***Original Research Article***

# A study on the pattern of genetic inheritance of polycystic ovarian syndrome

**Aims:** Inheritance of polycystic ovary syndrome (PCOS) is still a controversy. Our study aims to analyze the family history of PCOS features and related metabolic disturbances including the male members to determine the mode of their inheritance.

**Study design:** A cross sectional study with convenient sampling.
**Place and Duration of Study:** Department of Medicine, Kasturba Medical College, Mangalore between 2009 and 2012.
**Methodology:** Demographic data such as body weight and age was recorded. Menstrual, obstetric and medical history of 85 PCOS females was collected. Presence of metabolic syndrome (MetS) was confirmed. Blood pressure and waist circumference were measured. Biochemical and hormonal estimations were done. Relevant information required for the study of 604 members of first and second generation relatives was collected. SPSS (version 17.0) was used to analyze the numerical data. Univariate analysis was done by using one-way ANOVA and *Kruskal-Wallis test* (non-parametric). $P < 0.05$ was considered statistically significant. Segregation analysis was carried out to determine the pattern of inheritance.
**Results:** Seventy eight percent of the PCOS patients were either overweight or obese and 98% of them had hirsutism. Approximately, 33% of them had MetS which was higher in the first generation (62%) of PCOS relatives. An equal transmission of MetS characteristics from the paternal and maternal side indicated that it was not X-linked inheritance. Segregation analysis of nine families PCOS of patients suggested that MetS inheritance was autosomal dominant although PCOS inheritance was not.
**Conclusion:** PCOS daughters come from families of MetS suggesting that parental MetS features may be related to the occurrence of PCOS in their off-springs.

***Key words:*** *Polycystic ovary syndrome, Obesity, Metabolic syndrome, Inheritance*

## 1. INTRODUCTION

Polycystic ovary syndrome (PCOS) affects 5-10 % of the women in reproductive age group. An increase in the prevalence of PCOS among Indians is also a great concern. Estimates of PCOS in migrant Indians have been placed at 52% level and about 37% among the north Indian women have been reported to suffer from PCOS [1,2]. Gynecologists from Hyderabad in South India believe that 25% of the women visiting them do suffer from PCOS [3].

Genetic factors play an important role in the development of PCOS, but studies in this regard in India is scanty. Maitra *et al* [4]. conducted mutational analysis of CPY1A1 and leptin as genetic determinants of hyperandrogenicity and obesity in PCOS. A recent study has clearly demonstrated the heritable aspects of obesity and insulin resistance in PCOS even in infancy and also in the male progeny [5,6]. However, studies showing familial clustering of PCOS cases, greater concordance of symptoms of PCOS in identical twins, heritability of endocrine and metabolic features of PCOS are all compelling evidences that strongly suggest the involvement of genetic mechanism [7]. Although, search for candidate genes in PCOS has yielded some positive results, the controversy on the mode of inheritance (eg. autosomal dominance, modified autosomal dominance, X-linked, polygenic, oligogenic or multifactorial) still persists [8]. Therefore, we propose this study on the family history of PCOS subjects at length including male members, not only for PCOS but also for its related metabolic conditions to determine the pattern of inheritance of PCOS.

## 2. MATERIAL AND METHODS

By convenient sampling, 85 post-pubertal female subjects, preferably with a large family size, diagnosed with PCOS were inducted for the study. Institute's research ethical committee approved the study. Written consent was obtained from each of the 85 participants who were given a clear explanation of the purpose of the study. The diagnosis of PCOS was made according to the ESHRE/ASRM criteria based on the presence of two of the three following criteria: oligo- and/or anovulation (menstrual dysfunction), clinical and/or biochemical signs of hyperandrogenism and polycystic ovaries (PCO) at ultrasonogram [9].

All patients were questioned in detail regarding birth history, menstrual, obstetric and medical history. Medical history of diabetes mellitus, hypertension, cardiovascular diseases, dyslipidemia and malignancies of breast/ovary/endometrium and thyroid disorders were recorded. Also, a standard questionnaire was used to document personal history such as troublesome acne, excess sweating, excess body hair (hirsutism), male pattern hair loss, acanthosis nigricans, buffalo hump and goiter.

As a routine, *in vitro* tests for direct quantitative determination of fasting blood sugar (FBS), postprandial blood sugar (PPBS), total cholesterol (TC), triglyceride (TG) and high density lipoprotein (HDL-C) was carried out on Roche-Hitachi fully automated random access chemistry analyser (RH model P-800). Relevant hormones evaluation was conducted by Electrochemiluminescence immunoassay (ECLIA) on Cobase 411 modular immunoassay analyser. However, we are not providing any results or discussing this part of the data as it is not relevant for this communication.

Prevalence of metabolic syndrome (MetS) was also assessed by ATP-III standards [10,11]. Accordingly, MetS was diagnosed in subjects presenting with at least three of five of the following criteria: increased waist circumference (>80 cm), low serum HDL-C (<50 mg/dl in women), increased serum TG (>150 mg/dl), increased blood pressure (>130/>85 mm Hg) and high FBS (>100 mg/dl).

Relevant data of six hundred and four (604) family members of the PCOS patients was gathered from all 85 PCOS patients for analysis of the pattern of inheritance of PCOS. They were questioned for PCOS conditions and related MetS features in their first and second degree relatives and the information was recorded.

A statistical software package was used to analyse the numerical data (SPSS version 17.0). Univariate analysis was done by using one-way ANOVA and *Kruskal-Wallis test* (non-

parametric). $P < 0.05$ was considered statistically significant. The results are expressed as Mean ± SD. Segregation analysis was carried out to determine the inheritance of PCOS.

## 3. RESULTS

The mean age of the PCOS subjects in this study was 27.9±7.1 years. The average age of onset of menarche was 12.8±1.5 years. Body mass index (BMI) based grouping (for Asians) of the PCOS patients is shown in Table 1 along with blood pressure and waist circumference data. It was obvious that 34%, 44% and a very small group of the subjects were in overweight, obese and underweight categories, respectively.

**Table1. Body mass index (BMI), waist circumference (WC) and blood pressure (BP) of subjects grouped on BMI basis.**

| **BMI Range** | **n** | **%** | **BMI** (Kg/m$^2$) | **WC** (cm) | **Systolic BP** (mmHg) | **Diastolic BP** (mmHg) |
|---|---|---|---|---|---|---|
| <18.5 (Underweight) | 3 | 3.5 | 17.0 ±0.8 | 63.7±8.0 | 110.0±17.3 | 66.7±11.5 |
| 18.5-22.9 (Normal) | 16 | 19 | 20.9 ±1.4 | 75.4±8.8 | 126.2±6.1 | 79.3±7.7 |
| 23-27.4 (Overweight) | 29 | 34 | 25.6 ±1.4 | 81.4±6.5 | 124.4±9.8 | 78.2±6.0 |
| 27.5-34.9 (Obese I) | 32 | 38 | 30.6 ±1.8 | 90.0±9.4 | 133.0±12.7 | 83.1±8.5 |
| >35 (Obese II) | 5 | 6 | 38.9 ±4.1 | 111.2±19.9 | 140.0±20.0 | 88.0±8.3 |
| | | | | p< 0.000 | p< 0.001 | p< 0.001 |

Figure 1 represents certain clinical conditions suffered by the PCOS patients. More than 1/3 of the patients had shown hypothyroidism and MetS features and a considerable number of them had diabetes mellitus, hypertension and dyslipidemia. More than 80% of the subjects had gained extra body weight at puberty.

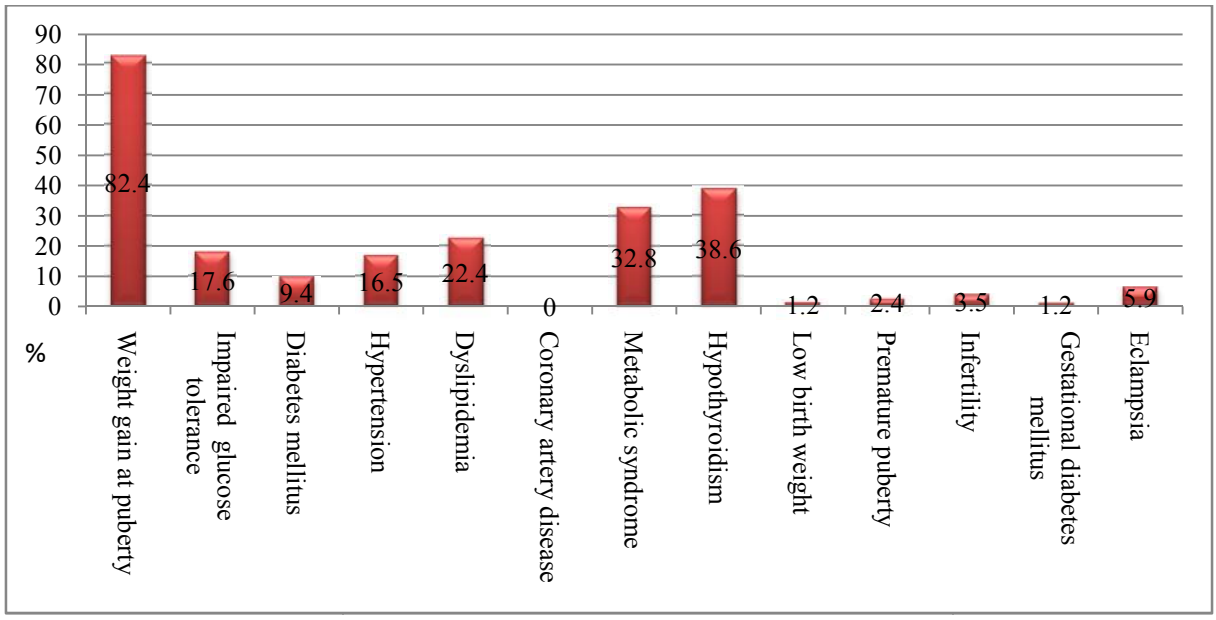


**Figure1. Clinical conditions (%) associated with the PCOS patients**

Figure 2 shows the clinical features of 85 PCOS patients where 98% of them had hirsutism, a characteristic of clinical hyperandrogenemia resulting in PCOS.

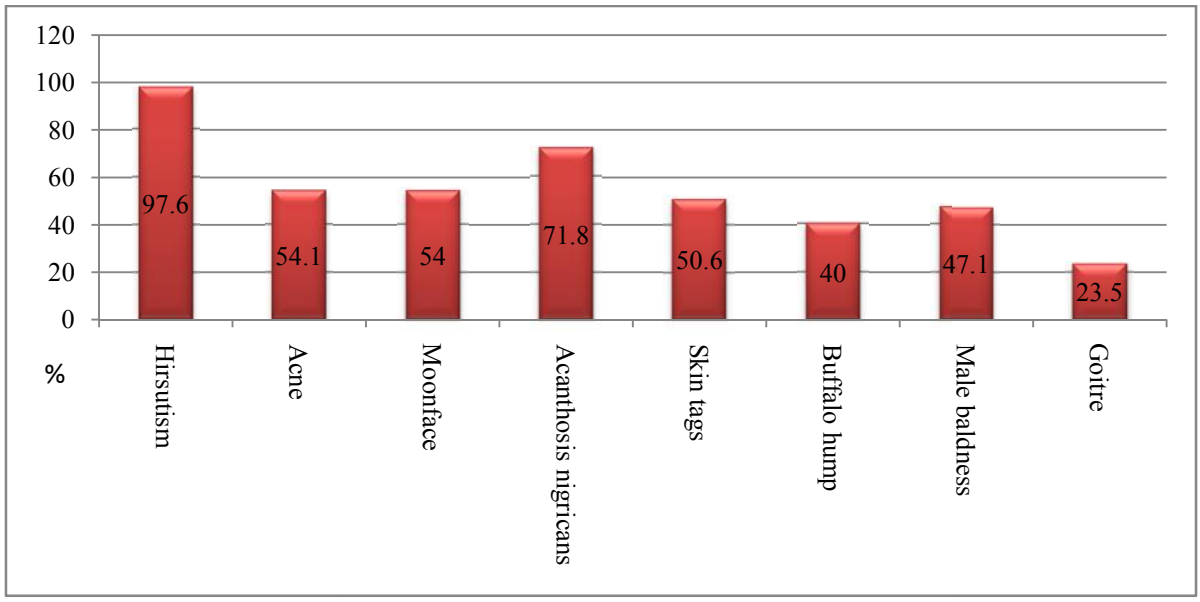


**Figure 2. Clinical features (%) of the PCOS patients.**

Figure 3 depicts the prevalence of PCOS and related MetS characteristics and coronary artery disease (%) in the first and second degree relatives of the PCOS patients in this study. The prevalence of all the conditions was relatively less in second degree relatives as compared to the first.

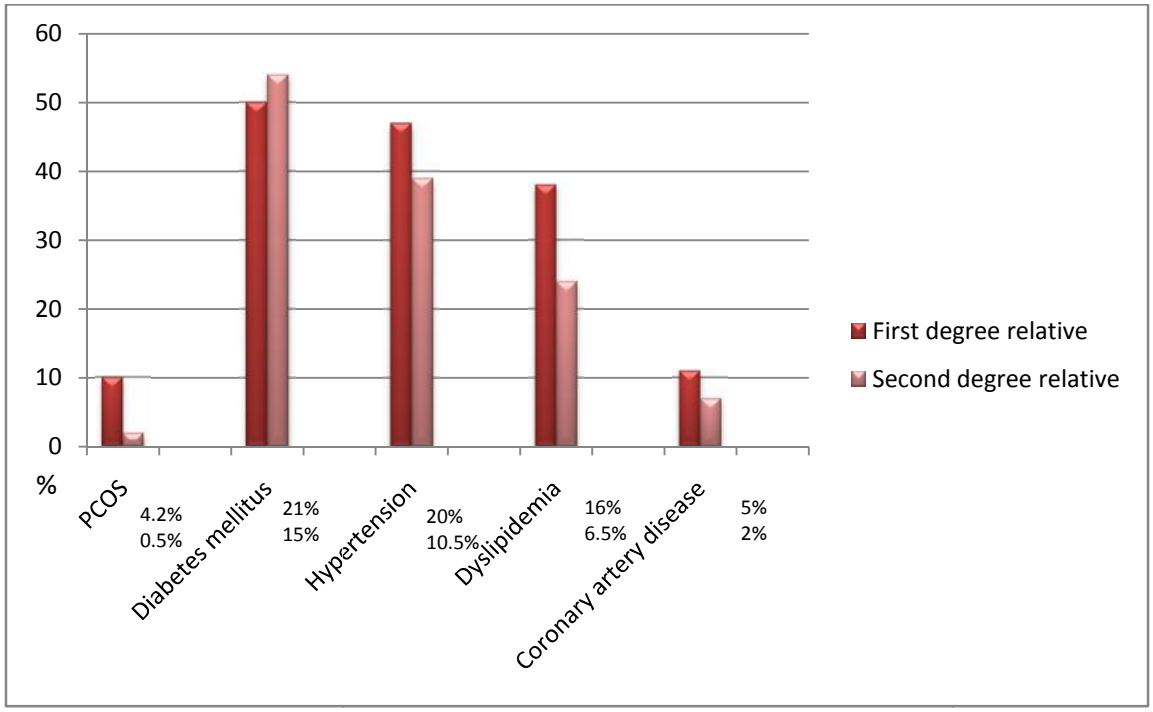


**Figure 3. Frequency of clinical conditions (%) in first and second degree relatives of PCOS patients.**

Table 2 shows the presence of some clinical conditions in the relatives of the PCOS subjects in detail as reported by them.

**Table 2. Distribution of polycystic ovary syndrome (PCOS) patients' relatives with of some clinical conditions; CAD = coronary artery disease.**

| PCOS patients' relatives | n | Diabetes mellitus | Hypertension | Dyslipidemia/Obesity | CAD | PCOS |
|---|---|---|---|---|---|---|
| | | n (%) | n (%) | n (%) | n (%) | |
| Father | 65 | 23 (35.4) | 23 (35.4) | 14 (21.6) | 7 (10.8) | - |
| Mother | 65 | 20 (30.8) | 18 (27.7) | 13 (20.0) | 2 (3.1) | 5 |
| Brother | 57 | 4 (7.0) | 3 (5.3) | 3 (5.3) | 2 (3.5) | - |
| Sister | 49 | 3 (6.1) | 3 (6.1) | 8 (16.3) | - | 5 |
| Father's Brother | 28 | 15 (53.6) | 5 (17.9) | 7 (25.0) | 3 (10.7) | - |
| Father's Sister | 25 | 5 (20.0) | 5 (20.0) | 5 (20.0) | - | - |
| Mother's Brother | 21 | 8 (38.1) | 4 (19.0) | 1 (4.8) | 1 (4.8) | - |
| Mother's Sister | 34 | 9 (26.5) | 6 (17.4) | 8 (23.5) | 1 (2.9) | - |
| Grand Father (P) | 65 | 3 (4.6) | 6 (9.2) | 1 (1.5) | 1 (1.5) | - |
| Grand Mother(P) | 65 | 4 (6.2) | 3 (4.6) | - | - | - |
| Grand Father (M) | 65 | 4 (6.2) | 3 (4.6) | 1 (1.5) | 1 (1.5) | - |
| Grand Mother(M) | 65 | 6 (9.2) | 7 (10.8) | 1 (1.5) | - | - |

Family pedigree analysis of 9 PCOS subjects with large families in our study showed that the mothers of three PCOS probands had PCOS. We also found PCOS in the siblings of three of the PCOS subjects with no history of PCOS in their mothers. Moreover, we also found MetS features being present in the parents and in most of the second degree family members in three of the PCOS probands who had one or more associated MetS characteristics at an early age. The segregation ratio (observed:expected) was consistent with autosomal dominant inheritance in all these cases. Figures 4a and 4b represents a sample of the pedigree tree of two of our PCOS patients.

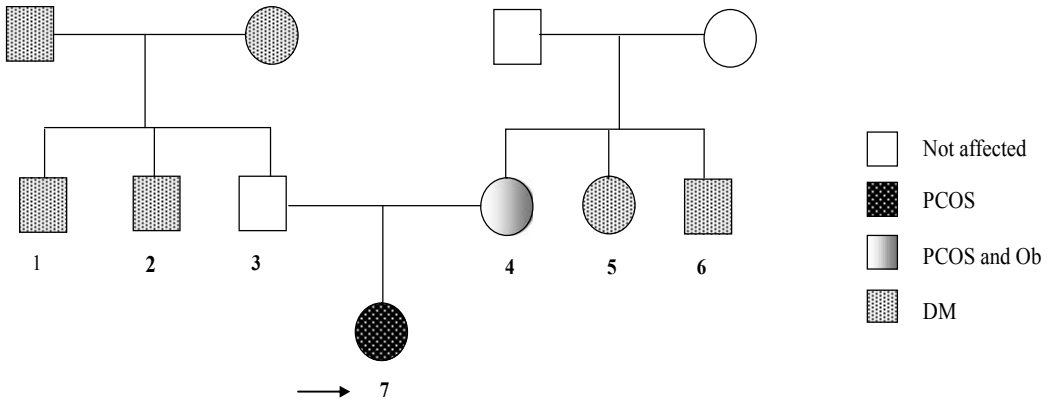


**Figure 4a**. The proband 7 in this family had polycystic ovary syndrome (PCOS). The proband's mother 4 had PCOS and obesity (Ob). Proband's paternal uncle (1) and maternal aunt (5) had diabetes mellitus (DM). Paternal grand parents had DM.

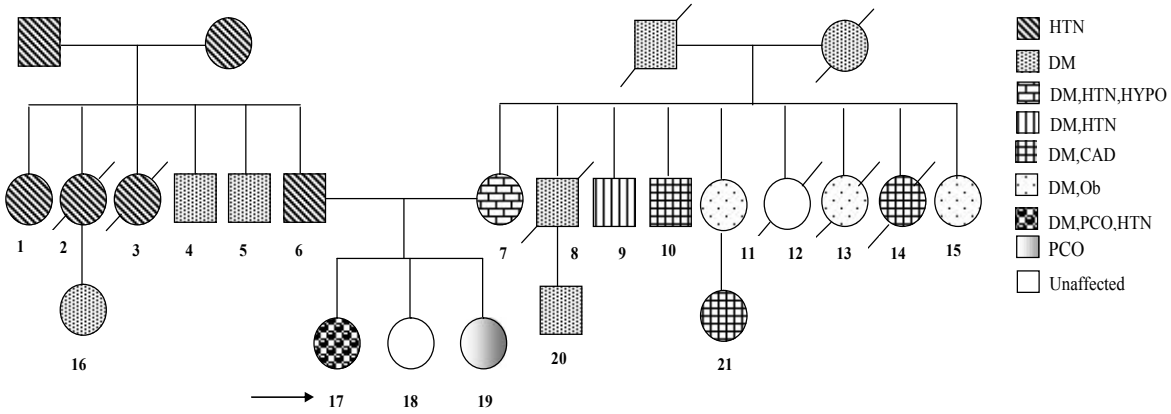


**Figure 4 b**. In this large family, the proband 17 had polycystic ovary (PCO), obesity (Ob), hypertension (HTN) and infertility (INF). One of her sisters (19) had PCO and Ob. The proband's mother (7) suffered from diabetes mellitus (DM), HTN and hypothyroidism (HYPO) and father (6) had HTN. DM was found in three maternal uncles (8,9,10) and three maternal aunts (11,13,15) of the proband. All maternal aunts were obese and two of them (11,12) were dead due to breast carcinoma. Proband's maternal grandparents had DM and paternal grandparents suffered from HTN. Three paternal aunts (1,2,3) had HTN and two paternal uncles (4,5) had DM. The off-springs of paternal aunt and maternal uncle (16, 21) also had features of metabolic syndrome (MetS).

## 4. DISCUSSION

PCOS has become a 'family affair'. Susceptibility to inheritance of PCOS seems to be equally probable from both the maternal and paternal side of the family. It is estimated that a woman's risk for developing PCOS is higher, if she has an affected sister, but at a lower risk, if other family members are affected [12]. Though, the genetic studies have not yet determined the pattern of heredity, most of the family studies have shown a simple Mendelian pattern of inheritance consistent with an autosomal dominant or X-linked pattern of inheritance [13]. Positive findings have been reported with candidate genes involved in both association and linkage studies [14]. However, twin studies on PCOS have revealed an incidence of 50% that suggest a complex pattern of polygenic inheritance [15]. On the other hand, a large family study (St Mary's family) from Franks' group concluded that PCOS is inherited on an oligogenic basis [16].

The high incidence of PCOS in first degree relatives of the PCOS affected members in some studies [13,15,17-18]. suggests a dominant pattern of inheritance based on the assumption that at least 50% of the siblings of the PCOS probands are affected with the disorder [13]. A few studies over the last 20 years have drawn attention to the phenomenon of familial clustering of PCOS cases [19-23]. In some of these studies, segregation analysis gave results that were consistent with autosomal dominant inheritance [19,22-23]. In one study by Govind *et al.,* that included 29 families of PCOS probands, segregation analysis showed that 52% of the mothers, 21% of the fathers, 66% of the sisters and 22% of brothers were affected with PCOS features that supported an autosomal dominant inheritance pattern of PCOS in families, perhaps caused by the same gene [13]. In another study, the prevalence of polycystic ovaries among siblings was too high to be explained by a simple dominant model [21]. Legro *et al*.,studied 80 PCOS probands and reported that 36 of 80 (45%) sisters were affected on the basis of hyperandrogenemia [24]. Another study has reported a prevalence of 50% hirsutism cases among the affected sisters of PCOS [17]. They also have shown that some characteristics of PCOS inherited were in different proportion; e.g. PCO 73%, hyperandrogenemia 87% and hyperinsulinemia 66%. A report by Givens *et al*., has suggested an X-linked mode [20]. Wilroy *et al*.,showed that 47% of female offspring of PCOS patients in their study were affected. Among the offspring of males with an elevated LH/FSH ratio, 89% of daughters were affected [25]. The finding is thus consistent with X-linked dominant inheritance.

Natasha *et al* [26] have tested the hypotheses that parental MetS would be related to the PCOS phenotype in their offspring and that MetS prevalence would be increased in adolescents with PCOS. Thirty-six adolescent girls with PCOS and their first degree relatives were evaluated for MetS characteristics in their study concluded that familial factors related to paternal MetS seem to be fundamental to the pathogenesis of PCOS.

Our study revealed that a total of 10 members from the families of 85 PCOS probands, referred to as first generation and two members from the second generation had PCOS features. We also diagnosed MetS in nearly one third of them. However, when we analyzed MetS characteristics associated with PCOS, we found a very high association suggesting autosomal dominant transmission. Break up data of the family history showed nearly 20% of the fathers and 20% of mothers of PCOS probands having diabetes mellitus, hypertension obesity/dyslipidemia each. Among the siblings of PCOS probands, nearly 10% of them had diabetes mellitus, hypertension, and obesity/dyslipidemia. However, among the uncles, aunts and grandparents of our PCOS probands, the percentage of diabetes mellitus, hypertension, and obesity/dyslipidemia was less than 10%. When any one of the MetS

features such as diabetes mellitus , hypertension or dyslipidemia was considered, we found a prevalence of 62% (146/236) and 33% (124/368) among the first degree and second degree relatives of our PCOS subjects respectively. This proves the autosomal dominant inheritance of the MetS features in PCOS.

## 5. CONCLUSION

The problems in genetic studies are manifold [15,27-28]. Although, several positive reports are available, no gene or genes is universally accepted as important in the pathogenesis of PCOS, though the numbers of candidate genes are steadily increasing. The current view supports the notion that PCOS is likely to represent a complex oligogenic trait with multiple genetic defects [29]. Despite these shortcomings, the study of familial aggregates has consistently suggested that the mode of inheritance to be dominant.

In our study there was an equal transmission of MetS characteristics from the paternal and maternal side indicating that it is not X- linked inheritance. Although, our results do not demonstrate the autosomal dominant pattern of inheritance of PCOS, the first degree relatives of the PCOS probands had metabolic characteristics indicating autosomal pattern of inheritance, suggesting that parental MetS features may be related to their off-springs. Such manifestations may be influenced by age, diet and environmental factors. In this context, the suggestion that PCOS should be treated as a quantitative trait disorder which does not necessarily imply a truly polygenic aetiology because it would be possible to explain the variable phenotype on the basis of a small number of key causative genes (a so-called oligogenic basis for disease) involved in androgen secretion and insulin secretion/action in conjunction with environmental, particularly nutritional factors should be noted [30].

## REFERENCES

1. Allahbadia GN, Merchant R. Ploycystic ovary syndrome in the Indian continent. Semin Reprod Med 2008; 26: 22-34. Thieme Medical Publisher, Inc, New York.
2. Dasgupta S, Mohan Reddy B. Present status of understanding on the genetic etiology of polycystic ovary syndrome. J Postgrad Med 2008; 54: 115-125.
3. Times of India, 2007/12/01
4. Maitra A, Pusalkar M, Gorkal J, Meherji P. Mutational analysis of CPY11A1 and Leptin as genetic determinants of hyperandrogenicity and obesity in PCOS: study in an Indian cohort group. International congress series 1271:2004, p. 38-41.http://www.ics-elsevier.com
5. Kalra A, Nair S, Rai L. Association of obesity and insulin resistance with dyslipidemia in Indian women with polycystic ovarian syndrome. Indian J Med Sci 2006; 60:447-453.
6. Recabarren SE, Smith R, Rios R, Maliqueo M, Echiburú B, Codner E, et al. Metabolic profile in sons of women with polycystic ovary syndrome (PCOS). J Clin Endocrinol Metab 2008; 93:1820–1826.
7. Vink JM , Sadrzadeh S, Lambalk CB, Boomsma DI . Heretibility of PCOS in Dutch twin family study. J Clin Endocrinol Metab 2006; 91: 2100-2104.
8. Sheikkha MH, Kalantar SM, Ghasemi MD. Genetics of polycystic ovary syndrome. Iranian J Repro Med 2007; 5: 1-5.
9.Zawadzki JK, Dunaif A. Diagnostic criteria for polycystic ovary syndrome: towards a rational approach. In: Dunaif A, Givens JR, Haseltine F, Merriam GR, eds. Polycystic ovary syndrome. Boston: Blackwell; 1992:377–384.
10. Executive Summary of the Third Report of the National Cholesterol Education Program (NECP), Expert Panel on Detection, Evaluation and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Journal of the American Medical

Association2001;285:2486–2497.
11. Bonora E, Kiechl S, Willeit J, Oberhollenzer F, Egger G, Bonadonna RC, et al. Metabolic syndrome: epidemiology and more extensive phenotypic description. Cross-sectional data from the Bruneck study. International Journal of Obesity-Related Metabolic Disorders2003;27:1283–1289.
12. Xita N, Georgiou I, Tsatsoulis A. The genetic basis of polycystic ovary syndrome. Eur J Endocrinol 2002; 147: 717-725.
13. Govind A, Obhrai MS, Clayton RN. Polycystic ovaries are inherited as an autosomal dominant trait: analysis of 29 polycystic ovary syndrome and 10 control families. J Clin Endocrinol Metab 1999; 84:38-43.
14. Waterworth DM, Bennett ST, Gharani N, McCarthy MI, Hague S, Batty S, et al.Williamson R.Linkage and association of insulin gene VNTR regulatory polymorphism with polycystic ovary syndrome. Lancet 1997; 349: 986- 990.
15. Jahanfar S, Eden JA, Warren P, Seppälä M, Nguyen TV. A twin study of polycystic ovary syndrome. Fertil Steril 1995; 63: 478-486.
16. Franks S, Gharani N, Waterworth D, Batty S, White D, Williamson R, et al. The genetic basis of polycystic ovary syndrome. Hum Reprod 1997; 12:2641–2648.
17. Norman RJ, Maasters S, Hague W. Hyperinsulinemia is common in family members of women with polycystic ovary syndrome. Fertil Steril 1996; 66: 942-947.
18. Legro RS. Polycystic vary syndrome, phenotype and genotype. Endocrinol and Metab Clin North Am 1999; 28: 379-396.
19. Cooper HE, Spellacy WN, Prem KA, Cohen WD. Hereditary factors in the Stein–Leventhal syndrome. Am J Obstet Gynecol 1968: 100:371–387.
20. Givens JR. Familial polycystic ovarian disease. Endocrinol Metab Clin North Am 1988; 17: 771-781.
21.Hague WM, Adams J, Reeders ST, Peto TE, Jacobs HS. Familial polycystic ovaries: a genetic disease? Clin Endocrinol 1988; 29: 593-605.
22. Lunde O, Magnus P, Sandvik L, Hoglo S. Familial clustering in the polycystic ovarian syndrome. Gynecol Obstet Invest 1989; 28: 23-30.
23.Carey AH, Chan KL, Short F, White D, Williamson R, Franks S. Evidence for a single gene effect causing polycystic ovaries and male baldness. Clin Endocrionol 1993; 38: 653-658.
24. Legro RS, Driscoll D, Strauss JF 3rd, Fox J, Dunaif A. Evidence for a genetic basis for hyperandrogenemia in polycystic ovary syndrome. Proc Nat Acad Sci USA 1998; 95: 14956–14960.
25. Wilroy RS Jr, Givens JR, Wiser WL, Coleman SA, Andersen RN, Summitt RL. Hyperthecosis: an inheritable form of polycystic ovarian disease. Birth Defects Orig Artic Ser 1975; 11, 81–85.
26. Natasha IL, Elizabeth EB, Masha K, Robert LR. Relationship of adolescent polycystic ovary syndrome to parental metabolic syndrome. J Clin Endocrinol Metab 2006; 91: 1275-1283.
27. Goodarzi MO. Looking for polycystic ovary syndrome genes: rational and best strategy. Semin Reprod 2008; Med 26:5–13.
28. Kimura I, Togashi K, Kawakami S, Nakano Y, Takakura K, Mori T, et al. Polycystic ovaries implications of diagnosis with MR imaging. Radiology 1996; 201: 549-552.
29. Urbanek M, Du Y, Silander K, Collins FS, Steppan CM, Strauss III JF, et al. Variation in resistin gene promoter not associated with polycystic ovary syndrome. Diabetes 2003; 52: 214-217.
30. Banaszewska B, Spaczynski RZ, Pelez M, Pawelczyk L. Incidence of elevated LH/FSF ratio in polycystic ovary syndrome women with normo- and hyperinsulinemia. Ann Acad Med Bialostocensis 2003; 48: 131-134.