

# THE EFFECT OF A HATHA YOGA EXERCISE PROGRAMME WITH SEGMENTAL STABILISATION EXERCISES ON TRUNK FLEXIBILITY

## UČINEK HATHA JOGE, STOPNJEVANE PO NAČELIH SEGMENTNE STABILIZACIJE HRBTENICE IN MEDENICE, NA GIBČNOST TRUPA

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### ABSTRACT

#### Introduction

In addition to sufficient trunk muscle endurance, adequate trunk flexibility, i.e. trunk muscle extensibility and spinal mobility, is an important element for the stability of the spine and pelvis. The aim of this intervention study was to investigate the effects of a preventive exercise programme on trunk flexibility.

### Keywords

Stabilisation exercise  
Prevention  
Low back pain

#### Methods

The participants were healthy adults without pain or injury in the lower back. They were divided into two groups: the exercise group (EG), which performed a hatha yoga exercise programme with segmental stabilisation exercises (12 weeks), and the control group (CG), in which they maintained their previous lifestyle during the study period. Before and after the intervention the measured variables, the extensibility of the trunk muscles and the mobility of the thoracolumbar spine were compared.

#### Results

Seventy-two participants ( $n_{EG}=36$ , age  $32.2\pm 6.8$  years;  $n_{CG}=36$ , age  $29.9\pm 7.8$  years) took part in the study. After the exercise programme, the EG participants achieved significantly better extensibility of the iliopsoas muscle ( $p\leq 0.001$ ), the V-Sit and Reach Test ( $p=0.001$ ) and the mobility of the thoracolumbar spine ( $p<0.05$ ). Significant differences between the two groups were found in four of five extensibility tests ( $p\leq 0.041$ ) and in flexion, left lateral flexion and right rotation of the spine ( $p\leq 0.036$ ).

#### Conclusions

The proposed exercise programme indicated a significant improvement in trunk flexibility. Future studies should investigate the long-term effects of the proposed exercise programme on a larger number of participants.

### IZVLEČEK

#### Uvod

Poleg primerne vzdržljivosti mišic trupa predstavljata pomembna elementa sistema stabilnosti hrbtenice in medenice tudi primerna raztegljivost mišic trupa in ustrezna gibljivost hrbtenice. Namen raziskave je bil preveriti učinke hatha joge, stopnjevane po načelih segmentne stabilizacije hrbtenice in medenice, na gibčnost trupa.

### Gljučne besede

stabilizacijska vadba  
preventiva  
bolečina v spodnjem delu hrbta

#### Metode

V raziskavo so bili vključeni zdravi odrasli brez bolečin in/ali poškodb hrbtenice in medenice, ki pred vključitvijo v raziskavo niso redno izvajali vadb za izboljšanje raztegljivosti mišic in/ali gibljivosti hrbtenice. Razdeljeni so bili v dve skupini: vadbena (VS), v kateri so v obdobju treh mesecev, dvakrat na teden po 60 minut, izvajali hatha jogo, stopnjevano po načelih segmentne stabilizacije hrbtenice in medenice; ali v primerjalno (PS), v kateri niso spreminjali svojega trenutnega življenjskega sloga. Ob vključitvi v raziskavo (PRED) in po končanem trimesečnem vadbenem obdobju (PO) je bila merjena raztegljivost mišic trupa in kolka ter gibljivost prsno-ledvenega dela hrbtenice. Analizirane so bile spremembe merjenih spremenljivk (PRED-PO, VS-PS).

#### Rezultati

V raziskavi je sodelovalo 72 preiskovancev ( $n_{VS} = 36$ , stari  $32,2 \pm 6,8$  let;  $n_{PS} = 36$ , stari  $29,9 \pm 7,8$  let). Preiskovanci VS so po zaključku vadbene programa dosegli statistično značilno boljše raztegljivost mišice iliopsoas in rezultat testa V-doseg sede ( $p \leq 0,001$ ) ter gibljivost prsno-ledvenega dela hrbtenice ( $p < 0,05$ ). Med skupinama VS in PS so bile statistično značilne razlike ugotovljene pri štirih od petih testov raztegljivosti mišic ( $p \leq 0,041$ ) ter pri izboljšanju obsega fleksije, lateralne fleksije v levo ter rotacije hrbtenice v desno stran ( $p \leq 0,036$ ).

#### Zaključki

S hatha jogo, stopnjevano po načelih segmentne stabilizacije hrbtenice in medenice, lahko pomembno izboljšamo gibčnost trupa, in sicer tako z vidika boljše raztegljivosti nekaterih mišic kot tudi gibljivosti prsno-ledvenega dela hrbtenice. V nadaljnjih raziskavah bi bilo smiselno preveriti še dolgoročne učinke vadbene programa na večjem vzorcu preiskovancev.

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## 1 INTRODUCTION

Low back pain (LBP) is an important global public health problem (1). In 2019, LBP was the leading cause of functional disability (2) and maintained its leading position in recent years (1). Preventive measures to reduce the incidence of LBP have the potential to significantly reduce the burden associated with this condition. There is moderate evidence that an exercise programme alone or in combination with education is effective in reducing the risk of a future episode of LBP (3).

The normal function of the spine stabilising system is to provide the spine with sufficient stability to accommodate momentary fluctuations in stability demands due to changes in spinal posture and static and dynamic loading (4). Trunk flexibility (i.e. muscle extensibility and joint mobility) and trunk muscle endurance are interrelated: any factor that reduces the extensibility of the muscle-tendon structures and/or the joint mobility of the spine also has a negative effect on muscular endurance and vice versa, which increases the risk of LBP (5). Research in this area suggests that reduced trunk muscle endurance, reduced lateral spinal flexion, reduced hamstring extensibility and reduced lumbar lordosis are important risk factors for musculoskeletal overload of the spine and the occurrence of LBP (6, 7).

Hatha yoga is one of the traditional types of yoga that emphasises the importance of physical fitness through various postures (asanas), breathing techniques (pranayamas), relaxation and concentration techniques, etc. (8, 9). In recent years, yoga has been increasingly studied as one of the effective treatment strategies for LBP (10). However, most of the available studies in the field of yoga research investigated the efficacy and appropriateness of yoga as a therapeutic approach in (chronic) LBP patients, while less is known about its preventive outcomes (11, 12).

When hatha yoga is combined with segmental stabilisation exercises, the endurance of the trunk muscles increases (13). Since adequate trunk flexibility is also a very important factor for spinal and pelvic stability, the effect of the above combination of exercises on muscle extensibility and joint mobility must also be investigated. The objective of this study was to investigate the effectiveness of a professional and scientifically based hatha yoga exercise programme that integrates the principles of the segmental stabilisation exercise model to improve muscle extensibility and spinal mobility in healthy adults, in order to provide evidence for an effective health intervention to prevent LBP or reduce the risk of recurrence of LBP.

## 2 MATERIALS AND METHODS

### 2.1 Study design, time frame and setting

The study was part of a larger intervention study (non-randomised controlled trial), and other parts of the study have already been published (13-15). It was conducted from September 2019 to March 2022 at the Faculty of Health Sciences of the University of Ljubljana (Slovenia).

### 2.2 Study participants

Potential candidates were invited to participate in the study via electronic media and chain reference sampling. The following inclusion criteria were considered for participation in the study: 1) healthy adults aged between 20 and 45 years, 2) without LBP at the time of enrolment in the study, 3) without musculoskeletal injuries or other conditions that could be a contraindication or pose a risk to the individual's health, and 4) without yoga practice or spinal stabilisation exercise programmes (continuous, at least once a week) in the last six months. All participants who met the inclusion criteria signed an informed consent form when participating in the study.

Participants were assigned to one of two study groups: a) an exercise group (EG) or b) a control group (CG) according to the case-control matching method (16), considering gender, age and physical activity. The EG participants took part in a three-month exercise programme (see below for more information on exercise), while the CG participants were asked to maintain their current lifestyle and level of physical activity during the study period. At the end of the study, CG participants were offered participation in the exercise programme.

### 2.3 Study instruments and protocols

First, the inclusion criteria were checked using a questionnaire on the participants' demographic data, health status and physical activity (17). If all inclusion criteria were met, the participants' height (in metres) and weight (in kilogrammes) were then measured.

Muscle extensibility measurements were then performed. The following tests were used: 1) modified Thomas test (18) for the extensibility of the iliopsoas and rectus femoris (in °, using a universal plastic goniometer (Baseline measurement instruments, USA)) and 2) V-Sit and Reach Test (19) for the flexibility of the lower back and hamstring (in cm; using a measuring tape (Enraf Nonius, Netherlands)).

The last series of measurements consisted of linear measurements of the mobility of the thoracolumbar part of the spine (in cm), specifically: thoracolumbar flexion (20, 21), extension (20), lateral flexion (left and right) (20) and rotation (left and right) (22).

All measurements described above were performed twice in the study: for the first time at enrolment (“BEFORE” measurements) and for the second time after the three-month study period (i.e. after completion of the exercise programme (EG participants) or after the three-month study period without exercise (CG participants); “AFTER” measurements). For clinically significant differences, a difference of  $\geq 5.0^\circ$  in goniometric measurements and  $\geq 1.3$  cm in tape measure measurements was used (23, 24).

## 2.4 Exercise programme

The exercise programme is based on hatha yoga practised according to the principles of the segmental stabilisation exercise model. A three-month exercise programme comprised a total of 25 training sessions, which were carried out twice a week for 60 minutes each. It consisted of yoga postures (asanas) and controlled breathing techniques (pranayamas). In accordance with the three-stage model of segmental stabilisation exercises (25), the contraction of the deep trunk muscles was emphasised in each asana, different positions or dynamic movements of the lower/upper limbs (in closed or open chain) during the holding of the basic asana were performed progressively, and so forth. Each training session began with 10 minutes of gradual warm-up exercises, followed by the main part of the training session to improve the endurance and flexibility of the trunk muscles (35 minutes) and gradual stretching and relaxation exercises at the end of the training session (15 minutes). All techniques and postures were gradually intensified during the exercise programme but remained in the range of low to moderate intensity exercises (ratings 9-15 on the Borg Rating of Perceived Exertion Scale 6-20) (26, 27).

The exercise programme and measurements were carried out by a physiotherapist (Master’s degree) who is also a yoga teacher (YT 500) and has several years of experience in these two professional fields. For implementation reasons, neither the participants nor the investigator were blinded.

## 2.5 Methods of analysis

All collected variables were checked for distribution. Since not all variables were normally distributed and we were interested in the differences within each individual value, the parametric test was used when the variables were normally distributed and a corresponding non-parametric test was used when the variables were not normally distributed. Changes in muscle extensibility and spinal mobility were compared between: 1) BEFORE and AFTER measurements using the t-test for related samples or the non-parametric Wilcoxon signed-rank test for related samples (BEFORE-AFTER comparison) and 2) EG and CG participants using the t-test for unrelated samples or the Mann-Whitney U-test for unrelated samples (EG-CG comparison). Statistical significance was set at  $p \leq 0.05$  for all analyses.

The data analysis was carried out using IBM SPSS Statistics 27 (IBM, New York, USA) and an Excel programme (Microsoft Corporation, Washington, USA).

## 3 RESULTS

### 3.1 Participants

At the beginning of the study, 85 participants met all inclusion criteria, of whom 13 participants withdrew from the study for various reasons (e.g. pregnancy, significant change in physical activity level and/or lifestyle). Seventy-two participants completed the study, including 36 participants in the EG (7 men and 29 women) and 36 participants in the CG (8 men and 28 women). There were no significant differences in baseline data between EG and CG participants (Table 1).

Table 1. Demographic characteristics of participants in EG and CG.

Characteristic	Group				p
	EG (n=36)		CG (n=36)		
	$\bar{x}$	SD	$\bar{x}$	SD	
Age (years)	32.2	6.8	29.9	7.8	0.187
Body height (m)	1.69	0.06	1.69	0.08	0.680
Body mass (kg)	65.9	9.7	67.2	13.2	0.662
BMI (kg/m <sup>2</sup> )	23.2	3.2	23.4	3.6	0.866

Legend: BMI=body mass index; EG=exercise group; n=number of participants; CG=control group

Participation in the training sessions was 85.1% (21.3 out of a total of 25 sessions).

### 3.2 Effectiveness of the exercise programme

At baseline (BEFORE measurements), there were no significant differences between the EG and CG in muscle extensibility ( $p>0.05$ ) or spinal mobility ( $p>0.05$ ).

#### 3.2.1 Muscle extensibility

A statistically significant improvement in the extensibility of the iliopsoas muscles was observed in the EG participants ( $p\leq 0.001$ ). In the V-Sit and Reach Test, both groups achieved statistically significant BEFORE-AFTER differences; the EG participants improved the distance ( $p=0.001$ ), and the CG participants achieved a worse distance on the second measurement ( $p=0.031$ ). The changes in the other measures of muscle extensibility were not statistically significant (Table 2).

When comparing the mean BEFORE-AFTER difference between the two groups, the analysis showed statistically significant differences in four out of five extensibility tests (except for the right rectus femoris muscle;  $p>0.05$ ) (Table 3). The calculated Cohen's *d* coefficients indicate a large effect, with the exception of the rectus femoris muscle, where the effect is small (Table 3).

#### 3.2.2 Spine mobility

The mobility of the thoracolumbar spine changed statistically significantly ( $p\leq 0.041$ ) in the EG participants by at least  $\geq 0.5$  cm in all measured directions; except for the thoracolumbar extension movement, which decreased, the ranges of all other movements increased. In CG participants, a slight decrease in thoracolumbar spinal mobility ( $\leq 0.5$  cm) was observed for most of the measured movements, but these changes were not statistically significant (Table 4).

**Table 2.** Results of muscle extensibility of the lower back and hip muscles (comparison of BEFORE-AFTER measurements).

Group	Test	m	$\bar{x}$	95% CI	SD	Me	Min.	Max.	p
EG (n=36)	L-IL (°)	BEFORE	16.1	13.7; 18.6	7.3	17.0	-1.0	34.0	0.001 <sup>b</sup>
		AFTER	18.6	16.5; 20.7	6.2	19.5	6.0	34.0	
	R-IL (°)	BEFORE	15.9	13.6; 18.3	6.9	16.5	3.0	34.0	<0.001 <sup>b</sup>
		AFTER	18.7	16.4; 21.0	6.9	19.0	7.0	34.0	
	L-RF (°)	BEFORE	54.1	51.3; 56.8	8.1	54.0	35.0	74.0	0.172 <sup>b</sup>
		AFTER	52.7	50.2; 55.2	7.4	54.0	31.0	65.0	
	R-RF (°)	BEFORE	55.5	52.5; 58.6	9.0	55.5	36.0	72.0	0.265 <sup>b</sup>
		AFTER	54.2	51.5; 56.9	8.0	56.0	34.0	70.0	
	V-SRT (cm)	BEFORE	8.1	5.8; 10.4	6.9	9.0	-14.5	20.5	0.001 <sup>b</sup>
		AFTER	10.6	8.8; 12.5	5.5	11.3	0.0	22.0	
CG (n=36)	L-IL (°)	BEFORE	18.6	16.1; 21.0	7.3	18.0	-6.0	35.0	0.501 <sup>a</sup>
		AFTER	18.0	15.2; 20.8	8.4	17.5	-3.0	43.0	
	R-IL (°)	BEFORE	18.4	15.9; 20.9	7.4	18.0	-7.0	38.0	0.260 <sup>a</sup>
		AFTER	17.8	15.3; 20.3	7.3	17.0	-3.0	38.0	
	L-RF (°)	BEFORE	51.6	49.6; 53.5	5.8	52.0	36.0	71.0	0.257 <sup>a</sup>
		AFTER	53.1	50.5; 55.8	7.8	53.0	35.0	68.0	
	R-RF (°)	BEFORE	52.9	50.9; 54.9	5.9	52.0	41.0	67.0	0.804 <sup>b</sup>
		AFTER	53.1	50.5; 55.7	7.7	55.0	39.0	70.0	
	V-SRT (cm)	BEFORE	7.8	4.6; 10.9	9.3	7.0	-25.0	26.5	0.031 <sup>a</sup>
		AFTER	6.6	3.4; 9.9	9.6	6.0	-26.0	22.0	

Legend: EG=exercise group; n=number of participants; CG=control group; L-IL=left iliopsoas muscle; R-IL=right iliopsoas muscle; L-RF=left rectus femoris muscle; R-RF=right rectus femoris muscle; V-SRT=V-Sit and Reach Test; m=measurement; BEFORE=measurements before the exercise programme; AFTER=measurements after the exercise programme; 95% CI=95% confidence interval; Me=median; Min.=minimum value; Max.=maximum value; a=Wilcoxon signed ranks test; b=paired samples t-test.

**Table 3.** Results of BEFORE-AFTER differences in muscle extensibility of the lower back and hip muscles (comparison of EG-CG measurements).

Test	Group	$\bar{x}$	SD	%	p	Cohen's d
L-IL (°)	EG	2.4	4.2	15.1	0.004	0.70
	CG	-0.6	4.4	-3.1		
R-IL (°)	EG	2.8	4.0	17.2	<0.001	0.83
	CG	-0.6	4.2	-3.2		
L-RF (°)	EG	-1.4	5.9	-2.5	0.041	-0.50
	CG	1.6	6.0	3.0		
R-RF (°)	EG	-1.4	7.2	-2.5	0.293	-0.25
	CG	0.2	5.3	0.4		
V-SRT (cm)	EG	2.6	4.0	31.6	<0.001	1.06
	CG	-1.2	3.1	-14.8		

Legend: L-IL=left iliopsoas muscle; R-IL=right iliopsoas muscle; L-RF=left rectus femoris muscle; R-RF=right rectus femoris muscle; V-SRT=V-Sit and Reach Test; EG=exercise group (n=36); CG=control group (n=36);  $\bar{x}$ =mean BEFORE-AFTER difference; %=percentage of BEFORE-AFTER difference; Cohen's d= Cohen's d coefficient.

**Table 4.** Results of mobility (in cm) of the thoracolumbar spine (comparison of BEFORE-AFTER measurements).

Group	Motion	m	$\bar{x}$ (cm)	95% CI (cm)	SD (cm)	Me (cm)	Min. (cm)	Max. (cm)	p
EG (n=36)	FL	BEFORE	8.4	7.9; 9.0	1.7	8.5	5.0	12.0	0.015 <sup>b</sup>
		AFTER	8.9	8.4; 9.5	1.6	9.0	5.0	12.0	
	EX	BEFORE	3.0	2.4; 3.6	1.7	3.0	0.5	8.0	0.038 <sup>a</sup>
		AFTER	2.4	2.0; 2.8	1.2	2.0	0.5	6.0	
	L-LF	BEFORE	19.6	18.3; 21.0	4.0	19.5	11.5	29.0	0.031 <sup>a</sup>
		AFTER	20.3	19.0; 21.6	3.8	20.0	13.0	31.5	
	R-LF	BEFORE	19.6	18.4; 20.9	3.7	19.5	12.5	28.0	0.041 <sup>a</sup>
		AFTER	20.3	19.1; 21.6	3.6	20.0	14.5	33.5	
	L-RO	BEFORE	8.3	7.7; 9.0	1.9	8.5	4.5	12.5	0.040 <sup>b</sup>
		AFTER	8.9	8.2; 9.6	2.0	9.0	5.0	13.0	
	R-RO	BEFORE	8.5	7.9; 9.0	1.7	8.5	6.0	12.0	0.003 <sup>b</sup>
		AFTER	9.1	8.5; 9.7	1.8	9.0	6.5	13.0	
CG (n=36)	FL	BEFORE	9.1	8.5; 9.7	1.8	9.0	5.0	13.0	0.416 <sup>a</sup>
		AFTER	8.8	8.3; 9.4	1.6	8.5	6.5	12.0	
	EX	BEFORE	2.6	2.2; 3.0	1.2	2.3	0.5	5.0	0.777 <sup>a</sup>
		AFTER	2.5	2.1; 3.0	1.4	2.5	0.5	7.0	
	L-LF	BEFORE	20.8	19.4; 22.2	4.2	21.3	12.0	30.0	0.143 <sup>b</sup>
		AFTER	20.3	18.9; 21.8	4.3	20.3	12.0	29.0	
	R-LF	BEFORE	20.8	19.5; 22.1	3.8	21.0	13.0	31.5	0.854 <sup>b</sup>
		AFTER	20.8	19.5; 22.2	4.0	21.5	12.5	31.0	
	L-RO	BEFORE	8.2	7.7; 8.6	1.4	8.0	5.0	10.5	0.408 <sup>b</sup>
		AFTER	8.0	7.5; 8.5	1.5	8.0	5.5	11.0	
	R-RO	BEFORE	8.3	7.8; 8.8	1.4	8.3	5.5	13.0	0.666 <sup>b</sup>
		AFTER	8.2	7.6; 8.8	1.7	8.0	4.0	11.5	

Legend: EG=exercise group; n=number of participants; CG=control group; FL=thoracolumbar flexion; EX=thoracolumbar extension; L-LF=left lateral spinal flexion; R-LF=right lateral spinal flexion; L-RO=left spinal rotation; R-RO=right spinal rotation; m=measurement; BEFORE=measurements before the exercise programme; AFTER=measurements after the exercise programme; 95% CI=95% confidence interval; Me=median; Min.=minimum value; Max.=maximum value; a=Wilcoxon signed ranks test; b=paired samples t-test.

**Table 5.** Results of BEFORE-AFTER differences in mobility (in cm) of the thoracolumbar spine (comparison of EG-CG measurements).

Motion	Group	$\bar{x}$ (cm)	SD (cm)	%	p	Cohen's d
FL	EG	0.5	1.1	5.8	0.036 <sup>a</sup>	0.64
	CG	-0.3	1.4	-2.7		
EX	EG	-0.6	1.5	-19.0	0.337 <sup>a</sup>	-0.40
	CG	-0.04	1.3	-1.6		
L-LF	EG	0.7	1.8	3.5	0.010 <sup>b</sup>	0.67
	CG	-0.5	1.8	-2.2		
R-LF	EG	0.7	1.9	3.7	0.135 <sup>b</sup>	0.32
	CG	0.1	1.8	0.3		
L-RO	EG	0.6	1.5	6.5	0.082 <sup>a</sup>	0.59
	CG	-0.2	1.2	-2.0		
R-RO	EG	0.6	1.2	7.5	0.003 <sup>a</sup>	0.56
	CG	-0.1	1.3	-1.2		

Legend: FL=thoracolumbar flexion; EX=thoracolumbar extension; L-LF=left lateral spinal flexion; R-LF=right lateral spinal flexion; L-RO=left spinal rotation; R-RO=right spinal rotation; EG=exercise group (n=36); CG=control group (n=36);  $\bar{x}$ =mean BEFORE-AFTER difference; %=percentage of BEFORE-AFTER difference; a=Mann-Whitney U-test for unrelated samples; b=t-test for unrelated samples; Cohen's d=Cohen's d coefficient.

Statistically significant differences in the BEFORE-AFTER increase/decrease in thoracolumbar spine mobility were found between the EG and CG for thoracolumbar flexion, left lateral flexion and the right-sided rotation range (Table 5). The calculated Cohen's d coefficients indicate a small to medium effect (Table 5).

#### 4 DISCUSSION

Regular performance of the hatha yoga exercise programme with segmental stabilisation exercises led to statistically significant improvements in trunk flexibility. Participants in the EG achieved statistically significantly better results in four out of five extensibility tests and statistically significantly better spinal mobility in flexion, left lateral flexion and right rotation compared to the CG participants. The improvement in the V-Sit and Reach Test was also clinically significant in the EG participants. Compared to the EG participants, the CG participants showed no statistically or clinically significant changes in most of the observed variables and even tended to show a worsening of the results in the second measurement.

Considering that reduced hamstring and lower back muscle extensibility and limited spinal mobility are associated with a higher risk of LBP (6, 7), it makes sense to include exercises to improve trunk flexibility in preventive exercise programmes. By gradually intensifying the exercises and moving the spine in all directions and through the full range of motion, regular yoga practice also contributes to trunk flexibility (28, 29). The EG participants in our study achieved statistically significantly better extensibility of the iliopsoas muscles as well as the hamstring and lower back muscles, while in the CG statistically significantly poorer extensibility was indicated. The extensibility of

the rectus femoris muscle did not change significantly in either group, and recent studies on risk factors suggest that poorer extensibility of the rectus femoris muscle does not correlate statistically significantly with the risk of LBP (6).

In a literature review on risk factors for LBP, Sadler et al. (6) also emphasised poorer mobility of the spine (particularly in the direction of lateral flexion) as an important risk factor. In our study, EG participants achieved statistically significantly better thoracolumbar spine mobility in all measured movements, except for extension, which was statistically significantly lower after completion of the exercise programme. The reason for this could be that the participants had better knowledge of the spinal stability system and higher trunk muscle tone after the three-month preventive exercise programme, while they may have performed the extension movement of the spine in a different, more muscle-supported way. However, this remains an area for further research. In terms of comparability of the range of motion on the left and right side of spinal mobility in the anatomical frontal and transverse planes, the effect of the exercise programme was consistent in the increase in lateral flexion range of motion and both rotations, but not all improvements were statistically significant. For most CG participants, the ranges of the individual movements remained the same or were even slightly smaller in the second measurement than in the first measurement. The improvement in mobility of the EG participants is comparable to the results of a pilot study on the effects of a regular five-month hatha yoga practice on flexibility in healthy young women (30), in which the participants (n=9, mean age 23.8±2.9 years) achieved similar improvements in thoracolumbar spine mobility at the second measurement (after two months of

practice) to those of the participants in our study ( $\geq 0.5$  cm for each movement). Therefore, the hatha yoga exercise programme with segmental stabilisation exercises can improve spinal mobility.

In a literature review on the therapeutic effects of yoga on spinal mobility, Rathore et al. (31) emphasised that improvements in various aspects of spinal mobility, including flexion, extension and lateral flexion, were also observed in patients with chronic LBP. However, overstretching without integrating endurance exercises for the trunk muscles could have the opposite effect in symptomatic and asymptomatic individuals by increasing the risk of developing LBP (32).

One limitation of the study is small sample size. In order to maintain the quality of the therapeutic exercise approach, participation in each training session of the exercise programme was limited to small groups (up to 11 participants per group). Another limitation is the gender imbalance among the participants, as most of the participants were women. A further limitation is that randomisation of the participants into EG and CG groups was not possible for implementation reasons, as sufficient motivation and time of the participants was crucial for the implementation of the study (especially in the EG group for participation in the regular training sessions). Another limitation is the lack of clinically significant changes in most outcome measures, and the absence of blinding of both participants and investigators should be maintained in future studies if possible.

From the preventive point of view, despite the limitations, this study offers an important basis for using hatha yoga for preventive purposes. Moreover, through various techniques, hatha yoga strives for a dynamic balance between strength and flexibility that takes place on a physical, mental and emotional level (8, 9). Since sufficient endurance and extensibility of the trunk muscles together with sufficient mobility of the spine are the basis for spinal health and thus for the prevention of musculoskeletal complaints in the lower back, the strength of our study lies in the combination of exercises. The regular hatha yoga practice in combination with segmental stabilisation exercises improves muscle endurance in all four major trunk muscle groups (13, 14), but also the extensibility of most trunk and hip muscles and thoracolumbar mobility, as the results of our study showed. There is much evidence to suggest that yoga could be a suitable preventive approach in the management of LBP. Additionally, it could be an important preventive approach for maintaining physical fitness in seniors (33), as well as for maintaining good physical fitness in professions where the lower back is more stressed during work, e.g., in health professions such as physiotherapists or occupational therapists (34).

## 5 CONCLUSIONS

Hatha yoga with the segmental stabilisation exercises can significantly improve trunk flexibility both in terms of the extensibility of the back and hip muscles and the mobility of the spine in healthy participants.

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## INFORMED CONSENT

Written informed consent was obtained from all individual participants included in the study. The study was approved by National Medical Ethics Committee of the Republic of Slovenia (0120-220/2019/6), and all procedures were conducted in accordance with the Declaration of Helsinki.

## CONFLICTS OF INTEREST

The authors declare that no conflicts of interest exist.

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## ETHICAL APPROVAL

The study was approved by National Medical Ethics Committee of the Republic of Slovenia (0120-220/2019/6).

## AVAILABILITY OF DATA AND MATERIALS

The data presented in this study can be obtained upon request from the corresponding author.

## AI USAGE STATEMENT

During the preparation of this article the authors did not use generative language models.

## PREPRINT STATEMENT

There is no preprint of this study.

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