INTRODUCTION

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Literature on various developmental aspects of both mammals and birds are in legion. A large number of studies on embryonic development of birds in general and domestic fowl in particular has been undertaken during the past decades. Many of these studies revealed the day to day dramatic changes occurring during the embryonic development of chicks, which attracted many workers interested in seeing as to how the body of the chick traversed from embryonic (neonate) to adult stage. The study of the transformation from egg to adult, apart from its pristine interest, is a fundamentally important aspect of avian biology. Developmentalists and poultry scientists, though had recognized this much earlier, avian biologists' attention has been drawn only recently (Ricklefs, 1983). Even so, researchers on poultry, restricted their attention to a narrow aspect of factors related to production and, developmental biologists concerned themselves with only early embryogenesis involving remarkable transformations. Ricklefs has adequately exposed the incompletedness in the study of avian development in the statement "In Marshalls (1960-61) treaties of two decades ago, Ruth Bellair's (1960) chapter, Development of Birds ended at hatching, as if development in the egg and growth of the chick conveniently defined different realms of enquiry, the latter perhaps a postscript concerned with the enlargement of structures established much earlier".

Growth of chicks after hatching concerns primarily with traversing the developmental gulf between the neonate and adult and could

justifiably involve many adjustments and growth patterns aimed at attaining the adult attributes. The problem of post-natal development is now more fully appreciated by developmental biologists in all its complexity and subtlety. The exact course of development to a certain extent depends on the size and body proportion of the neonate and adult and, the environment of the chick during its development. The conditions and functional capabilities of the neonate vary from total independence (precocial) to complete dependence on parents (altricial) and as such would warrant separate dealing. Early studies of post-natal development in birds were mostly descriptive and confined to growth of species in the wild (Bergtold, 1913; Stanwood, 1913). Latimer's work (1924, 1925a, b, 1927) in the same line in domestic fowl though, thorough, is long and tedious. Thus since early times, chicks of domestic fowl proved to be a good experimental model for neonatal studies. As far as the development and growth of chick is concerned, lot of descriptive information is available while, the changes at physiological levels still remain less well known. Chicks are in this sense, convenient subjects for experimental physiology and the observations of Pembrey et al. (1895) on the metabolic response of chicks to different temperatures constitute an early attempt on this line. In this context, the present work involves metabolic physiology as a principal theme of investigation.

The role of hormones during the ontogenetic development, specifically, the post-hatched development should be expectedly more dynamic and interesting, primarily because the avian post-natal development phase

serves as a link between hormone independent embryonic phase and hormone dependent adult phase and, secondarily because the organism shows varying sensitivity to quantitatively and qualitatively changing endocrine principles, and gradually adapt for later stages of life. Thus the role of hormones in avian growth becomes significant. Experimental work by various researchers from 1947-1974 have shown that growth hormone and thyroid hormone play important roles in avian post-natal development. It is obvious that the circulating levels of hormones would affect the growth and metabolism of various developing tissues. Investigations on the hormonal regulation of growth have remained restricted to only the effects of growth hormone and thyroid hormone.

Role of growth hormone is indicated by the observations of increased growth rate, nitrogen retention and bone growth in hypophysectomised chicks given chicken pituitary extracts (Libby et al., 1955; Glick, 1960b; Nalbandov, 1966). Disruption of thyroid activity by surgical thyroidectomy, radiothyroidectomy or chemical inhibition of thyroid hormones has been shown to have severe retarding effect on growth (Blivaiss, 1947; Winchester and Davis, 1952; Marks, 1971; King and King, 1973; Howarth and Marks, 1973). Blivaiss (1947) has observed 35% reduction in weight, retarded bone and feather growth and occurrence of obesity in thyroidectomised fowl. Age specific effects of thyroidectomy on developmental retardation has also been demonstrated (Voitkevich, 1966). Thyroidectomised chicks were found to be fat with retarded skeletal ossification and feather growth. The liver, adrenal glands and kidneys were however found to be four times larger than

those of controls based on percentage body weights. Thyroid secretion levels are not only correlated with growth rate (Tanabe, 1965; Voitkevich, 1966) but also with the development of homeothermy (Spiers et al., 1974). King and King (1973) observed that severe hypothyroidism reduced the muscle mass during growth and decreased the DNA level thereby suggesting a major effect on cell proliferation. Provision of exogenous thyroid hormone usually reverses the effects of thyroidectomy (Voitkevich, 1966; Raheja and Snedecor, 1970; King and King, 1973). It was also observed that providing supplementary thyroxine in moderate doses (2-4 µg/100 g/day) to intact chicks accelerated growth slightly while slightly higher doses (6 µg/100 g/day) depressed growth (Singh et al., 1968). Tanabe (1965) reported variations in secretion levels of thyroxine during post-natal growth. Accordingly, the levels decreased from about 2 µg/100 g/day at two weeks to about 0.5 µg/100 g/day at hundred days. In the experiment by Singh et al. (1968) the maximum increase in growth rate of about 5% occurred between 7 and 39 days. In general, study of hormones and growth tended to show that though the inadequacy of growth and thyroid hormones have severe retarding effects, administration of either of the two hormones to normal animals was unable to stimulate growth appreciably. Apparently, growth is regulated by a complex and subtle endocrine milieu, and not under the purview of any single hormone per se. Another reported role of thyroxine in neonatal chick is its thermogenic ability. Rectal temperatures were significantly increased by 30 minutes by intraperitoneal injections of thyroxine and triiodothyronine (Freeman, 1971). Both hormones were also effective in delaying the fall in rectal temperature

when the chicks were exposed to cold. The stimulatory effect of thyroid hormones on oxygen consumption and tissue metabolism especially carbohydrate metabolism and also on early morphogenesis of epidermis and feather growth and molting have been reviewed by Assenmacher (1973).

A scan of the literature on hormonal regulation of post-natal growth of birds reveals that apart from growth hormone and thyroid hormone, other hormones have been generally neglected. Of the various hormones, the probable role of adrenocortical hormones in post-natal development of birds would require attention in the light of the known effects on metabolism in adult animals (Riddle, 1937; Golden and Long, 1942; Stamler et al., 1954; Dulin, 1956; Brown et al., 1958; Baum and Meyer, 1960; Greenman and Zarrow, 1961). Apart from their direct effect on various facets of intermediary metabolism, corticosteroids also exert permissive effects on secretions and functions of other hormones as well (Mialhe, 1958, 1969). In this light, the need to study the role of adrenocortical steroids in the post-natal growth and maturation of chicks need not be overemphasized. The significance of glucocorticoids in the post-hatched phase of avian development can be gleaned from the reports of altered adrenocortical cell steroidogenic capacity during the transition from embryonic to post-embryonic phase of domestic fowl (Carsia et al., 1987), of increased circulating level of corticosterone at the end of incubation (Kalliecharan and Hall, 1974; Marie, 1981) and of the ability of administered glucocorticoids to stimulate hepatic T_4-5' monodeiodinase activity and the resultant increase in the

concentration of T_3 (Borges et al., 1981; Decuypere et al., 1983) in chick embryos and the reversed action of glucocorticoids to decrease T_3 with concomitant increase in reverse T_3 (rT_3) by stimulation of T_4-5 monodeiodinase activity in the post-natal phase (Kühn et al., 1984; Buyse et al., 1987). Though the functions of adrenocortical hormones on carbohydrate, lipid, protein and electrolyte metabolisms have been studied in greater detail in adult birds, the possible role of corticosteroids in post-hatched phase of development, especially in the wake of reported age dependent changes in endocrine milieu (Kühn et al., 1984; Sinsigalli et al., 1987), needs careful evaluation.

Great many reports on corticosterone and dexamethasone (DXM) on growth and metabolism in mammals are available (Ingle, 1950; Antopol, 1950; Follis, 1951; Bodansky and Money, 1954; Cannon et al., 1956; Faludi et al., 1964). Jennings and Ferguson (1984) reported that treatment of rats for 5 days with 1.5 mg/Kg DXM decreased body weight by 14% though liver weight or serum concentration of T_4 and T_3 were unaffected. Ober and Prachlad (1987) reported thymic lympholysis in adrenalectomized rats treated with DXM. Plant and Zorub (1984) reported decreased growth rate in adrenalectomized monkeys. Wilson et al. (1988) reported a markedly diminished weight gain in infants treated with DXM for 7 days. Dupouy et al. (1987) in their study of fetuses of rats given DXM acetate in drinking water reported a drastic reduction in body weight and severe atrophy of adrenals of fetuses. Chronic treatment of rats with DXM brought about significant decrease in the weight of adrenal gland (De Greef and Van der Schoot, 1987). Aoyama et al. (1987)

reported that DXM treatment in adult as well as young rats decreased body weight gain, atrophied the thymus and adrenals and also elevated the level of total blood cholesterol. Chronic treatment of rats with DXM for 30 days induced body weight gain and, a food intake decrease verses controls (Alario et al., 1987). They also reported adrenal atrophy with a decrease in DNA content in DXM treated animals. Bransome (1968) has shown that DXM produced a significant decrease in adrenocortical DNA. Wright and Appleton (1972) reported that in prepubertal rats, DXM inhibited adrenocortical cell proliferation by acting on a specific point in the cell cycle. Steiss et al. (1989) in their study in suckling rats treated with high dose of DXM reported a significantly reduced body weight gain.

The effects of body weight loss and growth inhibition have been noted in birds during cortisol treatment (Kowalewsky, 1962). The growth depressing properties of glucocorticoids have also been demonstrated in chicks (Gavora and Kondra, 1970; Gavora and Hodgson, 1970). Injection of corticosterone to chicks and castrated pheasants has been reported to depress body weight and to increase carcass fat content (Baum and Meyer, 1960; Nagra and Meyer, 1963; Nagra et al., 1963). Magdi and Hutson (1974) reported decreased body wieght in their studies on three week old male chicks treated with dexamethasone and corticosterone. They further showed that dexamethasone caused a significant reduction in ^{22}Na retention while corticosterone treatment lowered adrenal weight. Corticosterone markedly depressed growth and increased feed consumption and fat accumulation in the carcass as well as in the

liver of broiler chicks (Bartov et al., 1980a). Injections of steroids decreased growth rate (Sato and Glick, 1970) and lymphoid numbers and size (Dougherty et al., 1964). De la Cruz et al. (1981) reported that cortisol and corticosterone (4 mg/100 g b.w. for 7 days) treatment in laying quails decreased body weight and increased uric acid excretion, liver weight and hepatic glycogen content. Gross et al. (1980) reported that feeding chickens with corticosterone (5-80 ppm) for 10 days resulted in dose related decrease in weight gain, reduced size of lymphoid organs - spleen, thymus and bursa of Fabricius - testis, adrenals and breast muscle; and increased body and liver fat. The influence of cortisol has been observed in the chick (Bellamy and Leonard, 1965; Adams, 1968) where it caused an inhibition of growth. With high doses, animals lose weight; the liver however continued to increase in size. The size increase could be due to uptake of extra material, rather than any increase in growth rate (Mangnall and Bartley, 1973). Brake et al. (1988) reported reduction in body weight, relative bursa and spleen weights while adrenal weights increased significantly in 6 week old chicks treated with cortisol. Saadoun et al. (1987) showed that daily injections of two doses of corticosterone (1 or 5 mg/bird), depressed body weight gain, increased liver lipid and abdominal fat along with a dose-dependent increase in uric acid, glucose and insulin in genetically selected lines of fat (FL) and lean (LL) chickens.

Most of the above studies have principally concentrated on the influence of corticosterone on growth of organs as well as chick as a whole and

on carcass fat and lymphoid structures. In spite of the known influence of adrenal steroids on various facets of metabolism, its functional involvement in post-hatched chick development has not been studied. Hence in the present study, an attempt has been made to assess the effect of functional manipulation of the adrenal cortex on metabolic physiology and histophysiology of the testis during the first month of post-hatched development. The significance of this aspect is understandable in the light of the reported age specific alterations in the circulating levels of corticosterone (Carsia et al., 1987) and its increased secretion at the time of hatch and its sensitivity to modulations by the prevailing intrinsic and extrinsic factors (see Kühn et al., 1984). The influence of corticosteroids on reproductive functioning in mammals and birds has been documented (Leroy, 1952; Dulin, 1955; Boas, 1958; Conner, 1959; van Thienhoven, 1961; Soule and Assenmacher, 1966; Daniel and Assenmacher, 1969; Assenmacher and Boissin, 1972; Martin, 1973; Soliman and Hutson, 1974; Bengt, 1979; Datta et al., 1978; Chathurvedi and Thapliyal, 1978, 1980; Moreng et al., 1980; Juniewicz et al., 1987). However, an evaluation of adrenal-testis relationship during post-hatched phase of development characterized by growth and maturation of the gonads has not been looked into. The present study has in this context made an attempt on this line to evaluate histoarchitectural changes and histochemical alterations in steroid dehydrogenases of testis under functional manipulation of the adrenal cortex. Functional manipulation has been brought about by chronic treatment of chicks from the day of hatch till 30 days with

dexamethasone (DXM) and corticosterone (CORT). In many studies in mammals and birds, DXM has been used as a corticosterone mimic (Magdi and Hutson, 1974; Radke et al., 1985; Dave and Eskay, 1986; Harrelson and McEwen, 1987; Ranz et al., 1987; Stefanelli et al., 1987; Entrikin et al., 1988). Pertinently, number of studies have revealed the adrenocortical suppressive action of DXM by way of its inhibitory action on the synthesis and release of ACTH in various species of animals (D'Angelo, 1966; Chowers et al., 1967; Yates, 1967; Dallman and Yates, 1968; Fleisher and Battenbee, 1968; Kendall and Allen, 1968; Purves and Sirett, 1968; Arimura et al., 1969; Russel et al., 1969; Sirett and Gibbs, 1969; de Kloet et al., 1974; Obara et al., 1984; Macharg et al., 1985; Radke et al., 1985; Smoak and Birrenkott, 1986; Carnes et al., 1987; De Greef and Van der Schoot, 1987; Dupouy et al., 1987; Kloeti et al., 1987; Juniewicz et al., 1987; Medleau et al., 1987; Smith and Feldman, 1987; Brody and Black, 1988; Brooks et al., 1988; Katano, 1988; Wilson et al., 1988).

Based on previous studies from this laboratory on pigeon (Ayyar and Ramachandran, 1987) and pilot experiments on chicks, it was established that DXM in low doses served as effective adrenocortical suppressant thereby capable of inducing hypocorticalism. Hence in the present investigations, DXM and corticosterone have been used to induce chronic functional hypo- and hypercorticalism respectively in freshly hatched chicks by treating them for 30 days. Aspects studied include morphometric changes of organs and histological profile of the testis, adrenal and thyroid (Chapter II), alterations in, carbohydrate metabolism (as

evaluated by changes in tissue glycogen content, blood glucose, phosphorylase and glucose-6-phosphatase activities Chapter III), tissue protein and ascorbic acid contents (Chapter IV), lipid metabolism, as evaluated by changes in serum and tissue lipid and cholesterol contents (Chapter V), enzymes of glycolysis and TCA cycle (Chapter VI), other enzymes (Chapter VII), Steroid dehydrogenases in testis (Chapter VIII) and, glucose tolerance and insulin, glucagon and adrenaline response tests (Chapter IX). The findings of the above evaluations taken as a whole have provided evidence for a definite role of adrenal corticosteroids during post-natal growth in the development and establishment of adult homeostatic physiological attributes and also testicular development and metabolism.