 3-methylhistidine excretion following the rapid rise, may represent a metabolic adaptation in order to conserve muscle protein from loss through breakdown, as it was reported by the study of HAVERBERG *et al.* (19). However, animals fed on protein-depleted diet showed a decline in the excretion of 3-methylhistidine that lasted only two days, in contrast to the progressive and constant decrease monitored in the well nourished rats throughout the experimental period; and then, a new rise followed by a slow decline in the excretion of this amino acid derivative, was monitored within this protein-depleted group. Many workers have reported that lack of protein in the diet leads to a decrease in the rate of muscle protein synthesis both *in vivo* and *in vitro* 25, 36, 38, 39), and, as it has been pointed out above, this depletion on muscle protein synthesis is accompanied by a reduction in muscle protein breakdown, which can be monitored through the progressive fall in 3-methylhistidine output. This could explain the fact that rats fed on protein-depleted diet showed a less marked rise in the 3-methylhistidine output by a diet compensation, but later on, the catabolic action of the steroid overcame the effect of the diet and a new rise in the excretion of 3-methylhistidine was produced. These results are supported by the urinary urea-N and creatinine excretion monitored in the adrenalectomized group receiving 10 mg of costicosterone, in agreement with the data reported by EISENSTEIN and SING, (9); the dramatic rise in urinary urea-N output undergone by rats fed on the control diet is characteristic of elevated body protein catabolism (1); lack of protein in the diet lead to a fall in the excretion of this metabolite, similar to that reported by YOUNG and MUNRO (39), by feeding rats with a 0.5 % and 1 % lactalbumin diet; this indicated a fall in the rate of protein catabolism so that the body could be adapted to a poor dietary amino acids intake. The elevated creatinine output monitored in the adrenalectomized rats receiving the high dose of the steroid brought about more evidence about degradation of body proteins other than myofibrils (27) and confirmed the catabolic state of those animals.

Our data do not permit any conclusion about the mechanism of the observed increase in the rate of muscle protein breakdown in rats fed on either control or protein-depleted diets, although it has been shown that glucocorticoids administration leads to an increased activity of several non-lysosomal proteinases (22, 23). Concentrations of plasma corticosterone are elevated by a number or pathological stress conditions in which accelerated catabolism of body protein components is commonly associated. RYAN *et al.* (30), found that corticosterone administration to normal rats produced an increase in leucine oxidation and a decrease in leucine incorporation into protein similar to that observed following shock. However the same workers pointed out that fasting caused a simultaneous decrease in both leucine oxidation and incorporation into protein, and since the rate of protein synthesis in muscle appears to depend upon the leucine concentration (5), it seems that glucocorticoids administration and removal of protein (and therefore, essential amino acids) from the diet, have opposite effects on muscle protein turnover. Analogous results were reported by NISHIZABA *et al.* (27), studying the effect of starvation, refeeding and hydrocortisone administration on the turnover of myofibrillar

proteins in rats. Similar elevation in plasma corticosterone concentrations in response to physical stress have been reported by others (8, 34).

On the basis of this data, our results suggest that the increase on muscle protein breakdown caused by corticosterone is likely to be a feature of the response to severe stress and that the steroid has an effect on muscle protein breakdown only when plasma concentrations, well above the normal range, are present in the plasma of rats fed on either adequate or low-protein diets.

Acknowledgements

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Resumen

Se ha medido la influencia de la corticosterona sobre la degradación de las proteínas musculares, determinando la excreción de 3-metilhistidina (3-Mehis) en la orina, en ratas adrenalectomizadas a las que se les inyectaba 0.0 (vehículo), 0,8 (dosis fisiológica) y 10 (dosis farmacológica) mg de corticosterona/100 g de peso corporal/día (AdX, AdX 0,8 y AdX 10, respectivamente). Se incluye como control un cuarto grupo de ratas intactas (In) a las que se les inyecta únicamente vehículo. Las ratas se alimentaron con dieta control o con dieta baja en proteína (Co y b-P) durante ocho días consecutivos. No se encontraron diferencias entre los grupos AdX y AdX 0,8 comparados con el grupo In referente a peso corporal y de hígado. El grupo AdX 10 mostró una reducción significativa en peso corporal y un aumento en peso de hígado; estos resultados se encontraron en las ratas alimentadas con la dieta Co y b-P, aunque las ratas alimentadas con esta última dieta mostraron una disminución proporcional en estos parámetros, comparados con los de los animales alimentados con la dieta Co.

Los músculos gastrocnemius, tibialis y E.D.L. resultaron significativamente reducidos en peso en el grupo AdX 10, aproximadamente en la misma medida en los dos grupos de dietas y soleus aumentó en AdX 10 en la misma proporción en los dos grupos de dietas, comparados con el grupo In. Los niveles plasmáticos de corticosterona fueron significativamente más altos en el grupo AdX 10, en los dos regímenes de dietas, aunque se observó que la carencia de proteína en la dieta inducía un más alto nivel de hormona en el plasma que el detectado en las ratas alimentadas con la dieta Co. Urea y creatinina aumentaron significativamente en el grupo AdX 10. La excreción de 3-Mehis experimentó un inmediato y significativo aumento en el grupo AdX 10; este aumento resultó ser más persistente en los animales alimentados con la dieta b-P. No se encontraron diferencias entre los otros grupos. Se concluye que altos niveles plasmáticos de corticosterona pueden acelerar el grado de degradación proteica muscular, y que esta acción no es seriamente afectada por el contenido proteico de la dieta.

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