ORIGINAL RESEARCH PAPER

Volume-7 | Issue-8 | August-2018 | PRINT ISSN No 2277 - 8179

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

IMPROVING FITNESS AND WELL-BEING IN WOMEN WITH POLYCYSTIC OVARIAN SYNDROME – THE NEAT WAY

Physiotherapy

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ABSTRACT

Introduction: Polycystic Ovarian Syndrome (PCOS), a common endocrine disorder results from abnormal functioning of the hypothalamic-pituitary-ovarian (HPO) axis with probable genetic contributions. Its clinical manifestations may include: menstrual irregularities, signs of androgen excess, anovulation, obesity, insulin resistance, and increased risk of type 2 diabetes, cardiovascular events, anxiety and depression. Non-exercise activity thermogenesis (NEAT), is the thermogenesis or energy expended for everything that we do other than volitional exercise. It ranges from activities of daily living, fidgeting, spontaneous muscle contraction and maintaining posture, when not recumbent. NEAT varies between two people of the similar size because of people's different occupations and leisure-time activities

Methodology: As per inclusion and exclusion criteria, 30 subjects were included in the study and were assessed using PCOSQ, BMI, waist circumference, YMCA 3-min step test, vital capacity and sit-and-reach test. A list of the subject's ADLs were recorded. According to the NEAT principles, the subjects were given a personalized, modified list of 30 activities which were monitored by themselves and the therapist. The subjects had to maintain a record of the activities, out of which at least 10 had to be performed on a daily basis. Intervention program of four weeks was performed on the subjects. Post intervention evaluation was conducted with the same outcome measures. Results were recorded and analysed using Paired T-test.

Result: There was a significant decrease in the pre and post symptoms of PCOS on the PCOSQ, BMI, Waist Circumference, YMCA 3-min Step Test and an increase in the pre and post Vital Capacity and flexibility in Sit and Reach Test.

Conclusion: This study concludes that NEAT is effective in improving fitness and well-being in women with PCOS. There was a significant improvement in the parameters of PCOSQ, BMI, waist circumference, YMCA 3-min step test, vital capacity and sit-and-reach test.

KEYWORDS

PCOS, NEAT, fitness, exercise, increased activity

Introduction:

Polycystic Ovarian Syndrome (PCOS) has become a complex endocrine disorder occurring at a frequency of 11.2% in women of the reproductive age. According to a study by PCOS Society, one in every 10 women in India has polycystic ovary syndrome (PCOS), among women of reproductive age, out of which, prevalence of PCOS in teenage girls may as high as 50%. PCOS was described as early as 1935. However, even today there is a general lack of awareness regarding the condition in India and it often remains undetected for years.

PCOS is a syndrome of ovarian dysfunction along with the cardinal features hyperandrogenism and polycystic ovary (PCO) morphology. It results from abnormal functioning of the hypothalamic-pituitary-ovarian (HPO) axis with probable genetic contribution. Its clinical manifestations may include: menstrual irregularities, signs of androgen excess (hirsutism), anovulation, obesity, insulin resistance, increased risk of type 2 diabetes, cardiovascular events anxiety and depression, not all of which are present in any one woman. Women with PCOS may complain about irregular menstrual periods and/or heavy menstrual bleeding, infertility, excessive growth of coarse facial and body hair, obesity, oiliness of the skin, seborrhoea, and cystic acne. The impact of these symptoms on a woman's quality of life may be profound and can result in psychological distress that threatens her feminine identity. The condition may therefore result in altered self-perception, a dysfunctional family dynamic, and problems at work. Lifestyle modification, including exercise, is the first-line therapeutic approach in improving health outcomes in PCOS.[1,2]

According to research studies, women with PCOS should be advised to engage in at least 90 min of aerobic activity per week at moderate intensity (60–70% VO2max) to achieve improved reproductive and cardiometabolic outcomes.[3]

Non-exercise activity thermogenesis (NEAT), is the thermogenesis or energy expended for everything that we do other than volitional exercise and has a considerable potential impact on energy balance and weight gain. NEAT varies between two people of the similar size by 2000 kcal day^{-1} because of people's different occupations and leisure-time activities. NEAT represents the energy expenditure with spontaneous activity. There are three primary components that constitute total daily energy expenditure: resting metabolic rate, the thermic effect of food and physical activity thermogenesis. Highly active people expend three times more energy per day than inactive people.[4]

NEAT ranges from activities of daily living, fidgeting, spontaneous muscle contraction, maintaining posture, walking to work, gardening, toe-tapping, dancing or playing an instrument and many more activities, when not recumbent. These behavioural components have been synthesized into a simplified approach termed, STRIPE. STRIPE is an acronym which represents;

S = select a NEAT-activity that is enjoyed and start it,
T = targeted, specific individual goals must be defined,
R = rewards need to be identified for reaching the defined goals,
I = identify barriers & remove them,
P = plan NEAT-activity sessions,
E = evaluate adherence & efficacy.

Research studies prove that, by just doing simple daily manual task activities, NEAT can be enhanced throughout the workday and at home. These activities should be encouraged in childhood and continued during adulthood. NEAT decreases cardiovascular disease mortality and improves metabolic parameters. NEAT has good long-term adherence, with positive impact. A significant decrease in physical activity has contributed to the obesity pandemic. Complemented with moderate- to vigorous intensity exercise activity, NEAT seems to have a fundamental role in preventing and reducing the obesity pandemic.[5]

Exercise is defined as 'bodily exertion for the sake of developing and maintaining physical fitness' for example sport or, visiting the gym. The vast majority of world-dwellers do not participate in exercise, as so defined and for them, exercise activity thermogenesis is zero.[6] Present days' women have busy schedules and limited time lines, to dedicate time for exercising. Sedentary jobs have also been on the higher rise in recent times. Among this population, women with PCOS become more susceptible to the worsening of symptoms and its associated problems, thus making exercising imperative for them.

Research studies have proven NEAT to be effective in obesity, type 2 diabetes and cardiovascular diseases.[7] Evidence does not exist for the same in PCOS. Therefore, this study aims on assessing the efficacy of NEAT in improving the fitness and well-being in women with PCOS.

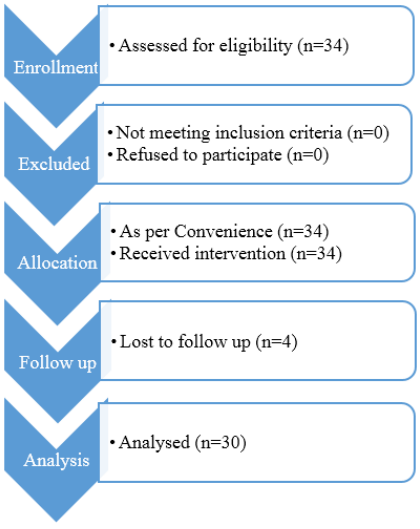
Literature Survey:

1) James A. Levine et al conducted a study, "The role of non-exercise activity thermogenesis in resistance to fat gain in humans", in which 16 healthy adults (12 males and 4 females, ranging in age from 25 to 36 years) underwent measures of body composition and energy expenditure before and after 8 weeks of supervised overfeeding by 1000 kcal/day after which they came to a conclusion that efforts to enhance NEAT activation, perhaps through behavioural cues, may be a fruitful approach to the prevention of obesity.[8]
2) Pedro A. Villablanca, MD, MSc et al conducted a literature review, "Non-exercise activity thermogenesis in obesity management" and came to a conclusion that the benefits of NEAT include not only the extra calories expended but also the reduced occurrence of the metabolic syndrome, cardiovascular events, and all-cause mortality. To overcome the obesity epidemic and its adverse cardiovascular consequences, NEAT should be part of the current medical recommendations.[5]
3) Cheryce L. Harrison et al conducted a systematic review, "Exercise therapy in polycystic ovary syndrome" in which five databases were searched with no time limit. A pre-specified definition of PCOS was not used. Studies were included if exercise therapy (aerobic and/or resistance) could be evaluated as an independent treatment against a comparison group. Quality analysis was performed based on the Cochrane Handbook of Systematic Reviews and the Quality of Reporting of Meta-Analyses checklist, thus concluding that women with PCOS should be advised to engage in at least 90 min of aerobic activity per week at moderate intensity (60–70% VO_2max) to achieve improved reproductive and cardiometabolic outcomes.[3]
4) The Rotterdam ESHRE/ASRM-Sponsored PCOS Consensus Workshop Group conducted a Revised 2003 consensus on diagnostic criteria and long-term health risks related to polycystic ovary syndrome which concluded that PCOS remains a syndrome, with no such single diagnostic criterion which may include menstrual irregularities, signs of androgen excess, and obesity. Insulin resistance and elevated serum LH levels are also common features in PCOS. PCOS is associated with an increased risk of type 2 diabetes and cardiovascular events.[9]
5) Ram Nidhi, MSc Yoga et al conducted a prospective study, "Prevalence of Polycystic Ovarian Syndrome in Indian Adolescents", on 460 girls aged 15 to 18 years from a residential college in Andhra Pradesh, South India, who underwent clinical examination. Out of which 72 girls with oligomenorrhea and/or hirsutism were invited for biochemical, hormonal, and ultra-sonographic evaluation for diagnosis of PCOS by Rotterdam criteria and concluded that the prevalence of PCOS in Indian adolescents is 9.13%, drawing attention to the issue of early diagnosis in adolescent girls.[10]
6) William L. Haskell et al conducted a study, "Physical Activity and Public Health: Updated Recommendation for Adults from the American College of Sports Medicine and the American Heart Association", to update and clarify the 1995 recommendations on the types and amounts of physical activity needed by healthy adults to improve and maintain health. The study concluded that, to promote and maintain health, all healthy adults aged 18 to 65 years need moderate-intensity aerobic (endurance) physical activity for a minimum of 30 min on five days each week or vigorous-intensity aerobic physical activity for a minimum of 20 min on three days each week. Combinations of moderate- and vigorous-intensity activity can be performed to meet this recommendation. Because of the dose-response relation between physical activity and health, persons who wish to further improve their personal fitness, reduce their risk for chronic diseases and disabilities or prevent unhealthy weight gain may benefit by exceeding the minimum recommended amounts of physical activity.[11]
7) L. Cronin et al developed a self-administered questionnaire for measuring health-related quality of life (HRQL) in 100 women with polycystic ovary syndrome (PCOS) in which they identified a pool of 182 items potentially relevant to women with PCOS through semi-structured interviews with PCOS patients, a survey of health professionals who worked closely with PCOS women, and a literature review thus proving to be useful in measuring health-related quality of life. The questionnaire should be tested prior to, or concurrent with, its use in randomized trials of new treatment approaches.[2]

Methods:

After ethical approval, consent was signed by the subjects. Women with PCOS within the age ranging from 18 to 45 years were included, those excluded were women following a regular exercise regime, any uterine malignancy, gravid women, any recent medical or surgical gynaecological or obstetric condition and women undergone recent medical termination of pregnancy (within 3 weeks). The subjects' demographic data consisting of weight, height, age and occupational status along with their daily activities were recorded. The study was conducted on a total number of thirty subjects with a convenience type of sampling.

Consort:



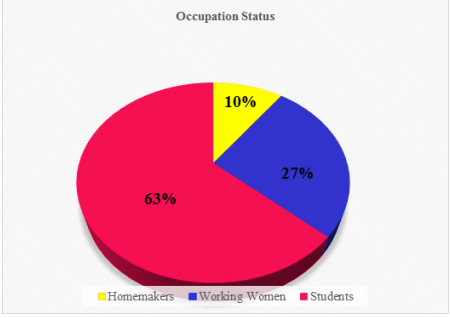
The subjects' baseline values of quality of life using the Polycystic Ovary Syndrome Questionnaire (PCOSQ) [2] and fitness using Body Mass Index (BMI), Waist Circumference, YMCA 3 – Minute Step Test, Vital Capacity and Sit and Reach Test were assessed respectively. According to the NEAT principles, the subjects were given a personalized, modified list of 30 activities which were monitored by themselves and the therapist. The subjects maintained a record of the activities, out of which at least 10 were performed on a daily basis. An intervention program of four weeks was performed on the subjects. Post intervention the subjects were evaluated with the same outcome measures.

Results:

Statistical analysis was done by using the Statistical Package of Social Sciences (SPSS) version 23. The results were concluded to be statistically significant with $p<0.05$. Paired t-test was used to compare the data.

There were 30 female subjects with PCOS, with a mean age of 24.03 ± 2.785, that were included into the study.

Graph 1: Representation of Occupation status of the subject

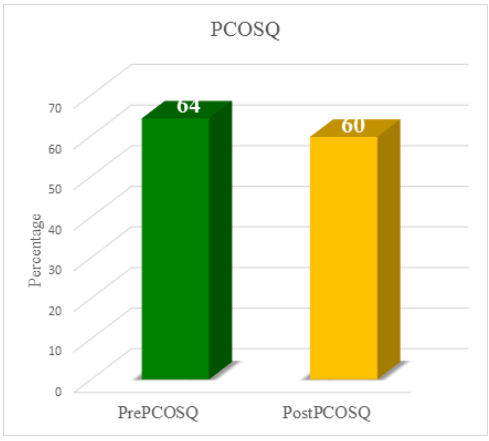


This diagram represents the percentage of the occupation status of the subjects, out of which 63% were students, 27% were working women and 10% were students

Table 1: Analysis of PCOSQ

Outcome Measure	Pre	Post	P value
PCOSQ	64 ± 11	59 ± 12	0.00

Graph 2: Polycystic Ovarian Syndrome Questionnaire

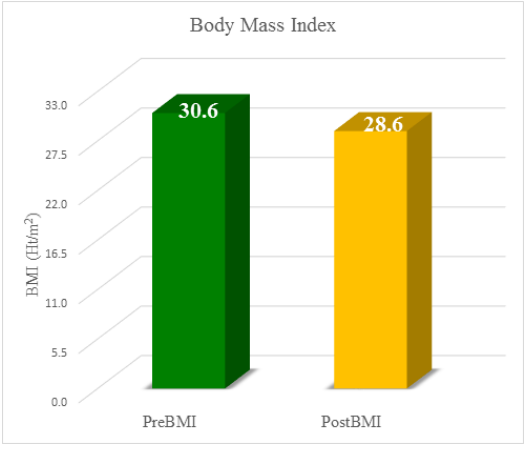


This graph shows a significant decrease in the pre and post symptoms of PCOS on the PCOSQ (p value ≤ 0.00)

Table 2: Analysis of BMI

Outcome Measure	Pre	Post	Sig. (P value)
BMI	30.6 ± 3.3	28.6 ± 2.8	0.00

Graph 3: Body Mass Index

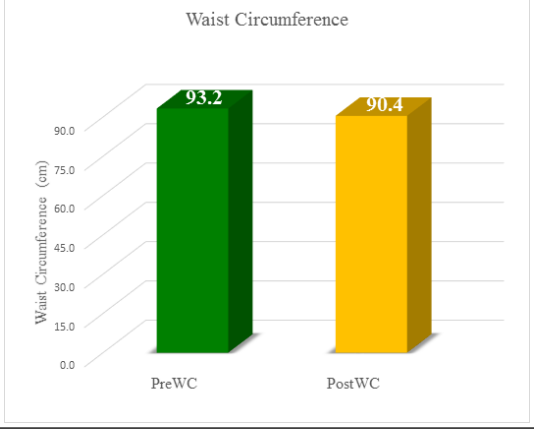


This graph shows a significant decrease in the pre and post BMI (p value ≤ 0.00)

Table 3: Analysis of Waist Circumference

Outcome Measure	Pre	Post	Sig. (P value)
WC	93.2 ± 7.4	90.4 ± 7.1	0.00

Graph 4: Waist Circumference

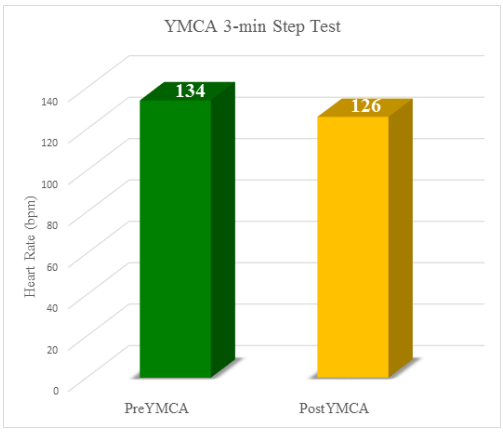


This graph shows a significant reduction in the pre and post Waist Circumference (p value ≤ 0.00)

Table 4: Analysis of YMCA 3-min Step test

Outcome Measure	Pre	Post	Sig. (P value)
YMCA	134 ± 11	126 ± 11	0.00

Graph 5: YMCA 3-min Step Test

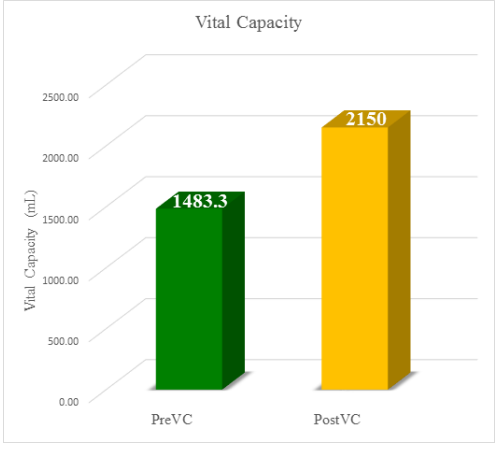


This graph shows a significant decrease in the heart rate pre and post YMCA 3-min Step Test (p value ≤ 0.00)

Table 5: Analysis of Vital Capacity

Outcome Measure	Pre	Post	Sig. (P value)
VC	1483.3 ± 463.9	2150.0 ± 374.8	0.00

Graph 6: Vital Capacity

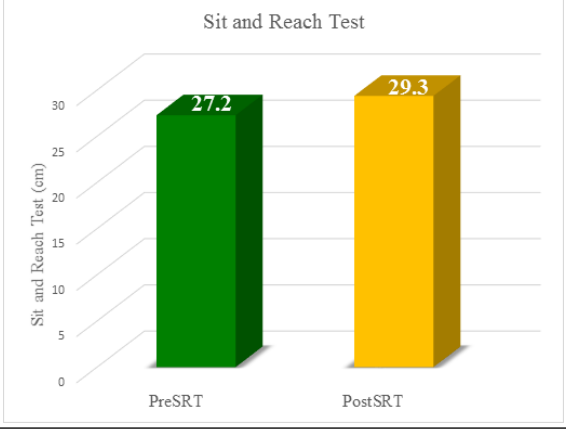


This graph shows a significant increase in the pre and post Vital Capacity (p value ≤ 0.00)

Table 6: Analysis of Sit and Reach Test

Outcome Measure	Pre	Post	Sig. (P value)
SRT	27.2 ± 3.2	29.3 ± 3.6	0.00

Graph 7: Sit and Reach Test



This graph shows a significant increase in the flexibility pre and post Sit-and- Reach Test (p value ≤ 0.00)

Discussion:

The amount of NEAT that humans perform, represents the product of the amount and types of physical activities and the thermogenic cost of

each activity. The factors that impact a human's NEAT are readily divisible into environmental factors, such as occupation or dwelling within a "concrete jungle," and biological factors such as weight, gender, and body composition. The combined impact of these factors explains the substantial variance in human NEAT [16].

The main outcome of this study was to analyse the effectiveness of NEAT in the fitness and overall well-being of women with PCOS, specifically not indulging in any exercise programme.

The data obtained pre and post the intervention was analysed and interpreted as follows:

Demographic data:
Graph 1 depicts the percentage of occupational status of the subjects included in the study. A total number of 30 female subjects were included in the study, with a mean age of 24.03 ± 2.785. Out of which, 19 were students, 8 were working women and 3 were homemakers.

The list of activities followed by the subjects were as per their occupation status or depending on the place where majority of their time was spent.

Polycystic Ovarian Syndrome Questionnaire (PCOSQ):
Table 1 and Graph 2 denote from pre to post intervention that there was a decrease in the severity of symptoms of PCOS.

Out of the five domains of the PCOSQ, there was an improvement in the emotions and weight domains that focus on depression, concerns about being overweight, easily tired, being moody and self-esteem and image. This maybe assumed to be caused by the contributions of the hypothalamic factors that are known to increase NEAT levels due to increased physical activity.[6] Hypothalamic contributions play an important role in releasing dopamine, a neurotransmitter that enhance mood and emotions. The hypothalamus also regulates the endocrine system to release FSH and LH, that regulate the menstrual cycle[17], but no significant change had been noted under the domain of menstrual cycle in the PCOSQ.

Body Mass Index (BMI):
Table 2 and Graph 3 indicate that there was a reduction in the BMI of the subjects from the category of Obese Class I (30 – 39.9 kg/m^2) to Pre Obese (25 – 29.9 kg/m^2).

Hypothalamic nuclei and the associated neurotransmitter, Orexin, have long been associated with the integration of body weight regulation. The model for the neuroendocrine regulation of non-exercise activity thermogenesis (NEAT) is the service of energy balance. To regulate NEAT according to changes in energy balance, the brain interprets external sensory cues of energy availability as well as internal metabolic cues. These signals are interpreted and integrated by several brain regions, including hypothalamic energy balance sites such as the arcuate nucleus, hindbrain regions including the area postrema and nucleus of the solitary tract, and the mesolimbic dopamine pathway.

Lastly, these brain systems have ascending and descending projections that affect the amount of physical activity through arousal and limbic pathways, as well as descending neural projections and endocrine signals that alter the energy efficiency of physical activity. In this way, the brain can enhance NEAT to adjust energy balance thus aiding in the resistance to fat gain [5].

Waist Circumference:
Referring to Table 3 and Graph 4, a significant decrease was noted in the waist circumference post intervention.

Physical activity is inversely related to waist circumference. Increased physical activity aids in weight management as explained above, thus impacting on energy expenditure. This results in effects on body composition through enhancing fat-free mass (FFM) and increasing total fat oxidation, thus reducing the visceral fat and reducing abdominal fat [18]. According to Manfred J. Müller, FFM-independent metabolic adaptations, i.e. adaptive thermogenesis (AT), has been explained by the ratio of glycolytic to oxidative enzymes together with an altered efficiency of free fatty acid oxidation in skeletal muscle, Bfutile^ cycles consuming ATP without a net change in products (e.g. hydrolysis of triglycerides and subsequent re-esterification in adipocytes), changes in the ATP costs per muscle contraction, mitochondrial uncoupling in brown adipose tissue, energy consuming pathways like lipogenesis, NEAT and/or partitioning of energy to FFM [19].

YMCA 3 – min Step Test:
Table 4 and Graph 5 indicate an enhancement in the fitness levels of the subjects post intervention as compared to the data prior to intervention. There was a significant decrease in heart rate, thus bringing the subjects from a category of Very Poor/Poor to Below Average/ Average.

The probable rationale behind it could be enhanced cardiorespiratory function, which is primarily a function of the heart's maximal ability and to pump blood (max. Cardiac Output) and the ability of the skeletal muscle to pump blood as well as oxygen. Through regular physical activity, the cardiac muscle gets stronger and contracts more forcefully. This results in reducing the heart rate.[20,21]

Vital Capacity:
From Table 5 and Graph 6, the analysis indicates that there is an increase in the vital capacity volume post intervention. Over a period of time with increased physical activity, muscles produce less carbon dioxide as they will require less oxygen to function. This causes a reduction in ventilator stimulation / ventilation due to lower levels of lactic acidosis. This permits greater time for expiration between breaths.

Increased activity levels make the heart stronger and lungs fitter enabling the cardiovascular system to deliver more oxygen to the body with every heart beat and pulmonary system to increase maximum amount of oxygen that the lungs can take in, thus recruiting more amount of alveoli in the lungs, enhancing its expansion and volumes.[22,23,24]

Sit and Reach Test:
Table 6 and Graph 7 depict an increase in the flexibility post intervention. There is an improvement in the fitness category from Below Average to Average. Increased activity levels improves blood flow and oxygen supply to the muscle.

This enhances the muscle mass and contractility. Weight bearing activities increase collagen synthesis thus enhancing tensile strength of tendons and ligaments.[25]

According to Marc T. Hamilton et al in their study on "Role of Low Energy Expenditure and Sitting in Obesity, Metabolic Syndrome, Type 2 Diabetes, and Cardiovascular Disease", NEAT is generally a much greater component of total energy expenditure than exercise or because any type of brief, yet frequent, muscle contraction throughout the day may be necessary to short-circuit unhealthy molecular signals causing metabolic/endocrine diseases. Thus, if the inactivity physiology paradigm is proven to be true, the dire concern for the future may rest with growing number of people unaware of the potential insidious dangers of sedentary lifestyles or sitting too much and who are not taking advantage of the benefits of maintaining non-exercise activity throughout much of the day.[7]

The recently updated American College of Sports Medicine and the American Heart Association recommendation, explicitly addressed the concept of accumulating short bouts of physical activity for a minimum length of 10 minutes. The recommendation currently states that minimum aerobic activity is in "addition to" the frequent and routine non-exercise activity such as walking to the parking lot or walking around the home/office. However, a cornerstone paradigm from years of exercise research has been the specificity principle; namely, that the magnitude and qualitative type of adaptive responses depend on the type of exercise training. It is axiomatic that the low resistances associated with aerobic training will not produce the same responses as high resistance weight training. Although the cumulative weekly energy expenditure in people who exercise regularly is a small part of the total energy expenditure, there are nonetheless healthy benefits of exercise. Exercises of relatively shorter duration and greater intensity may not be able to substitute for a NEAT deficiency, since non-exercise activity takes place over for a greater time span every day and continually interrupts sedentary time. This hypothesis is still largely untested and further research is much needed. In summary, both exercise and non-exercise physical activity patterns may be healthy, but if the specificity principle is accepted, then it should not be assumed that people can simply replace non-exercise physical activity

deficiency with a bolus of exercise a few times per week.[11]

Similarly, the results of this study illustrated that PCOS women are more likely to be overweight or obese and also supported that the effect of NEAT activities or non-exercise activities played a crucial role specifically in weight reduction, thus, improving fitness, boosting their morale, confidence and positive self-image, which is very important for maintaining good health in PCOS.

Conclusions:

This study concludes that NEAT is effective in improving fitness and well-being in women with PCOS. There was a significant improvement in the parameters of PCOSQ, BMI, waist circumference, YMCA 3-min step test, vital capacity and sit-and-reach test. Women who can dedicate time towards short bouts of aerobic exercises coupled with pacing up their NEAT levels throughout the day, may have more beneficial effects in curbing the symptoms of PCOS.

Future Scope:

The study did not depict any significant change in the menstrual cycle of the subjects due to the lack of the long term effects of NEAT activities on the menstrual cycle of PCOS women. Further research needs to be done for the same.

References:

1) Choudhary, A., Jain, S. and Chaudhari, P. (2017). Prevalence and symptomatology of polycystic ovarian syndrome in Indian women: is there a rising incidence? International Journal of Reproduction, Contraception, Obstetrics and Gynecology, 6(11), p.4971.
2) Cronin, L., Guyatt, G., Griffith, L., Wong, E., Azziz, R., Futterweit, W., Cook, D. and Dunaif, A. (1998). Development of a Health-Related Quality-of-Life Questionnaire (PCOSQ) for Women with Polycystic Ovary Syndrome (PCOS). The Journal of Clinical Endocrinology & Metabolism, 83(6), pp.1976-1987.
3) Harrison, C., Lombard, C., Moran, L. and Teede, H. (2010). Exercise therapy in polycystic ovary syndrome: a systematic review. Human Reproduction Update, 17(2), pp.171-183.
4) Levine, J. (2007). Nonexercise activity thermogenesis liberating the life-force. Journal of Internal Medicine, 262(3), pp.273-287.
5) Villablanca, P., Alegria, J., Mookadam, F., Holmes, D., Wright, R. and Levine, J. (2015). Nonexercise Activity Thermogenesis in Obesity Management. Mayo Clinic Proceedings, 90(4), pp.509-519.
6) Levine, J. (2002). Non-exercise activity thermogenesis (NEAT). Best Practice & Research Clinical Endocrinology & Metabolism, 16(4), pp.679-702.
7) Hamilton, M., Hamilton, D. and Zderic, T. (2007). Role of Low Energy Expenditure and Sitting in Obesity, Metabolic Syndrome, Type 2 Diabetes, and Cardiovascular Disease. Diabetes, 56(11), pp.2655-2667.
8) Levine, J. (1999). Role of Nonexercise Activity Thermogenesis in Resistance to Fat Gain in Humans. Science, 283(5399), pp.212-214.
9) Revised 2003 consensus on diagnostic criteria and long-term health risks related to polycystic ovary syndrome (PCOS). (2004). Human Reproduction, 19(1), pp.41-47.
10) Nidhi, R., Padmalatha, V., Nagarathna, R. and Amritanshu, R. (2011). Prevalence of Polycystic Ovarian Syndrome in Indian Adolescents. Journal of Pediatric and Adolescent Gynecology, 24(4), pp.223-227.
11) Physical Activity and Public Health: Updated Recommendation for Adults From the American College of Sports Medicine and the American Heart Association. (2007). Circulation, 116(9), pp.1081-1093.
12) Ferrera, L. (2005). Body mass index. New York: Nova Biomedical Books.
13) Waist circumference and waist-hip ratio. (2011). Geneva: World Health Organization.
14) Topendsports.com. (2018). Step Test: Testing your fitness at home. [online] Available at: http://www.topendsports.com/testing/tests/home-step.htm [Accessed 9 Mar. 2018].
15) Topendsports.com. (2018). Sit and Reach Test. [online] Available at: http://www.topendsports.com/testing/tests/sit-and-reach.htm [Accessed 9 Mar. 2018].
16) Levine, J. (2004). Nonexercise activity thermogenesis (NEAT): environment and biology. American Journal of Physiology-Endocrinology and Metabolism, 286(5), pp.E675-E685.
17) Hormone.org. (2018). Hypothalamus Hormones | Function of the Hypothalamus Gland. [online] Available at: http://www.hormone.org/hormones-and-health/brainy-hormones [Accessed 9 Mar. 2018].
18) Waller, K., Kaprio, J. and Kujala, U. (2007). Associations between long-term physical activity, waist circumference and weight gain: a 30-year longitudinal twin study. International Journal of Obesity, 32(2), pp.353-361.
19) Müller, M., Enderle, J. and Bosy-Westphal, A. (2016). Changes in Energy Expenditure with Weight Gain and Weight Loss in Humans. Current Obesity Reports, 5(4), pp.413-423.
20) Rai, R., Chugh, P. and Negi, M. (2013). A Study on Cardiovascular Fitness of Sedentary College Students. International Journal of Science and Research (IJSR), 4(6), pp.109-112.
21) Ohuruogu, B. (2016). The Contributions of Physical Activity and Fitness to Optimal Health and Wellness. Journal of Education and Practice, 7(20), pp.123-128.
22) Guenette, J., Chin, R., Cory, J., Webb, K. and O'Donnell, D. (2013). Inspiratory Capacity during Exercise: Measurement, Analysis, and Interpretation. Pulmonary Medicine, [online] 2013, pp.1-13. Available at: http://dx.doi.org/10.1155/2013/956081 [Accessed 7 Mar. 2018].
23) Troosters, D., Dupont, D., Bott, J. and Hansen, K. (2016). Your lungs and exercise. Breathe, 12(1), pp.97-100.
24) Marina, A. (2018). The Effects of Exercise on Lung Capacity. [online] LIVESTRONG.COM .Available at: https://www.livestrong.com/article/480176-the-effects-of-exercise-on-lung-capacity/ [Accessed 9 Mar. 2018].
25) Fatouros, I., Taxildaris, K., Tokmakidis, S., Kalapotharakos, V., Aggelousis, N., Athanasopoulos, S., Zeeris, I. and Katrabasas, I. (2002). The Effects of Strength Training, Cardiovascular Training and Their Combination on Flexibility of Inactive Older Adults. International Journal of Sports Medicine, 23(2), pp.112-119.