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ORIGINAL PAPER

Effects of a complex yoga-based intervention on physical characteristics

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Abstract

Empirical studies on yoga have shown that regular practice can have a beneficial effect on risk factors of cardiovascular diseases; also, it can decrease body weight, body fat and increase muscle mass. Positive effects on balance and flexibility were also reported. This study evaluated the impact of a 3-month complex yoga-based program, including physical exercises, education, and social support, with a quasi-randomized design in a middle-aged community sample. The intervention group consisted of 46 participants while the passive control group was 29 participants. The intervention group showed a significant increase in core muscle strength and hamstring flexibility and a decrease in body fat. No significant changes were found concerning risk factors of cardiovascular diseases, body weight, muscle mass, balancing ability, and dietary habits. A 3-month yoga intervention cannot substantially impact the cardiovascular system and body weight control in middle-aged adults.

Keywords Yoga, · Intervention, · Physical characteristics · Dietary habits

Introduction

Yoga has its origin in the ancient India, and although many in the Western world see it as a purely physical activity (MacDonald 2013; Sarbacker 2014), it is in fact a much more complex mind–body approach (Iyengar 1991). The idea that regular yoga practice can have both psychological and physiological benefits has been confirmed by a number of review studies focusing on various aspects of health (Büssing et al. 2012; Csala et al. 2021a, b; Dwivedi and Tyagi 2016; Govindaraj et al. 2016; Hendriks et al. 2017; Ross and Thomas 2010).

For example, empirical evidence shows that yoga has a positive effect on certain risk factors of cardiovascular disease. Cramer and colleagues' meta-analysis (2014) of randomized controlled trials found a decreased resting heart rate (HR) and blood pressure (BP) in healthy participants and also for those who are at risk for developing cardiovascular disease. This suggests that the cardiovascular system works more efficiently after a yoga intervention. Moreover, yoga interventions may have a positive effect on resting heart rate variability (HRV) which can be explained by an increased vagal (parasympathetic) impact on the heart (Tyagi & Cohen 2016). For example, a yoga intervention (3 sessions/week for one year) proved to be effective in improving indicators of vagal impact on the heart, such as HRV-RMSSD (the square root of the mean of the squared differences between adjacent normal RR intervals) and the high-frequency band of HRV (HRV-HF) in patients with breast cancer (Odynets et al. 2019). Also, a 3-month intervention (3 sessions per week) showed similar beneficial effects in patients with rheumatoid arthritis (Ganesan et al. 2020). In addition, a systematic review showed the positive effect of yoga on BP

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among healthy people and patients with cardiovascular diseases, hypertension, and type 2 diabetes (Yang 2007).

Yoga can also have an impact on body weight. Chauhan and colleagues (2017) found lowered body mass index in healthy adults after a one-month-long (one session/day) yoga intervention. In a similar vein, a weight-reducing effect was reported by a systematic review for healthy people and also for patients with hypertension, type 2 diabetes, and cardiovascular diseases (Yang 2007). Beyond body weight, some studies investigated the effects of yoga on body composition. For example, regular yoga practice (three times a week for 3 months) led to a decrease in body weight and body fat, and an increase in muscle mass in adolescents (Na Nongkhai et al. 2021). On the other hand, the study of Bera and Rajapurkar (1993) did not find any change in body fat after a one-year (3 days/week) long yoga intervention in the same age group. Reduction in body fat had been also observed among adult males (Manna 2018); however, Tran and colleagues (2001) did not find any change in body composition among young adults after an 8-week-long (4 times/week) yoga intervention.

Concerning balancing ability, the systematic review of Jeter and colleagues (2014) reported a positive effect. However, the number of high-quality studies was low, and the length of these interventions ranged from one month to three years. The positive effect has been confirmed by the results of more recent studies (Csala et al. 2021a, b; Jin et al. 2016; Polsgrove et al. 2016). Yoga also has a positive impact on flexibility. This has been shown in healthy adults practicing yoga asanas for six weeks (90 min per day) (Bal and Kaur 2009). Additionally, a 6-week-long (one 1.5-h long session per week) Iyengar yoga program has increased the pliability of middle-aged female participants (Amin and Goddman 2014). Also, a positive effect was reported for old-aged women as a result of a 14 week (Gonçalves et al. 2011), and for female university students after a 10-week long (1.5 h sessions per week) hatha yoga program (Csala et al. 2021a, b).

Yoga appears to be able to increase muscle strength too. Concerning the strength of hand grip, a positive effect was shown even after a few weeks (Dash and Telles 2001). This is confirmed by the study of Balakrishnan and colleagues (2008) after a six-week (1.5 sessions six times per week) yoga intervention. Core muscles' strength and flexibility can also be improved by regular yoga practice (Modak 2017; Csala et al. 2021a, b; Murugan and Durai 2019; Radhakrishnan 2019).

From the perspective of yoga, healthy eating is an important condition for the harmony of physical and mental functions (Junnarkar 2022). Three major categories of food are distinguished: the so-called sattvic, rajasic and tamasic types (Ramos-Jiménez et al. 2015). Sattvic foods are fresh, tasty, juicy, and rich in micronutrients (e.g.,, fruits and vegetables) (Ghosh 2021). The rajasic category includes bitter, salty, spicy and dry foods, as well as foods containing refined sugar or fried in oil (Agte and Chiplonkar 2007). Finally, tamasic foods are meat, overheated or undercooked food, fried in a lot of oil or in the oven, excessively and incorrectly used hot spices, and drinks high in sugar or alcohol. From a scientific point of view, increased consumption of foods belonging to the first category is considered healthy, whereas the latter two categories are associated with negative health consequences in the long run.

The present study aimed to investigate the impact of a complex 3-month yoga-based intervention on participants' physical fitness and certain aspects of eating habits. Based on the aforementioned empirical findings, the following hypotheses were tested: (i) the complex yoga program will have a positive cardiovascular effect, such as an increased HRV, decreased HR and BP. In a similar vein, (ii) positive changes in body composition are expected. It was also assumed that yoga leads to (iii) better balancing ability, (iv) improved flexibility, and (v) increased muscle strength. Concerning dietary habits, we assumed that (vi) the program can reduce the intake of fast food and convenience products, and meat and (vii) we expected an increase in the consumption of vegetables and fruits, or vegan and alternative products.

Materials and methods

Subjects

Participants were recruited by the AHIMSZA Yoga Center through social media (Facebook) and public lectures in Veszprém, Hungary. Inclusion criteria were (1) lack of cardiovascular, locomotor, or other disease that would have made regular yoga practice risky (participants were examined by a sports medicine physician with extensive experience with yoga), and (2) no previous experience with yoga. A total of 84 participants were recruited; as participation would have been risky for 3 participants due to various medical conditions, 81 participants were randomized. As 3 other participants were found during the intervention to be unable to complete the intervention and additional 3 participants did not attend post-test assessments (for reasons of the dropouts see Fig. 1), the final sample size was 75. The intervention group consisted of 46 participants, whose mean age was 47.4 (*SD* = 9.06) years, ranging between 30 and 63; 40 were female. The control group consisted of 29 participants, mean age was 48.2 (*SD* = 8.91) years, ranging between 32 and 64; 24 were female (For the total number of participants at each timepoint see Fig. 1). The study was approved by the Research Ethics Committee of the Faculty of Education and Psychology at ELTE Eötvös Loránd University under the registration number 2021/44 on 21 April 2021.

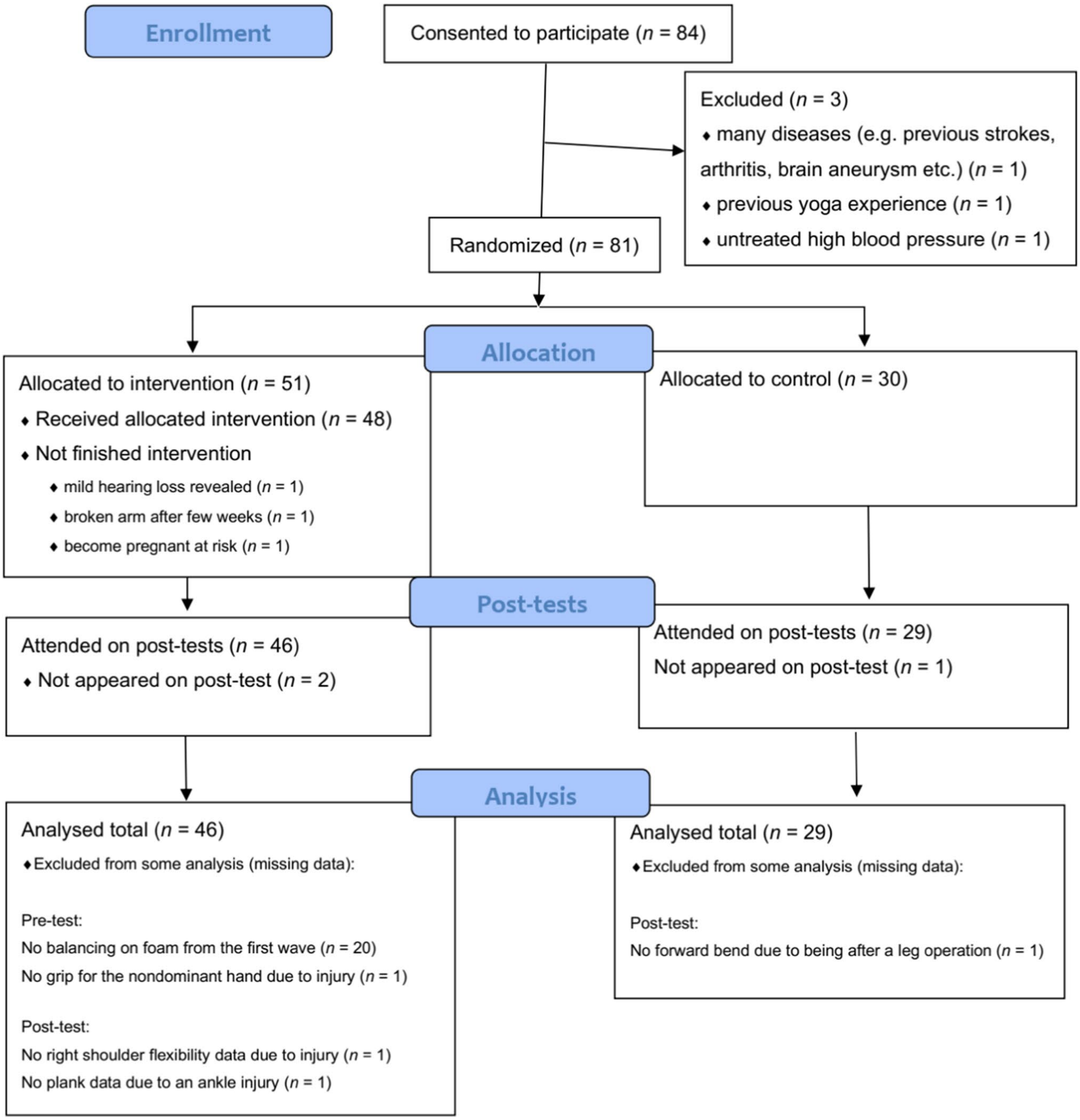

Fig. 1 Number of participants at each timepoint

Procedure

In this study, a quasi-randomized design was utilized to preserve the intended proportion of teachers and residents (1:3) in both groups. Eligible participants were assigned to the passive control (whose members received a 5000 HUF voucher for their participation) or to the experimental (intervention) group. Intervention (see below) was delivered and data were collected in three waves for three independent experimental groups and corresponding control participants; in the first wave, there was no control group due to the requirements of the grant the project was based on (see below). Pre-intervention and post-intervention measurements were carried out one week before and after the interventions, respectively.

Intervention

The complex yoga program used in this study was the same as described in detail in Koncz and colleagues' study (Koncz et al 2023), this can be found in the Online Appendix A. The program was supported by the EU (grant number: TOP-7.1.1-16-H-073-5.2) and designed and conducted by the Hungarian Yoga Teachers Association (HYTA) and the AHIMSZA Yoga Center, Veszprém, Hungary for teachers and local citizen of Veszprém. The aims of the project were (1) the dissemination of knowledge on healthy lifestyle among the citizens of Veszprém, a Hungarian city; (2) the promotion of lifestyle changes; and (3) creation of supportive small communities, especially with the inclusion of primary and secondary school teachers. The program was 12 week-long and consisted of 5 scientific lectures on health and healthy lifestyle, 12 (1.5 h/session) practical yoga classes, and 10 club meetings to facilitate social support. Participants were encouraged to practice yoga regularly at home and keep this habit. For home practice students were get written exercises and videos. Scientific lectures were held online; they started after the second practical yoga session and were repeated every week (ending at around half time of the program). Lectures covered the following topics: healthy sleeping habits for hormonal balance (1), physiological and psychological effects of nutrition, developing a healthy diet (2), the importance of stress management and relaxation (3), the relevance of breathing in stress management, physiology of breathing (4), the role of asana practice on developing healthy body awareness, effects of asanas on physiology (i.e., cardiovascular, neural and hormonal functioning) (5). In person yoga sessions were held at the AHIMSZA Yoga Center and encompassed physical movements, mindful body awareness and synchronized breathing techniques such as breath-focused exercises and some kind of relaxation. The proper execution of the exercises was checked by the yoga teachers however, sessions were not controlled by the experimenter. Club meetings were held every second week and aimed to establish a regular home practice and offered time and place for participants to share their experiences and the teachers and to discuss questions regarding their home practice or any other ones. Three out of the ten club meetings took place after the post-intervention measurement in order to assist the participants in maintaining their home practice and healthy lifestyle habits even after the end of the program.

Measurements

Home practice of the participants was measured by self-report as they reported their practice duration in a Facebook chat every week to encourage others to practice.

Resting heart rate and heart rate variability ECG was recorded with a sampling rate of 1024 Hz using the Firstbeat Teambelt system of FirstBeat SPORTS Team Pack (Firstbeat Technologies Ltd., Jyväskylä, Finland). Data were collected for 5 min; QRS complexes were detected by the Firstbeat Sports software (v4.7.2.1). Calculation of cardiac measures HR and RMSSD) was conducted with the KubiosHRV software (v2.2).

Systolic and diastolic blood pressure measurement was performed on the left arm in a lying position using an OMRON M2 blood pressure monitor (OMRON Healthcare Group, Kyoto, Japan). The average of two consecutive measurement values was used.

Body composition was measured with an InBody 270 device (Biospace, California, USA). The device measures body weight and is able to estimate body fat mass, skeletal muscle mass (SMM), and basal metabolic rate based on the results of bioelectrical impedance analysis (Larsen et al. 2021).

Hand grip strength was assessed using a Camry EH101 electric hand dynamometer (Zhongshan Camry Electronic Co. Ltd., Guangdong Province, China); hand dominance was registered. The highest value of three consecutive trials was registered for both the dominant and non-dominant hand.

Balancing ability was assessed using BTrackS™ Balance Plate (Balance Tracking Systems, Inc., San Diego, CA, USA) (O'Connor et al. 2016). Two conditions were used in a randomized order. In all three intervention waves, one condition was standing on the device with closed eyes which is intended to measure participants' balancing ability dominantly relying on proprioceptive and vestibular information (it is called the "proprioception" condition). The other condition was standing on a soft foam placed on the device with closed eyes, assessing balancing ability relying on the vestibular system ("vestibular" condition). This condition was administered only in the second and third waves due to a technical error. For each condition, three 20-s-long measurements were carried out and they were averaged. We used the Total COP Path Length index, provided by the BtrackS software, as the indicator of passive balancing ability) (Goble et al. 2018).

Flexibility of the lower back and hamstring muscles was measured by the modified sit and reach test (Hoeger and Hopkins 1992). Trunk flexibility was assessed with the side bend test of Suni and colleagues (1998). Flexibility is calculated by averaging the results of the two measurements for both sides.

Functional mobility of the shoulder and neck was measured by the following: The participant stood with his/her back to the wall while feet are 1.5 foot lengths from the wall. The buttocks, back and shoulders touched the wall. Subject raised their arms above their head at shoulder width and tried to touch the wall with the backs of his hands while keeping the elbows and wrists straight and extended. The researcher demonstrated the correct execution of the test before the assessement. There was one test measurement and no opportunity for practice.

Core muscle strength was measured by the forearm Plank test (Strand et al. 2014). The time for holding the position was recorded in seconds.

Dietary habits were measured by an adapted version of the Food Frequency Questionnaire (FFQ) (Sampson 1985). We assessed the consumption of four major groups of food in the previous 4 weeks. (Sampson 1985). The group of Meats included pork, beef, poultry, fish, liver pasty, ham, salami, and sausage. The Vegetables and Fruits group included fresh and pickled vegetables and fruits, cooked vegetables and fruits. The Fast-food group included a selection (pizza, hamburger, ice cream), as well as convenience products (semi-prepared pasta, sauces) and snacks (chips, popcorn). The Vegan and alternative group included meat substitutes (seitan), ghee, soya products, grains and alternative grains (e.g.,, chia), and honey.

Statistical analysis

Analyzes were carried out using JASP v0.16.2.0 software (JASP Team 2022). Data outside the range of the 1.5*interquartile range from the 25 or 75 percentile were considered outliers and removed. First, independent samples t-tests were used to compare the intervention and control group's baseline values. Hypotheses were tested with 2 × 2 mixed Analyzes of variance (ANOVA) with time as a within-subjects factor and condition as a between-subjects factor.

Results

Home practice

Participants in the intervention group practized on average 4.22 times at home a week ($SD = 1.52$), ranging between 0.92 and 7.25. The frequency of home practice was not associated with changes in any of the outcome indicators (see Online Appendix B).

Baseline differences

There were no significant baseline differences between the control and intervention group concerning heart rate, systolic and diastolic BP, body weight, body fat mass, SMM, hand grip of the dominant and the non-dominant hand, balancing ability relying on proprioceptive and vestibular information (closed eyes), and only on vestibular information (closed eyes and foam). Also, no significant difference between groups was found for flexibility of the right and left shoulder, the side bend test to the right and left side, and the sit and reach test. Significant differences were found for the plank test and for RMSSD. The control group was characterized by a higher level than the intervention group in both cases (for details, see Table 1). Regarding dietary habits, no significant difference was detected between the control and intervention groups concerning meats, vegetables and fruits, fast-food, and vegan and alternative food products. Overall, these findings indicate that randomization was successful. (see Table 1).

Effects of the intervention electrocardiography

In case of resting HR, one outlier was excluded and no significant main effect of time, condition, nor a significant time

Table 1 Baseline differences between the intervention and control group

Measurement	Values			
	t	*df*	*p*	*d*
Electrocardiography				
Heart rate (bpm)	0.801	68	.421	0.202
RMSSD (ms)	−2.821	64	.006*	−0.716
Blood pressure				
Systolic (Hgmm)	0.036	72	.972	0.009
Diastolic (Hgmm)	0.468	73	.641	0.112
Body weight and composition				
Body weight (kg)	1.498	75	.138	0.352
Body fat mass (kg)	1.360	75	.178	0.320
SMM (kg)	0.837	74	.405	0.198
Hand grip				
Dominant hand (kg)	−0.246	67	.806	−0.061
Non-dominant hand (kg)	−1.399	70	.166	−0.336
Balancing				
Closed eyes (t.p.s.)	1.007	76	.317	0.234
Closed eyes and foam (t.p.s)	0.536	71	.594	0.129
Flexibility				
Shoulder right	−1.631	75	.107	−0.384
Shoulder left	−0.438	76	.648	−0.107
Side bend right (cm)	1.144	75	.256	0.267
Side bend left (cm)	0.580	74	.564	0.136
Sit and reach (cm)	−0.280	75	.780	−0.066
Core muscle strength				
Plank (sec)	− 2.078	72	.041*	−0.495
	W		*p*	
Dietary habits				
Meats	613.000		.733	
Vegetables and fruits	558.000		.339	
Fast−food	495.000		.096	
Vegan and alternative	643.000		.996	

*$p < .05$

x condition interaction were found. For RMSSD, two outliers were excluded and again, no significant main effect of time, condition and no significant time x condition interaction emerged (for test statistics see Table 2, for descriptive statistics see Table 3 and Fig. 2).

Blood pressure

For systolic BP, three outliers were excluded and a significant main effect of time was detected, which is a significant decrease of systolic blood pressure in the whole sample. Additionally no significant main effect of condition, nor a significant time x condition interaction were found. Regarding diastolic BP, three outliers were excluded and time has a significant main effect, but not the condition and no significant time x condition interaction were found (for test statistics see Table 2, for descriptive statistics see Table 3 and Fig. 2).

Body composition

For body weight, two outliers were excluded. A significant main effect of time was found, i.e., the total weight of the participants decreased in the whole sample. There was no significant main effect of condition and no significant time x condition interaction were detected (see Fig. 2). As for body fat, two outliers were excluded. Time had a significant main effect, body fat decreased in the whole sample. There was no significant condition main effect, but we found a significant time x condition interaction; the intervention group had a higher body fat loss than the control group (see Fig. 2). Finally, in the case of skeletal muscle mass (SMM), three outliers were excluded. No significant main effect of time,

Table 2 Effects of the intervention on physical characteristics and dietary habits

Scale	Time				Condition				Time × Condition			
	F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Electrocardiography												
Heart rate (bpm)	0.508	1,72	.478	.007	0.786	1,72	.378	.011	0.007	1,72	.933	9.781e−5
RMSSD (ms)	0.661	1,71	.419	.009	0.315	1,71	.577	.004	0.007	1,71	.935	9.562e−5
Blood pressure												
Systolic (Hgmm)	11.701	1,70	.001*	.143	0.207	1,70	.651	.003	0.002	1,70	.966	2.678e−5
Diastolic (Hgmm)	43.910	1,70	< .001*	.385	0.115	1,70	.736	.002	0.090	1,70	.765	.001
Body weight and composition												
Body weight (kg)	5.441	1,71	.023*	.071	0.967	1,71	.329	.013	0.205	1,71	.652	.003
Body fat mass (kg)	23.098	1,71	< .001*	.245	0.437	1,71	.511	.006	8.578	1,71	.005*	108
SMM (kg)	0.014	1,70	.905	2.051e−4	1.956	1,70	.166	.027	2.343	1,70	.130	.032
Hand grip												
Dominant hand (kg)	4.569	1,64	.036*	.067	0.196	1,64	.659	.003	0.492	1,64	.486	.008
Non-dominant hand (kg)	5.978	1,66	.017*	0.083	0.692	1,66	.409	.010	0.613	1,66	.437	.009
Balancing												
Closed eyes (t.p.s.)	0.003	1,71	.959	3.364e−5	0.342	1,71	.561	.005	0.092	1,71	.763	.001
Closed eyes and foam (t.p.s)	9.729	1,51	.003*	.160	3.757e−4	1,51	.985	7.367e−6	0.190	1,51	.665	.004
Flexibility												
Shoulder right	4.597	1,67	.036*	.064	6.820	1,67	.011*	.092	0.057	1,67	.812	8.463e−4
Shoulder left	3.018	1,69	.032*	.072	4.932	1,69	.030	.067	1.763	1,69	.189	.025
Side bend right (cm)	8.121	1,72	.006*	.101	3.428	1,72	.068	.045	2.249	1,72	.138	.030
Side bend left (cm)	11.806	1,70	< .001*	.144	1.109	1,70	.296	.016	0.911	1,70	.343	.013
Sit and reach (cm)	15.670	1,69	< .001*	.185	1.055	1,69	.308	.015	9.604	1,69	.003*	.122
Core muscle strength												
Plank (sec)	20.287	1,72	< .001*	.022	0.152	1,72	.698	.002	11.590	1,72	.001*	139
Dietary habits												
Meats	1.129	1,72	.291	.005	0.233	1,72	.631	.003	0.860	1,72	.357	.012
Vegetables and fruits	0.437	1,72	.511	.006	0.016	1,72	.900	2.205e−4	0.011	1,72	.918	1.475e−4
Fast-food	30.548	1,72	< .001*	.298	2.722	1,72	.103	.036	0.025	1,72	.875	3.486e−4
Vegan and alternative food	1.955e−5	1,72	.996	2.716e−7	0.057	1,72	.812	7.908e−4	0.112	1,72	.739	.002

*$p < .05$, *SMM* Skeletal Muscle Mass

Table 3 Descriptive statistics of the assessed variables before and after the intervention

Measurement	Pre-test				Post-test			
	Intervention		Control		Intervention		Control	
	Mean (*SD*)	*n*	Mean (*SD*)	*n*	Mean (*SD*)	*n*	Mean (*SD*)	*n*
Electrocardiography								
Heart rate (bpm)	69.89 (11.4)	46	67.94 (9.37)	28	70.895 (9.50)	46	69.22 (13.08)	28
RMSSD (ms)	80.40 (191.66)	46	65.55 (70.47)	27	60.80 (116.72)	46	49.56 (51.06)	27
Blood pressure								
Systolic (Hgmm)	125.21 (14.22)	45	126.69 (12.92)	27	121.60 (14.15)	45	122.98 (12.27)	27
Diastolic (Hgmm)	78.17 (7.67)	45	77.37 (8.78)	27	73.89 (7.40)	45	73.46 (7.78)	27
Body weight and composition								
Body weight (kg)	74.22 (13.32)	45	70.94 (13.13)	28	73.20 (13.18)	45	70.25 (13.42)	28
Body fat mass (kg)	24.26 (9.36)	45	22.34 (7.76)	28	22.82 (9.02)	45	21.99 (8.04)	28
SMM (kg)	27.56 (4.36)	45	26.35 (4.50)	27	27.79 (4.26)	45	26.08 (4.30)	27
Hand grip								
Dominant hand (kg)	32.02 (5.56)	41	32.35 (5.58)	25	30.91 (5.99)	41	31.78 (4.81)	25
Non-dominant hand (kg)	29.94 (5.70)	41	31.52 (7.09)	27	29.28 (6.26)	41	30.25 (6.85)	25
Balancing								
Closed eyes (t.p.s.)	21.79 (5.63)	44	20.89 (5.02)	29	21.62 (6.54)	44	21.01 (5.34)	29
Closed eyes and foam (t.p.s)	58.38 (14.98)	25	58.95 (10.27)	28	54.48 (14.44)	25	53.79 (10.40)	28
Flexibility								
Shoulder right	4.24 (1.15)	45	4.67 (076)	24	4.51 (0.87)	45	5.00 (0.00)	24
Shoulder left	4.26 (1.14)	46	4.52 (0.87)	25	4.39 (1.02)	46	5.00 (0.00)	25
Side bend right (cm)	18.99 (3.53)	45	18.19 (3.69)	29	20.66 (3.16)	45	18.71 (3.79)	29
Side bend left (cm)	18.32 (3.16)	44	17.91 (3.39)	28	19.90 (3.14)	44	18.80 (3.68)	28
Sit and reach (cm)	32.43 (6.81)	44	32.42 (8.90)	27	36.46 (6.72)	44	32.91 (8.02)	27
Core muscle strength								
Plank (sec)	61.76 (41.40)	45	76.24 (50.06)	29	85.56 (50.32)	45	79.55 (48.57)	29
Dietary habits								
Meats	29.67 (8.41)	46	29.29 (13.52)	28	26.55 (10.95)	46	29.07 (14.10)	28
Vegetables and fruits	21.63 (5.81)	46	21.64 (7.99)	28	20.65 (7.21)	46	20.93 (8.23)	28
Fast-food	9.33 (2.90)	46	10.57 (5.03)	28	6.70 (3.05)	46	7.79 (3.75)	28
Vegan and alternative	10.17 (3.43)	46	10.14 (5.23)	28	10.35 (3.77)	46	9.96 (5.00)	28

RMSSD Root Mean Square of Successive Differences between normal heartbeats, *SMM* Skeletal Muscle Mass, *t.p.s.* total postural sway in centimeters

condition, and no significant time x condition interaction were found (for test statistics see Table 2, for descriptive statistics see Table 3 and Fig. 2).

Hand grip

For the dominant hand, nine outliers were excluded, and a significant main effect of time was found; the dominant hand's grip decreased in the whole sample (see Fig. 2). Furthermore, no main effect of condition, and no significant time x condition interaction have been found. Regarding the non-dominant hand's grip, one participant was excluded due to hand injury, and there were six outliers. Again, a significant main effect of time, indicating an overall decrease of grip strength, but no condition main effect, and no time x condition interaction have been observed (for test statistics see Table 2, for descriptive statistics see Table 3 and Fig. 2).

Balancing

For the proprioceptive and vestibular condition, one outlier was excluded and results showed no significant time, and condition main effect, and no significant time x condition interaction. In the case when participants could only rely on the information provided by the vestibular system, 20 participants were not included due to a technical error and two outliers were excluded. Time had a significant main effect, i.e., a decrease in total postural sway in the whole sample (see Fig. 2), but no condition main effect, and no significant

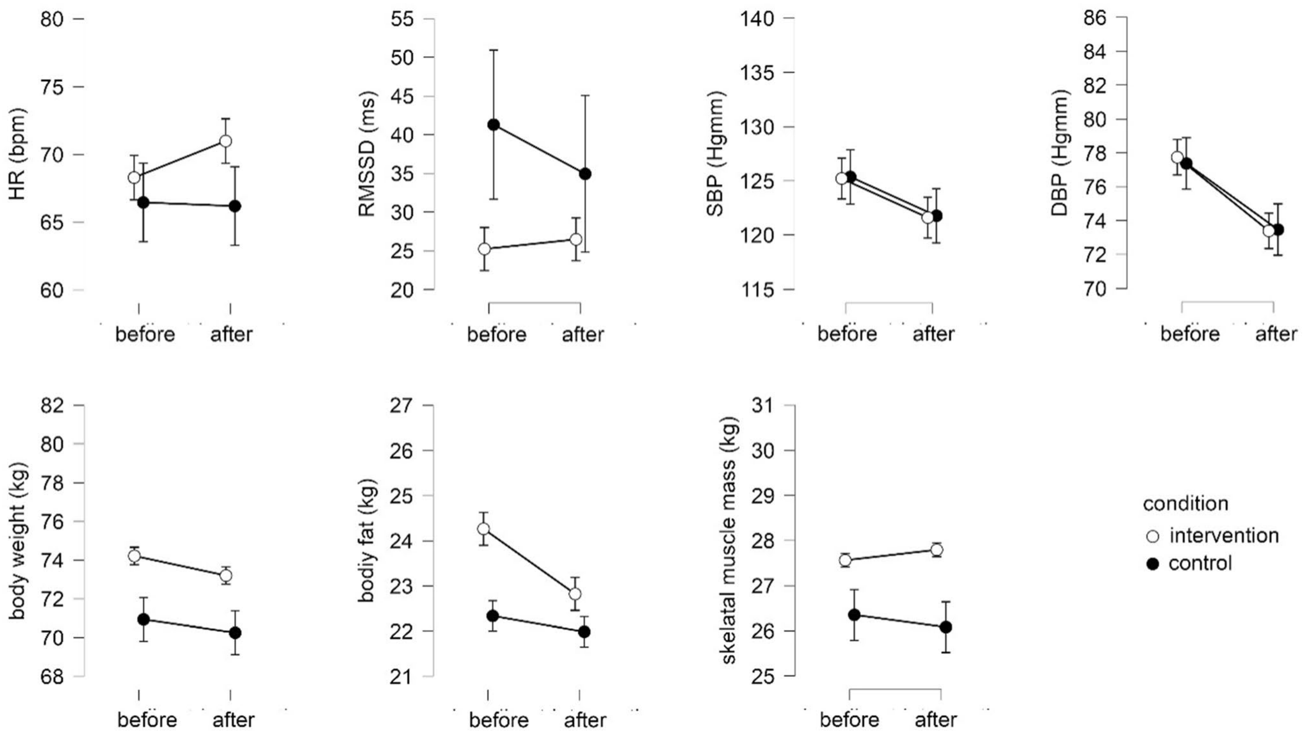

Fig. 2 Descriptive plots (means and 95% confidence intervals) of the cardiovascular and anthropometric variables. *HR* Heart Rate, *RMSSD* Root Mean Square of Successive Differences between normal heartbeats, *SBP* Systolic Blood Pressure, *DBP* Diastolic Blood Pressure

time x condition interaction were found (for test statistics see Table 2, for descriptive statistics see Table 3 and Fig. 3).

Flexibility

In case of the right shoulder's flexibility one participant was excluded because of a shoulder injury and additional five outliers were excluded. A significant main effect of time was found, i.e., an increase of the shoulder flexibility in the whole sample (see Fig. 2). Additionally, a significant main effect of condition was emerged, while no significant time x condition interaction was detected. Similar results were found for the left shoulder, after excluding four outliers. A significant main effect of time and condition, but no significant interaction were detected (for test statistics see Table 2, for descriptive statistics see Table 3 and Fig. 3).

In case of the side bend test to the right side, one outlier was excluded and a significant main effect was found in case of time, i.e., an increase of the flexibility in the whole sample (see Fig. 2). No significant main effect of condition, and no significant time x condition interaction were found. Side bend test to the left side showed similar results after excluding three outliers, i.e., a significant main effect of time, but no significant main effect of condition and no significant time x condition interaction were detected (for test statistics see Table 2, for descriptive statistics see Table 3 and Fig. 3).

Regarding the sit and reach test, one participant was excluded due to being after a leg operation and additional three outliers were excluded. A main effect of time has emerged, so the flexibility of the participants increased in the whole sample (see Fig. 2). No significant main effect of condition, but a significant time x condition interaction was found that means the flexibility of the intervention group increased to a greater extent (for test statistics see Table 2, for descriptive statistics see Table 3 and Fig. 3).

Core muscle strength (plank test)

In case of the plank test, one participant was excluded due to an ankle injury. Results showed a significant main effect of time, indicating an overall increase of time to maintain the plank position in the entire sample (see Fig. 2), but not significant main effect of condition was detected. The time x condition interaction was also significant, the intervention group improved its performance more than the control group (for test statistics see Table 2, for descriptive statistics see Table 3 and Fig. 3).

Dietary habits

This questionnaire was not completed by one control participant on the post-test. In case of meat consumption, results

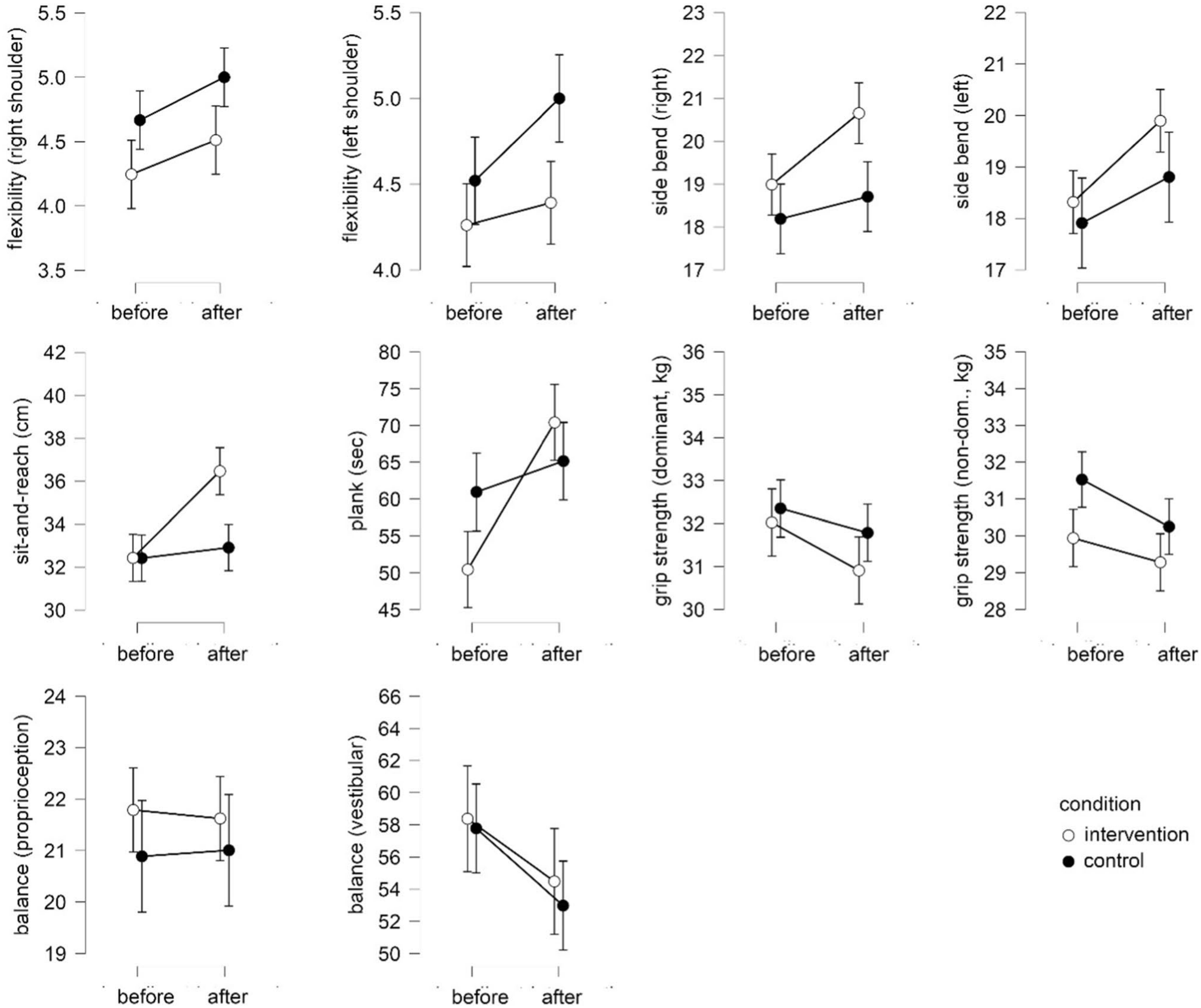

Fig. 3 Descriptive plots (means and 95% confidence intervals) of the muscle strength, flexibility and balance-related variables

showed no significant main effect of time or condition and no significant interaction. Regarding vegetables and fruits' consumption no significant main effect of time, condition and no significant interaction were found. In case of eating fast-food, time had a significant main effect but no significant main effect of condition, and no significant time x condition interaction were found. Finally, in case of vegan and alternative foods no significant main effect of time, condition and no significant interaction were found (for test statistics see Table 2, for descriptive statistics see Table 3 and Fig. 4).

Discussion

The present study reports the effects of a complex yoga-based intervention on physical characteristics and dietary habits in a healthy adult sample of school teachers and civil workers. The intervention consisted of practical yoga classes, scientific lectures, club meetings, and home practice.

Risk factors of cardiovascular diseases had not changed during the intervention. Concerning HR and BP, we

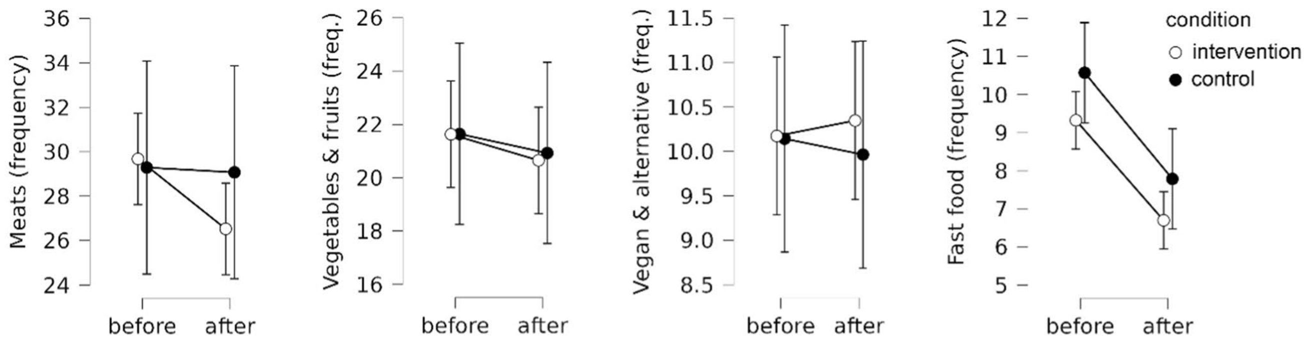

Fig. 4 Descriptive plots (means and 95% confidence intervals) of dietary habits

found no significant effect which contradicts the results of Cramer and colleagues' (2014) previous meta-analysis of yoga interventions and the systematic review of Yang (2007). Additionally, no significant change in HRV-RMSSD was found, which is also contradictory to previous findings (Odyents et al. 2019; Ganesan et al. 2020).

Concerning body weight, no significant change has been found in this study, which also contradicts previous results, such as the findings of Chauhan and colleagues (2017) who reported a decrease in BMI during a one-month intense yoga intervention, and the results of a systematic review of Yang (2007). Also, we could not replicate the results of a similarly long study that found a reduction in body weight and an increase in muscle mass (Na Nongkhai et al. 2021), however, similar to our study, a body fat loss was also observed. This positive effect is also in line with previous results of Manna (2018), obtained from a 3-month long yoga intervention, however these results of body fat loss are in contrast with Tran and colleagues' (2001) results who used a shorter intervention and also contradicts with Bera and Rajapurkar (1993) even though they have used a year-long yoga program.

With respect to hand grip strength, our results did not replicate the positive effects reported in previous studies of shorter interventions such as the improving effect of a six-week intervention have been found by Balakrishnan and colleagues (2008). Regarding the strength of core muscles, a review by Modak (2017) and some recent studies concluded that it can be improved by regular yoga practice (Csala et al. 2021a, b; Murugan and Durai 2019; Radhakrishnan 2019).

In summary, cardiovascular and anthropometric variables, with the exception of core muscle strength and body fat, did not improve during our intervention. This can be explained by the low physical load of practice (it is important to note that the intensity of the home practice was not assessed). In other words, the prescribed exercises' quantity and quality, as well as the overall length of the intervention might have not been sufficient to achieve the intended changes. On the other hand, participants were middle-aged adults with no previous yoga practice; therefore, a more intense program in the first several months would have been risky for them. As the core muscles are directly and intensely used in many yoga postures, their strength can be significantly improved even with once-a-week practice (Csala et al. 2021a, b; Tolnai et al. 2016). The decrease in body fat can be primarily attributed to the increased physical activity.

Balancing ability did not improve based on the present results, we could not replicate the positive effects found for either shorter interventions (Bal and Kaur 2009; Amin and Goddman 2014) or interventions of similar length (Gonçalves et al. 2011).

Additionally, the flexibility of the hamstrings and lower back of yoga participants increased, and such an increase was also shown by other studies (Bal and Kaur 2009; Amin and Goddman 2014; Csala et al. 2021a, b; Gonçalves et al. 2011). However, flexibility measured by other tests (e.g.,, shoulder or trunk flexibility) showed no improvement that could be explained by ceiling effect.

Finally, no positive changes in terms of dietary habits occurred, i.e., the intervention group was not characterized by consumption of less meat and fast food, and more vegetables, fruits, and alternative foods. If one has a look at the data, it is obvious that dietary habits of both groups were extremely heterogeneous; also, it is well-known that long-term change in eating habits is very difficult to maintain.

Limitations

Among the methodological limitations, it is important to note that randomization was not perfect because a baseline difference between the control and intervention group in RMSSD and plank test was found. Additionally, the sample size of the groups was far from equal. Dropout was 7.4% after the randomization which could be a source of risk of bias (Sterne et al. 2019). The group of the participants was heterogeneous, that could have led to higher variability of all assessed variables. Finally, even though participants were asked to practice every day, they only practized about 4 times a week.

Conclusions for future biology

To summarize, a complex yoga-based program has a significant effect on body fat, flexibility of the hamstrings and lower back and core muscle strength. No effect on any other measured outcome was observed. That we only see improvements for a small number of output indicators could be explained by the low amount of home practicing of the participants.

Future research should focus on more precise record of home practice. Additionally, a representative sample of the population would allow more certain conclusions to be drawn about the population. Furthermore, to get a clearer picture of the positive effects of practicing yoga, it would be worth conducting a 3-arm study where, in addition to a passive control condition, there would be an active control group who also exercise on a weekly basis.

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Author contributions FK and SB contributed substantially to the conception, design and interpretation of data. AK, FK, BC and SB prepared the manuscript. FK and AK conducted the statistical analyzes. CS set up and implemented the intervention. FK provided feedback to improve the manuscript. JK, ÁH, ZD, and SB contributed to the data collection.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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