Duško Lepir[1], Vesna Macanović[2] and Siniša Lakić[3]

LONG-TERM PRACTICE OF YOGA AS A CORRELATE OF HEART RATE VARIABILITY IN MIDDLE-AGED WOMEN: AN EXPLORATIVE STUDY

[1]Faculty of Physical Education and Sport, University of Banja Luka,
[2]PI Center for Education and Upbringing and Listening and Speech Rehabilitation - Banja Luka,
[3]Faculty of Philosophy, University of Banja Luka.

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Abstract
Previous research suggests that yoga benefits for various health problems such as physical and metabolic disorders, respiratory problems, mental disorders, while special attention in recent years has been paid to studying the positive effects of yoga on the improvement of the functioning of the cardiovascular system. The goal of our study was to examine whether practicing yoga for at least a year is related to the respiration mechanism (fewer respiratory cycles per minute and heart rate) and heart rate variability (HRV) in the population of middle-aged women. The sample consisted of two groups of women older than 40 years. Members of the first group ($n = 24$) practiced yoga for at least one year, while members of the comparison group ($n = 25$) did not practice any form of organized physical activity. Obtained results are in accordance with most of the published scientific literature on the topic. This means that practicing yoga on a sample was a correlate of more desirable heart rate variability and more efficient respiratory function, but that the observed effects were statistically small to moderate. Due to the weak statistical power, no statistically significant differences were observed when it comes to comparing groups, but statistically significant correlations were observed between the length of yoga practice and more desirable physiological parameters. In this paper, we discuss the advantages and limitations of our study, as well as the general importance of conducting correlational studies to assess the actual effects of various preventive activities.

Key words: heart rate variability, yoga, breathing, middle-aged women, correlation studies.

INTRODUCTION

The needs of the modern and increasingly information society are such that the work primarily uses intellectual capacities and contact with the body and its experience is neglected. This leads to an imbalance in the psychophysical load of the individual, which during many years of working life can endanger both physical and mental health. One of the potential preventative activities that attracts a lot of public attention around the world is yoga - that is, practicing some of the many related systems that usually integrate techniques of physical posture (asana), breathing (pranayama), relaxation-meditation exercises (pratyahara) and concentration exercises (dharana). Yoga is also a popular activity because it is an approach that can include physically less active groups such as middle-aged and elderly people. Scientific research shows the positive effects of practicing yoga techniques on various health outcomes. On the physical level, alleviation of chronic back problems (Romanov & Radak, 2013), more successful regulation of body weight and metabolic disorders (Supriya et al., 2018), improvement of respiratory conditions (Tomić, Novaković, and Gačić, 2012) and vascular disorders (Jayasinghe, 2004) have been recorded. Alleviaton of anxiety-depressive and other mental disorders have also been noticed (Deuskar, 2010; Kinser et al., 2013; Malathi & Damodaran, 1999; Janjušević, 2010), leading eventually to desirable changes in life habits (Park, Riley, & Braun, 2015).

It is assumed that the positive effects of yoga exercises are largely achieved through physiologically more immediate mechanisms. Among them, a special research focus has been on cardiac work, and especially on the physiological parameter marked as "heart rate variability" (hereinafter: HRV). HRV represents "variation in time intervals between heartbeats" (Khazan, 2013, p. 98), and this measure is taken as a good indicator of the functioning of the autonomic nervous system. In a healthy person, the heartbeat does not occur within the same time interval, because due to different internal and external stimuli, the body adapts to the given changes by speeding up or slowing down the heart. The main system affecting the heart rhythm is the autonomic nervous system, i.e. its two branches: the sympathetic nervous system which speeds up the work of the heart and the parasympathetic which slows it down. Heart rate variability can be represented as a balance measure between sympathetic and parasympathetic (vagal) heart stimulation. Decreased variability indicates decreased parasympathetic stimulation and increased sympathetic, while increased variability indicates the opposite.

Breathing is considered to be one of the main sources of heart rate variability, i.e. the interaction of sympathetic and parasympathetic stimulation. During inhalation, the sympathetic nervous system is activated, which speeds up the work of the heart, and during exhalation, the parasympathetic system is activated, which slows down the work of the heart. This phenomenon is called respiratory sinus arrhythmia and is an indicator of cardiac vagal tone that contributes to heart rate variability (Grossman, & Taylor, 2007). In addition to breathing, the baroreflex mechanism has a significant effect on HRV, which controls blood pressure through baroreceptors by accelerating or slowing down the heart. If these systems function properly, the organism will be able to adapt to various disorders, which will be expressed in the form of a complex heart work. However, if the HRV is low, it indicates the inability of the organism to make adjustments, which is stated as a reliable sign of impaired general health. (Dekker, 2000). Khazan (2013) cites numerous studies linking low HRV to higher mortality in patients with myocardial infarction, chronic heart disease, increased risk of developing life-threatening cardiac arrhythmias, anxiety, panic attacks, and increased HRV with improved health in asthmatics, people with coronary heart disease, chronic obstructive pulmonary disease, hypertension, and a number of other undesirable conditions.

Numerous studies indicate that the practice of yoga affects the autonomic control of heart rate. Regardless of whether these are subjects with pre-existing diseases (Bidwel, Yazel, Davin, Fairchild, & Kanaley 2012; Krishna et al., 2014) or people without health problems (Chu et al., 2017; Lin, Huang, Shiu, & Yeh, 2015; Pal et al., 2014; Patil, et al., 2013), application of breathing techniques, but also yoga postures, and meditation exercises had a positive effect on the modulation of cardiac activity, i.e. on HRV. Two systematic reviews (Posadzki et al., 2015; Tyagi & Cohen, 2016) conclude that the effects of yoga on various parameters of HRV are confirmed in a significant majority of studies, but that it is too early to conclude the existence of a systematic effect, and that this requires additional quality research.

Most of the published studies were experimental and their goal was to register the effects of interventions in controlled conditions during relatively short periods of time. Although experimental studies rightly serve as the gold standard when it comes to internal validity, i.e. establishing a causal link between independent (yoga) and dependent variables (health outcomes), at the same time they often lack adequate environmental validity. While experimental studies use clear and uniform activity protocols, there is great heterogeneity of decisions individuals make in their real life. In particular, people practice yoga with different training frequency and intensity, different forms of yoga with different instructors, and have different experience and consistency in practicing yoga. For that reason, in order to get a complete picture of the effect of behavioural interventions, it is necessary to supplement the picture with correlation studies. An example of such research in this context would be the study of Satin, Linden, and Millman (2013) who compared physical and psychological parameters, as well as the cardiovascular status of long-time yoga practitioners, recreational runners, and physically inactive individuals. The yoga practitioners and runners showed more desirable HRV values expressed by the greater activity of the parasympathetic nervous system. Also, a study conducted in India showed that Isha yoga practitioners showed significantly higher HRV values, compared to gender and age-similar respondents who did not practice yoga (Muralikrishnan, Balakrishnan, Balasubramanian, & Visnegarawla, 2012).

Having in mind all of the above, our study wanted to examine whether middle-aged women who practice yoga for a longer period of time have a different respiratory pattern, i.e. the values of HRV and heart rate. This population is particularly relevant to study since there is a large number of physically inactive middle-aged, although physical activity is important given the changes in hormonal status and overall health. In a recent survey of a large sample of 712 respondents from the Republic of Srpska over the age of 40, as many as 52.9% or virtually every other woman surveyed, was described as physically inactive (Šabić, 2018, p. 100). The situation is plausibly similar across the region. While related estimations have previously been obtained for developed Western countries (e.g. McTiernan et al., 1998 in the United States), there are indications of desirable improvements in the recent past (Bauman, et al., 2009). In addition to the fact that HRV values are known to decline with age (Umetani, et al., 1998), we considered it justified to estimate whether involvement in a regular yoga training program has a preventive effect and slows down the development of undesirable health outcomes. In particular, we assumed that middle-aged women who practice yoga for at least a year have a lower number of respiratory cycles and heartbeats per minute, and greater heart rate variability compared to middle-aged women who do not practice any form of organized physical activity.

METHOD

Sample and procedure

The theoretical population were females older than 40 years. In order to eliminate the possible effects of health status on measured parameters, we included only people without chronic diseases in the research; in particular, the exclusion criterion was that the person had cardio-respiratory, pulmonary or endocrine disorders, a mental disorder and/or use pharmacological therapy. The convenience sample included 49 respondents from the area of the city of Banja Luka (Republic of Srpska, Bosnia and Herzegovina). The first group consists of 24 respondents aged between 40 and 72 years (M = 53.8, SD = 8.7) who practiced the physical aspects of yoga between 1 and 16 years (M = 6.8, SD = 4.3), of which 75% did so at least 2 times a week. These respondents represented the Yoga group. The comparison group consisted of 25 respondents aged between 40 and 75 years (M = 52.3, SD = 9.6) who did not practice any type of regular physical exercise, and we named this group as the Control group, i.e. the Inactive group.
Measurement of physiological parameters was conducted at the Institute of Sports, Faculty of Physical Education and Sport, University of Banja Luka (Republic of Srpska, Bosnia and Herzegovina). The measurement was performed in the morning from 8:00 to 10:30, and the respondents were previously instructed to avoid any physical activity on the day of the measurement, and not to consume alcohol or any other caffeinated and energy drinks. The protocol for testing the required respiratory and cardiac parameters meant that the subjects were in a supine position during the measurement, given the sensitivity of the given parameters in relation to body position. Recording of these parameters for each subject lasted exactly seven minutes (short protocol for measuring HRV - see Malik et al., 1996), during which each of them was instructed to breathe as naturally as possible without use of any specific breathing techniques.

Instruments and variables

Relevant socio-demographic and health data were collected via a self-report questionnaire, while a biofeedback system with two sensors was used to measure physiological characteristics. We measured the number of respiratory cycles using a respiration sensor. To measure heart rate and HRV, we used the Blood Volume Pulse Sensor (BVP), which works on the principle of photoplethysmography, i.e. light technology was used to monitor changes in blood volume in blood vessels. The raw data obtained from these sensors is transmitted to the hardware component of the Mindmedia Nexus 10 MKII device, which converts the analogue signal into digital. The digital signal is then forwarded to the Mindmedia-Biotrace + program, in which quantitative data processing is performed for the individual subject. The variables we used for this study were: number of respiration cycles per minute (one cycle represents one inspiration and one expiration), heart rate, and heart rate variability (HRV).
When it comes to measuring HRV, the literature usually describes two different methods, called time and frequency domain (Malik, et al., 1996). Due to the lower reliability of the frequency domain (see Billman, 2013), in this paper we decided to use the HRV values obtained exclusively by applying the time domain. There are several HRV parameters that we obtained with this method and that we have considered as outcome variables:
SDNN - represents the standard deviation of all normal R-R intervals (interval between successive heartbeats), i.e. the root of their variance and is expressed in milliseconds (higher values indicate a higher HRV);
rMSSD – square root of the mean square difference between normal R-R intervals;
NN50 – number of pairs of consecutive R-R intervals that differ by more than 50 milliseconds;
pNN50 – percentage of NN50 to the total number of NN intervals.

Data analysis

After entering the data into the database, we checked its validity, i.e. whether the data fit within the theoretically possible values. We used usual measures of descriptive statistics (measures of central tendency and variability) to summarize group data, after which we calculated standardized measures of difference between groups and correlation coefficients.

Given the technical complexity of conducting the study, our resources were limited to a small sample, so the research itself had to be classified as explorative. In other words, it was not reasonable to expect that this individual research would provide a conclusive answer to the hypothesis of long-term yoga practice. In particular, a priori calculated statistical power of testing via the P-values should be considered weak: the sample size was sufficient to detect only a statistically large effect in the population (power = .77 for $\delta = .80$, $\alpha = .05$) which was theoretically improbable to arise. For the moderate effect, the statistical power was already below 50% (power = .40 for $\delta = .50$, $\alpha = .05$), while for detection of, the most plausible, small effects (e.g. as observed in Papp et al., 2013 when it comes to HRV) the power was extremely low (power = .10 for $\delta = .20$, $\alpha = .05$). This means that if there are indeed small statistical effects in the population, we would expect P-values to be lower than .05 in only one in ten studies with sample of this size.

As a result, we put the primary focus on descriptive analysis, meaning that in case of positive effects, it should serve as an argument for conducting more extensive research. However, to illustrate the objective findings informativeness, we used the Bayes Factor interval null procedure. This approach combines the advantages of classical BF and frequency equivalence testing with P-values (see more in Lakens et al., 2018, Lakić, 2019; Linde et al., 2020). We set equivalence margins for differences between groups - intervals that would imply that there are no practically relevant differences - to absolute values of $\delta = .20$. Since our study was of an exploratory nature, the default, we set weakly informative a priori parameter values for the alternative hypothesis ($\delta A \sim$ Cauchy (0, 0.71)), which did not take into account previous empirical findings of positive effects. For correlations, we set uninformative alternative hypotheses ($\rho A \sim$ Beta (1,1)). For the sake of convention, P-values were also calculated for the corresponding parametric and non-parametric methods (e.g. t-test for independent samples and Mann-Whitney test) after it was determined that the assumptions for performing both types of analyses were satisfied (e.g. no extreme scores). Data were analyzed in the statistical packages JASP (JASP team, 2020) and Jamovi (The Jamovi project, 2020).

RESULTS

Table 1 shows group comparisons for all physiological outcomes of interest. When it comes to respiration, it is evident that the subjects from the Yoga group had, on average, 1.5 respiratory cycles less than the subjects from the control group, which corresponds to a difference of 0.4 of the pooled standard deviation. Although we obtained a clinically suggestive result - where 95% confidence intervals on the one side reached values of 1 standard deviation - the obtained results were negligibly more probable under the condition of interval zero hypothesis compared to the objectively given alternative hypothesis (BF01 = 1.91). On the other hand, only negligible differences in heart rate were observed in our sample (d = -0.06). Accordingly, the calculated Bayes factor indicated that the data were 6 times more likely to be derived from populations that are virtually indistinguishable in terms of their heart rate compared to the hypothesis that the difference between populations was at least 0.2 standard deviations – either in positive or negative side. Finally, descriptive values clearly suggested that participants who practiced yoga had greater heart rate variability regardless of the specific measure with which it was operationalized. The differences in the sample ranged from more than one third of the pooled standard deviation (NN50) to over a half of the standard deviation (SDNN). Again, the confidence interval limits reached one standard deviation in the positive direction for each of the calculated measures, but they also included a possible zero population effect. As a consequence, the P-values did not reach the conventional cut-off values, and the values of the Bayes factors tell us that the data had almost equal probability to have been derived from the null interval hypothesis as from the weakly informed alternative hypothesis.

In sum, the presented statistical findings simultaneously suggest the existence of positive effects, but also the need to further verify the

Table 1 Comparison of Yoga and Inactive groups with respect to respiratory cycle, heart rate and cardiac variability parameters.

Variable	Yoga (n = 24)		Inactive (n = 25)						
	M	*SD*	*M*	*SD*	*d*	*95% C.I. d*	p_1	p_2	BF_{10}
Number of respiratory cycles	12.68	4.07	14.21	3.47	-0.40	(-0.97, 0.16)	.163	.166	0.52
Heart rate	68.61	9.33	68.92	10.34	-0.06	(-0.62, 0.50)	.829	.945	0.17
HRV-SDNN	63.10	37.74	46.70	20.22	0.55	(-0.03, 1.11)	.068	.199	1.05
HRV-RMSSD	57.66	42.45	40.32	25.66	0.50	(-0.07, 1.06)	.093	.345	0.82
HRV-NN50	94.50	89.57	65.28	72.38	0.36	(-0.21, 0.92)	.214	.373	0.43
HRV-pNN50	20.89	20.55	13.85	15.90	0.38	(-0.18, 0.95)	.188	.345	0.48

Note. M = arithmetic mean; SD = standard deviation;
d = standardized difference of arithmetic means;
p_1 = P-value for Welch's t-test;
p_2 = P-value for Mann-Whitney test;
BF_{10} = probability ratio of the alternative hypothesis versus the interval null hypothesis for the t-test.

replicability of such findings in other studies. However, the data on the length of yoga practice expressed in years gave us the opportunity to further consolidate the likelihood of the hypothesis that long-term practice of yoga leads to positive physiological changes. Table 2 shows the correlations between the length of Yoga practice and the measured parameters. Although the subsample for the analysis consisted of only 24 respondents from the Yoga group, the results reasonably support the basic hypothesis at this exploratory stage. We observed unambiguous positive correlations between the length of yoga practice and measures of respiratory rhythm and cardiac variability, most of which reached a level of nominal statistical significance ($P < .05$). The Bayes factors provided us with a more cautious picture, where more suggestive results were observed only for cardiac variability (no effect) and the NN50 parameter (longer yoga practice increases HRV).

Table 2 Association between years of yoga practice and measured physiological parameters ($n = 24$)

Variable	r	p1	rs	p2	BF10
Number of respiratory cycles	.24	.250	.20	.356	0.47
Heart rate	-.03	.872	-.11	.625	0.26
HRV-SDNN	.46	.026	.37	.072	2.67
HRV-RMSSD	.43	.034	.41	.047	2.11
HRV-NN50	.53	.008	.45	.028	7.14
HRV-pNN50	.43	.037	.34	.104	1.97

Note. r = linear correlation coefficient;
r_s = rank-correlation coefficient;
p_1 = P-values for r; p_2 = P-value for r_s;
BF_{10} = probability ratio of the alternative hypothesis versus the point-null hypothesis for linear correlation coefficient.

DISCUSSION

Based on the previous empirical literature, in which experimental interventions have been used more frequently, we hypothesized that prolonged yoga practice is associated with improved respiratory efficiency and increased heart rate variability among women over 40 years of age. And indeed, in our sample we found that the Yoga group had a lower average respiration rate compared to the control group, i.e. increased heart rate variability. However, we did not obtain statistically significant results for this, neither when using P-values, nor Bayes factors, and it is instructive to further clarify this contradiction with a specific example.

As an illustrative example, we will consider the paper by Satin et al. (Satin et al., 2013). That correlational study compared groups of yoga practitioners and inactive subjects (the third group were recreational runners). The average differences in terms of respiratory rhythm were very similar to what we obtained in our case: 12.44 vs. 14.07, while in our study it was 12.67 vs. 14.20. However, Satin et al. reported statistically significant differences between the groups. Why? There were two primary statistical reasons for this: in the mentioned study the subsamples consisted of twice as many respondents compared to our study, while the variability of measures within individual groups was significantly lower (both of which increase statistical power). Also, Satin and associates included only persons who have been practicing yoga in the Yoga group for at least two years (in our study it was one year) with the minimum of weekly practice was three trainings (in our study two). It should be noted that our finding on the association between the length of yoga practice and improved parameters of interest is fully consistent with this observation.

To continue on this topic of methodological limitations, it seems that low statistical power tends to be the main reason why there were many studies published which did not find statistically significant positive effects (see Posadzki et al., 2015; Tyagi & Cohen, 2016). A good illustration of this phenomenon is another exploratory study (Papp et al., 2013) where, as in our study, descriptive indicators of desirable changes were obtained for all six HRV measures; nevertheless, a significant result was achieved for only one of them and with the value close to a boundary of the significance ($p = .035$). Moreover, out of the 26 experimental studies that explored the association between the practice of yoga positions and HRV indicators (Tyagi & Cohen, 2016, Table 4), 20 of them had 50 or fewer participants. Another possible reason for inconsistent results could be the relatively frequent employment of the frequency domain of HRV estimation, which is generally less reliable than the time domain. Specifically, of the four correlation studies presented in the review paper by Tyagi & Cohen (2016, Table 5), three confirmed better HRV values in yoga practitioners compared to inactive ones, but only one of these studies employed time domain measures. In a recent correlational study (Subash et al., 2020) time domain measures were used and significant effects were obtained, but again there were differences in inclusion criteria (men who practiced yoga for at least 3 years compared to inactive participants). All in all, it is necessary to keep these methodological factors in mind if one wants to obtain more comprehensive evaluation of yoga effects on HRV.

It should also be noted, that in our study we did not observe differences between the Yoga and Inactive groups in terms of heart rate per minute during a seven-minute rest in a supine position. Some other correlational studies (Friis, & Sollers, 2013; Muralikrishnan et al., 2012) also did not find the difference, although the condition to be categorized in the Yoga group implied far more extensive yoga practice. On the other hand, the results in experimental studies were diverse. Some found no changes (Papp et al., 2013), while in others there was a significant decrease in heart rate (Krishna et al., 2014; Yunati, Deshp, & Yuwanate, 2014). One of the possible explanations for the existence of the effects of experimental yoga programs on the heart rate lies in the characteristics of training programs. The emphasis is those studies is primarily placed on slow breathing exercises, which have a greater effect on the examined parameter of heart rate than physical exercises, and this could partially explain the effects, together with the duration of the procedure. As an illustrative example, Chu and co-workers (2015) did not find significant effects on HRV in women during the first experiment which lasted for 8 weeks of yoga practice, but they confirmed a positive effect on HRV parameters in a later study where the program lasted for 12 weeks (Chu et al., 2017). Of course, we should not forget the already mentioned problem of the existence of several methods of measuring HRV, and their own reliability.

CONCLUSION

Given all the above, what do we see to be the contribution of our study? First of all, this is one of the few studies in our region that deals with this topic in general, and especially on the population of middle-aged women for whom it is particularly needed to get evidence of the benefits of physical activity. Second, our study emphasizes an added valued of high-quality correlational research, since they can confirm the effects of structured activities in real-life contexts, which vary significantly from person to person (e.g. a specific yoga system). Third, a positive correlation we found between the length of yoga practice and lowering HRV and a somewhat more efficient respiratory rhythm suggest a continuous and additive effect of the duration of yoga practice, which should be further examined. Finally, our results can be included in statistical meta-analyses which more accurately assess the true effects of an intervention. The very purpose of meta-analyses is to overcome limited resources in individual studies and to provide realistic estimates of the effects of intervention in different contexts (e.g. in terms of geographical area, target populations, length of intervention practice, types of yoga). The goal of science is, after all, to cumulatively put together a mosaic of knowledge about a phenomenon for which each individual research represents only one piece of a puzzle. Of course, we will be pleased if this paper inspires other researchers in the region to explore the promising effects of yoga as an accessible and engaging physical activity for which evidence of desirable health outcomes is increasingly being obtained.

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Corresponding author:
Duško Lepir, PhD
Faculty of Physical Education and Sport
University of Banja Luka
E-mail: dusko.lepir@ffvs.unibl.org

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