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High-frequency audiometry, speech perception in quiet and noise, and vestibular-evoked myogenic potential in women with polycystic ovary syndrome

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Abstract

Purpose: The study aimed to investigate the effect of PCOS on high-frequency thresholds, speech perception in quiet and in presence of noise, and vestibular functioning in women with and without PCOS and to correlate the speech perception scores with that of the pure-tone thresholds obtained at conventional and higher frequencies.

Methods: Women with and without PCOS in the age range of 18–40 years diagnosed between January 2019 and January 2020 were participants. Conventional and high-frequency audiometry (HFA), speech perception in quiet and in noise (SPIN), and cervical vestibular-evoked myogenic potentials (cVEMP) and ocular vestibular-evoked myogenic potentials (oVEMP) were assessed for both groups.

Results: Conventional audiometry (250 Hz to 8000 Hz) showed no statistically significant difference between both groups. High-frequency audiometry (9000 Hz to 20,000 Hz) showed significantly poorer pure-tone thresholds for women with PCOS compared to women without PCOS. SPIN results showed significantly lower SPIN scores for women with PCOS for – 3dB SNR, – 6 dB SNR, and – 9dB SNR. No difference in scores was observed for quiet conditions and 0 dB SNR for women with and without PCOS. cVEMP and oVEMP responses showed reduced amplitude in women with PCOS.

Conclusion: All the women diagnosed with having PCOS should be screened for hearing loss, speech perception difficulty in quiet and in presence of noise, and vestibular system functioning. If the hearing is affected, intervention should be started early in life.

Keywords: Polycystic ovary syndrome, High-frequency audiometry, Speech perception in noise, Vestibular-evoked myogenic potential

Background

Polycystic ovary syndrome (PCOS), a heterogeneous endocrine disorder also known as Stein-Leventhal syndrome or hyperandrogenic anovulation is seen in as many as 1 in 10 women of childbearing age [1]. PCOS is often

characterized by enlarged ovaries that contain a small collection of fluid and follicles which affect girls as young as 11 years old. PCOS is commonly seen in adolescence affecting 5–10% of women during their reproductive age [2]. The simultaneous presence of hyperandrogenism and menstrual disturbances are the diagnostic criteria proposed by the National Institute of Health (NIH) in 1990. Later in 2006, the Androgen Excess Society suggested that the presence of clinical or biochemical hyperandrogenism, oligovulation or anovulation, and/

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or polycystic ovary can be considered for the diagnosis of PCOS [2]. The exact causes of PCOS are unknown but some researchers have reported that the condition is a consequence of hormonal imbalance, increased body weight, heredity, excess insulin, and inflammation. Thus, it can be considered an idiopathic condition but is often associated with hyperandrogenism, oligomenorrhea, polycystic ovaries, and chronic anovulation [3]. PCOS can be considered a proinflammatory condition with higher proatherogenic inflammatory mediators and an imbalance between prooxidants and antioxidants [4–6]. Metabolic disorders like insulin resistance, dyslipidemia, glucose intolerance, obesity, non-alcoholic fatty liver, and hypertension are often associated with PCOS along with cardiovascular problems [4–6]. C-reactive protein (CRP) was 96% higher in women with PCOS than healthy women with renal abnormalities and atherothrombotic cardiovascular disease [7, 8].

Clinically, women with PCOS exhibit symptoms like infrequent menstrual cycles, infertility, and increased production of male hormones resulting in weight gain, acne, excess facial hair growth, skin problems, and baldness. Some investigations have also reported that women with PCOS are also at risk for high cholesterol, hypertension, diabetes, depression, and sleep apnoea whereas pregnant women are at increased risk for gestational diabetes, premature birth, and miscarriages [3]. Ciccone et al. also reported that women with PCOS had higher anteroposterior diameter than healthy women and suggested that atherosclerotic change starts early in women with PCOS thus, biochemical and hormonal changes can be considered to be more evident in individuals with PCOS which can result in vascular occlusion or vascular stenosis too [9].

The ability of hearing is altered as a result of insulin resistance, endothelial damage, cardiovascular problems, and hormonal and biochemical changes [1]. Women with PCOS show high-frequency hearing loss which could be the result of damage to the endothelial lining [10]. Oghan and Coksuer concluded that the increased carotid intima-media thickness (IMT) in PCOS results in biochemical and hormonal changes that affect the intravascular blood flow and leads to sensorineural hearing loss [1]. The oxygen supply for the inner ear is restricted due to vascular occlusions at the level of arteries or arterioles which may result in hearing loss in women with PCOS. If the blood and the oxygen supply to the ear get restored early in women with PCOS, there is a higher probability of restoring the low-frequency thresholds to normal or near-normal [11]. Kucur et al. also reported a statistically significant difference in hearing thresholds between women with PCOS in comparison to healthy women in hearing thresholds at higher frequencies [10].

High-frequency hearing loss is now an established finding in women with PCOS. The hearing loss at high frequencies may disturb the perception of the speech in the adverse listening condition (in presence of noise). The perception difficulty may increase even more when the conversation contains more high-frequency speech sounds. So, it was important to investigate the effect of PCOS on speech perception in quiet and in presence of noise and to correlate the speech perception scores with that of the pure-tone thresholds obtained at higher frequencies.

The hearing care professionals should focus on these endothelial damage diseases or disorders of lifestyle which affect individuals hearing ability and need to understand the clinical signs and symptoms to monitor further based on the type and the status of the clinical condition. The various research studies revealed the biological and hormonal variations in PCOS and their impact on hearing ability was clinically showed the difference to their counterpart thus a measurement of hearing thresholds in these individuals are much necessary thus the present study was considered to examine the hearing thresholds by advocating conventional audiometry and high-frequency audiometry in these individuals.

The present study is a preliminary work that aimed to investigate the high-frequency thresholds in women with PCOS along with cervical and ocular vestibular-evoked myogenic potentials (cVEMP and oVEMP). The authors postulated that due to the close anatomical and physiological relationship between the cochlea and the utricle and the saccule (otolith organ) of the inner ear, there is a probability of impaired otolith organ functioning along with the cochlear functioning in individuals with PCOS. Hence, the present study was conducted to evaluate the high-frequency audiometry, speech perception in quiet and in noise and otolith functioning in women with PCOS.

Methods

Participants

Forty volunteer women in the age range of 18–40 years were included in the study. The participants were divided into two groups. Group 1 comprised of women without PCOS and Group 2 had women diagnosed with PCOS. The women with PCOS were diagnosed by a practicing gynecologist based on ultrasound examination and hormonal analysis. Written informed consent was obtained from all the participants. The participants with complaints or history of otologic, neurological, and other associated systemic illnesses like diabetes, hypertension, noise exposure, ear surgeries, and intake of medications and hormonal therapy or any other autoimmune

conditions were excluded from the study. Institutional review board approval was taken before the study.

Procedure

Detailed case history was taken and otoscopic examination was carried out for all the participants. The study was carried out in two phases. Phase 1 included estimating the hearing thresholds of all the participants using conventional audiometry, high-frequency audiometry, and assessing the speech perception ability in quiet and in noise conditions. Phase 2 includes the evaluation of vestibular apparatus using cVEMP and oVEMP.

Phase 1 (Conventional audiometry, High-frequency audiometry, and Speech perception in quiet and in noise) - The hearing thresholds of all the participants were estimated using a calibrated audiometer and a set of headphones. Hearing thresholds for frequencies from 250 to 8000 Hz were assessed under conventional audiometry and from 9000 to 20,000 Hz under high-frequency audiometry (HFA). The hearing thresholds were tracked using modified Hughson and Westlake procedures [12]. Following the hearing assessment, the speech perception ability in quiet and in presence of noise was examined for all the participants.

The standardized high-frequency words and sentences developed at AIISH were considered as stimuli. The scores were calculated in quiet and at four different signal-to-noise ratios (0 dB SNR, - 3 dB SNR, - 6 dB SNR, and - 9 dB SNR). Ten high-frequency words and 6 high-frequency sentences were presented per condition. Both the ears were evaluated individually by presenting the stimuli monaurally. The stimuli were routed through an audiometer. The intensity dial for the speech was kept constant at 60 dB HL and the level of speech noise was varied to achieve different SNR. All the participants were asked to repeat the stimuli accurately and were asked to guess in case the stimuli were not understandable.

Phase 2 (cVEMP and oVEMP)

The functioning of the vestibular apparatus of the inner ear was examined using VEMP. cVEMP and oVEMP were recorded for all the participants of both the groups using intelligent hearing systems (IHS). The protocol for recording cVEMP and oVEMP is the same as suggested by Singh and Apeksha [13]. For recording cVEMP, the participants were made to sit on a straight back chair and have to maintain an upright posture of the upper body. The inverting electrode was placed at the sternoclavicular junction, the non-inverting electrode on the middle of the sternocleidomastoid (SCM) muscle, and the ground electrode on the forehead. Head rotation of 60–70° away from the ear of stimulation was maintained while recording cVEMP. Five hundred hertz tone-burst at 125 dB

SPL with a rise/fall time of 2 ms and plateau time of 1 ms was used. The electromyography (EMG) activity was recorded from the ipsilateral SCM muscle by considering 200 averages for each recording.

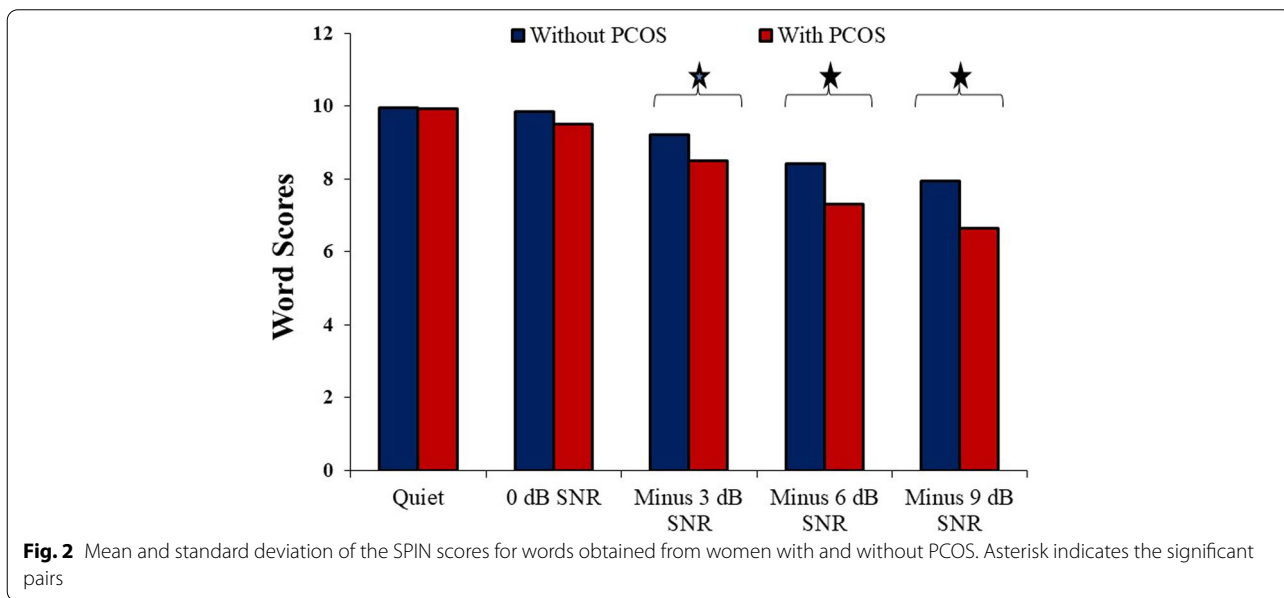
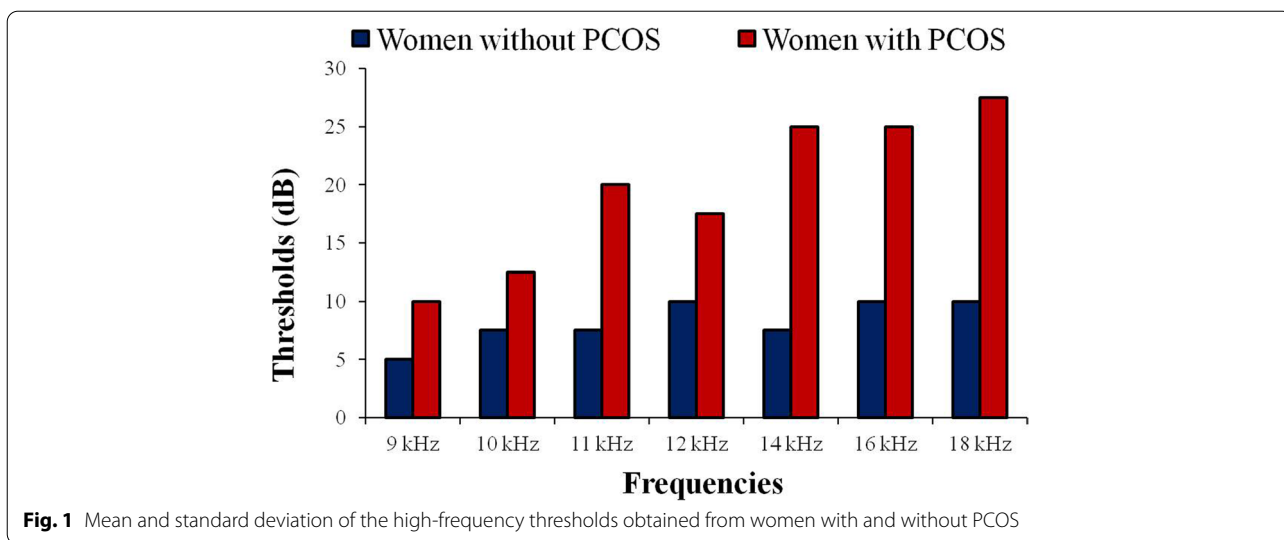
For recording oVEMP, the non-inverting electrode was placed 1 cm below the lower eyelid contralateral to the ear of stimulation, inverting electrode 2 cm below the non-inverting electrode, and ground on the forehead. All the participants had to maintain a 30° gaze elevation in the median plane. Five hundred hertz tone-burst at 125 dB SPL with a rise/fall time of 2 ms and plateau time of 1ms was used by considering 200 averages for each recording. Replicability of the peaks was ensured by recording both cVEMP and oVEMP responses twice. The responses were analyzed based on the latencies, amplitude, and asymmetry ratio for both cVEMP and oVEMP.

Results

The pure-tone thresholds, the speech recognition scores, and the cVEMP and oVEMP findings obtained were tabulated and analyzed using SPSS (version 17) software. Shapiro-Wilk's test of normality showed non-normal distribution ($p < 0.05$) of conventional hearing thresholds, HFA thresholds, SPIN data, and VEMP findings, thus non-parametric statistics were done. Wilcoxon signed-rank test was done to investigate the ear effect for both groups of participants. The result showed no ear effect for the conventional thresholds, HFA thresholds, SPIN scores, and VEMP results for both the groups, and thus the hearing thresholds and the SPIN scores for both the ears were combined making 80 ears of women with and without PCOS. Mann-Whitney U test was done to compare the values from both groups.

Conventional audiometry results suggested no significant difference for hearing thresholds from 250 to 8000 Hz for both the groups of women with and without PCOS. HFA showed significantly poorer thresholds for frequencies from 9000 to 20,000 for women with PCOS compared to women without PCOS. The median value of the HFA thresholds is given in Fig. 1.

Figures 2 and 3 show the median value of word scores and the sentence scores obtained from women with and without PCOS respectively. Mann-Whitney U test results showed women with PCOS to have significantly lower SPIN scores for words at - 3 dB SNR, - 6 dB SNR, and - 9 dB SNR. SPIN scores for sentences also showed women with PCOS to have significantly lower scores at 0 dB SNR, - 3 dB SNR, - 6 dB SNR, and - 9 dB SNR. Mann-Whitney U test results obtained for SPIN scores are provided in Table 1. Friedman test, done for both the groups across conditions showed a statistically significant difference between SNRs for women with PCOS ($\chi^2 = 240.69$, $p = 0.000$) and women



without PCOS ($\chi^2 = 225.21, p = 0.000$). Wilcoxon signed-rank test was done to find the significant pairs of SNRs. Results showed a statistically significant difference among all the conditions for both the groups of women with and without PCOS except among quiet and 0 dB SNR for women with PCOS.

cVEMP and oVEMP results obtained from both groups showed clear and identifiable responses. The median value of P13 and N23 and N10 and P15 latencies, peak-to-peak amplitude (Pk-Pk amplitude), and asymmetry ratio obtained from women with and without PCOS are shown in Figs. 4 and 5, respectively. The women with PCOS showed significantly lower Pk-Pk amplitude for

both cVEMP and oVEMP compared to women without PCOS. The cVEMP and the oVEMP latency did not show a significant difference across the groups. Mann-Whitney *U* test results obtained for cVEMP and oVEMP parameters are provided in Table 2.

Discussion

Women with PCOS showed significantly reduced HEA thresholds and SPIN scores compared to women without PCOS. This decreased hearing sensitivity at high frequencies and poor SPIN scores for words and sentences in women with PCOS suggests a direct link between the hormonal changes seen in women with PCOS and

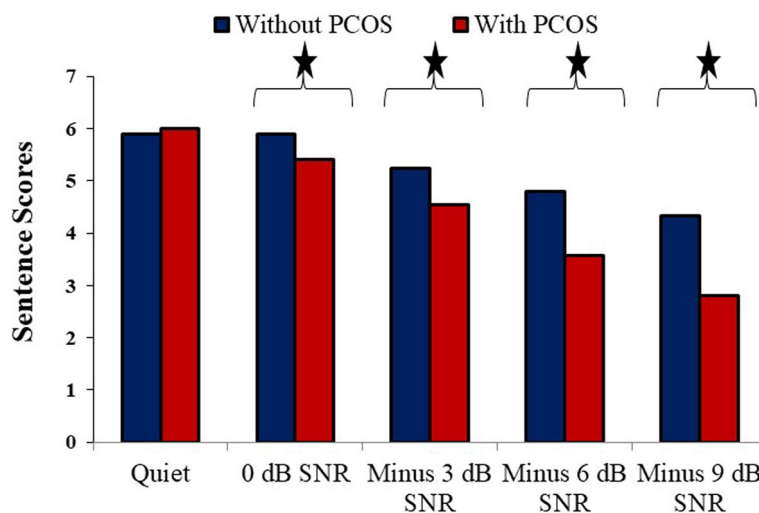


Fig. 3 Mean and Standard deviation of the SPIN scores for sentences obtained from women with and without PCOS. Asterisk indicates the significant pairs

Table 1 Mann-Whitney *U* test results for high-frequency audiometry (HFA) and SPIN (words and sentences) scores from women with and without PCOS

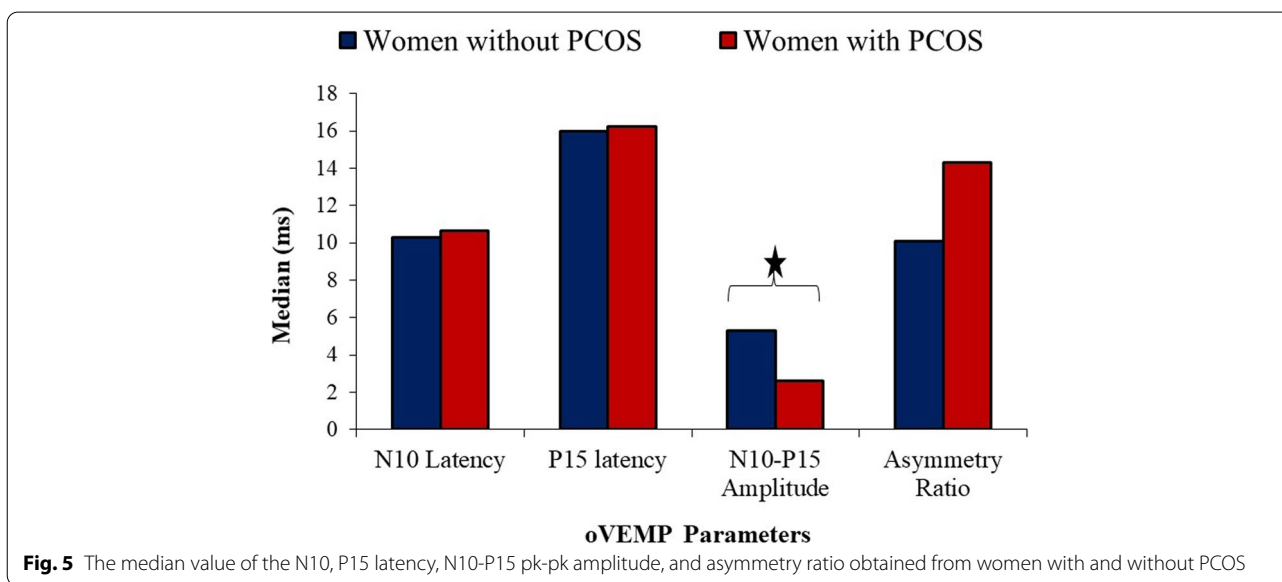
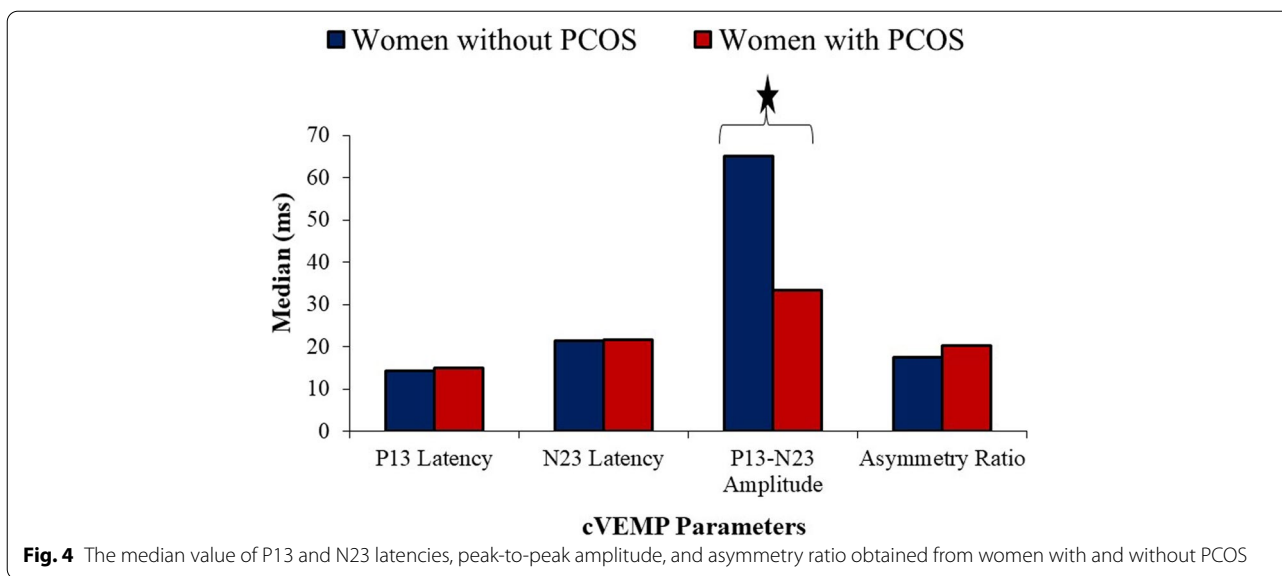
		Z value	P value
HFA thresholds	9 kHz	2.89	0.004*
	10 kHz	3.42	0.001*
	11 kHz	4.50	0.000*
	12 kHz	4.77	0.000*
	14 kHz	5.67	0.000*
	16 kHz	4.96	0.000*
	18 kHz	4.35	0.000*
	20 kHz	3.96	0.000*
SPIN scores (words)	Quiet	0.58	0.557
	0 dB SNR	1.84	0.065
	- 3 dB SNR	2.85	0.004*
	- 6 dB SNR	3.14	0.002*
	- 9 dB SNR	3.34	0.001*
SPIN scores (sentences)	Quiet	1.76	0.078
	0 dB SNR	2.75	0.006*
	- 3 dB SNR	2.47	0.013*
	- 6 dB SNR	4.51	0.000*
	- 9 dB SNR	4.20	0.000*

*Significant difference between the groups

the audio-vestibular function. It is believed that the atherosclerotic changes seen in women with PCOS are a result of biochemical and hormonal changes, which may directly affect the intravascular blood flow to the cochlear region [1]. The reduced blood to the cochlea leads to a reduction in the oxygen supply and results in

significant cochlear and neural damage and thus significantly reduced response at high frequencies. With medication, if the normal blood supply to the cochlear portion is restored, the hearing at low and mid frequencies might recover but the hearing at higher frequencies might not show improvement [11]. Based on previously published reports [1, 10, 14] and the report of the present study, it is found that women with PCOS have significant high-frequency hearing loss. Women diagnosed with PCOS should be screened for hearing loss using high-frequency audiometry (9000 Hz to 20,000 Hz) rather than conventional audiometry (250 Hz to 8000 Hz).

SPIN test results in the present study showed significantly reduced speech perception scores in women with PCOS compared to women without PCOS. This reduction in speech perception scores in noise suggests that women with PCOS find it difficult to perceive speech when the speech contains more high-frequency sounds. One of the recently published studies also showed significantly poorer SPIN scores in women with PCOS compared to healthy male adults [15]. The SPIN scores were compared between women with PCOS and healthy men in this study. Since the hormones are different in males and females, it is not wise to compare the SPIN scores among the two groups and this result can be categorized as under limitation of the study and should be interpreted with caution. The present report is the only study highlighting the SPIN scores in women with and without PCOS. There are also published reports suggesting a difference in cognitive functioning of women with and without PCOS [14, 16–18]. Barnard et al. suggested women with PCOS have impaired performance in terms of speed



and accuracy of the task, reaction time, and word recognition tasks [18]. Based on Functional MRI response during a working memory task, Soleman et al. found the area of activation of the brain to be more during the working memory task in women with PCOS compared to women without PCOS [16]. This suggests that women with PCOS require additional areas of the brain for carrying out a working memory task. Hephzibah et al. reported poorer performance of women with PCOS on backward digit task, ascending digit task, and descending digit task compared to women without PCOS [14].

The reduced amplitude of cVEMP and oVEMP in women with PCOS suggests hypofunction of the

sacculo-collic pathway and utriculo-ocular pathway. The impaired functioning of the otolith organs can be a consequence of the inadequate blood flow to the vestibular structures. This suggests that the patient might have difficulty while moving in the horizontal and the vertical plane. Despite a significant reduction in the VEMP amplitude in women with PCOS, they do not report vertigo in the daily living situation. This could be because of the substitution of the function of the vestibular system with either the visual or proprioceptive system. Central compensation can also be one of the remedial measures for women with PCOS. It can be hypothesized that if the severity of the syndrome becomes more, it might have a

Table 2 Mann-Whitney *U* test results for the cVEMP and oVEMP parameters

	Z value	P value
cVEMP		
P13 latency	1.627	0.104
N23 latency	1.317	0.188
P13-N23 Pk-Pk	3.002	0.003*
AR	0.601	0.548
oVEMP		
N10 latency	1.339	0.181
P15 latency	0.547	0.584
N10-P15 Pk-Pk	5.168	0.000*
AR	1.182	0.237

Note: *Pk-Pk* peak-to-peak amplitude, *AR* asymmetry ratio

*Significant difference between the groups

significant impact on the locomotion ability of women with PCOS. This hypothesis needs exploration.

Considering the findings of the present study as well as previously published studies on women with PCOS, all the women diagnosed with PCOS must be screened for hearing, vestibular and speech perception issues soon after the diagnosis of PCOS and should also be monitored later in life. Early identification of significant hearing loss and poor perception of speech in women with PCOS will help in early intervention. Early treatment may reverse the effect of hormonal disturbance seen in women with PCOS and can bring back the cochlear-vestibular function to normal/near normal. The study has few limitations which makes the finding of this study less reflective of the population. This study was done on a small sample of women with PCOS; thus, it is difficult to generalize the result of this study to the general population. The present study can be validated with more women with PCOS. Different tests which assess other audio-vestibular structures should be considered. Electrophysiological test measures can be used along with behavioral measures to conclude the results with more confidence.

Conclusion

Women with PCOS show poorer thresholds at higher frequencies than women without PCOS. Women with PCOS show poor speech perception scores in presence of noise compared to women without PCOS. No significant difference was seen at conventional frequencies and speech perception scores in quiet among the groups. Women with PCOS also showed significantly poorer cVEMP and oVEMP responses.

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Authors' contributions

Conceptualization: KA, Methodology: KA, AB, and DD, Formal analysis and investigation: KA, AB, and DD, Writing – original draft preparation: KA, DD, Writing – review and editing: KA and DD. All authors read and approved the final version of the manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request

Declarations

Ethics approval and consent to participate

Institutional ethical committee approval was taken before this study. Obtained from the JSSISH ethical committee with reference No. JSSISH/2022/P7. Informed consent was obtained from all individual participants included in the study.

Consent for publication

Patients signed informed consent regarding publishing their data and photographs.

Competing interests

The authors have no competing interests to declare that are relevant to the content of this article.

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