General Discussion
Physical exercises form an important metabolic stress on the animal body (Moorthy et al., 1981; Pedersen et al., 1981). During physical exercises dopamine level of the brain drops owing to its mobilization towards the synthesis of norepinephrine, a neurotransmitter. In view of decreased dopamine level, inhibition on the lactotrophs will be released leading to activation of lactotrophs resulting into higher prolactin concentration in the body (MacLeod, 1976; Massara et al., 1980). Increased levels of prolactin have been widely reported in the exercising animals including man (Shangold et al., 1981; Cavanaugh et al., 1983; Hale et al., 1983; Borer et al., 1983). The increase in prolactin concentration results into blocking of gonadotrophins and thereby hypogonadotropinism results (Bohnet et al., 1976; L'Hermite et al., 1978; Lamberts et al., 1981).

In exercising animals hypogonadotropinism has been extensively reported (Boren et al., 1981; Bovden et al., 1982; Hale et al., 1983; Axelsson, 1987). Thus by inducing physical exercises animals with hypogonadotropinism and hyperprolactinemia can be developed. In the present experimentation such an attempt has been made to elucidate the mechanisms underlying the female reproductive physiology of albino rats under induced hypogonadotropinism and hyperprolactinemia by utilizing the swimming exercise as a tool. Thus the animal model with endocrinological significance at hypothalamo-hypophysial-gonadal axis can be developed
through the mediation of physical exercises and at the same
time without administering any hormone factors.

The exercised rats recorded irregular estrous cycles
with extended luteal phase. The length of the cycle was
remarkably extended after 30 days of swimming exercise,
which was correlated to insufficient gonadotropin circulation
in the body. Extended luteal phase was correlated to
high prolactin circulation in the body. Similar reports of
extended luteal phase of different animals are available in
the literature (Przekop et al., 1984; Rama Prasad et al.,
1986; Axelson, 1987). Besides the luteal phase, the
follicular phase consisting of proestrus and estrus stages
has been considerably extended and it was correlated to in-
sufficient gonadotropins in circulation. In women atheletes,
the follicular phase was extended considerably (Shangold et
al., 1981; Loucks and Horvath, 1985). Thus physical
exercises induce irregularities in sexual cycles. In case
high prolactin concentration was responsible for such
irregularities, modulations of circulating prolactin levels
should invariably bring about suitable alterations in
estrous cycle. In prolactin administered exercised (EP)
animals owing to higher prolactin concentration further
extension of estrous cycle was witnessed, indicating that
prolactin was resonsible for inducing irregularities in the
operation of sexual cycles. In bromocriptine administered
exercised (EB) animals owing to low prolactin concentration,
the operation of estrous cycle was significantly activated and it was more or less at the control level even in the exercised group of animals after bromocriptine administration. Thus prolactin levels in circulation seem to be important for the synchrony in the estrous cycles of rat and this observation has close correlation with earlier findings (Selye, 1939; Meites, 1974; Borer et al., 1983; Rama Prasad et al., 1986). During the periods of gestation and lactation the prolactin level in circulation will be high with extended periods of sexual cycles (Marrow et al., 1969; Tyson et al., 1972; Meites, 1974; Biswas and Rodeck, 1976). In view of these observations and also due to the fact that vaginal cytology was the true reflection of the ovarian activity, an attempt has been made to analyse the changes in the ovary and accessory sex organs after subjecting the animals to swimming exercises.

The ovary of the control animal at the estrus stage had rough surface with well developed follicles indicating normal pattern of follicular development. In normal exercised (NE) animals the surface of the ovary was smooth with ill developed follicles suggesting ovarian inactivation towards follicular development which can be attributed to insufficient gonadotropins on one side and elevated prolactin levels on the other. In EP animals, where exogenous prolactin was administered, the ovary had complete smooth surface without indication of follicular development. Thus
higher prolactin concentration was found to be inhibiting the follicular development in exercised rats. In EB animals the surface of the ovary was rough with well developed follicles. In view of these observations it can be suggested that the exercise effect on the ovary appears to be mediated through the prolactin. Similar observations can be witnessed in the sections of the ovary. The control animal ovary had all developmental stages of the follicles indicating active nature of the ovary at the estrus stage. In normal exercised (NE) animals the ovary taken at the same stage i.e. estrus stage was devoid of all the developmental stages of the follicles. It had only atretic follicles and regressing corpora lutea. This observation indicates inactive condition of the ovary with follicular atresia which can be attributed to high prolactin concentration in the body. When exogenous prolactin was administered to the exercised (EP) animals, only atretic follicles were witnessed in the ovary even during estrus stage. However, in EB animals where bromocriptine was administered to induce hypoprolactinemia, the ovary had all the developing stages of the follicles. Thus prolactin seems to be one of the factors which was responsible for the ovarian inactivation after the exercise programme. This type of inactivation of ovarian follicular development through the mediation of prolactin was reported widely during gestation and lactation (Zarate et al. 1972; Tyson et al. 1972). Thus the exercise programme seems to be synonymous with that of lactation period since both the
conditions were inhibiting the ovarian follicular development through the mediation of prolactin.

In view of inactive condition of the ovary for follicular development during the course of exercise, impaired steroidogenic function can also be expected. The total cholesterol content of the ovary of NE and EP animals was markedly elevated suggesting the possibility of its suppressed mobilization towards steroidogenic function. The activity level of $3\beta$ HSD was significantly suppressed in the ovaries of these animals confirming such a possibility of decreased cholesterol mobilization into sex steroid synthesis. This pattern can be attributed to insufficient gonadotropins and higher prolactin levels observed in the present study in NE and EP animals. But $3\beta$ HSD activity was increased in EB animal ovary suggesting activated mobilization of cholesterol into steroidogenesis under the conditions of hypoprolactinemia in exercised animals. In NE and EP animal ovaries $17\beta$ HSD activity was elevated over the control level and thereby increased testosterone formation can be expected in them. This observation was confirmed by personal observations on the elevated plasma testosterone level of these animals with activated androgen-dependent serum marker enzymes such as acid phosphatase. The aromatase activity which leads to the formation of estrogens was shown to be inhibited under the conditions of higher prolactin levels (Tsai-Morris et al., 1983; Munabi et al., 1984).
Hence diversion of steroid intermediaries towards testosterone formation with suppressed estrogenesis can be expected in the ovaries of NE and EP animals. The increased testosterone level can be due to its release not only from the ovary but also from adrenal cortex. In athletic women interstitial cells of the ovary seem to be activated towards the testosterone synthesis (Keizer et al., 1984; Locks and Horvath, 1985). Thus ovarian testosterone formation increases. Physical exercises form stress condition on the animals (Moorthy et al., 1981) and stress condition favours the release of ACTH from the hypophysis (Few et al., 1975; Rougier et al., 1980), consequently ACTH stimulates the formation of androgens in the adrenal cortex (Baker et al., 1982; Keizer et al., 1984). Thus the adrenal cortical region also will be responsible for the elevation of androgens in the exercised animals. This observation will be further confirmed by the observation of decreased estrogen levels and elevated testosterone levels in these animals (personal observations). Interestingly, the ovaries of EB animals had elevated 3β HSD activity with suppressed 17β HSD activity which denotes the mobilization of steroid intermediaries into estrogenesis and activated follicular development. Thus the steroidogenic function of the ovary was suppressed in NE and EP animals and activated in the EB animals. Exercise-induced hyperprolactinemia, hypogonadotropinism and lower estrogen circulation with higher testosterone levels were evident in the present study.
In view of above endocrinological changes, suitable modulations in the functions of the reproductive tissues can be expected. Hence the intermediary metabolic events of reproductive tissues were analysed in NE, EP, EB and control animals.

The tissue somatic indices of the reproductive organs such as ovary, vagina were markedly lower in exercised animals in comparison to the control animals, indicating the insufficiency of gonadotropins and gonadal hormones. However, the uterine TSI was higher owing to accumulation of water. The dry weight of all the tissues was decreased with elevated water content which may denote the prevalence of higher hydrolytic activities in the tissues of NE and EP animals. However, such a situation seem to be minimum in EB animals. The levels of organic constituents were markedly lower in the exercised group of animals in comparison to the controls, supporting the possibility of higher hydrolytic activities in these tissues. Such a condition of lower levels of organic components in the reproductive tissues form an adverse situation for their proper function. Both ovary and vagina had accumulation of lipids, which can be correlated to low estrogen levels, because estrogens will be essential for the mobilization of lipids in these tissues (Bibbo et al., 1969; Miyamoto et al., 1984; Venkatarami Reddy et al., 1984). The hepatic tissue of the exercised group of animals also recorded lower levels of organic
components, probably due to their mobilization towards energy requirements of the exercising muscles. Thus the reproductive tissues contained low levels of organic components which might be a limiting factor for the proper functioning of reproductive system. Thus the hormone imbalances induced by the exercise seem to be responsible for the development of non-congenial metabolic events in reproductive tissues.

The ovarian glycogen level was markedly decreased in the NE and EP animals. In view of essentiality of glycogen towards follicular development, low glycogen content of the tissue might be a limiting factor for the proper follicular development. The estrogen dependent metabolic events of the carbohydrates were found to be inhibited with lesser yield of energy for the ovarian function. Similarly, the glycogen metabolic events of accessory sex organs indicated non-congenial conditions for their proper functioning in NE and EP animals. This type of metabolic events observed in the reproductive tissues of exercised animals have been widely reported in the tissues subjected to atrophic conditions (Anderson and Alexander, 1979; Manohar Reddy et al., 1984; Gillian and Bell, 1982). Thus reproductive tissue metabolic events pertaining to carbohydrates were impaired probably due to insufficient estrogen levels in circulation.
The lipid components such as triacyl glycerol, free fatty acids and cholesterol have been accumulated in the ovary, which denotes the probable impairment at the lipid metabolism of the tissue, which can be attributed to the insufficiency of estrogen level. Similarly, the vagina also recorded accumulation of glycerol, free fatty acids, phospholipids and cholesterol, which was indicative of improper functioning of vaginal tissue, probably due to estrogen deficiency.

The serum glucose level was markedly decreased in exercised group of rats with accumulation of lactic acid. Since reproductive tissues largely depend upon serum glucose as a source of carbohydrates, the existing condition in the exercised group of animals was indicative of prevalence of adverse conditions for the proper functioning of reproductive organs. Acid phosphatase activity which has been androgen-dependent was increased in the serum of exercised group of animals which was in close consonance with the observed elevation in the testosterone level of the serum (personal observation). However, estrogen-dependent enzyme activity, alkaline phosphatase was inhibited, which was correlated with the decreased estrogen level of the serum. Several organic components which form the reserves in the serum such as triacyl glycerol, free fatty acids, cholesterol and $\alpha, \beta$-globulins have been found to be in depleted levels in the serum of exercised animals. Thus the exercised
female albino rats had depleted level of organic components in the serum which will be a limiting factor for the reproductive tissue functioning.

In general, it can be concluded that the swimming exercise was inducing imbalances at the hormone levels of hypophysial-gonadal axis leading to hypogonadotropinism, hyperprolactinemia and insufficient gonadal hormones in circulation. The existence of hyperprolactinemic conditions seem to be responsible for inactivation of reproductive organs. Thus physical exercises seem to decrease the fertility of the animals, probably through the mediation of hypophysial prolactin. Hence the effects of physical exercises can be exploited towards the fertility regulation of the animals.