



Resistance Training as Therapeutic Management in Women with PCOS: What is the Evidence?

PAMELA J. WRIGHT^{†1,2}, CYNTHIA F. CORBETT^{†1,2}, BERNARDINE M. PINTO^{‡1}, ROBIN M. DAWSON^{†1,2}, and MICHAEL WIRTH^{‡1}

¹College of Nursing, University of South Carolina, Columbia, SC, USA; ²Advancing Chronic Care Outcomes through Research and iNnovation, University of South Carolina, Columbia, SC, USA

[†]Denotes graduate student author, [‡]Denotes professional author

ABSTRACT

International Journal of Exercise Science 14(3): 840-854, 2021. Polycystic ovary syndrome (PCOS), the most common chronic endocrinopathy and the leading cause of infertility in women, has significant clinical consequences, including cardiovascular, endocrinological, oncological, and psychological co-morbidities. Endocrine Society Clinical Practice Guidelines on the Diagnosis and Treatment of PCOS recommend exercise and physical activity as first-line treatment to combat chronic disease risk. However, details about what type of exercise are not provided. Given the known beneficial effects of resistance training on the management of other chronic diseases, the purpose of this scoping review was to evaluate the scientific evidence about the physical and psychosocial effects of resistance training among women with PCOS. Studies were identified through a systematic search of PubMed, SPORTDiscus, and CINAHL databases. Peer-reviewed research studies published between January 2011 and January 2021 that evaluated a resistance training intervention for premenopausal women with PCOS were included. Studies that offered multi-component programs were excluded. Nine articles met the inclusion criteria of which seven were sub-studies of one larger clinical trial. One article reported findings from a small randomized controlled trial and the last article reported feasibility study findings. Each intervention yielded positive results across a wide range of outcome variables; however, the studies had small sample sizes and assessed different outcome variables. Evidence regarding the effects of resistance training on health outcomes for women with PCOS is positive but preliminary. Adequately powered clinical trials are required to confirm health benefits, answer research questions as to therapeutic dose, and discover behavioral strategies to promote resistance training for therapeutic management.

KEYWORDS: Polycystic ovarian syndrome, metabolic syndrome, strength training, symptom management

INTRODUCTION

Polycystic ovary syndrome (PCOS) is the most common chronic endocrinopathy and the leading cause of infertility in women (5). Based on conservative estimates, 5 million women in the United States (US) have PCOS (28). According to the 2003 Rotterdam diagnostic criteria, the most widely used criteria, PCOS is diagnosed when two or more of the following conditions are met:

ovulatory dysfunction or ultrasound evidence of polycystic ovaries, and clinical and/or biochemical signs of hyperandrogenism (23). The Endocrine Society endorses the 2003 Rotterdam Criteria because these criteria require a more comprehensive evaluation than other criteria, as it is the only criteria to include ovarian morphology (23). Women with PCOS are at risk for insulin resistance, obesity (specifically, visceral adiposity), dyslipidemia, and endometrial disturbances, thereby increasing the likelihood of comorbidities such as metabolic syndrome, cardiovascular disease, and endometrial cancer (10). Psychological morbidities are also significant, as women with PCOS are eight times more likely to have anxiety and depression than women without PCOS (8, 34). Given its various definitions and phenotypes, as well as significant and varied comorbidities, optimal treatment and management typically involves a multi-pronged approach of targeted medications and weight-management lifestyle changes.

Accordingly, the Endocrine Society Clinical Practice Guidelines on the Diagnosis and Treatment of PCOS recommend exercise and physical activity as first-line treatment to combat chronic disease risk yet details about what type of exercise are not included (23). Based on a 2011 systematic review of aerobic exercise (e.g., walking, cycling) for women with PCOS, the PCOS Australian Alliance adult guidelines advised at least 150 minutes per week of moderate-intensity physical activity, of which 90 minutes should be moderate-to-high intensity aerobic activity, to maintain health and/or help prevent chronic comorbidities by reducing body weight (1). The literature at that time had only examined the isolated use of aerobic exercise or aerobic exercise with diet. Therefore, any recommendations for resistance training are absent from these guidelines (38).

Resistance training (RT) is the anaerobic category of exercise involving the repeated movements against unaccustomed loads to stimulate a stronger muscle contraction (38). There is a wealth of research describing the beneficial effects of RT on symptoms and management of several chronic diseases such as diabetes, cardiovascular disease, and cancer (7). Since muscle contraction involves both mechanical and metabolic properties (39), this exercise modality is associated with increased functional strength (40), improved insulin sensitivity, quicker rapid glucose uptake (38), clinically decreased blood pressure over time, and increased basal metabolic rate (responsible for approximately two thirds of total energy expenditure) (39). These benefits are the reasons cardiac rehabilitation programs now include RT (29). Additionally, in a study by Schmitz et al. (35) a sample of women aged 30-50 years lost more visceral fat than men after an intervention of RT. Visceral fat, a type of fat stored in the abdomen, is a typical PCOS symptom and associated with risk of metabolic syndrome, diabetes, and hypertension (9, 39). Thus, the myogenic or muscular adaptations induced by RT are often accompanied by a range of physiological (metabolic) and functional adaptations that may be clinically important among women with PCOS.

A recent systematic review and meta-analysis also reported on the “discordant and limited findings on exercise characteristics” that could lead to more complete and detailed exercise guidelines for women with PCOS (9). This study reported on ten exercise interventions: eight aerobic, one RT, and one high-intensity training. The findings revealed high heterogeneity for major outcomes of reproductive function (menstrual cycle, ovulation, and fertility) and minor

outcomes such as body composition. The research team noted low certainty evidence for little to no effect of exercise on reproductive hormones and moderate certainty evidence that aerobic exercise reduced body mass index (BMI) in women with PCOS (9). Many studies, however, do not delineate what type of body mass is lost (fat weight vs. lean mass). If the women are losing lean muscle mass, the basal metabolic rate slows, producing diminishing returns over time. Aerobic exercise was also credited for improved cardiorespiratory function, whereas resistance training increased functional strength (9). The authors recommended further research on the benefits of the unique characteristics of exercise with more consideration for RT (9).

Additionally, evidence exists that some women with PCOS are often dissatisfied with the typical medical model, including pharmaceutical treatment (e.g., metformin and birth control pills). These women report actively seeking alternative therapeutic management strategies such as acupuncture and herbal remedies (44). Despite the high prevalence and serious clinical implications of PCOS throughout the woman's lifespan, no standard long-term treatment prevails, and current medications are only moderately effective at controlling symptoms and preventing complications (23). However, non-pharmacological therapeutic management strategies such as RT are relatively unexplored in women with PCOS. Exercise as therapeutic management will be defined as planned and structured movement designed to attenuate clinical symptoms of PCOS and reduce associated risk of comorbidities over the long-term. The objective of this scoping review was to present current literature specific to the isolated use of RT and delineate evidence of its effectiveness in this population. To the best of our knowledge, this is the first scoping review on this topic in the United States.

METHODS

Protocol

The search strategy was based on the Arksey and O'Malley (4) framework for scoping reviews. A search of PubMed, CINAHL, and SPORTDiscus was conducted. Search strategies for all databases were adapted from the PubMed search strategy (Table 1). Database searches were limited to the last 10 years (January 2011 - January 2021), as this time span is relevant given the publication of the Australian Physical Activity Guidelines in 2011 and the Endocrine Society Clinical Practice Guidelines in 2013. The search was also limited to full-text articles written in English. MeSH and TIAB terms were used for the database search (Table 1). This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (29).

Table 1. Concepts with MeSH and TIAB terms used for the database search.

Concept	MeSH Term	TIAB Terms
Polycystic Ovary Syndrome	Polycystic Ovary Syndrome	PCOS* Polycystic ovar*
Resistance Training	Resistance Training	Resistance exercise* Resistance training Progressive resistance training Strength training Strengthening Weight bearing Weightlifting Weight training Exercise band Medicine ball

Articles were deemed eligible for review if they were published in a peer-reviewed journal between January 2011 and January 2021, reported the results of research that evaluated a RT intervention, and involved a sample of premenopausal women with PCOS. In all studies, the diagnosis of PCOS was determined by the 2003 Rotterdam Criteria and confirmed by either the participant’s general practitioner or specialist. Studies that offered multi-component programs (nutrition, aerobic exercise, and counseling) were excluded to assess the effects of the isolated use of RT. No studies were excluded based on age.

The reviewer documented the number of articles at each stage of the screening process using the PRISMA flow diagram (Figure 1). Each eligible article was then reviewed for general content, results, and contribution to the literature.

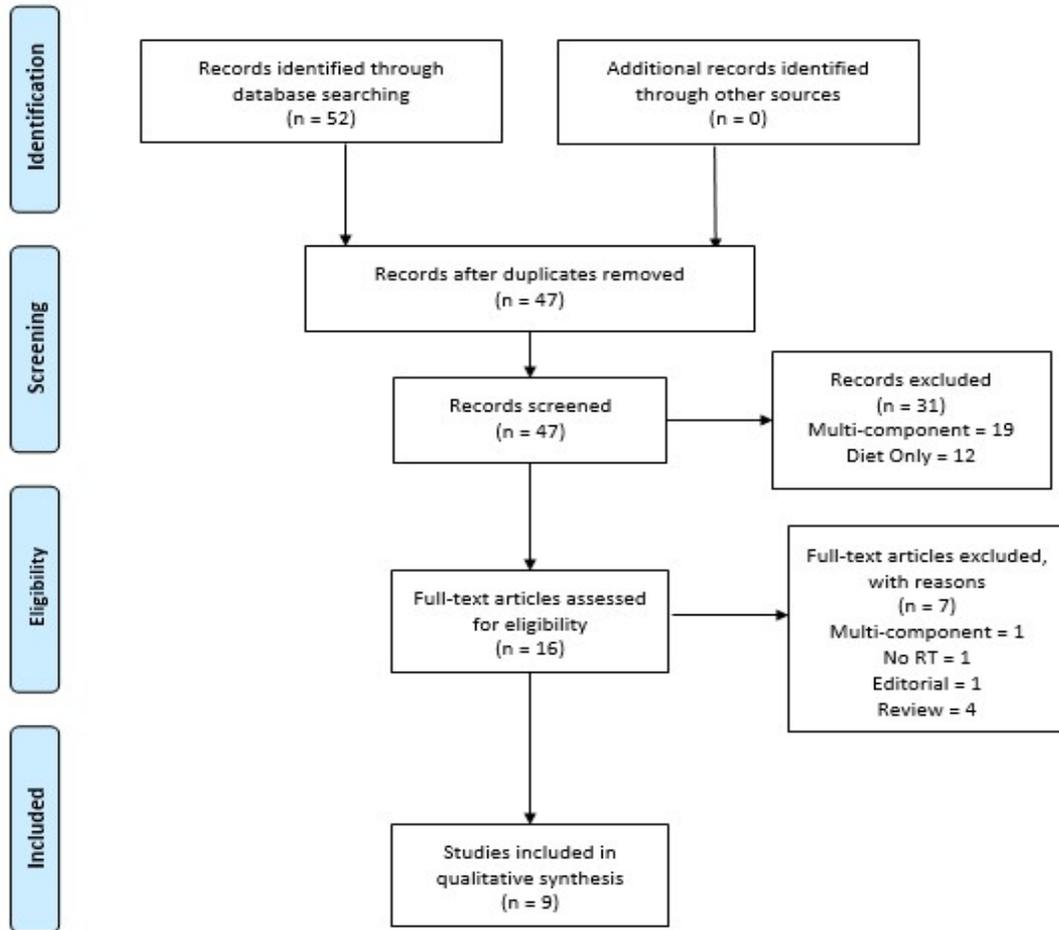


Figure 1. PRISMA flowchart.

As shown in Table 2, the following data were extracted from each article: study purpose, design, sample, intervention, measures, and results. We also present the potential benefits of RT for women with PCOS and offer recommendations for future research. The Johanna Briggs Institute’s Critical Appraisal Checklist was used to assess the methodological quality of each study (17).

Table 2. Summary of resistance training studies from January 2009-July 2020. The studies in the bold outlined box are sub-studies of a larger trial.

Article	Purpose	Study Design	Sample	Intervention	Measures	Results (Women w/PCOS)
Kogure et al., 2019 (18)	Obesity indices & telomere content	nonrandomized control trial	PCOS = 73 No PCOS = 97 Age Range: 18-37	4 months RT (progressive linear periodization); 3 1hr sess/week	Anthropometrics, telomere length, HOMA-IR, hormone panel	↓ WC, ↓ WHtR
Kogure et al., 2018 (20)	Muscle strength	nonrandomized control	PCOS = 45 No PCOS = 52 Age Range: 18-37	4 months RT (progressive linear periodization); 3 1hr sess/week	Anthropometrics, max strength, HOMA-IR, hormone panel	↑ max strength ↓ %BF, ↑ LMM ↓ testosterone ↓ glycemia
Miranda - Furado et al., 2016 (25)	Telomere content & metabolism	nonrandomized control	PCOS = 45 No PCOS = 52 Age Range: 18-37	4 months RT (progressive linear periodization); 3 1hr sess/week	Telomere content, anthropometrics, homocysteine, fasting insulin, hormone panel	↓ telomere length ↓ WC, ↓ %BF ↓ testosterone ↓ sex hormone binding globulin ↓ free androgen ↑ androstenedione ↑ homocysteine ↓ glycemia
Ramos et al., 2016 (32)	QOL	nonrandomized control	PCOS = 43 No PCOS = 51 Age Range: 18-37	4 months RT (progressive linear periodization); 3 1hr sess/week	QOL (SF-36), anthropometrics, BP, HOMA-IR, hormone panel	↑ functional capacity ↓ WC ↓ testosterone ↑ androstenedione
Ribeiro et al., 2016 (33)	Autonomic modulation of HR variability	nonrandomized control	PCOS = 27 No PCOS = 26	4 months RT (progressive linear periodization);	HR variability, ovarian volume, follicle size &	↓ testosterone

	& endocrine function		Age Range: 1837	3 1hr sess/week	#, %BF, HOMA-IR, hormone panel	
Kogure et al., 2015 (19)	LMM	nonrandomized control	PCOS = 45 No PCOS = 52 Age Range: 1837	4 months RT (progressive linear periodization); 3 1hr sess/week	Anthropometrics, hormone panel	↓ WC, ↑ LMM ↓ testosterone ↑ androstenedione ↓ sex hormone binding globulin ↓ glycemia
Lara et al., 2015 (22)	Sexual function & emotional status	nonrandomized control	PCOS = 43 No PCOS = 51 Age Range: 1837	4 months RT (progressive linear periodization); 3 1hr sess/week	Sexual function	↑ desire ↑ excitement ↑ lubrication ↓ pain ↓ depression
Vizza et al., 2016 (37)	Assess feasibility of large scale PRT intervention for women w/PCOS	Feasibility nonrandomized control	PRT = 8 Control Group = 7 Age Range: 1842	3 months RT; 2 supervised sess/wk + 2 home-based sess/wk of 1hr ea	recruitment, attrition, adherence, adverse events, isometric strength, cyclicity, anthropometrics, HbA1C, insulin, glycemia, CRP, hormone panel	FB ↑recruitment Supervision ↑ adherence No adverse events ↓ BW, ↓ WC, ↑ LMM ↑ lower body strength ↓ HbA1C ↓ depression scores ↑ exercise self-efficacy
Almenni et al., 2015 (2)	Metabolic, cardiovascular, & hormonal outcomes	3-arm randomized control trial	HIT = 8 ST = 8 PA = 9 Age Range: UNK	10 weeks HIT, ST, or PA; HIT/ST 3 sess/wk; PA ≥ 150min/wk mod-intensity exercise	HOMA-IR, T chol, TG, CRP, cardiovascular markers, insulin, anthropometrics, hormone panel	↓ BF% ↓ anti-Mullerian hormone

*Abbreviations: %BF = percent body fat, BMI = body mass index, CRP = c-reactive protein, FB = Facebook, HIT = high intensity training, HR = heart rate, HbA1C = glycated hemoglobin test, HOMA-IR = homeostatic model assessment of insulin resistance, LMM = lean muscle mass, PA = physical activity, PCOS = polycystic ovary syndrome, QOL = quality of life, ST = strength training TG = triglycerides, T chol = total cholesterol, UNK = unknown, WC = waist circumference, WHtR = waist to height ratio

RESULTS

Of the 52 articles identified from the selected databases, five were removed as duplicates and 31 were removed based on titles and abstracts that indicated exclusion criteria. Of the remaining 16 articles, full-text reviews yielded nine articles that matched criteria (Figure 1). Of these nine articles, seven were from the same parent study, a nonrandomized case-control study. The other two articles featured a randomized controlled trial and a nonrandomized feasibility study. Thus, these nine articles represent three separate interventions. The geographic location of these studies included Brazil, Norway, and Australia. Brazil was the site for the parent study (and hence, its six associated studies). Refer to Table 3 for the summary of the Johanna Briggs Institute’s Critical Appraisal Checklists using the research designs of three RT interventions.

Table 3. Summary of the Johanna Briggs Institute’s Critical Appraisal Checklist using the RT intervention research designs.

Checklist Item	Kogure et al., 2015 (19)	Almenning et al., 2015 (2)	Vizza et al., 2016 (37)
Is it clear in the study what is the ‘cause’ and what is the ‘effect’ (i.e. there is no confusion about which variable comes first)?	Yes	Yes	Yes
Were the participants included in any comparisons similar?	Yes	Yes	Yes
Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	No Both groups received RT	Yes 3-arm parallel	Yes
Was there a control group?	Yes	Yes	Yes
Were there multiple measurements of the outcome both pre and post the intervention/exposure?	Yes	Yes	Yes
Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	Yes	Yes	Yes
Were the outcomes of participants included in any comparisons measured in the same way?	Yes	Yes	Yes
Were outcomes measured in a reliable way?	Yes	Yes	Yes
Was appropriate statistical analysis used?	Yes	Yes	Yes
Overall Appraisal	Include	Include	Include

Note: The same research design was implemented in the six sub-studies, thus matching that of Kogure et al., 2015 (18, 19, 20, 22, 25, 32, 33).

Study sample sizes ranged from 15 to 73 participants; all participants were overweight or obese, sedentary, premenopausal women with PCOS in the age range of 18-42. In one randomized controlled trial, the participants’ age range was not mentioned; however, 26 years old was the mean age for the intervention group (2). In all three studies, the diagnosis of PCOS was confirmed by the participants’ primary care providers (2, 19, 37), and in two studies, PCOS was diagnosed using the 2003 Rotterdam criteria (2, 19). The larger randomized controlled trial and its associated studies (all based on secondary analysis of the parent study) included a control group of premenopausal sedentary and overweight or obese women who did not have PCOS (19). The study by Vizza et al. (37) included all women with PCOS; however, one group (*n* =8)

received progressive RT and the control group ($n = 7$) did not receive an intervention. The feasibility study included only women with PCOS but compared three types of exercise: high intensity training ($n = 8$), strength training ($n = 8$), and physical activity ($n = 7$) (2) (Table 2). High intensity training differs from strength training in terms of higher intensity and shorter duration. For example, high-intensity training involves shorter, more intense unsustainable bursts of physical activity, combined with short periods of rest, such as running sprints on the treadmill followed by a quick recovery period. In contrast those in the strength training group received an intervention consistent with progressive linear periodization, which involves anaerobic activity only at a slower pace. Physical activity is a type of aerobic (versus anaerobic) exercise defined by the World Health Organization as any body movement that requires more energy than rest (43).

Terms used in the three interventions for RT include progressive resistance training and strength training. The protocol for all interventions was the same, that of progressive linear periodization. Periodization is a commonly used RT method involving planned manipulation of training variables (load, sets, and repetitions) to maximize neuromuscular adaptations to unaccustomed load or stressors. The linear model is based on changing exercise volume and load across several predictable mesocycles. Based on a 12-month period, the program is referred to as a macrocycle; the 2 subdivisions are the mesocycle (3-4 months) and the microcycle (1-4 weeks) (23). All the studies included interventions that progressed through a microcycle and into a mesocycle.

The overall purpose of the studies was to examine the impact of RT among overweight or obese and sedentary premenopausal women with PCOS. The parent study and its six associated studies (one large non-RCT) each emphasized a different primary variable: lean muscle mass (19), sexual function (22), autonomic regulation of heart rate variability (33), quality of life (32), telomere content (25), muscle strength (20), and obesity indices (18). The study by Vizza et al. (37) was designed to assess the feasibility of executing a randomized controlled trial of progressive RT in women with PCOS. Although the primary outcomes were recruitment and attrition, adherence, adverse events and completion of assessments, secondary outcomes were also collected and included a range of biopsychosocial variables (37). Almenning et al. (2) aimed to measure metabolic (e.g., total cholesterol), cardiovascular (e.g., resting heart rate), and hormonal (e.g., free androgen index) outcomes from 10 weeks of strength training, high intensity training, or physical activity. Table 2 provides more detail as to purpose, study design, sample, intervention, measures, and results.

Anthropometrics: Although each article focused on a different primary outcome, the articles also shared common secondary outcomes. For example, each study revealed a significant decrease in percent body fat due specifically to reduced visceral fat, thus decreased waist circumference. Visceral fat, that is abdominal adiposity, is an important predictor of obesity-related health risks such as cardiovascular and metabolic disorders (16). Visceral fat has also been implicated in the etiology of insulin resistance in PCOS (15). Additionally, each RT intervention produced a significant increase in lean muscle mass among women with PCOS when compared with other women with PCOS who served as control and with women without PCOS. The decrease in

percent body fat plus the increase in lean muscle mass equaled no change in body mass index for women with PCOS in the RT intervention groups.

Metabolic: A common metabolic outcome measured in all studies was fasting glucose. This measure decreased with statistical significance after a program of RT in all studies. Interestingly, RT produced a significantly lower fasting glucose in women with PCOS as compared to women without PCOS who engaged in the same RT program (19).

Hormonal: Each study involved biochemical assays to obtain a hormonal panel on each participant. The selected hormonal tests for each study's panel differed with only two common variables: serum testosterone and sex hormone binding globulin (SHBG). Serum testosterone significantly decreased after a program of resistance training in two studies (19, 37) and did not change at all in the feasibility study (2), which was attributed to difficulty with interpretation within a small-scale study. Women with PCOS often present with below normal levels of SHBG, a glycoprotein that serves to limit exposure to androgen (31). Interestingly, the three main studies indicated mixed results: a decrease without statistical significance (37), an increase with statistical significance (19), and no change at all (2).

Almenning et al. (2) was the only study to consider anti-Mullerian hormone (AMH), a glycoprotein often used as a measure of certain aspects of ovarian function. Evidence has shown that increasing the level of AMH improves fertility due to its inhibitory effect on follicular sensitivity to follicle-stimulating hormone (6). In the study by Almenning et al. (2), women with PCOS had a significant decrease in AMH after a program of resistance training, high intensity training, and physical activity.

DISCUSSION

Endocrine Society Clinical Practice Guidelines on the Diagnosis and Treatment of PCOS recommend exercise and physical activity as first-line treatment to combat the risk of chronic comorbidities. However, detail about the type of exercise is not provided. The scientific literature includes information about cardiovascular or aerobic activity, but notably lacks attention to RT. Given the known beneficial effects of RT on the management of other chronic diseases, RT may provide therapeutic management for PCOS.

A scoping review of three databases over the last ten years revealed nine articles that involved three interventions. The primary outcomes of each intervention shared broad categories of anthropometric, hormonal, cardiovascular, and fitness variables. Common outcome measures across all three interventions that resulted in positive and significant changes after RT included waist circumference, percent bodyfat, lean muscle mass, testosterone, sex hormone binding globulin, and fasting glucose. Kogure et al. (18) and Vizza et al. (37) measured waist circumference as an operational definition for central adiposity, whereas Almenning et al. (2) used percent bodyfat to operationalize total body fat mass. Although percent bodyfat is the best measure for overall obesity, central adiposity is associated with a greater risk for chronic disease (11). Further, a distinction must be made between types of body mass. The body mass index is

a function of bodyweight and height. Schmitz et al. (35) found that sedentary, overweight women lost a significant amount of visceral fat after a RT intervention. In Kogure et al. (19), findings revealed that women with PCOS had no change in body mass index; however, lean muscle mass increased. Logistically, this indicates a loss of fat mass. The increase in muscle mass increases the basal metabolic rate, which is responsible for up to two-thirds of total energy expenditure in healthy adults (39). In this scenario, the body fat percentage is relevant and the better indicator of a healthier metabolism (35). The example of body mass measurements illustrates the current paucity of data that can be equivocally compared now or with future results. More research is needed to develop a solid knowledge base and determine relationships between variables.

RT protocols were detailed in each intervention, with each program significantly differing in terms of load, frequency, intensity, and supervision, indicating that the state of the science is still in an exploratory phase. However, each RT program was associated with reduced body fat as an outcome in women with PCOS, and primarily due to reduced abdominal adiposity. This outcome is promising, as a modest weight loss of 5-10% of total body weight is likely to produce health benefits, such as improved insulin sensitivity and total cholesterol (41). Interestingly, findings from two studies indicated improved depressive symptom scores (22, 37), also a positive outcome for women with PCOS who have a high rate of depressive symptoms (44).

Research that examines the hormonal response to RT does exist; however, most of the studies involve men or trained athletes (21). Several positive hormonal outcomes unique to RT have been documented, all of which create a cascade of events that support energy production, improved insulin sensitivity, and increased strength (3). A hypothesis still under investigation and of relevance to women with PCOS is the possible upregulation of androgen receptors due to RT (13). Although RT may or may not directly affect SHBG, two factors do increase SHBG, and both are positive outcomes of RT: reduced visceral adiposity and improved insulin resistance (38). An increase in SHBG helps bind the excess bioavailable testosterone (31).

Overall, the effect of RT on the hormonal profiles of women with PCOS is mixed among the three interventions discovered during this scoping review. As such, it remains unknown at this time if RT can alter certain hormones. If RT does alter the hormone panel of women with PCOS, the variation of response to anaerobic stress would depend on exercise frequency and intensity and program duration. More research is necessary that targets a range of selected hormonal variables among larger samples of women with PCOS who complete more detailed RT programs.

Additional useful data gleaned from the feasibility study by Vizza et al. (37) were the success of Facebook as a recruitment tool and the increased adherence with supervised exercise sessions. The researchers concluded that a randomized control trial of RT for women with PCOS would be feasible, as evidence reveals that this mode of exercise can elicit a therapeutic effect on a wide range of health outcomes. The authors noted challenges recruiting women with PCOS to participate in their feasibility study. However, the authors further stated that this challenge is expected in clinical research, especially in interventions that require behavioral change (37).

The geographic location of these studies included Brazil, Norway, and Australia. To date, the US has not been a site for research trials investigating RT as a therapeutic management strategy for PCOS in premenopausal women. Few studies have shown differences between geographical location or race; however, the existing data remains inconclusive as to significant differences in the prevalence of PCOS across geographical location, racial, or ethnic groups (42).

Also inconclusive is the effect of culture on the perception of RT. In a qualitative study by Moghadam et al. (26), women of Persian descent expressed stigma-related concerns due to perceived masculine characteristics of PCOS and RT. Wright et al. (44) found the same sentiment among women with PCOS in the US about femininity, along with stigma associated with being overweight or obese. Myre et al. (27) examined barriers to RT among women without PCOS and found that these women also endorsed a masculine stereotype to RT. Additionally, women without PCOS, who were overweight or obese, described stigmatizing concerns due to body size (14). Many women with PCOS have both hirsutism and overweightness or obesity, leading them to avoidance of body-conscious activities and social situations (27). Stigma related to weight issues is a barrier to health-seeking behaviors (11). Further research is needed to discover innovative strategies to mitigate negative perceptions of RT and the harmful consequences of stigma-related stress.

The evidence about the effects of RT on health outcomes for women with PCOS is largely preliminary, but positive, and none of the studies showed an absence of benefit. The nine identified articles that reported on studies involving RT to determine effects on health outcomes for women with PCOS were representative of only three interventions: a nonrandomized case control study (a parent study with six sub-studies), a small, randomized controlled trial, and a nonrandomized feasibility study. Except for one study (19), sample sizes were small, thus limiting the generalizability to the broader PCOS population. Although detailed protocols were described, robust trials are needed to determine the minimum dose of RT to produce optimal health outcomes, including the potential symptom management benefits and contribution toward risk reduction of other chronic diseases. Other limitations of these studies included no assessment of prior physical activity or nutrition and the use of indirect measures of insulin resistance (2, 19, 37). Additional research with adequately powered clinical trials are required to establish health benefits, answer research questions as to therapeutic dose, and discover sustainable behavioral change strategies for women with PCOS. Lastly, if RT is deemed appropriate and effective as a therapeutic treatment strategy for women with PCOS, further investigation of facilitators and barriers to exercise unique to women with PCOS is necessary. This information would strengthen any proposed intervention.

ACKNOWLEDGEMENTS

This work was supported by the University of South Carolina SmartState Center for Advancing Chronic Care Outcomes through Research and iNnovation (ACORN).

REFERENCES

1. Alliance PA. Evidence based guidelines for assessment and management of polycystic ovary syndrome. Jean Hailes Foundation for Women's Health on behalf of the PCOS Australian Alliance; 2011.
2. Almenning I, Reiber-Mohn A, Lundgren KM, Lovvik TS, Garnæs KK, Moholdt T. Effects of intensity interval training and strength training on metabolic, cardiovascular and hormonal outcomes in women with polycystic ovary syndrome: A pilot study. *PLoS ONE* 10(9): e0138793, 2015.
3. Alvidrez LM, Kravitz L. Hormonal responses to resistance exercise variables. Retrieved from: <https://www.unm.edu/~lkravitz/index.html>; 2021.
4. Arksey H, O'Malley L. Scoping studies: Towards a methodological framework. *Int J Soc Res Method* 8(1): 19-32, 2005.
5. Azziz R. Epidemiology and pathogenesis of polycystic ovary syndrome in adults. UpToDate. Retrieved from: <http://www.upToDate.com/contents/epidemiology-and-pathogenesis-of-the-polycystic-ovaraysyndrome/>; 2019.
6. Broer SL, Broekmans FJM, Laven JSE, Fauser BCJM. Anti-mullerian hormone: Ovarian reserve testing and its potential clinical implications. *Hum Reprod Update* 20(5): 688-701, 2014.
7. Ciccolo JT, Nosrat S. Resistance training and chronic disease: A summary of the current evidence. *ACSM's Health Fit J* 20(5): 44-49, 2016.
8. Cinar N, Kizilarshanlglu MC, Harmanci A, Aksoy DY, Bozdogan G, Demir B, Yildiz BO. Depression, anxiety, and cardiometabolic risk in polycystic ovary syndrome. *Hum Reprod* 26(12): 3339-3345, 2011.
9. dos Santos IK, Ashe MC, Cobucci RN, Soares GM, de Oliveira Maranhão TM, Silva Dantas PM. The effect of exercise as an intervention for women with polycystic ovary syndrome A systematic review and meta-analysis. *Med* 99(16): 1-11, 2020.
10. Dumitrescu R, Mehedintu C, Briceag I, Purcarea BL, Hudita D. The polycystic ovary syndrome: An update on metabolic and hormonal mechanisms. *J Med Life* 8(2): 142-145, 2015.
11. Flegal KM, Shepherd JA, Looker AC, Graubard BI, Borrud LG, Ogden CL, Harris TB, Everhart JE, Schenker N. Comparisons of percent body fat, body mass index, waist circumference, and waist-stature ratio in adults. *Am J Clin Nutr* 89(2): 500-508, 2009.
12. Golberstien E, Eisenberg D, Gollust SE. Perceived stigma and health-seeking behavior: Longitudinal evidence from the Health Minds Study. *Psychiatr Serv* 60(9): 1254-1256, 2009.
13. Hunter I, Hay CW, Esswein B, Watt K, McEwan IJ. Tissue control of androgen action: The ups and downs of androgen receptor action. *Mol Cell Endocrinol* 465: 27-35, 2017.
14. Hurley KS, Flippin KJ, Blom LC, Bolin JE, Hoover DL, Judge LW. Practices, perceived benefits, and barriers to resistance training among women enrolled in college. *Int J Exerc Sci* 11(5): 226-238, 2018.
15. Hutchinson SK, Stepko NK, Harrison CL. Effects of exercise on insulin resistance and body composition in overweight and obese women with and without polycystic ovary syndrome. *J Clin Endocrinol Metab* 96(1): E48-56, 2011.
16. Janssen I, Katzmarzyk PT, Ross R. Waist circumference and not body mass index explains obesity-related health risk. *Am J Clin Nutr* 79(3): 379-384, 2004.
17. Johanna Briggs Institute. Checklist for randomized controlled trials. Critical Appraisal Tools. Retrieved from: <https://jbi.global/critical-appraisal-tools>; 2021.
18. Kogure GS, Miranda-Furtado CL, Pedrosa DCC, Ribeiro VB, Eiras MC, Silva RC, Caetano LC, Ferriani RA, Calado RT, dos Reis RM. Effects of progressive resistance training on obesity indices in polycystic ovary syndrome and the relationship with telomere length. *J Phys Act Health* 16(8): 601-607, 2019.

19. Kogure GS, Miranda-Furtado CL, Silva RC, Melo AS, Ferriani RA, De Sa MFS, dos Reis RM. Resistance exercise impacts lean muscle mass in women with polycystic ovary syndrome. *Med Sci Sports Exerc* 48(4): 589-598, 2015.
20. Kogure GS, Silva RC, Miranda-Furtado CL, Ribeiro VB, Pedroso DCC, Melo AS, Ferriani RA, dos Reis RM. Hyperandrogenism enhances muscle strength after progressive resistance training, independent of body composition, in women with polycystic ovary syndrome. *J Strength Cond Res* 32(9): 2642-2651, 2018.
21. Kraemer WJ, Ratamess NA. Hormonal responses and adaptations to resistance exercise and training. *Sports Med* 35(4): 340-361, 2005.
22. Lara LA, Ramos FK, Kogure GS, Silva de Sa MF, Ferriani RA, dos Reis RM. Impact of physical resistance training on the sexual function of women with polycystic ovary syndrome. *J Sex Med* 12(7): 1584-1590, 2015.
23. Legro RS, Arslanian SA, Ehrmann DA, Hoeger KM, Murad HM, Pasquali R, Welt CK. Diagnosis and treatment of polycystic ovary syndrome: An endocrine society clinical practice guideline. *J Clin Endocrinol Metab* 98(12): 4565-4592, 2013.
24. Lorenz DS, Morrison S. Periodization: Current concepts in periodization of strength and conditioning for the sports physical therapist. *Int J Sports Phys Ther* 10(6): 734-747, 2015.
25. Miranda-Furtado CL, Ramos FK, Kogure GS, Santana-Lemos BA, Ferriani RA, Calado RT, dos Reis MA. A nonrandomized trial of progressive resistance training intervention in women with polycystic ovary syndrome and its implications in telomere content. *Reprod Sci* 23(5): 644-654, 2016.
26. Moghadam ZB, Fereidooni B, Saffari M, Montazeri A. Polycystic ovary syndrome and its impact on Iranian women's quality of life: A population-based study. *BMC Women's Health* 18(164): 1-8, 2018.
27. Myre M, Glenn NM, Berry TR. Exploring the impact of physical activity-related weight stigma among women with self-identified obesity. *Qual Res Sport Exerc Health* 4: 1-18, 2019.
28. National Institutes of Health. Evidence-based methodology workshop on polycystic ovary syndrome: Executive Summary. NIH; 2020.
29. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. *Int J Exerc Sci* 12(1): 1-8, 2019.
30. Price KJ, Gordon BA, Bird SR. A review of guidelines for cardiac rehabilitation programmes: Is there an international consensus? *Eur J Prev Cardiol* 23(16): 1715-1733, 2016.
31. Qu X, Donnelly R. Sex hormone-binding globulin (SHBG) as an early biomarker and therapeutic target in polycystic ovary syndrome. *Int J Mol Sci* 21: 1-17, 2020.
32. Ramos FK, Lara LA, Kogure GS, Silva RC, Ferriani RA, Silva de Sa, dos Reis MA. Quality of life in women with polycystic ovary syndrome after a program of resistance exercise training. *Rev Bras Ginecol Obstet* 38(7): 340-347, 2016.
33. Ribeiro VB, Kogure GS., Reis RM, Gastaldi AC, de Araujo JE, Mazon JH, Borghi A, Souza HCD. Polycystic ovary syndrome presents higher sympathetic cardiac autonomic modulation that is not altered by strength training. *Int J Exerc Sci* 9(5): 554-566, 2016.
34. Sadeega S, Mustafa, Latif S. Polycystic ovarian syndrome – related depression in adolescent girls: A review. *J Pharm Bioallied Sci* 10(2): 55-59, 2018.
35. Schmitz KH, Jensen MD, Kugler KC, Jeffery RW, Leon AS. Strength training for obesity prevention in midlife women. *Int J Obes Relat Metab Disord* 27: 326-333, 2003.
36. Teede H, Gibson-Helm M, Norman RJ, Bolyle J. Polycystic ovary syndrome: Perceptions and attitudes of women and primary health care physicians on features of PCOS and renaming the syndrome. *J Clin Endocrinol Metab* 99(1): E107-11, 2014.

37. Vizza L, Smith CA, Swaraj S, Agho K, Cheema BS. The feasibility of progressive resistance training in women with polycystic ovary syndrome: A pilot randomized controlled trial. *BMC Sports Sci Med Rehabil* 8(14): 1-12, 2016.
38. Westcott WL. Resistance training is medicine: Effects on strength training on health. *Curr Sports Med Rep* 11(4): 209-216, 2012.
39. Williams MA, Haskell WL, Ades PA, Amsterdam EA, Bittner V, Franklin BA, Gulanick M, Laing ST, Stewart KJ. Resistance exercise in individuals with and without cardiovascular disease: 2007 update: A scientific statement from the American Heart Association Council on Clinical Cardiology and Council on Nutrition, Physical Activity, and Metabolism. *Circulation* 116: 572-584, 2007.
40. Williams MA, Stewart KJ. Impact of strength and resistance training on cardiovascular disease risk factors and outcomes in older adults. *Clinics Geri Med* 25: 703-714, 2009.
41. Wing RR, Lang W, Wadden TA, Safford M, Knowler WC, Bertoni AG, Hill JO, Brancati FL, Peters A, Wagenknecht L. Benefits of modest weight loss in improving cardiovascular risk factors in overweight and obese individuals with type 2 diabetes. *Diabetes Care* 34(7): 1481-1486, 2011.
42. Wolf WM, Wattick RA, KinKade ON, Offert MD. Geographical prevalence of polycystic ovary syndrome as determined by region and race/ethnicity. *Int J Environ Res Public Health* 15(11): 2589, 2018.
43. World Health Organization. Physical activity fact sheet. WHO. Retrieved from: <https://www.who.int/news-room/fact-sheets/detail/physical-activity>; 2020.
44. Wright PJ, Dawson R, Corbett CF. Social construction of biopsychosocial and medical experiences of women with polycystic ovary syndrome. *J Adv Nurs* 76(7): 1728-1736, 2020.

