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Original Research Article

Yoga as a therapeutic modality for hormonal and metabolic regulation in premenopausal women with polycystic ovary syndrome

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ABSTRACT

Background: Polycystic ovary syndrome represents a significant health challenge for women during the premenopausal phase, characterized by hormonal imbalances, metabolic dysfunction, and chronic inflammation. Traditional pharmacological approaches often provide incomplete relief and may be associated with unwanted side effects. This investigation examined yoga practice as a non-pharmacological therapeutic strategy for addressing the multidimensional pathophysiology of PCOS.

Methods: Forty premenopausal women aged 35-55 years diagnosed with PCOS participated in this three-month randomized controlled investigation at GVN Hospital, Trichy, Bangalore. Participants were allocated to control (n=10) and yoga intervention (n=30) groups. The yoga protocol consisted of structured 30-minute sessions held three times per week, incorporating physical postures, breathing techniques, and meditation. Comprehensive assessments included reproductive hormone profiles, inflammatory biomarkers, metabolic parameters, and clinical outcomes.

Results: Participants engaging in yoga interventions demonstrated substantial improvements across multiple physiological domains. Significant reductions were observed in high-sensitivity C-reactive protein and interleukin-6 levels, indicating decreased systemic inflammation. Hormonal assessments revealed favorable changes in luteinizing hormone, estradiol, and prolactin concentrations. Metabolic indices showed improvement, with enhanced insulin sensitivity and reduced markers of metabolic dysfunction. Enhanced pregnancy rates were observed among participants seeking conception.

Conclusions: A structured 12-week yoga intervention effectively modulates hormonal balance, reduces inflammatory burden, and improves metabolic health in premenopausal women with PCOS. These findings support yoga as a valuable complementary therapeutic approach that addresses multiple pathophysiological aspects of the syndrome, offering a holistic, sustainable, and patient-centered management strategy for women with PCOS.

Keywords: Hormonal balance, Inflammatory markers, Metabolic health, Non-pharmacological intervention, Polycystic ovary syndrome, Premenopausal women, Yoga therapy

INTRODUCTION

Polycystic ovary syndrome (PCOS) constitutes one of the most prevalent endocrine disorders affecting women during their reproductive years, with global estimates suggesting that approximately 8-13% of women experience this condition.[1,2] The syndrome's clinical manifestation encompasses a constellation of reproductive, metabolic, and psychological disturbances that significantly impact quality of life and long-term health outcomes.[2,3] The premenopausal transition period represents a particularly vulnerable time for women with PCOS, as hormonal fluctuations during this phase may exacerbate existing symptoms and introduce new health challenges.[4,5]

The pathophysiology of PCOS encompasses multiple interconnected systems, with hormonal dysregulation manifesting as elevated androgens, disrupted gonadotropin secretion patterns, and insulin resistance.[3,6,7] These endocrine disturbances contribute to anovulation, menstrual irregularities, and infertility- hallmark features of the syndrome.[6,8] Women with PCOS frequently exhibit a pro-inflammatory state characterized by elevated circulating inflammatory cytokines and markers, which compounds metabolic dysfunction and contributes to long-term cardiovascular risk.[9-11] Emerging evidence implicates gut dysbiosis in PCOS pathophysiology through its impact on systemic inflammation, insulin resistance, and reproductive hormone imbalance.[12-14]

Current therapeutic approaches for PCOS management predominantly rely on pharmacological interventions targeting specific symptoms. Hormonal contraceptives address menstrual irregularity and hyperandrogenism, while insulin-sensitizing medications aim to improve metabolic parameters.[15,16] However, these treatments often provide only partial symptom relief and may be associated with adverse effects or contraindications in certain patient populations.[2,16] Furthermore, pharmaceutical approaches typically do not address the syndrome's multifactorial nature comprehensively, leaving many women seeking alternative or complementary therapeutic options.[14,17]

Lifestyle interventions have emerged as fundamental components of PCOS management, with growing evidence supporting their efficacy in improving both reproductive and metabolic outcomes.[18,19] Among various lifestyle modifications, yoga has garnered particular attention due to its holistic approach that addresses physical, mental, and emotional well-being simultaneously.[20-22] Yoga practice encompasses physical postures (asanas), controlled breathing techniques (pranayama), and meditation, offering a comprehensive intervention that may target multiple pathophysiological aspects of PCOS.[23,24]

Emerging research suggests that yoga exerts beneficial effects through several mechanisms relevant to PCOS pathophysiology. Physical aspects of yoga practice may enhance insulin sensitivity and promote favorable body composition changes.[23,25] Stress-reducing components of yoga, including meditation and breathing exercises, may modulate hypothalamic-pituitary-adrenal axis function, potentially influencing reproductive hormone regulation.[26,27] Additionally, yoga has been associated with reduced systemic inflammation and improved autonomic nervous system balance.[28-30] Recent studies indicate that yoga may also influence the gut microbiota-brain axis, contributing to metabolic and endocrine improvements.[31,32]

Despite growing interest in yoga as a therapeutic modality for PCOS, comprehensive investigations examining its effects on the interconnected hormonal, metabolic, and inflammatory disturbances characteristic of the syndrome remain limited.[21,22] Understanding these mechanisms is essential for developing evidence-based treatment protocols that can be readily implemented in clinical practice.[33]

This investigation aimed to evaluate the therapeutic potential of a structured yoga intervention on hormonal profiles, inflammatory markers, and metabolic parameters in premenopausal women diagnosed with PCOS. We hypothesized that regular yoga practice would beneficially modulate these interconnected physiological systems, offering a non-pharmacological approach to comprehensive PCOS management.

METHODS

Study type and design

This study was conducted as a randomized controlled trial with parallel group design over a 12-week intervention period.

Study place and period

The study was conducted at S-VYASA (Swami Vivekananda Yoga Anusandhana Samsthana) Hospital and Research Center, Bangalore, Karnataka, India, from April 2021 to October 2021.

Ethical approval

The study protocol received approval from the institutional ethics committee of S-VYASA (RES/IEC-SVYASA/198/2021) and was prospectively registered with the Clinical Trial Registry-India (CTRI/2021/04/033196). All procedures were conducted in accordance with the Declaration of Helsinki principles. Written informed consent was obtained from all participants prior to enrolment after detailed explanation of study procedures, potential risks, and benefits.

Inclusion criteria

Premenopausal women aged 35-55 years. Clinically confirmed diagnosis of PCOS based on Rotterdam consensus criteria (at least two of the following: oligo-ovulation or anovulation, clinical or biochemical signs of hyperandrogenism, polycystic ovarian morphology on ultrasound examination). Willingness to participate in yoga sessions three times per week for 12 weeks. Ability to provide written informed consent.

Exclusion criteria

Current pregnancy or lactation. Use of hormonal medications within three months prior to enrolment. Diagnosed thyroid disorders (hypothyroidism or hyperthyroidism). Diabetes mellitus or other significant endocrine conditions. Regular yoga practice within the previous six months (defined as more than once per week).

Medical contraindications to physical activity. Severe cardiovascular, respiratory, or musculoskeletal conditions preventing participation in yoga practice. Unwillingness to comply with study protocol.

Sample size and randomization

Forty premenopausal women meeting the eligibility criteria were enrolled in the study. Following baseline assessments, participants were randomly assigned to one of two groups using computer-generated random numbers in a 3:1 allocation ratio: yoga intervention group (n=30) or control group (n=10). The unequal allocation was designed to provide adequate statistical power for primary outcome comparisons while maximizing data collection from the intervention group. Randomization was performed by an independent researcher not involved in participant recruitment or assessment.

Procedure

Control group (n=10)

Participants in the control group maintained their usual lifestyle habits and received standard medical care from their primary healthcare providers throughout the 12-week study period. They were instructed not to initiate any new exercise programs or lifestyle interventions during this time. Control group participants underwent the same assessment procedures as the intervention group at baseline and post-intervention.

Yoga intervention group (n=30)

The yoga intervention consisted of structured 60-minute sessions conducted three times per week (Monday, Wednesday, and Friday) under the direct supervision of certified yoga instructors at S-VYASA. Each session followed a standardized protocol designed specifically for PCOS management:

Session structure

Initial relaxation and centering (5 minutes): participants began each session in a comfortable seated or supine position with guided body awareness and initial breath observation to transition from daily activities into practice.

Physical postures- asanas (30 minutes): the asana sequence emphasized postures targeting the pelvic region, abdominal strengthening, and spinal flexibility. Specific postures included: Surya Namaskar (Sun Salutations)- 3 rounds, Tadasana (Mountain Pose), Trikonasana (Triangle Pose), Bhujangasana (Cobra Pose), Dhanurasana (Bow Pose), Sarvangasana (Shoulder Stand) - with modifications as needed, Matsyasana (Fish Pose), Paschimottanasana (Seated Forward Bend), Baddha Konasana (Butterfly Pose), Supta Baddha Konasana (Reclined Butterfly Pose).

Breathing techniques- Pranayama (15 minutes): Nadi Shodhana (Alternate Nostril Breathing)- 10 minutes, Bhramari (Humming Bee Breath)- 3 minutes, Kapalabhati (Skull Shining Breath)- 2 minutes.

Guided meditation and deep relaxation (10 minutes): sessions concluded with guided meditation focusing on breath awareness followed by Yoga Nidra (yogic sleep) for deep physical and mental relaxation.

Instructors were trained to modify practices based on individual fitness levels and physical limitations. Participants were provided with printed guides and encouraged to practice brief 15-20 minute sessions at home on non-class days, though home practice was not mandatory. Attendance was recorded at each session.

Outcome assessments

Comprehensive assessments were performed at two time points: baseline (week 0) and post-intervention (week 12). All measurements were conducted by trained personnel blinded to group allocation.

Anthropometric measurements

Body weight was measured using a calibrated digital scale (accuracy ±0.1 kg) with participants in light clothing without shoes. Height was measured using a wall-mounted stadiometer (accuracy ±0.1 cm). Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m²). Waist circumference was measured at the narrowest point between the lower costal margin and iliac crest using a non-stretchable measuring tape, with measurements recorded to the nearest 0.1 cm.

Biochemical analyses

Sample collection: Fasting venous blood samples (15 mL) were collected in the early morning (7:00-9:00 AM) following a minimum 12-hour overnight fast. Blood was drawn from the antecubital vein using standard venipuncture technique. Samples were allowed to clot at room temperature for 30 minutes, then centrifuged at 3000 rpm for 15 minutes at 4°C. Serum was separated and aliquoted into cryovials, then immediately stored at -80°C until batch analysis.

Hormonal assays: Reproductive hormones including luteinizing hormone (LH), follicle-stimulating hormone (FSH), estradiol, progesterone, prolactin, and total testosterone were measured using electrochemiluminescence immunoassays (ECLIA) on a Cobas e411 analyzer (Roche Diagnostics). Inter-assay and intra-assay coefficients of variation were <5% for all hormonal assays.

Metabolic parameters: Fasting glucose was measured using the glucose oxidase-peroxidase method. Fasting insulin was quantified using chemiluminescent

immunoassay. Glycated hemoglobin (HbA1c) was measured by high-performance liquid chromatography (HPLC). Lipid profile components (total cholesterol, HDL-cholesterol, LDL-cholesterol, and triglycerides) were analyzed using enzymatic colorimetric methods on an automated chemistry analyzer.

Insulin resistance: The homeostatic model assessment for insulin resistance (HOMA-IR) index was calculated using the formula: HOMA-IR = (fasting insulin in μIU/mL × fasting glucose in mg/dL) / 405.

Inflammatory markers

High-sensitivity C-reactive protein (hs-CRP) was quantified using immunoturbidimetric nephelometry with a detection limit of 0.1 mg/L. Serum interleukin-6 (IL-6) concentrations were determined using commercially available enzyme-linked immunosorbent assay (ELISA) kits (R&D Systems) following manufacturer protocols. All samples were analyzed in duplicate, and mean values were used for statistical analysis. Inter-assay coefficient of variation was <8% for inflammatory markers.

Clinical outcomes

Menstrual cycle regularity was documented through participant-maintained diaries throughout the study period. Irregular cycles were defined as cycle length <21 days or >35 days. For participants actively attempting conception, pregnancy outcomes were recorded and confirmed through serum β-hCG testing and ultrasound examination. Additional parameters including modified Ferriman-Gallwey scores for hirsutism and self-reported symptom questionnaires were collected but are not reported in this analysis.

Statistical analysis

All statistical analyses were performed using SPSS version 25.0 (IBM Corporation, Armonk, NY, USA) and GraphPad Prism version 9.0 (GraphPad Software, San Diego, CA, USA). The level of statistical significance was set at $p < 0.05$ for all analyses.

Baseline comparisons: Baseline characteristics between groups were compared using independent samples t-tests for continuous variables and chi-square tests for categorical variables. Normality of data distribution was assessed using Shapiro-Wilk tests.

Within-group changes: Changes from baseline to post-intervention within each group were evaluated using paired t-tests for normally distributed variables or Wilcoxon signed-rank tests for non-normally distributed variables.

Between-group comparisons: Differences between groups in the magnitude of change were analyzed using one-way analysis of variance (ANOVA) with post-hoc Tukey tests for pairwise comparisons.

Effect sizes: Cohen's d was calculated to assess the magnitude of treatment effects, with values of 0.2, 0.5, and 0.8 interpreted as small, medium, and large effect sizes, respectively.

Data presentation: Continuous variables are presented as mean±standard deviation (SD). Categorical variables are presented as frequencies and percentages.

Missing data: Intention-to-treat analysis principles were employed. As there were no dropouts in this study, all participants completed both baseline and post-intervention assessments, and no imputation for missing data was necessary.

RESULTS

Participant characteristics and study completion

All 40 enrolled participants (100%) completed the 12-week study protocol with no dropouts or withdrawals reported. Baseline characteristics were comparable across the two groups, with no statistically significant differences in age, BMI, waist circumference, duration of PCOS diagnosis, or baseline biochemical parameters (Table 1). The mean age of participants was 42.3±5.7 years in the overall cohort. Mean BMI was 27.8±4.2 kg/m², indicating that the majority of participants were classified as overweight according to WHO criteria.

Adherence to the yoga intervention was excellent, with participants in the yoga group attending an average of 34.2±1.8 out of 36 scheduled sessions, representing 95.0±5.0% attendance rate. No adverse events related to the yoga intervention were reported throughout the study period.

Table 1: Relative risk of abnormal Doppler indices with adverse perinatal outcome.

Parameter	RR (95% CI)	RR (95% CI)
UA S/D ratio	4.46 (1.40-14.17)	0.86 (0.72-1.02)
UA PI>2 SD	2.80 (0.91-8.53)	0.91 (0.79-1.00)
UA RI>2SD	3.36 (1.03-10.61)	0.89 (0.78-1.03)
MCA	4.46 (1.4-14.17)	0.86 (0.7-1.02)
MUPI	0.35 (0.11-1.13)	1.04 (0.92-1.18)

Hormonal profile changes

Significant improvements in reproductive hormone profiles were observed in the yoga intervention group compared to controls (Table 2). The yoga group demonstrated a reduction in mean LH levels from 15.8±4.2 IU/l at baseline to 11.3±3.5 IU/l post-intervention ($p < 0.01$, Cohen's d = 1.15), while the control group showed minimal change (15.6±4.0 to 15.4±3.9 IU/l, $p = 0.723$).

The LH:FSH ratio, a key diagnostic marker in PCOS, decreased significantly in the yoga group from 2.4±0.6 to 1.8±0.5 ($p<0.01$, Cohen's d = 1.08), approaching the normal physiological range. No significant change was observed in the control group (2.4±0.6 to 2.4±0.6, p = 0.891).

Estradiol concentrations showed favorable shifts in the yoga intervention group, increasing from 49.1±12.5 pg/mL to 55.6±13.2 pg/ml ($p<0.05$, Cohen's d = 0.52). Prolactin levels decreased significantly in the yoga group from 16.5±4.7 ng/ml to 13.8±3.9 ng/ml ($p<0.05$, Cohen's d = 0.63). Progesterone levels increased in the yoga group from 2.9±1.2 ng/ml to 4.2±1.5 ng/ml ($p<0.05$, Cohen's d = 0.97), suggesting improved ovulatory function.

Total testosterone levels showed a decreasing trend in the yoga intervention group (69.1±15.6 to 62.3±14.1 ng/dL), though changes did not reach statistical significance (p = 0.082).

Inflammatory marker responses

The yoga intervention group demonstrated substantial reductions in inflammatory biomarkers (Table 3). High-sensitivity C-reactive protein decreased significantly from 4.8±1.9 mg/l at baseline to 2.9±1.2 mg/l post-intervention ($p < 0.001$, Cohen's d = 1.32). In contrast, the control group exhibited minimal change (4.7±1.8 to 4.6±1.7 mg/l, p = 0.823).

Interleukin-6 concentrations paralleled hs-CRP findings. The yoga group experienced a significant reduction in Il-6 from 3.6±1.4 pg/ml to 2.2±0.9 pg/ml ($p < 0.01$, Cohen's d = 1.18), representing clinically meaningful decreases in inflammatory burden. Control group IL-6 levels remained essentially unchanged (3.5±1.3 to 3.4±1.2 pg/ml, p=0.762).

Metabolic parameters and insulin sensitivity

Metabolic assessments revealed significant improvements in the yoga intervention group (Table 4). While fasting glucose concentrations remained within normal ranges across all groups, fasting insulin levels decreased significantly in the yoga group from 18.7±6.3 µIU/ml to 14.2±4.8 µIU/ml ($p<0.05$, Cohen's d = 0.84), indicating enhanced insulin sensitivity. Control group fasting insulin showed minimal change (18.2±6.1 to 17.9±5.9 µIU/ml, p = 0.834).

The HOMA-IR index improved substantially in the yoga intervention group, decreasing from 4.2±1.8 to 3.1±1.3 ($p < 0.05$, Cohen's d = 0.71). This reduction represents enhanced insulin sensitivity, a key therapeutic target in PCOS management. Control group HOMA-IR remained stable (4.1±1.7 to 4.0±1.6, p = 0.812).

Lipid profile improvements were observed in the yoga group. Total cholesterol decreased from 199.7±33.2 mg/dL to 186.3±29.8 mg/dl ($p<0.05$). HDL-cholesterol increased from 46.8±8.4 mg/dl to 51.2±8.9 mg/dl ($p<0.05$), while triglycerides decreased from 143.9±29.1 mg/dl to 128.7±25.4 mg/dl ($p<0.05$).

Body weight decreased by 2.1±1.4 kg in the yoga group ($p <0.05$), while waist circumference showed a reduction of 3.4±2.1 cm ($p<0.01$), suggesting improvements in abdominal adiposity.

Clinical outcomes

Menstrual cycle regularity improved notably in the yoga intervention group. At baseline, 22 of 30 participants (73.3%) in the yoga group reported irregular cycles, compared to 7 of 10 (70.0%) in the control group. Following the 12-week intervention, the proportion with irregular cycles decreased to 14 of 30 (46.7%) in the yoga group, while remaining unchanged at 7 of 10 (70.0%) in the control group.

Among the 18 participants actively attempting to conceive during the study period (14 in yoga group, 4 in control group), two pregnancies were confirmed in the yoga group (14.3%), while no pregnancies occurred in the control group. These pregnancies were confirmed at 8-10 weeks post-intervention through serum β-hCG testing and transvaginal ultrasound demonstrating intrauterine gestational sacs with fetal cardiac activity.

DISCUSSION

This randomized controlled trial demonstrates that a structured 12-week yoga intervention effectively addresses multiple pathophysiological aspects of PCOS in premenopausal women. Our findings reveal significant improvements in hormonal profiles, inflammatory markers, and metabolic parameters three interconnected domains central to PCOS pathophysiology.[1-3] The substantial benefits observed across multiple systems support yoga as a valuable complementary therapeutic approach that addresses the syndrome's multifaceted nature.[20-22]

The hormonal improvements documented in this study are particularly noteworthy. The significant reductions in LH levels and normalization of LH:FSH ratios represent favorable shifts toward endocrine balance. Elevated LH and altered LH:FSH ratios are diagnostic hallmarks of PCOS and contribute directly to ovarian dysfunction and hyperandrogenism.[6-8] The mechanism by which yoga influences these hormonal parameters likely involves multiple pathways. Stress reduction through meditation and pranayama may modulate hypothalamic-pituitary function, leading to more regulated gonadotropin secretion.[26,27] Additionally, improvements in insulin sensitivity as evidenced by reduced HOMA-IR in our study may indirectly influence reproductive hormone regulation, as insulin resistance is known to exacerbate hyperandrogenism in PCOS.[34,35]

The substantial reduction in inflammatory markers observed in the yoga intervention group represents a clinically significant finding. Chronic low-grade inflammation is increasingly recognized as a key contributor to PCOS pathophysiology, linked to insulin resistance, endothelial dysfunction, and increased cardiovascular risk.[9-11] The mechanisms underlying yoga's anti-inflammatory effects likely involve multiple components of the practice. Physical postures may reduce adipose tissue inflammation through favorable changes in body composition and adipokine secretion.[28,29] Stress-reduction techniques may dampen sympathetic nervous system activity and hypothalamic-pituitary-adrenal axis activation, both of which influence inflammatory responses.[30-36]

The metabolic improvements observed, particularly enhanced insulin sensitivity, align with previous research on lifestyle interventions in PCOS. Insulin resistance affects approximately 70% of women with PCOS and plays a central role in syndrome pathophysiology by promoting androgen excess and contributing to metabolic complications.[34,35] Yoga's effects on insulin sensitivity may operate through several mechanisms: increased skeletal muscle glucose uptake during physical practice, reduced cortisol levels through stress reduction, and improved autonomic balance favoring parasympathetic activity.[23,25]

The improvements in menstrual regularity and pregnancy rates, while based on relatively small numbers, are clinically meaningful outcomes that directly impact women's quality of life and reproductive goals. The restoration of more regular menstrual cycles likely reflects improved endocrine balance and ovarian function secondary to the hormonal and metabolic improvements documented in our study.[13,37]

Emerging evidence suggests that yoga may also influence the gut microbiota-brain axis, potentially contributing to the metabolic and endocrine improvements observed.[31,32] Recent research indicates that gut dysbiosis is associated with PCOS pathophysiology through its impact on systemic inflammation, insulin resistance, and reproductive hormone imbalance.[12,34] Lifestyle interventions, including yoga, may beneficially modulate gut microbial communities and restore metabolic and hormonal homeostasis.[33,38]

From a clinical perspective, these findings support yoga as a valuable complementary approach to conventional PCOS management. The intervention's favorable safety profile, absence of adverse effects, and benefits across multiple physiological domains make it an attractive option, particularly for women seeking non-pharmacological alternatives or those for whom certain medications may be contraindicated.[19,21,22]

Several limitations of this study should be acknowledged. The relatively small sample size, particularly in the control group, limits the precision of effect size estimates and subgroup analyses. The unequal allocation ratio, while intentional to maximize intervention group data, may limit direct comparisons. The 12-week intervention duration, while sufficient to demonstrate significant changes, does not address long-term sustainability of benefits. The study's single-center design in a yoga-specialized institution may limit generalizability to broader populations and settings. Future research should include larger multicenter trials with longer follow-up periods, mechanistic studies examining biological pathways including gut microbiota effects, and comparative effectiveness research against other lifestyle interventions.[33,39]

CONCLUSION

This randomized controlled trial provides robust evidence that a structured 12-week yoga intervention produces significant improvements across multiple physiological domains in premenopausal women with PCOS. The intervention effectively modulated reproductive hormone profiles, with normalized LH:FSH ratios approaching physiological ranges. Substantial reductions in inflammatory markers, including hs-CRP and IL-6, indicate decreased systemic inflammation. Enhanced insulin sensitivity and improved metabolic parameters demonstrate yoga's impact on the metabolic dysfunction characteristic of PCOS. Clinical improvements in menstrual regularity and potential reproductive benefits further support the therapeutic value of this intervention.

The excellent safety profile with no adverse effects, combined with high participant adherence, demonstrates yoga's feasibility as a practical therapeutic option. These findings support yoga as an effective, safe, and holistic non-pharmacological intervention that addresses the interconnected hormonal, metabolic, and inflammatory disturbances characteristic of PCOS. Healthcare providers should consider recommending structured yoga practice as a complementary therapeutic strategy for women with PCOS, particularly those seeking non-pharmacological management options or as an adjunct to conventional treatments.

Future research should focus on examining long-term sustainability of benefits beyond 12 weeks, determining optimal practice parameters and session frequency, investigating underlying mechanisms including potential gut microbiota modulation, conducting larger multicenter trials to confirm generalizability, and developing personalized intervention approaches based on individual PCOS phenotypes and patient characteristics.

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