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ORIGINAL ARTICLE
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The effects of a 6-month moderate-intensity Hatha yoga-based training program on health-related fitness in middle-aged sedentary women: a randomized controlled study

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ABSTRACT

BACKGROUND: There is paucity of data examining the effectiveness of long-term Hatha yoga-based (HY) programs focused on the health-related fitness (H-RF) of asymptomatic, sedentary women. The purpose of this study was to examine the effects of a 6-month HY-based training program on H-RF components in sedentary middle-aged women.
METHODS: Eighty sedentary women were randomly assigned into either the HY group (HYG) (N.=42) or the control group (CG) (N.=38). The 6-month HYG program involved a progressive series of Vinyasa Flow poses performed 3 times/week for 60 minutes (40 minutes within the exercise zone of 60-75% HR_{max}). The CG participants did not undergo any physical training or education. Health-related fitness parameters included measures of pre- and post-training: body composition, muscular strength and maximal voluntary isometric torques of elbow flexors and knee extensors, cardio-respiratory fitness, lower back and hamstring flexibility and a static-dynamic balance.
RESULTS: Two-way mixed design ANOVA revealed significant main effects for all the indicators of H-RF. Tukey *post-hoc* tests confirmed that the HYG demonstrated significant improvements in every variable tested. Examples of the benefits achieved include (all P<.001): an average loss of 1.03 kg and a 4.82% decrease in body fat, 14.6% and 13.1% gains in isometric strength of the knee extensors and elbow flexors respectively, an increase in relative VO_{2max} of 6.1% (33.12±5.30 to 35.14±4.82 mL/kg/min), a 4-cm or 10.4% increase in their MSAR, and an average improved Balance Index of 5.6 mm/s. Reversely, the CG showed non-significant changes in H-RF variables (all P>0.05; percent range from -1.4% to 1.1%).
CONCLUSIONS: By participating in a moderate-intensity 6-month HY-based training program, middle-aged women can significantly improve their HR-F status. The application of progressive target heart rate goals facilitated greater than expected improvements in cardio-respiratory fitness and improvements in body composition.

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KEY WORDS: Yoga; Physical fitness; Middle aged; Women.

Traditional yoga was designed to facilitate the development and integration of the human body, mind, and breath in order to produce structural, physiological, and psychological adaptations.[1, 2] There are a number of recognized classical yoga methods or systems.

A commonly practiced form is Hatha yoga (HY). Hatha yoga incorporates combinations of isometric muscular contractions, stretching maneuvers, relaxation techniques, cognitive focusing skills, and breathing exercises.[3] Although HY is more physical in nature than the other forms of yoga, it is referred to as the “psychophysical yoga” form.[2] Practitioners define HY as using psychophysical energy movements that including specific body poses (postures or asanas), energetic and deep breathing exercises (*pranayama*), mindfulness/meditation activities (*dharana*), and concentration exercises (*pratyahara*).[1] Due to the continuous attention to postural alignment, relaxation, body awareness, and meditation, HY is a noncompetitive, process-oriented, self-care practice that could support sports performance and rehabilitation. Practitioners claim that HY can correct biomechanical abnormalities and provide a qualitatively different exercise experience which may be perceived as less strenuous and more pleasurable than other modes of physical activity.[3] Based on cross-sectional and interventional studies, the practice of HY has been shown to interact with various somatic and physiological mechanisms bringing about potentially therapeutic effects.[4]

Prior studies demonstrate that HY can be used as an alternative and cost-effective therapy for a variety of psychophysical problems in both asymptomatic and symptomatic women. Moliver *et al.*[5] showed that increased HY experience predicts lower body mass index and reduced medication use in women over 45 years old. Tran *et al.*[6] reported a significant improvement in H-RF components after 8-week HY practice in 10 healthy untrained women (age range 18-27 years), specifically in isokinetic muscular strength (19-31%), isometric muscular endurance (57%), and flexibility indices (13-188%). Similarly, Kim *et al.*[7] showed the substantial effects of 16-week HY exercise on body composition, serum lipids, and H-RF components (grip strength, back strength, push-ups, sit-ups, Harvard step test, and sitting trunk flexion) in 18 middle-aged women. HY-focused studies by Cowen and Adams,[8] Kim *et al.*,[7] and Grabara[9] have confirmed these observations.

Although the majority of interventional studies in young, middle-aged and older participants suggest that HY is an acceptable form of PA for enhancing muscular strength, balance and flexibility, the literature is conflicting regarding the effectiveness of yoga training in general and HY specifically to elicit cardiorespiratory fitness benefits. Most cross-sectional and interventional studies that included cardiorespiratory variables have reported that regular short-term practice of HY is not associated with improvements in cardiorespiratory fitness.[4, 10, 11] These authors contend that the intensity of traditional HY is too low to provide an adequate training stimulus to improve cardiorespiratory fitness.[10, 11] Another, though secondary, factor may be the relatively short duration of most HY studies that typically range from 6 to 20 weeks.[6, 11-16]

In addition to the investigation of HY programs that intentionally aim to improve cardiorespiratory fitness, there is a paucity of data examining the effectiveness of long-term HY-based training programs on the overall health-related fitness[17] (H-RF) of asymptomatic, middle-aged, sedentary women.[18, 19] Therefore, this study was performed to determine whether and to what extent an exercise intensity focused, 6-month HY-based training program would elicit improvements in the cardiorespiratory and H-RF status of sedentary middle-aged women.

Materials and methods

Participants

Of the 118 women who responded to our recruitment efforts, 89 met the study's requirements and were randomly assigned to either the control group (CG, N.=40) or the HY group (HYG, N.=49). More participants were randomized into the HYG to compensate for potential dropouts. Inclusion criteria included: good general health (PAR-Q), regular menstruation (24-35 days); 30 and 45 years (arbitrary age range to provide homogenous group), and no extensive (<12 months) prior experience with HY. Exclusion criteria included: Body Mass Index (BMI) >30 kg/m^2; musculoskeletal conditions that would prevent the participant from safely performing the HY-based poses; and engaging in regular high-intensity (>6 MET) physical training >2 days per week over the prior 12 months (International Physical Activity Questionnaire [L7DPAR]). Olsztyn University's Ethical Advisory Commission approved the study's design and procedures. After the initial screening, the participants provided their written, informed consent.

Study design

This study used a longitudinal, single-center, controlled experimental approach. The study design was developed according to CONSORT statement guidelines (Figure 1). HYG participants engaged in the training program 3 times/week for 6 months (72 sessions). In order to facilitate adherence to the required schedule (participants were encouraged to attend sessions separated by at least one day), HY sessions were held twice daily, 6 times/week to provide participants a choice of day and hour to attend. The HY program was conducted in a traditional yoga studio and led by a certified HY instructor. This 6-month study focused solely on exercise, with no formal education provided regarding other lifestyle habits such as diet, cigarette smoking, body mass loss, etc. Participants in the CG were encouraged to maintain their usual daily lifestyles (diet,

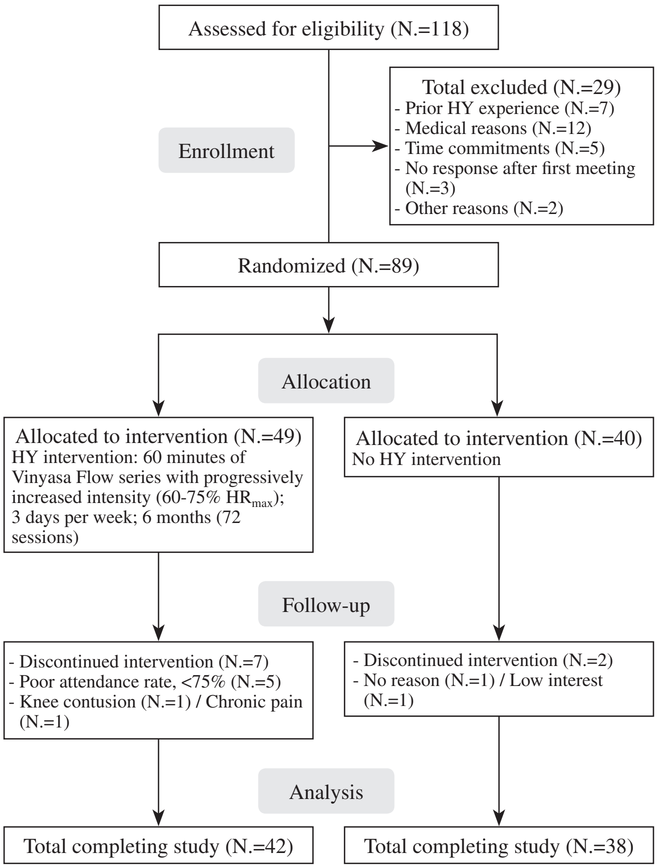

Figure 1.—Flow chart of the recruitment process and research design (CONSORT, 2010).

physical activity, etc.) and were not given any other instructions or directions.

Baseline testing (pre-test) was completed one week before the initiation of the HY-based training program, and the post-test was completed one week after the completion of the 6-month study period. For testing, participants reported to the controlled environmental laboratory conditions (~20 °C, 31-47% relative humidity, 752-769 mmHg) at the same time each morning. After familiarization with testing procedures, the participants completed the performance tests in the following order: body composition, static-dynamic balance, muscular strength, cardiorespiratory fitness, and flexibility.

Assessment of demographic characteristics

Body height to the nearest 0.1 cm and weight to the nearest 0.1 kg were measured, shoes removed, using a WB-150 stadiometer (ZPU Tryb-Wag, Poland). BMI was calculated by the standard formula, kg/m^2.

Body composition

Body composition was determined using bioelectrical impedance analysis (BIA) using a C-780U Multi Frequency Segmental Body Composition Analyzer (Tanita Corporation, Japan). Body composition assessments were carried out in the early follicular phase (between days 3-8 of a normal menstrual cycle). BIA was used to estimate fat-free mass and percentage body fat. All measurements were carried in compliance with standard procedures recommended by the International Society for Advancement of Kinanthropometry.

Static-dynamic balance

Body balance was assessed by the Ellipsis static-dynamic test. This bipedal test was performed on a PLA2-4P tensometric platform, integrated with a WTM5 tensometric amplifier and computer software KKD v. 1.1 (JBA-Staniak, Warsaw, Poland).[20, 21] This novel test is based on controlling the position of the center of body mass using a dynamometric platform. The participant had to keep the cursor (the center of gravity) at the point moving along a perfect ellipsis on the screen. The mean error was recorded as the value of integral in time function from the difference between the model curve course and the course of the imaging curve. The Balance Index (BI) — mean error quantity (mm/s) — was calculated as the quotient of error quantity and the time of continuation of the test (46 s). The lower BI, the better score. The mean error of three trials served as the dependent variable.

Muscular strength

General muscular strength was assessed using handgrip dynamometry as per accepted standardized guidelines; performed with the participant standing upright with the device in their dominant hand and a rest period of 30 s between each trial. The best of three trials, maximal force (F_{max}, in N), was recorded to the nearest 0.1 N.

The maximal voluntary isometric torques (MVIT) of dominant side elbow flexors and knee extensors were measured using a Biodex-3 Pro (Biodex Medical Systems, Inc., Shirley, NY, USA) as per the manufacturer instructions. The MVIT of the elbow flexors (angle 90°) was measured in a sitting position with the trunk stabilized. The MVIT of the knee extensors were measured in a stabilized and seated position with the hip and knee angles set at 90°. Participants performed three maximal efforts, and the highest value was recorded (Nm).

Cardiorespiratory fitness

Cardiorespiratory fitness was assessed using the physical working capacity (PWC) standardized protocol using an Ergomedic 828 E cycle ergometer (Monark Exercise AB, Vansbro, Sweden).[22] Two 5-minute submaximal workloads were used for estimation of the PWC index ($PWC_{85\%HRmax}$) and maximal oxygen uptake (VO_{2max}) according to the Karpman formula.[22]

Flexibility

Flexibility was assessed using a modified sit-and-reach test (MSAR) according to the procedure described by Hoeger and Hopkins.[23] The best of three efforts was recorded to the nearest 0.1 cm.

Hatha yoga sessions

The training program for this study was based on the HY derivative style of Ashtanga yoga - Vinyasa Flow yoga. Each 60-minute HY session began with a 10-minute warm-up consisting of a set of gentle exercises combined with standing breathing exercises. The warm-up was followed by an ordered progressive series of Vinyasa Flow standing and seated poses, lasting 40 minutes (Table I). Each pose had a specific focus: relaxation, strength building, flexibility, or large-muscle movement. The HY instructor, in accordance with the individual's limits, stressed concentration, breath control, and correct exercise techniques. Every pose was performed for 25–30 seconds. The order of poses was consistent from week to week. Rest periods between the poses lasted 10–15 seconds, depending on the individual's HR. The transitions between the poses occurred by means of slow-dynamic short movements. A 10-minute cool-down phase consisting of light stretching, seated breathing visualization techniques, and guided deep relaxation exercises was performed at the conclusion of each session. No assistive devices or props were used.

Participants' maximal heart rate ($HR_{max} = 205 - 0.5 \times$ age) was determined with the objective to maintain their HR within the target HR exercise zone (60-75% HR_{max}) during the 40-minute exercise portion of each session. Participants were instructed to keep their HR closer to the lower limit of the zone during the first weeks, and, in the coming weeks, they were encouraged to systematically increase the intensity towards the upper limit. Participants monitored their heart rate during each session using a Polar T-31 heart rate monitor (Polar Electro OY, Kempele, Finland). The participants were taught to adjust the inten-

TABLE I.—*Characteristics of chosen 26 poses (asanas) of the HY-based training program (composed of 54 asanas).*

Pose	Name	Description/comments
Boat	*Ardha navasana*	Angle pose, on back hands to knees
Bow	*Dhanurasana*	*Dhanur*, "bow" pose on the abdomen
Bridge	*Setu bandhasana*	Backbend, head on the floor
Cat	*Vidalasana*	Alternate arching of the back on all-fours
Child	*Balasana*	Classic forward bend
Chair	*Utkatasana*	Sitting on an imaginary chair
Cobra	*Bhujangasana*	Also called serpent or snake pose
Corpse	*Savasana*	Resting, restorative pose
Down-dog	*Adhomukha svanasana*	Dog "stretch" pose, face down
Forward bend	*Uttanasana*	Standing in an intense forward bend
Four limbs	*Chaturanga dandasana*	Push-up or dip pose
Half moon	*Ardha chandrasana*	*Ardha*, "half" leg and arm balance
Head-to-knee	*Paschimottanasana*	Sitting in a forward bend
Locust	*Salabhasana*	*Salab*, "locust" pose
Lunge	*Anjanyasana*	Dynamic standing pose
Pigeon	*Eka pada rajakapotasana*	Stretch with a bent leg under chest
Plank	*Kumbhakasana*	Push up
Restrained angle	*Baddhakonasana*	Also called bound angle posture
Revolved crescent lunge	*Parivrtta anjanyasana*	Low lunge twist
Sitting	*Sukhasana*	Comfortable sitting pose; "easy" or "pleasant"
Spinal twist	*Ardha matsyendrasana*	*Ardha*, "half" lateral twist
Spinal twist	*Marichyasana*	Intense twist in a sitting pose
Sun salute	*Surya namaskar*	Series of power stretch poses
Triangle	*Trikonasana*	*Trikona*, "triangle" pose
Up-dog	*Urdhvamukha Svanasana*	Reverse dog stretch, face up
Warlord	*Virabhadrasana*	Warrior, standing variations I, II, III

sity of exercise by adjusting the speed of movement. Once a week, the investigators monitored and recorded each participant's HR and confirmed that the exercise intensity goals were being met. Additionally, participants self-reported their exercise intensity using the Borg 6-20 Ratings of Perceived Exertion Scale (RPE) mid-way through each HY session.

Statistical analysis

The statistical analyses were performed using the Statistica PL v. 10 software package (StatSoft Inc., Tulsa, OK, USA). For a given participant's data to be considered for analysis, they must have participated in at least 75% of the potential 72 HY-based sessions over the 6-month intervention period. Distribution of the data set in each group was screened for normality using the Shapiro-Wilk test. Homogeneity of variance was verified by the Levene's test. The sample size was determined using a magnitude of the effect corresponding to 1.4 times the range of 95%, resulting in $\beta=0.817$ and $P<0.05$ (Jandel Scientific). Group differences in baseline values (pre-test data) for the dependent variables were determined by independent *t*-tests and effect size measure (Cohen's *d*). Two-way mixed model analysis of variance (ANOVA) (group [HYG *vs*. CG] × time [pre-test *vs*. post-test]) with repeated measures was used to analyze group responses to the intervention. Where appropriate, Tukey's *post-hoc* test was applied to the data. In the presence of significant group × time interactions, the effect size was estimated by partial eta square (η^2_p). The interpretation of partial eta squared effect sizes was based on benchmarks established by Cohen:[24] 0.01 (small effect), 0.06 (medium effect) and 0.14 (large effect). The alpha level was set *a priori* to 0.05 to indicate statistical significance. In order to determine the reliability of the measures across time for the CG participants, intraclass correlation coefficients (ICC) were calculated for each dependent variable between the values from month 0 (pre-test) and month 6 (post-test).

Results

Baseline

To observe the effects of the intervention which would occur under optimal conditions we used a per-protocol (PP) analysis. By including only those participants who complied with the trial protocol, the PP analysis reflected the effects of the intervention unaffected by protocol deviations or non-adherence. Of the initial 89 participants, 80 completed the study. Program adherence was considered excellent with the average attendance rate during the 6 months of this HY-based training program being 84.6% (range: 75.2-91.4%). Seven individuals from HYG (16.7%) did not meet the adherence criteria of 75% attendance and two CG (5.3%) did not return for the post-testing; all were excluded from the data analysis. Descriptive statistics for the 80 participants included in the data analysis are shown in Table II. Statistical testing confirmed the normal distribution of the data set in each group and confirmed the assumption of homogeneity of variance between the groups for all variables. Analysis of the pre-test data showed that there were no significant between-group differences in any of the measured variables (all P>0.05; trivial effect size). Neither the HYG nor the CG groups met the recommended minimal weekly PA level (>600 MET/week) at baseline, 307.7±133.9 MET/week and 350.5±147.3 MET/week, respectively[25] (Table II). The pre-post ICC's for the dependent variables demonstrated the stability of the measures in the CG and ranged from relative maximal hand grip strength (0.83) to percentage body fat (0.95).

TABLE II.—*Baseline characteristics of the study sample.*

Variable	HYG (N.=42)	CG (N.=38)	Relevance level (P value)	Effect size (Cohen's *d*)
Age, years	37.0±5.4	33.7±3.8	0.231	0.09
Body height, cm	164.0±4.9	165.6±6.2	0.879	0.02
Body mass, kg	65.4±9.9	62.5±6.8	0.336	0.05
Body Mass Index, kg/m^2	24.1±3.0	22.8±2.1	0.539	0.08
Body fat, %	28.9±4.9	27.4±4.0	0.874	0.05
Fat-free mass, kg	45.7±3.5	45.2±3.4	0.922	0.06
Resting HR, bpm	77.8±6.9	72.6±5.4	0.079	0.09
Resting systolic BP, mmHg	132.3±10.2	129.6±8.6	0.451	0.07
Resting diastolic BP, mmHg	85.1±6.4	82.7±5.1	0.365	0.09
Self-reported total PA, MET×min/wk	307.7±133.9	350.5±147.3	0.178	0.13

Values are expressed as mean±SD.
HR: heart rate; BP: blood pressure; PA: physical activity; MET: metabolic equivalent task.

TABLE III.—*Body composition variables in the two research groups before (pre-training) and after (post-training) 6-month intervention.*

Variables	Group	Pre-training		Post-training		Group × time interaction
		Mean±SD	95% CI	Mean±SD	95% CI	
BM, kg	HYG	64.72±8.28	48.48-80.95	63.69±7.79	48.43-78.96	$F_{(1,80)}$=81.69; P<0.001; η^2_P=0.505
	CG	62.50±6.76	49.25-75.75	62.73±6.79	49.42-76.04	
BMI, kg/m²	HYG	24.14±3.16	17.95-30.33	23.76±2.94	18.00-29.52	$F_{(1,80)}$=80.64; P<0.001; η^2_P=0.502
	CG	22.78±2.08	18.70-26.86	22.86±2.06	18.82-26.90	
BF, %	HYG	29.03±5.39	18.47-39.59	27.63±4.90	18.03-37.23	$F_{(1,80)}$=115.81; P<0.001; η^2_P=0.591
	CG	27.44±4.01	19.58-35.30	27.83±4.09	19.81-35.85	
FFM, kg	HYG	45.63±3.32	39.12-52.14	45.86±3.45	39.10-52.62	$F_{(1,80)}$=39.47; P<0.001; η^2_P=0.334
	CG	45.15±3.36	38.56-51.74	45.07±3.34	38.52-51.62	

BM: body mass; BMI: Body Mass Index; BF: body fat; FFM: fat-free mass; HYG: Hatha yoga group; CG: control group.

TABLE IV.—*Muscular strength measures in research groups before (pre-training) and after (post-training) 6-month intervention.*

Variables	Group	Pre-training		Post-training		Group × time interaction
		Mean±SD	95% CI	Mean±SD	95% CI	
F_{max}, N	HYG	337.7±33.76	271.5-403.9	366.4±33.41	300.9-372.9	$F_{(1,80)}$=225.13; P<0.001; η^2_P=0.738
	CG	332.1±57.79	218.8-445.4	333.5±54.35	226.9-440.0	
F_{max}, N/kg	HYG	5.27±0.66	3.98-6.56	5.80±0.67	4.49-7.11	$F_{(1,80)}$=309.60; P<0.001; η^2_P=0.795
	CG	5.33±0.80	3.76-6.90	5.34±0.73	3.91-6.77	
Elbow flexors						
MVIT, N×m	HYG	42.70±5.79	31.35-54.05	47.59±5.24	37.32-57.86	$F_{(1,80)}$=320.60; P<0.001; η^2=0.799
	CG	41.18±6.45	28.54-53.78	41.64±6.14	29.61-53.67	
MVIT (N×m/kg)	HYG	0.664±0.08	0.504-0.824	0.751±0.09	0.571-0.931	$F_{(1,80)}$=370.55; P<0.001; η^2_P=0.822
	CG	0.657±0.06	0.537-0.777	0.663±0.05	0.565-0.761	
Knee extensors						
MVIT, N×m	HYG	137.8±22.83	93.1-182.6	154.0±23.89	107.2-200.8	$F_{(1,80)}$=111.98; P<0.001; η^2_P=0.583
	CG	130.4±21.64	88.0-172.4	131.1±20.51	90.9-171.3	
MVIT (N×m/kg)	HYG	2.14±0.31	1.53-2.75	2.42±0.32	1.79-3.05	$F_{(1,80)}$=141.97; P<0.001; η^2_P=0.639
	CG	2.08±0.21	1.67-2.49	2.09±0.19	1.72-2.46	

F_{max}: maximal force; MVIT: maximal voluntary isometric torque; HYG: Hatha yoga group; CG: control group.

Body composition

The mean BMI (range: 22.8 to 24.1 kg/m²) of both groups throughout the intervention was considered to be in the normal/healthy range (Table III). However, 11 participants from HYG (range: 25.6-29.9 kg/m²) and seven from CG (range: 25.3-29.7 kg/m²) and were classified as overweight. ANOVA showed interaction effects for all body composition variables with the largest effect observed for %BF ($F_{(1,80)}$=115.81; P<0.001; η^2_P=0.591) and the lowest for FFM ($F_{(1,80)}$=39.47; P<0.001; η^2_P=0.334). The HYG demonstrated significant (P<0.001) improvements in all of the body composition variables including a 4.82% decrease in %BF and an improvement in their health status as expressed by a reduced BMI. The CG achieved non-significant (P>0.05) increases in BM, BMI and %BF by 0.4%, 0.4% and 1.4%, respectively. Simultaneously, a minimal decrease was observed in FFM (0.2%; P>0.05).

Flexibility and static-dynamic balance

The HYG demonstrated a 4 cm or 10.4% (P<0.001) increase in their performance of the MSAR (Table IV). For this measure we observed interaction effect with large effect size ($F_{(1,80)}$=164.49; P<0.001; η^2_P=0.673). A large improvement in static-dynamic balance for the HYG was also observed with the BI decreasing from 23.3±5.2 mm/s to 17.7±17.7 mm/s, or 18.5% (P<0.001) with CG showing no appreciable change; there was again significant interaction effect ($F_{(1,80)}$=59.82; P<0.001; η^2_P=0.472).

Muscular strength

Significant between-group differences over time were found for all muscular strength variables expressed both in absolute and relative values (P<0.001) (Table V). As it is shown in Table V, the muscular strength improvements in relation to BM were similar in HYG for the upper and lower extremities. The largest strength increase in this group

Table V.—*Cardio-respiratory fitness variables in research groups before (pre-training) and after (post-training) 6-month intervention.*

Variables	Group	Pre-training		Post-training		Group × time interaction
		Mean±SD	95% CI	Mean±SD	95% CI	
VO_{2max}, L/min	HYG	2.12±0.28	1.57-2.67	2.22±0.27	1.69-2.75	$F_{(1,80)}$=54.84; P<0.001; η^2_P=0.407
	CG	2.29±0.27	1.76-2.82	2.27±0.25	1.78-2.76	
VO_{2max}, mL/kg/min	HYG	33.12±5.30	22.73-43.51	35.14±4.82	25.69-44.59	$F_{(1,80)}$=95.39; P<0.001; η^2_P=0.544
	CG	36.91±5.29	26.54-47.28	36.54±5.26	26.23-46.85	
$PWC_{85\%HRmax}$, W	HYG	96.95±21.30	55.20-138.70	107.03±21.22	65.44-148.62	$F_{(1,80)}$=58.07; P<0.001; η^2_P=0.421
	CG	102.25±23.46	56.27-148.23	101.19±22.95	56.21-146.17	
$PWC_{85\%HRmax}$, W/kg	HYG	1.51±0.33	0.86-2.16	1.68±0.28	1.13-2.23	$F_{(1,80)}$=92.11; P<0.001; η^2_P=0.535
	CG	1.64±0.37	0.91-2.37	1.62±0.36	0.91-2.33	

VO_{2max}: maximal oxygen uptake; $PWC_{85\%HRmax}$: Physical Working Capacity Index measured at 85% of maximal heart rate; HYG: Hatha yoga group; CG: control group.

Table VI.—*Flexibility and static-dynamic balance in research groups before (pre-training) and after (post-training) 6-month intervention.*

Variables	Group	Pre-training		Post-training		Group × time interaction
		Mean±SD	95% CI	Mean±SD	95% CI	
MSAR, cm	HYG	38.1±5.68	27.0-49.2	42.4±4.43	33.7-51.1	$F_{(1,80)}$=164.49; P<0.001; η^2_P=0.673
	CG	38.8±6.76	25.5-52.1	38.4±6.04	26.6-50.2	
BI, mm/s	HYG	23.29±5.20	13.10-33.49	18.96±2.61	13.84-24.08	$F_{(1,80)}$=45.49; P<0.001; η^2_P=0.363
	CG	24.08±7.26	9.85-38.31	23.12±5.03	13.26-32.98	

MSAR: modified Sit And Reach Test; BI: Balance Index; HYG: Hatha yoga group; CG: control group.

was a 14.6% (P<0.001) gain in relative muscular strength of the knee extensors (MVIT N×m/kg) with stable results observed in CG (P>0.05). Similar increase was noted for MVIT (N×m/kg) of elbow flexors (13.1%; P<0.001). Relative handgrip strength (F_{max}, in N/kg) also increased with training for HYG (10.1%; P<0.001), but again not for CG (P>0.05). ANOVA revealed the lowest interaction effect for MVIT of knee extensors expressed both in absolute ($F_{(1,80)}$=141.97; P<0.001; η^2_P=0.639) and relative values ($F_{(1,80)}$=141.97; P<0.001; η^2_P=0.639).

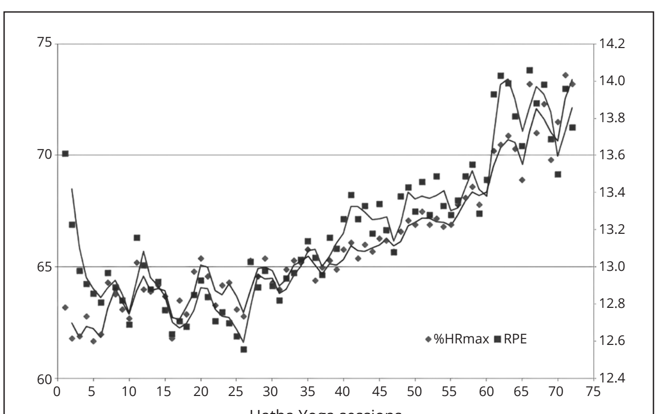

Figure 2.—The average intensity trend of HY practice expressed as $\%HR_{max}$ and RPE points in the subsequent training sessions of the 6-month intervention.

Cardiorespiratory fitness

Participation in the HY-based training program resulted in significant improvements in all of the measured absolute and relative cardiorespiratory fitness variables (P<0.001) (Table VI). The largest interaction effects were observed in relative values of VO_{2max} (mL/kg/min) where the HYG improved significantly from pre- to post-training (6.1%; P<0.001) while the CG trended towards a decrease, though not significantly (P>0.05); the interaction effect was ($F_{(1,80)}$=95.39; P<0.001; η^2_P=0.544). Those in the HYG demonstrated an increase in relative $PWC_{85\%HRmax}$, which is a sensitive indicator of cardiorespiratory adaptation to physical effort. These pre- to post-training improvements averaged 11.2%, with a large interaction effect ($F_{(1,80)}$=92.11; P<0.001; η^2_P=0.535).

Exercise intensity outcomes

The mean value of HR_{max} for the HYG was 186.5±2.7 bpm (183 to 190 bpm). The calculated upper and lower HR limits for training intensity for the HYG were 139.9±2.0 bpm (137 to 143 bpm) and 111.9±1.6 bpm (110 to 114 bpm), respectively. The average intensity ($\%HR_{max}$) of the 40-minute HY specific portion of the training session across the HYG participants progressively increased from the lowest value recorded in the 5th week (61.7%) to the highest value recorded in the 71st week (73.9%) (Figure

2). In contrast to the %HR_{max} increase, the RPE scores decreased from 5th (12.9±3.2) to 25th week (12.6±2.8) or 7.4%.

Discussion

This study focused on the potential training-related effects across a spectrum of H-RF variables of a progressive 6-month exercise intensity focused HY-based training program, specifically, on a group of non-HY trained, asymptomatic, sedentary, middle-aged women.

As anticipated, the results of this study demonstrated significant improvements in all of the measured components of H-RF including body composition, muscular strength, flexibility, and static-dynamic balance. This study also demonstrated that when exercise intensity is emphasized significant gains can be obtained when participating in a HY-based program 3 times/week.

Body composition

Systematic reviews and meta-analyses have examined the short- and long-term effects of HY-based programs on anthropometric measures and body composition in both healthy and symptomatic populations.[26, 27] These reviews supported the belief that HY-based programs may result in improvements in multiple body composition markers including: BMI,[28, 29] %BF,[6, 30] fat mass,[30, 31] and fat-free mass.[6, 28] In the present study, significant improvements in all of the BM and composition variables were observed in the HYG. The decreases in BM (1.6%), BMI (1.6%), %BF (4.8%) along an increase in FFM (0.5%) are consistent with the results of several other yoga-based interventional studies.[32, 33]

Static-dynamic balance

The effectiveness of maintaining balance requires the proper functioning of the vestibular, visual, somatosensory, muscular, and central nervous systems.[34] With this in mind, this HY-based intervention consisted of poses designed to improve not only muscular strength, cardiovascular fitness, and flexibility but also the body's neuromuscular responses. By challenging one's ability to maintain their center of pressure, these poses appeared to elicit significant changes in the static-dynamic balance of the participants.

Crucial for development of the improved BI observed in this study was the systematically repeated balance poses with isometric co-contractions the targeted of individual body parts involved in the movement.[14] This style of exercise can enhance muscular strength and proprioceptive adaptations. The findings of this study support those of many studies including Ahmadi *et al.*[35] Their study, 60-70 minute HY-based classes performed 3 times/week over an 8-week period, revealed significantly ($P<0.05$) improved balance scores (from 46.19 to 53.81 points or 12.8%) measured with the Berg Balance Scale (BBS) in 11 middle-aged women with multiple sclerosis. However, Schmid *et al.*,[36] after 12-week yoga intervention, reported in 15 healthy older adults no change in the global BBS score, but they reported a significant 4% change in the static balance subscale. Whereas Zettergen *et al.*,[37] in older participants, showed a significant improvement in the global score for BBS but not for its subscales. These varied outcomes demonstrate that while improved static balance may be amenable to a yoga intervention, changes in dynamic balance may not. Indeed, in the present study, a significant improvement in the BI of the HYG was demonstrated. However, there is at least one limitation of our approach concerning the use of BI. This index expresses the combined static and dynamic dimensions of body balance. Thus, when BI score is improved, it is unclear which aspects of balance (static or dynamic or both) have been altered. Therefore, in the future, the assessment of body balance should be *via* a battery of static and dynamic functional balance tests versus the BI alone.

Muscular strength

It is generally understood that yoga type exercises are primarily associated with controlled isometric or co-contraction muscular contractions, with both eccentric and concentric muscle actions being elicited when moving between postures. These postures and movements involve multiple muscle groups of the trunk, upper and lower body.[38] The HY-based training program in this study focused on overall strength building and large-muscle movements, therefore the significant improvements in strength gains were anticipated. It is understood that isometric HGR correlates well with other muscle function tests and is a strong predictor of total muscle strength in young healthy adults.[39] Overall the vast majority of studies indicate profound HY-based program related HGR strength improvements.[12, 40] The HY-trained participants in this study reinforced this finding by demonstrated significant improvements in both absolute (8.5%) and relative (10.1%) HGR.

Upper and lower extremity MVIT strength, expressed by percent change, was also an important variable in this study. In general, our findings, were consistent with the consensus in the literature.[9, 16, 41] Tran *et al.*[9] reported that even a short-term yoga type exercise program influenced multiple health-related aspects of physical fitness including muscle function. Their study showed that two HY-based sessions per week for an 8-week period significantly increased muscular strength in young (18-27 years), healthy, predominantly female participants. These researchers noted a higher relative increase in lower than in upper extremities (28% and 19%, respectively).

It appears that the evidence supports that even short-term HY-based yoga practice will positively impact overall muscular strength. In our study, the muscular strength of both the upper and lower extremities increased significantly.

Cardiorespiratory fitness

Some cross-sectional and interventional studies have reported that the regular practice of HY is not associated with improvements in cardiorespiratory fitness.[4, 10, 11] These authors suggest that HY may have little cardiorespiratory benefit in young and middle-aged adults. Clay *et al.*[10] claim that the intensity of HY may be too low to provide an adequate training stimulus for improving cardiorespiratory fitness. This view is supported by Boehde *et al.*,[11] who stated that metabolic intensity of HY does not appear to be sufficient to improve cardiorespiratory fitness measures. In fact, HY, by its nature, is performed at low-to-moderate intensities.[42] Blank[43] reported that the mean cumulative metabolic expenditure for a 90-min HY-based practice was 149.4±50.7 kcal; ranging from 80.3 to 277.5. Hagins *et al.*[3] demonstrated in 20 intermediate-to-advanced level yoga practitioners (18 female and two male, mean age 31.4±8.3 years) that the metabolic costs of yoga averaged across a full 60-minute session represented low levels of physical activity; <3.0 MET.[42] Because the reported metabolic expenditure of standard HY is relatively low, a goal of this study was to increase the exercise intensity and to achieve and maintain mean HR values within the target HR exercise zone (60-75% HR_{max}). This procedure resulted in almost five times greater pre- to post-training metabolic cost (expressed by MET) of this HY-based intervention in the HYG (from 307.7±133.9 to 1526.6±169.7) than has been previously described in the literature. The exercise intensity in this study was progressively raised from 61.7% HR_{max} in the 5th week to 73.9% HR_{max} in the 71st week of the experimental period. General recommendations for developing and maintaining cardiorespiratory fitness from the ACSM Position Stand[42] are that the exercise intensity range should be 55-90% of the HR_{max}, performed 3 to 5 days per week, and should last 20-60 minutes (continuous or intermittent).[42] The HY-based training program used in this study met all of these recommendations. As a result, significant increases in both absolute and relative measures of estimated VO_{2max} and $PWC_{85\%HRmax}$ were found in this study. These findings clearly demonstrate the positive impact of this exercise intensity focused HY-based training program. We believe that training intensity (combined with duration and frequency) was one of the main factors that influenced the observed changes in cardiorespiratory fitness in the HYG participants. A limitation of this study is we did not test the effectiveness of this HY-based training program with standardized cardiorespiratory training program (*e.g.*, an intensity matched walking program) but only to the passive control group. A three-group model with HYG, alternative training program (matched for frequency, volume but with different intensity) and passive control group would provide the optimal research scheme to provide fully objective information about the effectiveness of the studied HY-based training program.

Flexibility

The practice of HY combines the actions of both static and dynamic stretching practices in a proper and safe method to improve overall flexibility[12, 44] While flexibility is closely connected with the structure and function of the musculoskeletal system, it determines the range of motion (ROM) achievable without injury in a joint or a group of joints.[42] In the current study, the MSAR test which reflects lower back and hamstring flexibility,[2] demonstrated significant increases in the HYG by an average of 11.29% after the 6-month HY-based training program. According to the MSAR norms,[23] the HYG participants averaged in the 70th percentile initially and by the end of the program, met the criterion assigned to the 80th percentile or above for women 36-49 years of age. The outcomes of our study, adds to the abundance of evidence supporting the effectiveness of HY programs in improving flexibility in middle-aged women.[6, 12, 44]

Our data provide a solid foundation for determination of exercise dose-response model and for future work targeting samples with known physical fitness concerns. Furthermore, the high compliance and adherence to the moderate-intensity HY-based training program observed in the present study indicate that this type of training was well tolerated, feasible, and safe for sedentary, asymptomatic middle-aged women with limited to no HY experience. However, despite our limited understanding of these dose-response relationships between the training load and training-induced changes in HR-F, the primary expected benefits of such exercises are to maximize cardiorespiratory measures, as these are the basis for optimal health status.

Conclusions

The current findings suggest that middle-aged women of normal health can significantly improve their H-RF components by participating in a 6-month HY-based training program (containing 54 poses). It is essential that more exercise-based activities with evidence-based outcome evaluations be incorporated in yoga studios for people at various age and performance level to enhance their health and document the progression of any health-related fitness improvements. Due to significant improvements in body composition of participants in the HYG in this study, our program may be used as a straightforward-to-learn and effective non-pharmacological method for healthy reduction of fat tissue content. Consequently, HY may be prescribed as part of a wider preventive and health program for overweight and obese persons. Simultaneously, the observed improvements in the static-dynamic balance ability of HY-trained participants indicate that specifically designed HY-based training programs can potentially reduce the risk of falls; thus, it might be useful in prevention from fall-related injuries, especially in older individuals. Long-term HY programs typically impact positively muscular strength of the upper and lower extremities. However, 6-month participation in our program favors higher strength gains in the lower extremities. Additionally, the regular performance of our set of poses led to improved lower back and hamstring flexibility. Our study also confirmed earlier results showing the positive effects of yoga-type interventions on the cardiorespiratory fitness in middle-aged, unfit women. It appears that regular (3 times/week), long-term, moderately intensive version of the HY-based training program (Vinyasa Flow with designated training intensity of 60-75% HR_{max}) provides a sufficient HR exercise zone to significantly improve VO_{2max} and $PWC_{85\%HRmax}$. However, different program parameters, such as group size and training intensity could be applied to different populations. The results of this study provide new preliminary evidence regarding the effectiveness of HY-based training programs that justify additional studies to examine their effects on H-RF components in older subjects of both sexes as well as to be compared with other exercise interventions.

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Authors' contributions.—Michał T. Boraczyński carried out the laboratory testing, controlled hatha yoga sessions, and drafted the manuscript. Tomasz W. Boraczyński conceived of the study, and participated in its design and coordination and helped to draft the manuscript. Zbigniew Wójcik participated in the laboratory testing and data analysis. Jan Gajewski performed the statistical analysis. James J. Laskin participated in design of the study and helped to draft the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

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