The effects of PCOS on physical fitness in young adult females

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***Abstract*—Polycystic ovary syndrome (PCOS) is a complex hormonal disorder affecting many women during their reproductive years. It is characterized by enlarged ovaries with irregular function, elevated androgen levels, and insulin resistance. Symptoms commonly seen in females with PCOS include cravings for sugary foods, frequent urination, slow wound healing, fatigue, blurred vision, tingling sensations, mood swings, anxiety, depression episodes, pelvic pain, fever, nausea, vomiting, urinary issues, and constipation. Insulin resistance and obesity often lead to reduced physical fitness. However, hyperandrogenism, a hallmark of PCOS, can potentially enhance aspects of physical fitness such as muscle strength and cardiovascular endurance in case of healthy individuals, it is also adversely affecting in case of PCOS females. Research has shown that higher levels of insulin resistance, hyperandrogenism and obesity are associated with decreased cardiovascular and muscular endurance, as well as compromised body balance and flexibility. Hyperandrogenism also increases body fat percentage and BMI, contributing to reduced body balance and flexibility. Our study aimed to investigate how PCOS impacts cardiovascular endurance, muscular endurance, balance, and flexibility in young adult women aged 18-30 years.**

***Key words*—PCOS ,cardiovascular endurance, muscular endurance, balance, flexibility.**

I. INTRODUCTION

Polycystic Ovarian Syndrome (PCOS) was first described by Stein and Leventhal in 1935, who identified it as a condition characterized by amenorrhea, hyperandrogenism, obesity, menstrual irregularities, and sometimes infertility, along with bilaterally enlarged polycystic ovaries. Initially, Stein and Leventhal theorized that these symptoms were caused by crowding of the ovarian cortex. However, this theory has since been proven wrong, and the current understanding suggests that a complex interplay of multiple hormonal factors causes PCOS symptoms [1][2]. The prevalence of PCOS varies between 6% and 20%, depending on the diagnostic criteria, with the Rotterdam criteria (2003) being the most widely used for diagnosis. These criteria emphasize the presence of at least two of the following three characteristics: hyperandrogenism, oligo- or anovulation, and polycystic ovaries [3][4][5][6]. PCOS is a heterogeneous endocrine and gynecological disorder that impacts many women of reproductive age, with an estimated 1 in 10 women developing PCOS before menopause [7][8]. It is typically present in 5-7% of reproductive-aged women when diagnosed based on hyperandrogenism and anovulation [9].

PCOS is a result of hormonal imbalances, which lead to the formation of cysts in the ovarian antral follicles. These cysts, which contain eggs, prevent ovulation, disrupting the menstrual cycle and causing amenorrhea. The hormonal imbalance in the ovaries leads to the formation of multiple cysts, preventing ovulation, which in turn makes fertilization difficult. Women with PCOS may experience infertility and an increased risk of pregnancy-related complications such as miscarriage, gestational diabetes, and pregnancy-induced hypertension [10][11][12]. Symptoms of PCOS often include anovulation or oligovulation, which results in irregular periods. Additionally, cysts in the ovaries may produce excess androgens, leading to male-like traits such as hirsutism (excessive facial and body hair), male-pattern baldness, acne, and other signs of hyperandrogenism [8][13][14][16]. Metabolic alterations are common as well, including insulin resistance, diabetes, hypertension, cardiovascular issues, dyslipidemia, and obesity (with a BMI of 30 or higher) [14][15][17]. Women with PCOS may also experience symptoms such as fatigue, sugar cravings, delayed healing, mood swings, anxiety, depression, pelvic pain, nausea, and sleep apnea [11][18][19][20][24]. The condition is also linked to an increased risk of uterine cancers and endometrial hyperplasia [21]. The exact pathophysiology of PCOS is complex and remains unclear. Contributing factors include genetics, lifestyle, thyroid dysfunction, hyperprolactinemia, androgen-secreting tumors, Cushing's syndrome, and congenital adrenal hyperplasia [11][22][23][24].

Physical fitness is defined as a set of attributes that people have or achieve that are related to the ability to perform physical activity [25]. It encompasses the capacity to perform daily tasks with vigor and alertness, without fatigue, and with ample energy for leisure activities or emergencies [26]. Physical fitness is an indicator of overall physiological and mental health and is essential for effective functioning in everyday life, resisting diseases, and performing physical activities [37]. President-elect John F. Kennedy emphasized the importance of physical fitness for both physical health and dynamic intellectual activity [28][29]. The components of physical fitness are divided into health-related and skill-related categories, with major health-related components including cardiovascular endurance, muscular strength and endurance, balance, and flexibility [26][30].

Cardiorespiratory endurance (also known as cardiorespiratory fitness) is a measure of an individual's ability to efficiently deliver oxygen to tissues during prolonged physical activity. It is an indicator of overall physical health and is crucial not only for athletic performance but also for everyday tasks like walking, running, and climbing stairs [31][32][37]. Cardiorespiratory endurance is assessed using VO2max, which represents the maximal oxygen consumption during exercise. VO2max is considered the gold standard for evaluating cardiorespiratory fitness [34][35][36]. It can be measured directly through pulmonary gas analysis during a maximal exercise test or estimated indirectly using submaximal tests. Indirect tests, such as the 1.5 Mile Run Test, the Queen's College Step Test, and the 20-meter Shuttle Test, are commonly used for their simplicity and lower cost [37][39][42]. Submaximal tests are often preferred, particularly for sedentary or clinical populations, as they carry a lower risk of injury and do not require medical supervision [40].

Muscular endurance refers to the ability of a muscle or muscle group to perform repeated contractions or sustain a static contraction over an extended period [49][50]. It is a critical component of physical fitness and serves as a predictor of overall health,

longevity, and the ability to maintain independence in daily life [51]. Muscular endurance can be assessed through dynamic tests, such as sit-ups, push-ups, or pull-ups, or static tests like planks and flexed arm hangs. The tests may involve performing as many repetitions as possible within a set time or holding a position for as long as possible [52][53][54][55]. This component helps assess the muscle's ability to sustain strength over time.

Balance is a skill-related component of physical fitness that involves maintaining equilibrium while stationary or in motion [50]. It is essential for performing daily activities, preventing falls, and maintaining posture. Balance is assessed through a variety of tests, including the Flamingo Balance Test, Stork Stand Test, and Y Balance Test, which involve maintaining stability on one leg for a specified period or reaching in multiple directions [56][57][62][63][67][68]. Balance is crucial for coordinating movements and ensuring stability during physical activities, making it an important part of overall physical fitness.

Flexibility refers to the ability of joints to move through their full range of motion. It is influenced by muscle length, connective tissue, joint structure, and factors like age and gender. Flexibility is a key component of physical fitness and is often assessed using laboratory or field tests. Laboratory tests use goniometers, devices designed to measure the range of motion at specific joints [85][86]. Field tests are practical and include the Sit and Reach Test, which measures flexibility in the lower back and hamstrings, the Shoulder Stretch Test, and the Back Scratch Test, which assess shoulder flexibility [87][88][89][90]. Flexibility plays a significant role in injury prevention and sports performance, and it is associated with improved range of motion and overall joint health [70][73][85][86][87].

Polycystic Ovary Syndrome (PCOS) have significant effects on health-related physical fitness, influencing parameters such as cardiorespiratory endurance, muscular endurance, muscle strength, flexibility, and body balance. These impacts are shaped by underlying features of PCOS, including insulin resistance, obesity, and hyperandrogenism.

Insulin resistance (IR), a key feature of PCOS, is linked to reduced cardiorespiratory and muscular endurance. Insulin resistance impairs glucose uptake, mitochondrial function, and oxygen delivery, which ultimately reduces aerobic capacity and muscle endurance [98][99][100][101]. A higher degree of IR is also associated with a higher BMI, which negatively impacts body balance and flexibility [103][104]. The altered vasculature due to IR, with reduced vasodilation and blood flow, further hampers oxygen and nutrient delivery, worsening cardiorespiratory fitness [105][106][107]. Additionally, insulin resistance shifts muscle fiber composition toward fewer type 1 fibers, which are more efficient in glucose metabolism and muscle endurance, leading to diminished muscle strength [114][115][116]. The association between insulin resistance and obesity suggests that hyperinsulinemia may promote fat accumulation by inhibiting fat breakdown, thus contributing to weight gain. Increased body fat percentage, in turn, further compromises flexibility and body balance, ultimately impairing overall physical fitness [117][118].

Obesity is another prominent factor negatively affecting physical fitness in women with PCOS. Increased body fat is associated with decreased cardiorespiratory endurance, muscular endurance, and strength. Obesity often leads to a greater proportion of type 2 muscle fibers, which are more glycolytic and less efficient at oxygen uptake, reducing aerobic capacity. Furthermore, the additional body mass associated with obesity increases metabolic costs during exercise, which can lead to premature fatigue and lower endurance [123][124][125]. Obesity also contributes to muscle impairments, such as increased fat infiltration within muscle fibers, oxidative stress, inflammation, and a shift towards more type 2 muscle fibers. These factors result in reduced muscle strength and endurance. Additionally, obesity increases fat mass and decreases body balance and flexibility, which further detracts from overall fitness levels [129][130][131].

Hyperandrogenism, a hallmark of PCOS, has a more nuanced relationship with physical fitness. Elevated androgens have been shown to improve aspects like muscle strength and endurance as they promote muscle hypertrophy [133][134][135]. However, high androgen levels are also associated with increased body fat and a higher BMI, which may lead to decreased body balance and flexibility. While androgens can enhance certain components of physical fitness, such as strength and endurance, their association with insulin resistance and obesity in women with PCOS may indirectly reduce fitness outcomes by exacerbating those conditions [136][137][138].

In summary, while insulin resistance and obesity are detrimental to physical fitness parameters like cardiovascular endurance, muscle endurance, and strength, hyperandrogenism in PCOS presents a more complex relationship where it may enhance certain aspects of physical fitness while potentially exacerbating others. Understanding these dynamics is crucial for developing targeted interventions to improve overall health outcomes in women with PCOS.

II. METHODOLOGY

Study design was observational study design with a convenient sampling method. The study included 30 participants on the basis of inclusion and exclusion criteria in the age group 18-30years. The participants were all collage going students.

➢ Instrumentation

16.25 inches /41.3 cm step stool ,Stopwatch ,Cadence tape ,Oximeter ,Ruler /measuring tape ,Y balance test kit ,Sit and reach test box and data collection forms are prepared for data extraction.

➢ Procedure

The participants were selected based on the inclusion criteria, and once selected, they were informed about the purpose of the research, with their written consent obtained before proceeding. After consent, the participants were included in the study. Demographic details were collected from each participant, and they were then directed to the examination room. A rest period of 15 minutes was provided before an appropriate warm-up was performed. Following the warm-up, another 15-minute rest period was given before the physical fitness tests were conducted. Each variable was tested using the appropriate equipment, and the results for each test were carefully recorded. After data was collected from all 30 participants, statistical analysis was performed on the gathered data.

- **Cardiovascular endurance test :**

Queen's college step test (QCT) The step test was performed using a tool of 16.25 inches height. Stepping was done for a total duration of 3 minutes at the rate of 24 steps up per minute for males and 22 steps up per minute for females which was set by a metronome. After completion of exercise, the carotid pulse rate was measured from the fifth to the twentieth second of recovery period. The 15 seconds pulse rate was converted into beats per minute and following equation was used to predict VO2

max: For males: VO2 max = 111.33 – [0.42 × pulse rate beats/min] For females: VO2 max= 65.81–[0.1847×pulse rate beats/min].

- **Muscular endurance test :**

The push-up test is used to assess upper limb muscular endurance. The test begins with the participant in a position where their hands and toes are touching the floor, their body and legs are in a straight line, their feet are slightly apart, and their arms are shoulder-width apart and fully extended. Maintaining a straight back and knees, the participant lowers their body until their elbows form a 90° angle, then returns to the starting position. This process is repeated until the participant can no longer continue due to exhaustion. The total number of completed push-ups is recorded. For lower limb muscular endurance, the squat test is performed. The participant starts in an upright standing position with feet shoulder-width apart and arms relaxed alongside the body. The trunk is lowered until both hands can touch the ground, then the participant returns to the starting position. The test continues until exhaustion or until 60 seconds have passed. The number of correctly performed squats is recorded.

- **Balance tests :**

The Stork Stand test is used to assess static balance. To perform this test, the participant removes their shoes and places their hands on their hips. They then position the non-supporting foot against the inside of the knee of the supporting leg. Once in position, the stopwatch is started, and timing continues until the position changes, at which point the stopwatch is stopped and the time is recorded. The Y-Balance test is used to assess dynamic balance. The test begins with the participant standing on one leg at the stance plate, with the toes of the standing foot aligned with the red line, while the other leg lightly touches the ground just behind the plate. The non-stance foot is then reached out in the desired direction, pushing the reach indicator as far as possible while maintaining balance. The free foot must be returned to the starting position under control. Each test is repeated three times, and the maximum reach in each direction is recorded. The results are calculated taking limb length into consideration, to determine a "composite reach distance".

- **Flexibility tests :**

The Sit and Reach test is used to assess lower body flexibility. The participant sits against a wall, with their feet placed at the 15-inch mark on a measuring tape. Keeping their knees straight and feet plantarflexed, the participant reaches forward with both hands joined together. The distance reached is then recorded. The Back Scratch test is performed to assess upper body flexibility. In a standing position, the participant places one hand on their lower back with the palm facing outwards and moves it up the spine toward the head. The opposite hand is placed behind the neck, with the palm touching the spine, and moved down the back, aiming to overlap the other hand. The distance of overlap is measured and scored.

III. RESULTS

The study was conducted on 30 female students (18 – 20 years) with PCOS. The mean age of the participants was 21.57 ± 1.6 years. The mean BMI of the participants was 26.27 ± 5.30 Kg/m^2. Test for each fitness variable is done and the observations were recorded for each test.

1. Cardiorespiratory endurance:

Queens college step test was conducted. The test estimated the value of VO_{2max}. The mean value of VO_{2max} for the population was 42.7014 ± 2.75 ml/kg/min. on comparison of our VO_{2max} values with the standard VO_{2max} classification. Out of 30 PCOS women of age between 18 – 25, only 3% is having below average cardiorespiratory endurance levels , only 23% is having cardiorespiratory levels within average ranges and only 17% have good cardiorespiratory endurance levels, and the majority 57% of the sample population has been observed with their cardiorespiratory endurance levels lying in the above average cardiorespiratory levels.

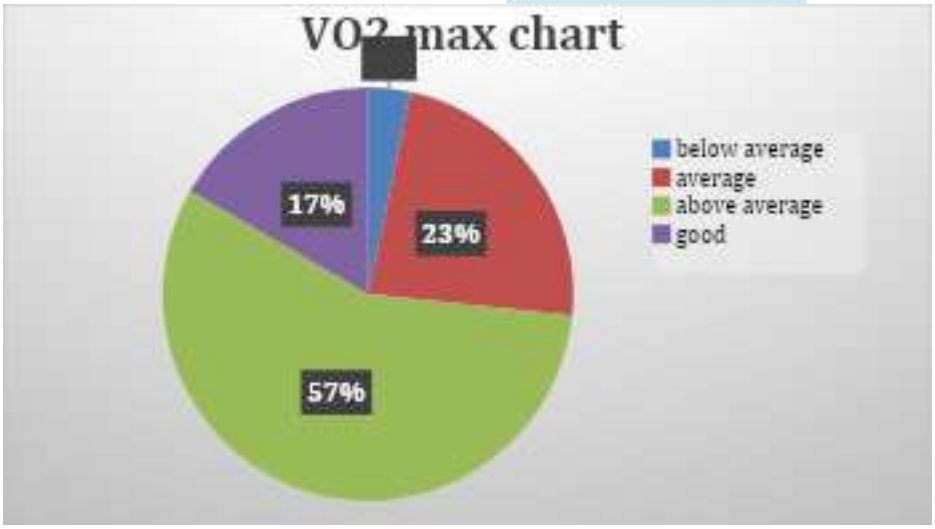

Figure 1.0 : shows the total percentage of women with PCOS having different grades of cardiovascular endurance.

2. Muscular endurance:

The tests for upper limb muscle endurance and lower limb muscle endurance were done using push – up test and squat test, respectively. The mean push-ups performed by the population are 25.1 ± 6.79, out of 30 PCOS women only 10% were having super grade; 10% were having excellent grade; 10% lies under poor grade; 27% were those that performed within the range of good grade; and the rest 43% performed within fair grade range i.e. they were having fair muscle strength endurance level. The mean number of squats performed were 33.9 ± 6.98, out of 30 PCOS women only 14% were having excellent grade; 20% were having good grade; 7% lies under below average grade; 13% were those that performed within the range of poor grade;23% performed within the average range and the rest 23% performed within above average grade range.

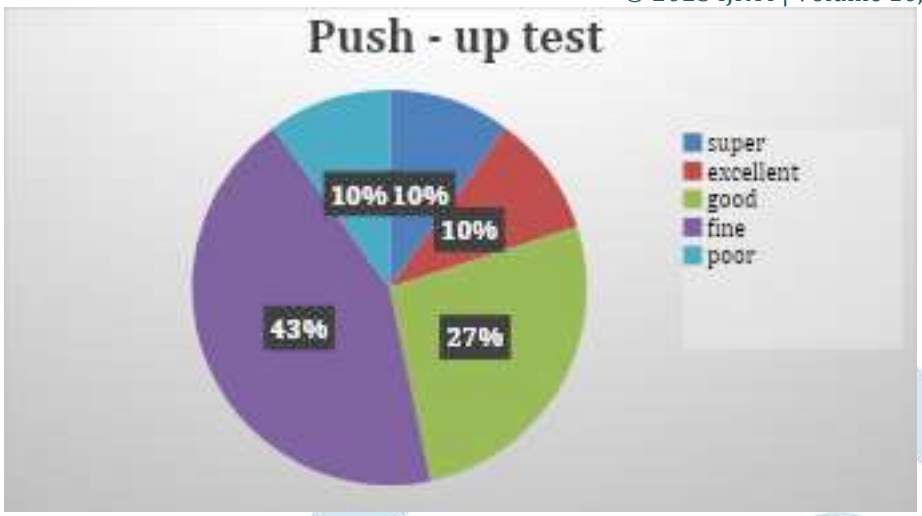

Figure 2.0 : shows the total percentage of women with PCOS having different grades of upper limb muscle strength endurance on the basis of correctly performed no. of push-ups in 1minute.

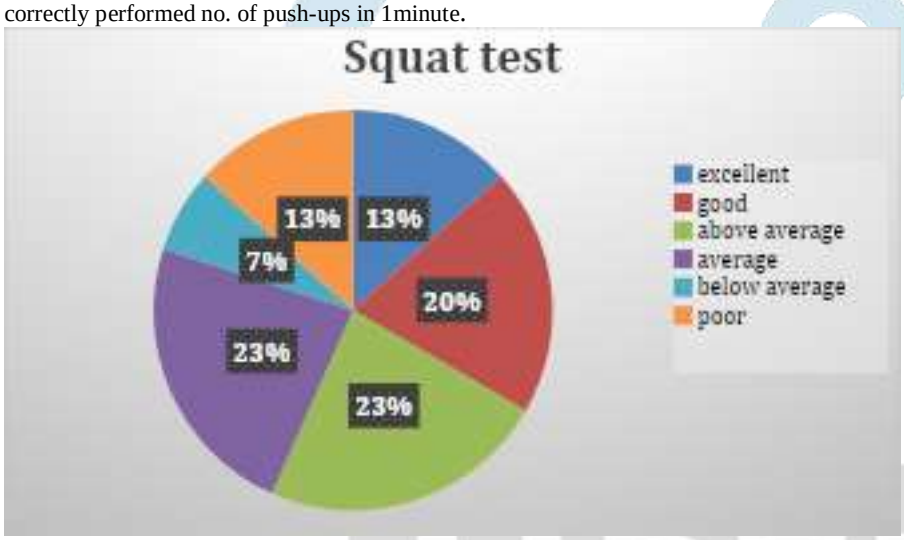

Figure 3.0 : shows the total percentage of women with PCOS having different grades of lower limb muscle strength endurance on the basis of correctly performed no. of squats in 1minute.

3. Balance:

The tests for static and dynamic balance were performed using stork balance test and Y balance test respectively. The mean values for stork balance test were 54.16 ± 4.9 seconds for right leg and 54.16 ± 4.9 seconds for left leg, out of 30 PCOS women only 18% were having good static body balance and the rest 82% were having excellent static body balance. While, the mean values for Y balance test were 76.34 ± 19.65 cm for left leg and 112.22 ± 193.12 cm for right leg, out of 30 PCOS women only 17-23% were having excellent dynamic balance and stability; 3-6% were having good balance and stability; 7% were having average balance and stability; 30% were those with fair balance and stability; and the remaining 37-40% were observed having poor dynamic balance and stability.

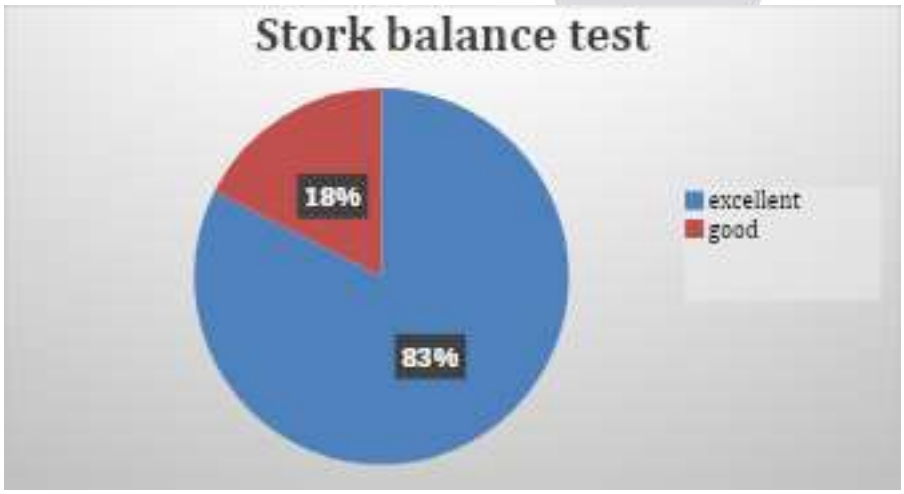

Figure 4.0 : shows the total percentage of women with PCOS having different grades of static body balance.

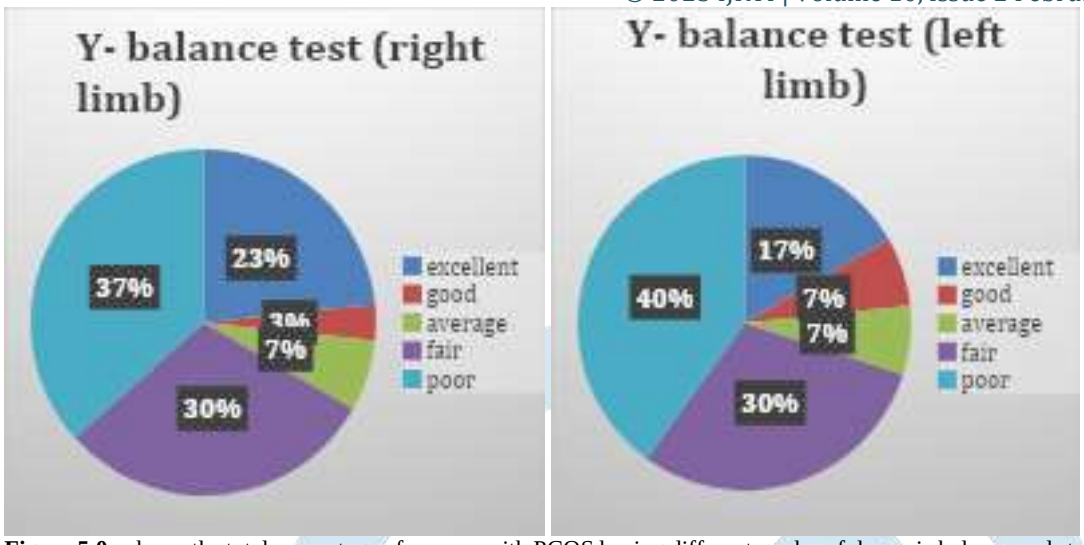

Figure 5.0 : shows the total percentage of women with PCOS having different grades of dynamic balance and stability of both left and right lower limb respectively.

4. Flexibility:

The tests for upper limb and lower limb flexibility were performed separately using back scratch test and sit and reach test respectively. The mean values for back scratch test for the population were 3.64 ± 4.30 cm for left arm and 3.34 ± 4.41cm for right arm, out of 30 PCOS women only 20% were having poor upper limb flexibility; and the other 20% were having good upper limb flexibility; and the rest 60% were observed having excellent upper limb flexibility while performing back scratch test. The mean values for sit and reach test for the population was 35.28 ± 8.53 cm, out of 30 PCOS women only 6% were having good lower limb flexibility; and 27% were having excellent lower limb flexibility; and the rest 67% were observed having super level of lower limb flexibility while performing sit and reach flexibility test.

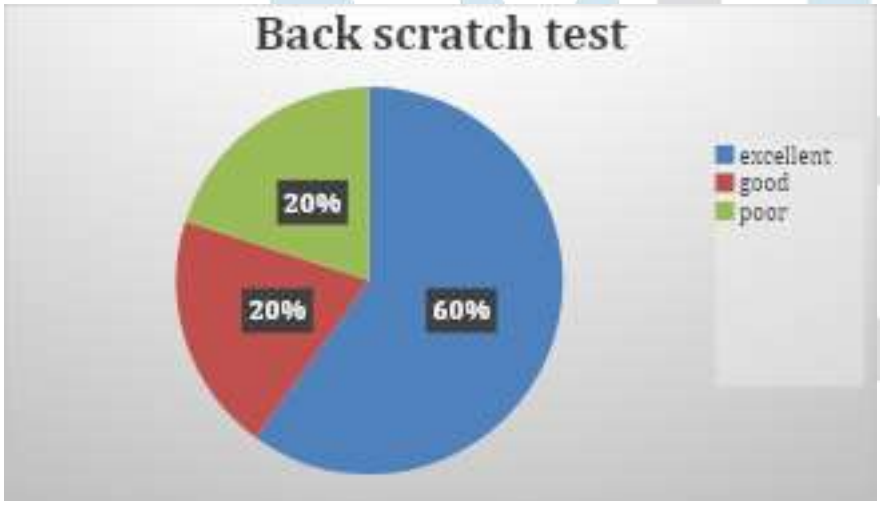

Figure 6.0 : shows the total percentage of women with PCOS having different grades of flexibility of both left and right upper limb.

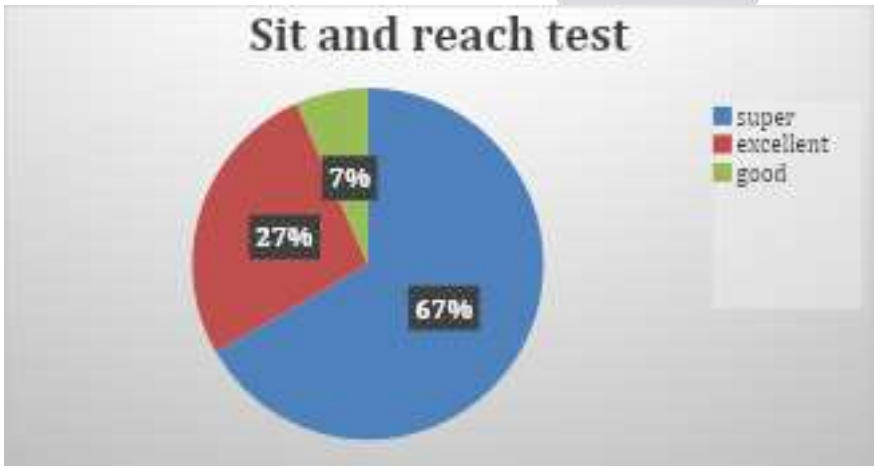

Figure 7.0 : shows the total percentage of women with PCOS having different grades of flexibility of lower limb.

IV. DISCUSSION

This study aimed to assess the effect of polycystic ovary syndrome (PCOS) on physical fitness in young adult women aged 18-30 years. A total of 30 participants, all previously diagnosed with PCOS, were included in the study. The level of physical fitness was tested by evaluating four fitness variables: cardiorespiratory endurance, muscular endurance, balance, and flexibility. Specific

tests were used for each variable: the Queens College Step Test for cardiorespiratory endurance, the push-up and squat tests for muscular endurance, the Stork Balance and Y-Balance tests for balance, and the Sit and Reach and Back Scratch tests for flexibility. The test results were compared to normative values for each test performed.

The results from this study indicate a significant detrimental effect of PCOS on the physical fitness levels of young adult females. While no studies have previously assessed all these physical fitness variables in a single study, several existing studies provide evidence that supports the results obtained in this study for individual variables. Similar results were found in the studies by Antti-Pekka E. Rissanen, Tiina Koskela-Koivisto, Harriet Hägglund, Anne S. Koponen, Jyrki M. Aho, Maritta Pöyhönen-Alho, Aila Tiitinen, Heikki O. Tikkanen, and Juha E. Peltonen on the topic "Altered cardiorespiratory response to exercise in overweight and obese women with polycystic ovary syndrome" [153]. Another study by Hanife Doğan and Melike Demir Çaltekin titled "Does polycystic ovary syndrome with phenotype D affect the cardiovascular endurance, core endurance, body awareness, and the quality of life? A prospective, controlled study" [154] also aligned with the findings. Furthermore, Pamela J. Wright, Cynthia F. Corbett, Robin M. Dawson, Michael D. Wirth, and Bernardine M. Pinto's study, "Fitness Assessments of Women with Polycystic Ovary Syndrome: A Prospective Process Feasibility Study", provided additional support for the results. Moreover, a systematic review and meta-analysis by Domenica Cirone, titled "Health-related physical fitness in women with polycystic ovary syndrome versus controls: a systematic review and meta-analysis" [97], compared physical fitness variables in women with PCOS and healthy controls, demonstrating that women with PCOS generally have lower physical fitness levels compared to controls.

PCOS is a heterogeneous endocrine disorder that affects many women of reproductive age and is commonly associated with enlarged and dysfunctional ovaries, elevated androgen levels, and insulin resistance. Other complications of PCOS include an increased risk of cardiovascular diseases, type 2 diabetes mellitus, metabolic syndrome, depression, anxiety, and an elevated body mass index (BMI) of 30 or higher. Insulin resistance, obesity, and hyperandrogenism are three key features of PCOS that contribute to lowered physical fitness. Insulin resistance negatively impacts vascular function, impairing the delivery of substances necessary for aerobic metabolism. It reduces insulin-stimulated vasodilation, capillary recruitment, and resting blood flow [105][106][107][108], leading to decreased glucose uptake and mitochondrial dysfunction, which reduces the capacity for aerobic metabolism and cardiorespiratory endurance [109][110][111][112][113].

Additionally, insulin resistance alters muscle fibre composition, leading to a lower proportion of type 1 muscle fibres, which are critical for glucose utilization during muscle contraction. This reduction in type 1 fibres results in decreased muscle strength, as muscle fibres with better glucose-handling capacities are replaced with less efficient fibres [114][115][116]. Insulin resistance also suppresses fat breakdown and enhances fat synthesis, contributing to increased adipose tissue accumulation and weight gain, which negatively impacts body balance and flexibility [117][118].

Obesity, which is common in women with PCOS, exacerbates these effects by promoting fat infiltration into muscles. This results in a greater proportion of type 2 muscle fibres, which are more glycolytic and less efficient at utilizing oxygen compared to oxidative type 1 fibres. Consequently, women with PCOS often experience reduced muscle endurance and flexibility. Studies by Hung et al. (2014) and Valenzuela et al. (2020) support this, indicating that obesity leads to a greater proportion of type 2 muscle fibres, which have lower oxygen uptake compared to type 1 fibres due to increased fat infiltration into muscles [123][124][125][126][127][123][128][129].

While hyperandrogenism is generally linked to improved muscle strength and endurance and cardiorespiratory endurance in healthy individuals, in the context of PCOS, it can exacerbate both insulin resistance and obesity. This indirect effect can lead to worsened physical fitness in women with PCOS [136][137][138]. Hyperandrogenism may also contribute to increased body fat percentage and BMI, further impairing body balance and flexibility [133][134][135].

In conclusion, this study demonstrates that PCOS has a significant negative effect on physical fitness among young women, affecting multiple fitness variables such as cardiorespiratory endurance, muscular endurance, balance, and flexibility. These findings align with the existing body of research and emphasize the role of insulin resistance, obesity, and hyperandrogenism in reducing physical fitness levels in women with PCOS. Addressing these underlying physiological factors could improve the physical fitness and overall health of women with PCOS.

V. Conclusion

In summary, collecting data regarding physical fitness from the women with PCOS was feasible. The data analysed from physical fitness assessments may help identify complications of PCOS in terms of physical fitness and thus help reveal other possible health risk among women with PCOS. Research evidence although limited at this time, clearly explains the effects of PCOS on different physical fitness components, the effects of PCOS clinical features were totally visible for most of the physical fitness parameters assessed in the research such as for components like: cardiorespiratory endurance; muscle strength endurance; dynamic balance; and upper limb flexibility. While there were some parts of physical fitness components that were not evidently affected by PCOS within the selected population, such as components like: static balance; and lower limb flexibility. Proper fitness tests were performed by the women with PCOS, separately for each component of physical fitness considered in this research, following proper tests protocols.

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