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Effects of a 12-Week Yoga Training Intervention on Blood Pressure and Body Composition in Obese Female Adolescents: A Randomized Controlled Pilot Study

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Abstract

This study delves into the pressing issue of obesity, a condition characterized by abnormal fat accumulation and a significant contributor to non-communicable diseases like diabetes, cardiovascular ailments, hypertension, and hyperlipidemia. With over 1 billion individuals globally classified as obese, addressing this epidemic is paramount.

Purpose: this research aimed to evaluate the impact of a 12-week yoga training intervention on blood pressure and body composition among obese adolescents.

Material & Methods: twenty four female adolescents 4 participants discared, aged 18-20 years, female adolescents were randomly assigned to two groups. One group performed yoga training intereven-tion (YPG, n=10, age 19.2±0.4) for 12 weeks with two sessions (morning & evening) for three days a week. A second group acted as an control group (CG, 18.9±0.9). All participants completed the following tests before and after intervention; body weight, body mass index, free fat mass, body fat, systolic blood pressure, diastolic blood pressure, mean arterial pressure, pulse pressure. The results yielded promising outcomes, with all participants successfully completing the study, showcasing a 100% adherence rate without any training or test-related injuries.

Results: the intervention led to significant improvements in several key parameters. In present study, body weight ($p<0.001$), a notable reduction in (BMI), BF% ($p<0.001$), SBP ($p<0.001$), MAP ($p<0.001$), and PP ($p<0.001$) were changed significantly.

Conclusion: in conclusion, the 12-week yoga training program emerged as an effective strategy for reducing body composition indicators such as body weight, BMI, and BF%, while also positively impacting blood pressure parameters (MAP and PP) in obese female adolescents. These findings underscore the potential of yoga as a holistic approach in combating the obesity crisis and its associated health risks, offering a path toward healthier lifestyles for affected individuals.

Key words: yoga training intervention, blood pressure, obesity, body composition, adolescents.

Вплив 12-тижневого втручання з йоги на артеріальний тиск і склад тіла у підлітків з ожирінням: рандомізоване контрольоване пілотне дослідження

Це дослідження присвячене актуальній проблемі ожиріння, стану, що характеризується аномальним накопиченням жиру та значною мірою сприяє розвитку неінфекційних захворювань, таких як діабет, серцево-судинні захворювання, гіпертонія та гіперліпідемія. Оскільки понад 1 мільярд людей у всьому світі класифікуються як страждаючі ожирінням, боротьба з цією епідемією є першорядною.

Мета: оцінити вплив 12-тижневого тренування йоги на артеріальний тиск і склад тіла серед підлітків із ожирінням.

Матеріал і методи: двадцять чотири підлітки, 4 учасники, віком 18-20 років, підлітки були випадковим чином розподілені на дві групи. Одна група проводила втручання з йоги (YPG, n=10, вік 19,2±0,4) протягом 12 тижнів з двома сеансами (вранці та ввечері) протягом трьох днів на тиждень. Друга група була контрольною (CG, 18,9±0,9). Усі учасники пройшли наступні тести до та після втручання; маса тіла, індекс маси тіла, маса вільного жиру, жирові відкладення, систолічний артеріальний тиск, діастолічний артеріальний тиск, середній артеріальний тиск, пульсовий тиск. Результати: усі учасники успішно завершили дослідження, продемонструвавши 100% рівень прихильності без будь-яких травм, пов'язаних із навчанням чи тестуванням.

Результати: втручання призвело до значних покращень кількох ключових параметрів. У цьому дослідженні було виявлено,що показники маси тіла (p<0,001) помітно знизилися (ІМТ), BF% (p<0,001), SBP (p<0,001), MAP (p<0,001) і PP (p<0,001) істотно змінилися.

Висновки: 12-тижнева тренувальна програма з йоги виявилася ефективною стратегією для зниження показників складу тіла, таких як маса тіла, ІМТ і BF %, а також позитивно впливає на параметри артеріального тиску (MAP і PP) у підлітків з ожирінням. Ці висновки підкреслюють потенціал йоги як цілісного підходу до боротьби з кризою ожиріння та пов'язаними з нею ризиками для здоров'я, пропонуючи шлях до більш здорового способу життя для постраждалих осіб.

Ключові слова: втручання йоги, артеріальний тиск, ожиріння, будова тіла, підлітки.

Introduction

In industrialized countries, obesity has emerged as a predominant health issue, with its prevalence showing a significant increase over recent decades (Asiah et al., 2023). Obesity is a lifestyle disease that places a heavy yet avoidable burden on health. The World Health Organization (WHO) defines obesity for adults as having a BMI greater than or equal to 30 kg/m^2 and defines overweight for adults as having a BMI larger than or equal to 25 kg/m^2 (Alert et al., 2013). The frequency of obesity has risen globally since 1975 (Templin et al., 2019). Although 650 million of the roughly 1.9 billion adults in the world over the age of 18 were obese in 2016, 13% of persons over the age of 18 were obese, and 39% were overweight (Ahmed & Konje, 2023; Zubery et al., 2021). Obesity is a known risk factor for several health risks and chronic illnesses, including depression, osteoarthritis of the knee, type 2 diabetes mellitus, hypertension, hyperlipidaemia, coronary heart disease, and stroke (Guo et al., 2016; Luppino et al., 2010; Renehan et al., 2008; Riaz et al., 2018; Silverwood et al., 2015). Numerous elements, including personal behavior, social and lifestyle choices, psychological issues, socioeconomic factors, biological and environmental variables, and health-related elements, are linked to the development of obesity (Hendricks et al., 2022; Safaei et al., 2021).

Adolescence, a crucial time for growth and development, is marked by various physical and physiological changes (Lorås, 2020). Among them, body composition changes significantly impact how healthy and happy adolescent girls are (KavehFarsani et al., 2020; Ramos-Campo et al., 2021). The relative ratios of the body's fat, muscle, bone, and other components are referred to as body composition (Na Nongkhai et al., 2021). These body composition ratios significantly change during adolescence (Batrakoulis, 2022). Differential changes in body composition, primarily brought on by hormonal changes related to puberty, distinguish infancy from maturity (Kwarteng et al., 2023). These alterations differ from person to person, but they typically entail an increase in fat mass, particularly in the middle, and an accumulation of lean muscle mass. Understanding these alterations is crucial for treating such potential health issues and enhancing young women's general wellbeing. Therefore, it is vital to look at the connections between body composition and other health-related issues throughout this crucial life stage because these changes can significantly impact an adolescent girl's physical, mental, and emotional health (Štefanová et al., 2020).

Past research stated that teenagers, especially young ladies, are more prone to this troubling trend, as the prevalence of obesity has reached alarming proportions worldwide (Chew & Lopez, 2021). This demographic's increasing rates of obesity have led to serious worries about an increase in the risk of non-communicable diseases (NCDs) (Budreviciute et al., 2020). The term "non-communicable diseases," sometimes known as "lifestyle diseases," refers to a group of illnesses that include diabetes, cardiovascular disease, some malignancies, and respiratory disorders, ultimately posing a significant threat to public health (Reddy & Mathur, 2022; Yadav et al., 2020). These illnesses are characterized by their chronic nature and are significantly impacted by lifestyle choices, such as diet and exercise (Alfawaz et al., 2021). Therefore, the search for holistic and sustainable solutions to this health concern has become of utmost importance in an era characterised by the rising incidence of obesity on a global scale (Di Cesare et al., 2019). Among these strategies, the age-old art of yoga has emerged as a promising route with potential advantages beyond the sphere of the physical wellbeing (Patel & Veidlinger, 2023). Researchers who are particularly interested in understanding yoga's complex impacts on cardiovascular health, morbidity, and mortality, as well as its wider benefits for general wellbeing, have focused a lot of attention on the effects of yoga on obese women (Gour et al., 2020; Manchanda & Madan, 2022). Previous research found that the most common cause of morbidity and mortality from these illnesses, affecting both men and women, is cardiovascular disease (CVD) (Noale et al., 2020). However, obese women frequently encounter physiological and behavioral difficulties, necessitating interventions to effectively reduce their health risks (Gao et al., 2019).

Therefore, this study aims to offer useful insights into the potential function of yoga as a supplemental therapy modality in managing obesity-related health concerns in women by thoroughly analysing the existing literature and conducting a systematic investigation into the outcomes of structured yoga intervention. Understanding the complex interactions between yoga, obesity, and women's health can help us design well-informed interventions and empower women on their path to better health and wellbeing by fostering the mind-body connection that is so important for young women's holistic health and empowerment.

Material and methods of research

Study Subjects

Twenty-four (n=24) obese sedentary adolescent women (mean age: 18.9±0.8 years; body mass index: 28.9±1.4 kg/m^2) were recruited for the study through advertisements (posters, emails, social media platforms). Table 1 lists their physical characteristics as participants. In the current investigation, patients with the following conditions were included: (1) those who did not take any medicine; (2) those whose BMI was greater than 25 kg/m^2; and (3) those who engaged in just minimal activity (no exercise in the previous six months). Participants provided written consent after thoroughly understanding the experiment and potential adverse effects. We excluded adolescent women with chronic diseases, joint replacements or fractures of the lower limbs within the last six months, and severe cognitive impairments. All study protocols complied with the Helsinki Declaration, and institutional ethics committee approval was obtained from SRM Medical College Hospital and Research Centre (SRM MCH & RC/9494/IEC-2022).

Study Design

Before getting baseline measurements, all participants were fully briefed about all the testing and procedures of the study. A computerized random number generator was then used to divide the participants into two groups: a control group (CG; n=10) and a yoga practice group (YPG; n=10). Due to withdrawal, the remaining four participants' data (n=4) were discarded (Figure 1). The sample size was determined using effect size (ES=0.49), an alpha of (0.05) and a power of (0.80) (Park et al., 2020) and was calculated to reach statistical significance with 12 samples. G*Power software (version 3.1.9.7, Heinrich-Heine-Universität, Düsseldorf, Germany) was used to calculate the sample size.

Experimental Design

All participants took part in a pre-testing session one day before starting and a post-testing session one day after completing a 12-week yoga intervention programme. All individuals underwent a fast for over eight hours on the pre and post-testing days. The participant's body composition measurements were also taken on the day of pre-testing.

Preparatory Phase

All study participants of the YPG practiced or learnt yoga for the starting week as part of the preliminary phase. The purpose of this phase was to introduce the participants to several facets of yoga, such as asana (yoga postures), pranayama (breathing techniques), and meditation practices. The major objective was to ensure that the participants get familiar with the yoga techniques to be used in the main intervention. During this stage, coaching on keeping perfect posture and employing appropriate techniques during yoga sessions was also taught. The tools used to monitor blood pressure (BP) and bioelectrical impedance analysis (BIA) were also explained to the participants. These familiarization sessions were essential to ensure that everyone entered the research with equal knowledge and skill in performing yoga techniques.

Training Intervention

The YPG participants engaged in yoga practice

Table 1. The demographic characteristics of the participants (mean ± SD).

Variables	CG (n=10)	YPG (n=10)	*p*-Value
Age (years)	18.9 ± 0.9	19.2 ± 0.4	0.134
Height (cm)	168.6 ± 5.6	167.4 ± 5.2	0.406
Weight (kg)	81.6 ± 5.1	81.7 ± 3.6	0.660
BMI (kg/m^2)	28.7 ± 0.7	29.0 ± 0.8	0.309
FFM (kg)	45.5 ± 3.6	45.2 ± 2.1	0.667
BF (%)	32.6 ± 1.7	32.3 ± 1.6	0.674

Note: SD: Standard deviation; BMI: Body mass index; FFM: Fat free mass; BFP: Body fat percentage; YPG: Yoga practice group; CG: Control group.

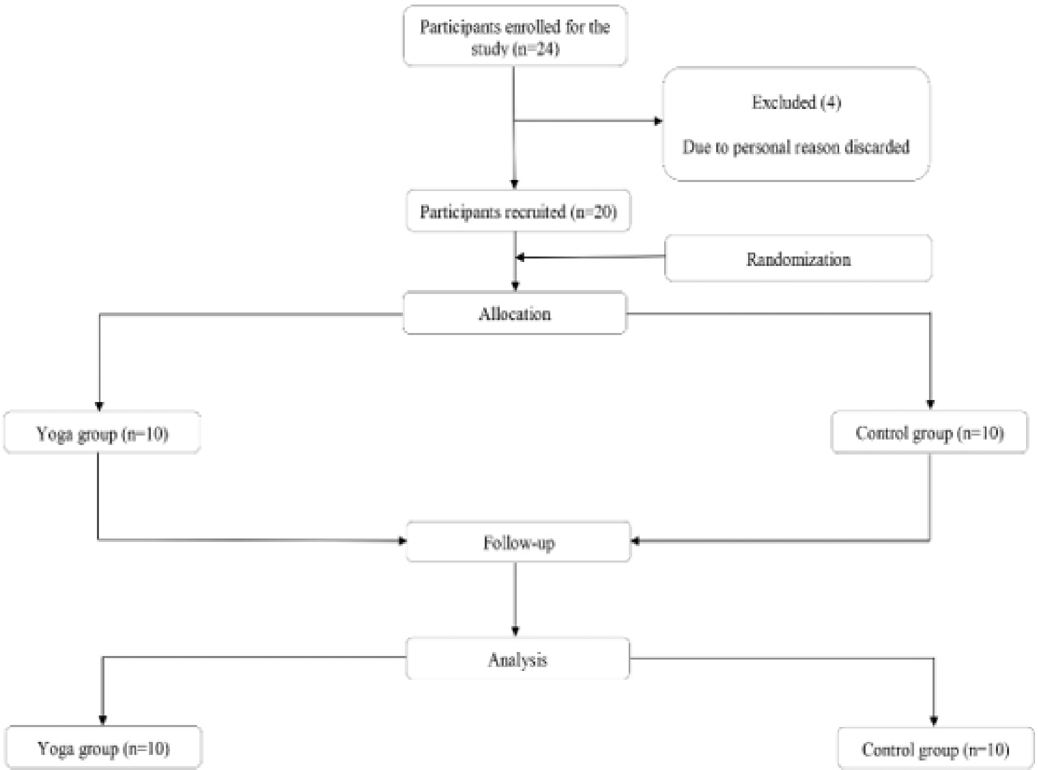

Figure 1. Participant's selection flow chart.

for 60 minutes, twice a day, on two separate time slots: (i) from 6:00 AM to 7:00 AM and (ii) from 5:00 PM to 6:00 PM. This routine was followed for three days a week over a period of 12 weeks. The choice of two yoga sessions per day was considered practical for home practice. The yoga sessions were supervised by an experienced instructor who held qualifications in yoga and naturopathy, with 17 years of study and practice. Out of each 60-minute yoga practice session, 23 minutes were kept for practicing breathing techniques. The rest of the time was dedicated to specific yoga postures. The participants were encouraged to repeat yoga postures as many times as they could within the allocated 60-minute session. The specific information about the yoga intervention can be found in the Table 2.

Outcome Measures

Anthropometric Characteristics and Body Composition

Standing height (cm) was measured using a stadiometer (SECA model 213, Hamburg, Germany) with standardized protocols. Subjects were to stand barefoot with their backs against the wall and heels together; the head should be positioned in the Frankfurt plane. The body weight (kg) of the subjects was recorded using a calibrated weighing scale (SECA model 813, Hamburg, Germany). It was made sure that the scale was properly calibrated and zeroed before each measurement. The subjects stood barefoot and wear minimal clothing. In order to calculate body mass indexes, body weight in kilograms (kg) was divided by the square of the height in meters (kg/m^2). Body composition was assessed using bioelectrical impedance analysis (BIA) (Tanita Corp., Tokyo, Japan). BIA measures body tissues' electrical impedance and estimates body composition by passing an electrical current through them. The reliability of the BIA device used in the present study was accessed by Kelly & Metcalfe [17] and was found satisfactory.

Blood Pressure

Participants were seated comfortably in a quiet and temperature-controlled room. They were instructed to sit with their back supported, feet flat on the floor, and arms resting on a table or armrest. The participants were in a relaxed and upright position, with their legs uncrossed. Blood pressure measurements were taken on the participant's non-dominant arm, specifically the left arm, in accordance with established guidelines and recommendations. The selection of the non-dominant arm was made to minimize the potential influence of muscle activity on the readings. Using an automatic sphygmomanometer, we measured blood pressure (BP)-(HBP-9020, Omron, Osaka, Japan) (Park et al., 2020). In order to assess everyone at once and reduce error, we let the device have a stabilizing period of at least 10 minutes before every test. During testing for blood pressure, at least a 30-minute interval was kept between subsequent measurements for any participant. The mean result from the two measurements was chosen as the measurement value for blood pressure.

Statistical Analysis

We conducted statistical analyses to assess the im-

Table 2. List of yoga practice intervention

Sl. No	Name of the yoga practices		Duration
1.	**START** Sukhasana + Pranamasana +Prarthana Mantra(Universal Prayer)		**1 min**
2.	**LOOSENING EXERCISES**		**5 min**
3.	**ASANA**		**24 min**
	Standing Asana		6 min
	a.	Tadasana (mountain pose)	1 min
	b.	Vriksasana (tree pose)	1 min
	c.	Utkatasana (chair pose)	1 min
	d.	Virabhadrasana (warrior pose)	1 min
	e.	Parivrtta Trikonasana (revolved triangle pose)	1 min
	f.	Utthita Trikonasana (extended triangle pose)	1 min
	Sitting Asana		6 min
	a.	Vajrasana (thunderbolt pose)	1 min
	b.	Upavistha Konasana (seated wide-legged straddle)	1 min
	c.	Ustrasana (camel pose)	1 min
	d.	Sasangasana (rabbit pose)	1 min
	e.	Ardha Matsyendrasana (half lord of the fishes pose)	1 min
	f.	Paschimottonasana (seated forward pose)	1 min
	Prone Posture		6 min
	a.	Bhujangasana (cobra pose)	1 min
	b.	Dhanurasana (bow pose)	1 min
	c.	Makarasana (crocodile pose)	1 min
	d.	Salabhasana (locust pose)	1 min
	e.	Ardha Bhekasana (half frog pose)	1 min
	f.	Chaturanga Dandasana (four limbed staff pose)	1 min
	Supine Posture		6 min
	a.	Setu Bandhasana (bridge pose)	1 min
	b.	Uttanpadasana (double leg rise pose)	1 min
	c.	Pawanmuktasana (wind pose)	1 min
	d.	Supta Baddha Konasana (supine butterfly pose)	1 min
	e.	Matsyasana (fish pose)	1 min
	f.	Shavasana (corpse pose)	1 min
4.	**PRANAYAMA**		**23 min**
	Kapalabhati (energizing yoga breathing practice)		500 to 650 strokes/10 min
	Bhramari (humming bee breath)		10 to 12 rounds /4 min
	Bhastrika (bellows breathing)		46 to 55 strokes / 4 min
	Nadi Suddhi Pranayama (alternate nostril breathing)		15 to 20 rounds / 5 min
5.	**MEDITATION**		
	Mindfulness Meditation		**5 min**
6.	**CLOSING PRAYERS**		**2 min**
	TOTAL		**60 min**

pact of yogic practice intervention programs on our primary dependent variables. The Kolmogorov–Smirnov test was utilized to ensure that all outcome measures had normal distributions. The means and standard deviations (SD) were determined for each of the variables. In order to examine the effect of yoga practices over time, we performed a two-way analysis of variance (two-way ANOVA), specifically looking at the interactions between the variables 'group' and 'time'. The variable 'group' had two levels: CG and YPG while the other variable 'time' also had two levels: Pre and Post. To quantify the magnitude of the effects, we determined Cohen's d effect sizes and calculated partial eta-squared (η^2) values. We interpreted η^2 as follows: small (≥0.01), medium (≥0.06), and large (≥0.14) (Park et al., 2020). To identify changes within each group over time if there was a significant interaction effect, we conducted post-hoc tests using the Bonferroni method. A paired t-test was used to compare the values of dependent variables of each group's pre and post test sessions. Every statistical analysis was performed utilizing IBM Corp's Statistical Package for Social Science (SPSS) version 23.0.1. For statistical significance, were set the alpha level at 0.05 level.

Results of the study

Table 3 illustrates the result of the initial body composition (BC) assessment between the CG and the YPG. The result reveals that there are no statistically significant differences between both groups. However, when examining the changes in BC initial and final the yoga practice intervention, we conducted repeated two-way (ANOVA) analyses, which unveiled a noteworthy interaction effect ($p<0.001$, $\eta2>0.439$) for all of the body composition parameters. Subsequent post-hoc analyses demonstrated distinct outcomes for each group. In the Control Group (CG), there was a significant reduction in Fat-Free Mass (FFM) ($p=0.013$) and a simultaneous increase in the percentage of body fat ($p<0.001$). Conversely, the Yoga Practice Group (YPG) exhibited substantial improvements in various body composition metrics. Specifically, the yoga intervention led to a significant decrease in body weight ($p=0.001$), a notable reduction in Body Mass Index (BMI) and percentage of body fat ($p=0.001$).

Table 4 illustrates a notable disparity in blood pressure (BP) levels between the Control Group (CG) and the Yogic Practice Group (YPG) both before and after the intervention. A significant interaction was observed between time and group across several BP parameters, specifically, Systolic Blood Pressure (SBP), Mean Arterial Pressure (MAP), and Pulse Pressure (PP), with all p-values below 0.017 and effect sizes ($\eta2$) exceeding 0.219. Furthermore, the study findings indicate that the 12-week yoga intervention had a significant and exclusive impact on reducing SBP ($p<0.001$), MAP ($p<0.001$), and PP ($p<0.001$) among the adolescent participants who were obese women.

Discussion

The results of the study reveals that there was a lack of significant difference in BC between the YPG and CG. Establishing homogeneity between intervention and control groups is a foundational step to ensure that any observed post-intervention disparities are attributable to the intervention itself rather than pre-existing discrepancies (Hulley et

Table 3. Mean (±SD) values of anthropometric characteristics and body composition for the 2 groups

Parameters	Group	Pre-test (Before)	Post-test (After)	p (Cohen´s d) 95% CI		
				Group (effect)	Time (effect)	Group x Time (Interaction)
BW (kg)	YPG	81.7±3.6	80.0±1.2**	0.053 (0.337)	0.093 (0.187)	0.446 (0.001)†
	CG	81.6±5.1	81.2±5.4			
Height (cm)	YPG	167.4±5.2	167.4±5.2	–	–	–
	CG	168.6±5.6	168.6±5.6			
BMI ($kg.m^{-2}$)	YPG	29.0±0.8	28.3±0.5**	0.039 (0.416)	0.104 (0.175)	0.454 (0.001)†
	CG	28.7±0.7	28.6±0.4			
FFM (kg)	YPG	45.2±2.1	46.5±3.7	0.002 (0.806)	0.118 (0.147)	0.439 (0.001)†
	CG	45.5±3.6	44.3±3.2*			
BF (%)	YPG	32.3±1.6	30.2±1.2***	0.331 (0.008)†	0.062 (0.286)	0.934 (0.001)†
	CG	32.6±1.7	34.3±1.8***			

Note: Data are mean values (±SD), BW: body weight, BMI: body mass index, FFM: free fat mass, BF: body fat, YPG: yogic practice group, CG: control group. Statistical significance levels (*p<0.05; **p<0.01; ***p<0.001) are indicated to denote † significant interactions or main effects when compared to baseline measurements (pre-test intervention).

Table 4. Mean (± SD) values of blood pressure variables for the 2 groups

Parameters	Group	Pre-test (Before)	Post-test (After)	p (Cohen´s d) 95% CI		
				Group (effect)	Time (effect)	Group x Time (Interaction)
SBP (mmHg)	YPG	135.7±3.1	133.2±2.7***	0.098 (0.187)	0.172 (0.081)	0.784 (0.001)
	CG	134.4±2.5	135.7±3.7**			
DBP (mmHg)	YPG	91.5±4.5	92.3±2.8	0.234 (0.027)†	0.091 (0.192)	0.124 (0.167)
	CG	89.2±3.8	90.4±4.2			
MAP (mmHg)	YPG	106.8±2.4	105.5±1.7***	0.267 (0.024)†	0.031 (0.397)	0.472 (0.004)†
	CG	104.6±4.1	105.4±1.8			
PP (mmHg)	YPG	45.1±3.7	42.6±3.6***	0.042 (0.339)	0.312 (0.092)	0.432 (0.001)†
	CG	45.7±3.4	45.2±4.5			

Note: Data are mean values (± SD), BW: body weight, BMI: body mass index, FFM: free fat mass, BF: body fat, YPG: yogic practice group, CG: control group. Statistical significance levels (*p < 0.05; **p < 0.01; ***p < 0.001) are indicated to denote † significant interactions or main effects when compared to baseline measurements (pre-test intervention).

al., 2011). Further in the results of the analysis of post-intervention, the repeated two-way ANOVA analyses highlighted a pronounced interaction effect across all BC parameters. This suggests that the dynamics of BC evolution were evidently different between the groups, which implies the intervention's potential role in mediating these effects (Field, 2013). While the CG's increased percentage of body fat coupled with a reduction in FFM is of particular concern, increases in body fat percentages are frequently linked with a plethora of health risks, including cardiovascular diseases, metabolic syndrome, and other non-communicable diseases (Popkin et al., 2012). Moreover, the decrease in FFM can be indicative of muscle atrophy, which has negative implications for metabolic health and functional capacity (Mitchell et al., 2012). On the other hand, the YPG's post-intervention results support the beneficial impacts of yoga on body composition. The reduction in both body weight and BMI in the YPG is significant. Though BMI has its critics, largely due to its inability to distinguish fat from muscle, it remains a globally recognized tool to assess weight status and its associated health risks (Romero-Corral et al., 2008). Furthermore, the decline in body fat percentage for the YPG is a compelling indicator of the potential health benefits of yoga. This observation resonates with Ross & Thomas's (2010) work, which posits that yoga can significantly reduce body mass index and body fat. In addition, the rise in FFM for the YPG is indicative of muscle or lean tissue gain. Yoga, which integrates strength-building postures, can serve as a resistance training modality (Saeidifard et al., 2020). Thus, its role in potentially augmenting muscle mass or lean tissue becomes plausible, consistent with earlier findings which show that yoga can augment muscular strength (Tran et al., 2001).

The initial assessment of BP variables in both groups reveals a general congruence in their pretest values, thus implying that any divergence in post-test measurements can be confidently ascribed to the interventional effects rather than inherent group disparities (Hulley et al., 2011). This bolsters the internal validity of the study. The significance of blood pressure in health research and clinical settings is highlighted by its consistent association with cardiovascular risks, especially elevated SBP (Whelton et al., 2018). Furthermore, the MAP serves as a valuable proxy for perfusion to vital organs, while PP is indicative of arterial stiffness (Franklin et al., 1997). Our study, focusing on obese adolescent women, demonstrates the remarkable efficacy of a 12-week yoga intervention in controlling these BP parameters. Notably, the YPG exhibited substantial reductions in SBP, MAP, and PP post-intervention. These findings cohere with prior research. Hughson et al. (1996) established the importance of aerobic exercise in mediating blood pressure. Moreover, Cohen et al. (2007) suggest that yoga, by integrating elements of both meditation and physical postures, can lower stress-induced sympathetic activity and promote parasympathetic dominance, thus modulating BP. The efficacy of yoga in reducing BP specifically among obese adolescent women is noteworthy. Obesity is known to predispose individuals to hypertension and related cardiovascular complications (Taksali et al., 2008). Furthermore, hormonal changes during adolescence can influence BP, making the observed BP reduction post-yoga intervention even more impactful (Reinehr et al., 2005).

The study provides compelling evidence of yoga's therapeutic potential in influencing body composition and blood pressure, especially among obese adolescent women. Initial results support the foundational strength of the study, ensuring that observed variations post-intervention are genuinely attributable to the yoga intervention. The outcomes elucidate yoga's substantial benefits, with the YPG demonstrating notable improvements in body composition and critical BP parameters. These findings, juxtaposed with existing literature, underscore the multidimensional benefits of yoga. As yoga integrates both meditation and physical postures, it not only improves body composition but also confers cardiovascular advantages by modulating blood pressure. Given the rising global concerns associated with obesity-related complications, this research accentuates the importance of incorporating holistic approaches, such as yoga, into health-promotion strategies, particularly for vulnerable demographics like obese adolescent women.

Conclusions

The modern surge in obesity, especially among young women, in industrialized countries, is alarmingly persistent, leading to grave concerns about escalating rates of non-communicable diseases. With obesity being an antecedent to various health challenges including heart diseases, diabetes, and depression, understanding its root causes, from behavioral patterns to environmental factors, becomes pivotal. The adolescent phase is particularly susceptible due to significant body composition changes driven by hormonal shifts. Albeit the increasing awareness around obesity's impacts, young women continue to be at risk.

Our comprehensive study undertook an investigation into the role of yoga, an ancient art emphasizing the holistic harmony of body and mind, in addressing obesity-induced health problems in young women. The study reveals that combating the obesity epidemic requires a multi-dimensional approach. While lifestyle modifications remain fundamental, our study underscores the significance of traditional practices like yoga in offering a holistic solution. Addressing obesity, particularly in the vulnerable demographic of adolescent women, not only pertains to the physical well-being but is also intrinsically linked to their mental and emotional health. As we stride towards a healthier future, interventions combining modern understanding with ancient wisdom, like yoga, can provide a balanced and holistic approach to the obesity problem.

Authors Contributions

Conceptualization, M.P, N.C.R, K.G; methodology, M.P, N.C.R, K.G; software, M.E, H.G; check, M.E., H.G., K.G and M.P; formal analysis, H.G., K.G; investigation, M.P, and N.C.R; resources, M.P, K.G; data curation, M.P, K.G; writing - rough preparation, M.P, K.G and H.G; writing - review and editing, M.E, N.C.R; visualization, M.E., H.G., K.G; supervision, N.C.R; project administration, M.P; receiving funding, K.G and H.G All authors have read and agreed with the published version of the manuscript.

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Conflict of Interest

The authors declare no conflict of interst.

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References

Ahmed, B., & Konje, J.C. (2023). The epidemiology of obesity in reproduction. *Best Practice & Research. Clinical Obstetrics & Gynaecology*, 89, 102342. https://doi.org/10.1016/j.bpobgyn.2023.102342

Alert, M.D., Rastegar, S., Foret, M., Slipp, L., Jacquart, J., Macklin, E., Baim, M., Fricchione, G., Benson, H., Denninger, J., & Yeung, A. (2013). The effectiveness of a comprehensive mind body weight loss intervention for overweight and obese adults: A pilot study. *Complementary Therapies in Medicine*, *21*(4), 286-293. https://doi.org/10.1016/j.ctim.2013.05.005

Alfawaz, H., Amer, O.E., Aljumah, A.A., Aldisi, D.A., Enani, M.A., Aljohani, N.J., Alotaibi, N.H., Alshingetti, N., Alomar, S.Y., Khattak, M.N.K., Sabico, S., & Al-Daghri, N.M. (2021). Effects of home quarantine during COVID-19 lockdown on physical activity and dietary habits of adults in Saudi Arabia. *Scientific Reports*, 11(1), 5904. https://doi.org/10.1038/s41598-021-85330-2

Asiah, A.S.S., Norhayati, M.N., Muhammad, J., & Muhamad, R. (2023). Effect of yoga on anthropometry, quality of life, and lipid profile in patients with obesity and central obesity: A systematic review and meta-analysis. *Complementary Therapies in Medicine*, 76, 102959. https://doi.org/10.1016/j.ctim.2023.102959

Batrakoulis, A. (2022). Psychophysiological Adaptations to Yoga Practice in Overweight and Obese Individuals: A Topical Review. *Diseases*, 10(4), 107. https://doi.org/10.3390/diseases10040107

Budreviciute, A., Damiati, S., Sabir, D.K., Onder, K., Schuller-Goetzburg, P., Plakys, G., Katileviciute, A., Khoja, S., & Kodzius, R. (2020). Management and Prevention Strategies for Non-communicable Diseases (NCDs) and Their Risk Factors. *Frontiers in Public Health*, *8*, 574111. https://doi.org/10.3389/fpubh.2020.574111

Chew, H.S.J., & Lopez, V. (2021). Global Impact of COVID-19 on Weight and Weight-Related Behaviors in the Adult Population: A Scoping Review. *International Journal of Environmental Research and Public Health*, 18(4), 1876. https://doi.org/10.3390/ijerph18041876

Cohen, B., Kanaya, A., Macer, J., Shen, H., Chang, A., & Grady, D. (2007). Feasibility and acceptability of restorative yoga for treatment of hot flushes: A pilot trial. *Maturitas*, *56*, 198-204. https://doi.org/10.1016/j.maturitas.2006.08.003

Di Cesare, M., Sorić, M., Bovet, P., Miranda, J.J., Bhutta, Z., Stevens, G.A., Laxmaiah, A., Kengne, A.-P., & Bentham, J. (2019). The epidemiological burden of obesity in childhood: A worldwide epidemic requiring urgent action. *BMC Medicine*, 17(1), 212. https://doi.org/10.1186/s12916-019-1449-8

Field, A. (2013). *Discovering Statistics Using IBM SPSS Statistics*. SAGE Publications. https://books.google.co.in/books?id=srb0a9fmMEoC

Franklin, S.S., Gustin, W., Wong, N.D., Larson, M.G., Weber, M.A., Kannel, W.B., & Levy, D. (1997). Hemodynamic Patterns of Age-Related Changes in Blood Pressure. *Circulation*, *96*(1), 308-315. https://doi.org/10.1161/01.CIR.96.1.308

Gao, Z., Chen, Z., Sun, A., & Deng, X. (2019). Gender differences in cardiovascular disease. *Medicine in Novel Technology and Devices*, *4*, 100025. https://doi.org/10.1016/j.medntd.2019.100025

Gour, P., Choudhary, A., Sahoo, K.C., Jirwe, M., Hallgren, M., Diwan, V.K., Mahadik, V. K., & Diwan, V. (2020). Experience of Elderly People Regarding the Effect of Yoga/Light Exercise on Sedentary Behavior: A Longitudinal Qualitative Study in Madhya Pradesh, India. *Geriatrics*, *5*(4), 103. https://doi.org/10.3390/geriatrics5040103

Guo, Y., Yue, X.-J., Li, H.-H., Song, Z.-X., Yan, H.-Q., Zhang, P., Gui, Y.-K., Chang, L., & Li, T. (2016). Overweight and Obesity in Young Adulthood and the Risk of Stroke: A Meta-analysis. *Journal of Stroke and Cerebrovascular Diseases: The Official Journal of National Stroke Association*, *25*(12), 2995-3004. https://doi.org/10.1016/j.jstrokecerebrovasdis.2016.08.018

Hendricks, G., Savona, N., Aguiar, A., Alaba, O., Booley, S., Malczyk, S., Nwosu, E., Knai, C., Rutter, H., Klepp, K.-I., & Harbron, J. (2022). Adolescents' Perspectives on the Drivers of Obesity Using a Group Model Building Approach: A South African Perspective. *International Journal of Environmental Research and Public Health*, *19*(4), 2160. https://doi.org/10.3390/ijerph19042160

Hughson, R.L., Shoemaker, J.K., Tschakovsky, M.E., & Kowalchuk, J.M. (1996). Dependence of muscleV˙o 2on blood flow dynamics at onset of forearm exercise. *Journal of Applied Physiology*, *81*(4), 1619-1626. https://doi.org/10.1152/jappl.1996.81.4.1619

Hulley, S.B., Cummings, S.R., Browner, W.S., Grady, D.G., & Newman, T.B. (2011). *Designing Clinical Research*. Wolters Kluwer Health. https://books.google.co.in/books?id=L3GQoFQdJ-MC

KavehFarsani, Z., Kelishadi, R., & Beshlideh, K. (2020). Study of the effect of family communication and function, and satisfaction with body image, on psychological well-being of obese girls: The mediating role of self-esteem and depression. *Child and Adolescent Psychiatry and Mental Health*, *14*(1), 39. https://doi.org/10.1186/s13034-020-00345-3

Kwarteng, E.A., Shank, L.M., Faulkner, L.M., Loch, L.K., Fatima, S., Gupta, S., Haynes, H. E., Ballenger, K.L., Parker, M.N., Brady, S.M., Zenno, A., Tanofsky-Kraff, M., & Yanovski, J.A. (2023). Influence of puberty on relationships between body composition and blood pressure: A cross-sectional study. *Pediatric Research*, *94*(2), 781-788. https://doi.org/10.1038/s41390-023-02503-7

Lorås, H. (2020). The Effects of Physical Education on Motor Competence in Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports*, *8*(6), 88. https://doi.org/10.3390/sports8060088

Luppino, F.S., de Wit, L.M., Bouvy, P.F., Stijnen, T., Cuijpers, P., Penninx, B.W.J.H., & Zitman, F.G. (2010). Overweight, obesity, and depression: A systematic review and meta-analysis of longitudinal studies. *Archives of General Psychiatry*, *67*(3), 220-229. https://doi.org/10.1001/archgenpsychiatry.2010.2

Manchanda, S.C., & Madan, K. (2022). Yoga for Primary and Secondary Prevention of Coronary Heart Disease. In I. Basu-Ray & D. Mehta (Eds.), *The Principles and Practice of Yoga in Cardiovascular Medicine* (pp. 243–252). Springer Nature Singapore. https://doi.org/10.1007/978-981-16-6913-2_19

Mitchell, W., Atherton, P., Williams, J., Larvin, M., Lund, J., & Narici, M. (2012). Sarcopenia, Dynapenia, and the Impact of Advancing Age on Human Skeletal Muscle Size and Strength; a Quantitative Review. *Frontiers in Physiology*, 3. https://doi.org/10.3389/fphys.2012.00260

Na Nongkhai, M.P., Yamprasert, R., & Punsawad, C. (2021). Effects of Continuous Yoga on Body Composition in Obese Adolescents. *Evidence-Based Complementary and Alternative Medicine*, *2021*, 1-7. https://doi.org/10.1155/2021/6702767

Noale, M., Limongi, F., & Maggi, S. (2020). Epidemiology of Cardiovascular Diseases in the Elderly. In N. Veronese (Ed.), *Frailty and Cardiovascular Diseases* (Vol. 1216, pp. 29-38). Springer International Publishing. https://doi.org/10.1007/978-3-030-33330-0_4

Park, W., Jung, W.-S., Hong, K., Kim, Y.-Y., Kim, S.-W., & Park, H.-Y. (2020). Effects of Moderate Combined Resistance- and Aerobic-Exercise for 12 Weeks on Body Composition, Cardiometabolic Risk Factors, Blood Pressure, Arterial Stiffness, and Physical Functions, among Obese Older Men: A Pilot Study. *International Journal of Environmental Research and Public Health*, 17(19), 7233. https://doi.org/10.3390/ijerph17197233

Patel, R., & Veidlinger, D. (2023). Exploring the Benefits of Yoga for Mental and Physical Health during the COVID-19 Pandemic. *Religions*, *14*(4), 538. https://doi.org/10.3390/rel14040538

Popkin, B.M., Adair, L.S., & Ng, S.W. (2012). Global nutrition transition and the pandemic of obesity in developing countries. *Nutrition Reviews*, *70*(1), 3-21. https://doi.org/10.1111/j.1753-4887.2011.00456.x

Ramos-Campo, D.J., Andreu Caravaca, L., Martínez-Rodríguez, A., & Rubio-Arias, J.Á. (2021). Effects of Resistance Circuit-Based Training on Body Composition, Strength and Cardiorespiratory Fitness: A Systematic Review and Meta-Analysis. *Biology*, *10*(5), 377. https://doi.org/10.3390/biology10050377

Reddy, K.S., & Mathur, M.R. (2022). Addressing the Common Risk Factors for Reducing the Burden of Cardiovascular Diseases: The Impact of Yoga. In I. Basu-Ray & D. Mehta (Eds.), *The Principles and Practice of Yoga in Cardiovascular Medicine* (pp. 39-43). Springer Nature Singapore. https://doi.org/10.1007/978-981-16-6913-2_2

Reinehr, T., Andler, W., Denzer, C., Siegried, W., Mayer, H., & Wabitsch, M. (2005). Cardiovascular risk factors in overweight German children and adolescents: Relation to gender, age and degree of overweight. *Nutrition, Metabolism, and Cardiovascular Diseases : NMCD*, *15*, 181-187. https://doi.org/10.1016/j.numecd.2004.06.003

Renehan, A.G., Tyson, M., Egger, M., Heller, R.F., & Zwahlen, M. (2008). Body-mass index and incidence of cancer: A systematic review and meta-analysis of prospective observational studies. *Lancet (London, England)*, *371*(9612), 569-578. https://doi.org/10.1016/S0140-6736(08)60269-X

Riaz, H., Khan, M.S., Siddiqi, T.J., Usman, M.S., Shah, N., Goyal, A., Khan, S.S., Mookadam, F., Krasuski, R.A., & Ahmed, H. (2018). Association Between Obesity and Cardiovascular Outcomes: A Systematic Review and Meta-analysis of Mendelian Randomization Studies. *JAMA Network Open*, *1*(7), e183788. https://doi.org/10.1001/jamanetworkopen.2018.3788

Romero-Corral, A., Somers, V.K., Sierra-Johnson, J., Thomas, R.J., Collazo-Clavell, M.L., Korinek, J., Allison, T.G., Batsis, J.A., Sert-Kuniyoshi, F.H., & Lopez-Jimenez, F. (2008). Accuracy of body mass index in diagnosing obesity in the adult general population. *International Journal of Obesity*, *32*(6), 959-966. https://doi.org/10.1038/ijo.2008.11

Ross, A., & Thomas, S. (2010). The Health Benefits of Yoga and Exercise: A Review of Comparison Studies. *The Journal of Alternative and Complementary Medicine*, *16*(1), 3-12. https://doi.org/10.1089/acm.2009.0044

Saeidifard, F., Medina-Inojosa, J.R., West, C.P., Olson, T.P., Somers, V.K., Bonikowske, A.R., Prokop, L.J., Vinciguerra, M., & Lopez-Jimenez, F. (2020). The association of resistance training with mortality: A systematic review and meta-analysis. *European Journal of Preventive Cardiology*, *26*(15), 1647-1665. https://doi.org/10.1177/2047487319850718

Safaei, M., Sundararajan, E.A., Driss, M., Boulila, W., & Shapi'i, A. (2021). A systematic literature review on obesity: Understanding the causes & consequences of obesity and reviewing various machine learning approaches used to predict obesity. *Computers in Biology and Medicine*, *136*, 104754. https://doi.org/10.1016/j.compbiomed.2021.104754

Silverwood, V., Blagojevic-Bucknall, M., Jinks, C., Jordan, J.L., Protheroe, J., & Jordan, K.P. (2015). Current evidence on risk factors for knee osteoarthritis in older adults: A systematic review and meta-analysis. *Osteoarthritis and Cartilage*, *23*(4), 507-515. https://doi.org/10.1016/j.joca.2014.11.019

Štefanová, E., Bakalár, P., & Baška, T. (2020). Eating-Disordered Behavior in Adolescents: Associations with Body Image, Body Composition and Physical Activity. *International Journal of Environmental Research and Public Health*, *17*(18), 6665. https://doi.org/10.3390/ijerph17186665

Taksali, S.E., Caprio, S., Dziura, J., Dufour, S., Calí, A.M.G., Goodman, T.R., Papademetris, X., Burgert, T.S., Pierpont, B.M., Savoye, M., Shaw, M., Seyal, A.A., & Weiss, R. (2008). High Visceral and Low Abdominal Subcutaneous Fat Stores in the Obese Adolescent: A Determinant of an Adverse Metabolic Phenotype. *Diabetes*, *57*(2), 367-371. https://doi.org/10.2337/db07-0932

Templin, T., Cravo Oliveira Hashiguchi, T., Thomson, B., Dieleman, J., & Bendavid, E. (2019). The overweight and obesity transition from the wealthy to the poor in low- and middle-income countries: A survey of household data from 103 countries. *PLoS Medicine*, *16*(11), e1002968. https://doi.org/10.1371/journal.pmed.1002968

Tran, M.D., Holly, R.G., Lashbrook, J., & Amsterdam, E.A. (2001). Effects of Hatha Yoga Practice on the Health-Related Aspects of Physical Fitness. *Preventive Cardiology*, *4*(4), 165-170. https://doi.org/10.1111/j.1520-037X.2001.00542.x

Whelton, P.K., Carey, R.M., Aronow, W.S., Casey, D.E., Collins, K.J., Himmelfarb, C.D., DePalma, S.M., Gidding, S., Jamerson, K.A., Jones, D.W., MacLaughlin, E.J., Muntner, P., Ovbiagele, B., Smith, S.C., Spencer, C.C., Stafford, R.S., Taler, S.J., Thomas, R.J., Williams, K.A., … Wright, J.T. (2018). 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension*, *71*(6), 1269-1324. https://doi.org/10.1161/HYP.0000000000000066

Zubery, D., Kimiywe, J., & Martin, H.D. (2021). Prevalence of Overweight and Obesity, and Its Associated Factors Among Health-care Workers, Teachers, and Bankers in Arusha City, Tanzania. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*, *14*, 455-465. https://doi.org/10.2147/DMSO.S283595