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Interaction of Mercury and Water Deprivation on Growth, Feed Consumption, and Mortality in Chickens[1,2]

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In a chronic inorganic mercury (Hg) study by Parkhurst and Thaxton (1973), the addition of Hg to the drinking water of newly hatched chicks at 250 ppm or greater resulted in a general toxicity. A short-term study by Grissom (1982) showed that the addition of 500 ppm of Hg to the drinking water of four-week-old chickens that had not previously consumed Hg resulted in a similar toxicity. In both the chronic and short-term studies, inhibition of growth, decreased feed and water consumption, and increased mortality were observed. The toxic effects in both studies were explained as the direct consequence of Hg; however, the rapid onset of effects with a marginal amount of Hg consumption raised doubt as to whether Hg alone was responsible for all of the effects. Grissom (1982) postulated that the observed toxicity was the result of the combined effects of Hg and dehydration caused by the refusal of the Hg-contaminated water.

Information concerning recovery of birds after Hg treatment, dehydration, and Hg coupled with dehydration is not available. The question *a priori* is, do birds return to a pretreatment physiologic condition following insult or are these effects permanent?

The objectives of the present study were (1) to assess the effects of dietary Hg treatment, dehydration, and Hg treatment combined with dehydration on growth, feed and water consumption, and mortality in young chickens, and (2) to determine if the effects persisted following a 14-day recovery.

MATERIALS AND METHODS

The chicks used in this study were cockerels obtained from a breeder flock maintained at the North Carolina State University poultry farm. The chicks were brooded in heated metal batteries until they were three weeks of age. The chicks were then transferred into five

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unheated metal cages with raised wire floors for the duration of the experiment. The chicks were randomly assigned to five groups; each group contained 32 birds. Eight of the 32 birds in each group were maintained in one of four tiers in each cage. These cages were located in an environmentally controlled room with an ambient temperature of 20-25^{o}C. The birds were allowed one week to acclimate to the new conditions prior to the start of experimentation. During the four weeks prior to the initiation of treatments, feed and water were supplied ad libitum and fluorescent lighting was provided continuously.

In each of the five cages, one of the four tiers of eight birds received one of the following treatments: limited water and Hg (LW + Hg), limited water without Hg (LW), ad libitum water and Hg (ALW + Hg), or ad libitum water without Hg (ALW). This 2x2 factorially arranged design was indicated by the results of a previous study (Grissom, 1982). Specifically, when 500 ppm, i.e. 500 mg/L of Hg^{+2} as $HgCl_2$, was added to the drinking water of four-week-old birds, a marked reduction in the rate of water consumption was recorded, and this reduction was continuous for 15 days. The approximate average daily intake levels of Hg-contaminated water were: 25, 55, 70, 50 and 80 ml/kg of body weight for the 0-3, 3-6, 6-9, 9-12, and 12-15 day treatment periods, respectively. Similar water intake levels were employed to achieve the LW treatment in this study. Approximately 20, 35, 60, 70 and 70 ml of water/kg of body weight were intubated into the crop of each bird using a 50 ml syringe fitted with a number 11 gavage needle. The LW + Hg treatment was achieved by substituting a solution of 500 ppm of Hg^{+2} as $HgCl_2$ for the water, as described for the LW treatment. One-third of the daily dose was intubated at 0800, 1600 and 2400 hours. Based on 1% absorption of the dietary intake of inorganic Hg (Jugo 1979), the estimated amounts of absorbed Hg were: 0.11, 0.28, 0.58, 0.97, and 1.31 mg/kg/day of body weight for the 0-3, 0-6, 0-9, 0-12, and 0-15 day treatment groups respectively. The ALW + Hg treatment consisted of a continuous supply of water which did not contain Hg; however, Hg solutions at the levels described for the LW + Hg treatment were intubated at 0800, 1600, and 2400 hours. The ALW treatment was performed by providing the birds with a continuous supply of water which did not contain Hg; however, the gavage needle was inserted into the crop at 0800, 1600, and 2400 hours, but solutions were not intubated.

Prior to initiation of treatment and at 3, 6, 9, 12, and 15 days of treatment, the birds from one treatment group were weighed and rates of feed consumption were determined. Mortality was recorded daily. Each treatment group was given a 14-day recovery period at the termination of treatment. During recovery, the birds received feed and non-contaminated water ad libitum. Body weights were determined on the first day of the recovery period, as well as the end of the 14-day period. Feed and water consumption were calculated for the recovery period.

Statistical analyses were performed using the General Linear Models procedure of the Statistical Analysis System (SAS 1979) and means were separated using the Duncan (1955) option. Statements of significance are based on probability at 5%.

RESULTS AND DISCUSSION

The effects of Hg and limited water on body weights are presented in Table 1. Water limitation resulted in a significant inhibition of growth within three days of treatment and this effect was continuous throughout the 15-day treatment period. Hg did not cause a significant inhibition of growth until the 12-15 day treatment period. The only significant Hg x water interaction was found at 15 days of treatment.

Table 1. Effect of mercury (Hg) and limited water (LW) on mean ± SE body weights (g) in young chickens

Duration of Treatment (days)	Water Treatment	Treatment: No Hg	Hg	$\bar{x}$
0	ALW	795±14	769±18	782
	LW	790±25	821±18	806
	$\bar{x}$	793	795	
3	ALW	925±10	920±10	923
	LW	684±10	671±10	677^{+}
	$\bar{x}$	804	796	
6	ALW	1070±15	1080±15	1075
	LW	655±15	638±16	647^{+}
	$\bar{x}$	863	859	
9	ALW	1227±20	1200±21	1213
	LW	667±20	644±21	656^{+}
	$\bar{x}$	947	922	
12	ALW	1372±26	1334±26	1353
	LW	721±26	696±28	709^{+}
	$\bar{x}$	1047	1015	
15	ALW	1600±32	1413±31	1506
	LW	793±30	752±33	773^{+}
	$\bar{x}$	1196	1083*	

ALW= water available at all times; LW= water limited as described in text; No Hg= no Hg given; and Hg= Hg given at levels described in text.

$^{+,*}$Pooled means at each treatment interval with a different symbol differ significantly ($P \leq .05$).

The effects of limiting water and Hg on feed consumption are presented in Table 2. Feed consumption was dramatically influenced by limiting water. Specifically, limiting water caused a significant reduction in feed consumption within three days of treatment and this reduction was significant throughout the 15-day treatment period. Hg caused a significantly reduced feed intake during the 9-12 and 12-15 day treatment periods. Hg caused numerical, but not significant, reductions in feed consumption during the 0-3, 3-6, and 6-9 day treatment periods.

Table 2. Effect of mercury (Hg) and limited water (LW) on mean ± SE rates of feed consumption (g) per day in young chickens

Duration of Treatment (days)	Water Treatment	Treatment		
		No Hg	Hg	$\bar{x}$
3	ALW	86±1.7	82±8.3	84
	LW	48±1.7	44±2.9	46^{+}
	$\bar{x}$	67^{-}	63^{-}	
6	ALW	93±6.7	93±4.2	93
	LW	38±2.8	31±5.0	34^{+}
	$\bar{x}$	65^{-}	62^{-}	
9	ALW	100±2.1	91±10.0	96
	LW	38±0.8	33±1.0	36^{+}
	$\bar{x}$	69^{-}	62^{-}	
12	ALW	102±1.7	96±4.6	99
	LW	52±1.7	42±0.3	47^{+}
	$\bar{x}$	77^{-}	69^{*}	
15	ALW	108±0.1	99±3.2	103
	LW	55±2.1	47±2.0	51^{+}
	$\bar{x}$	81^{-}	72^{*}	

$^{+,*}$Pooled means at each treatment interval with different symbols differ significantly ($P \leq .05$). Abbreviations are the same as Table 1.

The effects of Hg and LW on mortality are shown in Table 3. During the 0-3 day treatment interval, there was no mortality. Over the 15-day treatment period, eight birds on LW treatment died as compared to the three birds that received ALW treatment. During this same time, six birds that were treated with Hg died as compared to five birds that did not receive Hg. Examination of the mortality data revealed that two ALW birds, three LW birds, one ALW + Hg bird, and five LW + Hg birds died in this study. In the groups receiving no Hg, 6.25% of the birds died, while 7.5% of the birds died in the groups receiving Hg. In the groups receiving water *ad libitum*, 3.75% died and 10.00% of the birds died in the group receiving LW.

Table 3. The effect of mercury (Hg) and dehydration on mortality (%) in young chickens

Treatment	Treatment: No Hg	Hg	Average Mortality (%)
ALW	5.00	2.50	3.75
LW	7.50	12.50	10.00
Avg. Mortality (%)	6.25	7.50	

[1]Values are for 40 birds in each of the treatments over the 15-day treatment period. Abbreviations are the same as in Table 1.

The final body weights, as well as body weight gains after the 14 days of recovery are presented in Table 4. After 15 days of treatment both Hg and LW caused significant reductions in growth when compared to controls (Table 1). The reduced body weights in the Hg and LW groups remained after 14 days of recovery. Additionally, the LW + Hg group had lower body weights after recovery than any of the other groups. However, when body weight gains were calculated for the 14-day recovery period, a marked difference was found. Specifically, the LW birds had a significantly greater gain than the ALW birds. Gain by the Hg birds was similar to body weights, i.e. the Hg group gained significantly less weight than the No Hg group. The interaction between Hg and LW for body weight was not significant.

Table 4. Body weight (g) and body weight gain (g/bird) after 14 days of recovery

Water Treatment	Treatment: No Hg	Hg	$\bar{x}$
Bd. Wt. after Recovery:			
ALW	2464 ± 59	2080 ± 46	2272
LW	1906 ± 42	1719 ± 83	1819^{+}
$\bar{x}$	2167	1899^{*}	
Bd. Wt. Gain after Recovery:			
ALW	805 ± 43	641 ± 49	752^{+}
LW	1115 ± 33	954 ± 64	1040
$\bar{x}$	997	798^{*}	

+,*Pooled means with a different symbol differ significantly ($P \leq .05$). Abbreviations are the same as in Table 1.

Feed and water consumption rates, as well as the water:feed ratios, during recovery are presented in Table 5. LW increased water consumption significantly during recovery; however, this treatment caused significantly lower feed consumption. Hg treatment did not affect water or feed consumption significantly during recovery. Significant interactions between Hg and LW on feed and water consumption rates were not found. The water:feed ratios were significantly greater in the LW group than in the ALW group; however, no significant effects due to Hg or the interaction of Hg and LW were found.

Table 5. Feed and water consumption during the 14-day recovery period in young chickens

Water Treatment	Treatment		
	No Hg	Hg	$\bar{x}$
	Water (ml/day)		
ALW	227± 6	236±33	232+
LW	401±61	356± 6	379
$\bar{x}$	314	296	
	Feed (g/day)		
ALW	103± 2	90±12	97
LW	93± 5	84±11	88+
$\bar{x}$	98	87	
	Water/Feed		
ALW	2.2	2.6	2.4+
LW	4.3	4.2	4.3
$\bar{x}$	3.2	3.4	

+Pooled means and ratios with this symbol differ significantly ($P \leq .05$) from the corresponding value. Abbreviations are the same as in Table 1.

Reduced water consumption in chickens is known to cause reduced feed consumption (Bierer et al. 1965). Consequently, reduced growth rate or weight loss, as well as increased mortality can occur. Hg has been shown to cause anorexia (Cassidy and Furr 1978); therefore, the sequence of events in the present study are common to both water deprivation and Hg toxicity. Thus, the results can be explained by water deprivation, Hg toxicity, or by an interaction between Hg and water deprivation.

The results also indicate that the birds did not attain complete physiologic recovery from either water deprivation or Hg consumption. Body weight gain of birds that had received Hg was lower at the end of the 14-day recovery period than the non-Hg birds; however, the gain of LW birds was greater than gain of ALW birds. Apparently, the birds ate and drank to meet their nutritional requirements, since feed and water were supplied ad libitum. The physiologic processes involved in weight gain were operable, since all birds gained rather than lost weight. Failure to attain body weights similar to those of the controls may have occurred due to an insufficient recovery period.

The weight losses during the 15-day treatment may have been permanent since water deprivation and Hg treatment occurred at a time of rapid growth. The physiologic alterations caused by water deprivation and Hg in young, rapidly growing animals have not been elucidated completely.

The increased gain by the LW birds suggests that dehydration of growing birds alters the normal pattern of water and feed consumption. Specifically, after forced dehydration when water and feed were supplied on an ad libitum basis, the dehydrated birds increased their water intake and decreased feed consumption. During two weeks of recovery, they did not attain body weights equal to non-dehydrated birds, but total gain exceeded that of controls. A physiological explanation of this effect is not apparent, but compensatory growth is suggested. The finding that limited water intake also limited feed intake and that following a period of dehydration, water intake increased dramatically while feed intake decreased, is in agreement with previous reports (Kare and Biely 1948; Kellerup et al. 1965; Lepkovsky et al. 1960; Marks 1981). It is possible that following dehydration digestion and/or metabolism of nutrients was changed. Marks (1981) has postulated that broiler chickens fed without water have a lower rate of digestion than chickens fed with water.

Previous work such as that performed by Parkhurst and Thaxton (1973) and El-Begearmi et al. (1980) has shown that adding Hg to the diets of chickens reduced weight gains, decreased feed and water consumption, and increased mortality. Grissom (1982) suggested that reduced feed and water consumption could contribute to such results. The present experiment allowed us to partition the effects of Hg, dehydration, and Hg x dehydration. The results of this study indicate that water deprivation had a dramatic early effect and that Hg exerted a later, less dramatic effect. Hg and water deprivation appear to be interrelated since the effect caused by LW + Hg was greater than the effects caused by either Hg or water deprivation alone, and this interaction appeared to concur within three days of treatment.

These data indicate clearly that contamination of drinking water by Hg can cause direct, as well as indirect effects. The effects of Hg occur, but require continuous consumption over a two-week period when Hg concentration is 500 ppm. However, the element appears to cause refusal of the contaminated source of drinking water and thus when the bird consumes this water, it is then subject to the compound effects of dehydration and Hg toxicity. This finding indicates that results previously attributed to Hg could have been due to an interaction of Hg toxicity and dehydration.

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