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The Effectiveness of A 4-Week Yoga Intervention on Core Muscle Activation, Pain and Functional Disability Among Healthy and Low Back Pain Participants

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Abstract

Low Back Pain (LBP) poses a significant long-term health problem and requires the exploration of complementary alternative medicines, such as yoga. LBP patients often present with a delay in the onset of contraction of core musculature, which is necessary to stabilize the spine in dynamic movements. The aim of this study was two-fold. First, it was to determine the effectiveness of a 4-week yoga intervention on the timing of muscle activation and activation ratio of the Transversus Abdominis (TrA) and Lumbar Multifidus (LM) muscles among all participants. Second, it was to determine the effectiveness of a 4-week yoga intervention on the Visual Analog Pain Scale (VAS) and functional disability levels as measured by the Oswestry Disability Index (ODI) among LBP participants. A controlled laboratory study was conducted in healthy participants (n=10) and those with LBP (n=14) between the ages of 18-30. All participants underwent a 30-minute bi-weekly 4-week yoga intervention for LBP taught by a certified yoga teacher. The primary outcome measures were the ODI, VAS, and TrA and LM muscle activation and timing. All outcomes were measured before and after the 4-week intervention. Statistical analyses of the results were performed using 2x2 analysis of variance for group comparison of the outcomes measures, and t-tests were used for intra-group comparison of the LBP participants. The pain scores were not significantly different between conditions (p=.239), but there was a strong effect size (0.87) indicating that the change in pain score may be clinically important. The ODI scores were statistically significant (p=.049) but does not show clinical significance due to the weak effect size and confidence interval that crossed 0 (CI -0.55-0.94). There were no significant differences between the groups for muscle timing or thickness after 4 weeks of yoga for either TrA (p=.101) or LM (p=.437). A 4-week yoga intervention may provide benefits to participants with and without LBP for decreasing pain and functional disability however a larger and longer duration study may be required to provide more definite evidence.

Keywords: Core Muscle Performance; Complimentary Alternative Medicine; Oswestry Disability Index; Rehabilitation; Ultrasound Imaging; Visual Analog Pain Scale

Introduction

Low Back Pain (LBP) is one of the most common musculoskeletal health problems in society today and has reached an epidemic level [1,2] It is estimated to affect at least 70% of the general population at some point in their lives2-4 and 5-10% of American adults will experience chronic LBP [3,4]. LBP is defined as non-specific pain between the 12th rib and the inferior gluteal folds that can be accompanied by leg pain [1] Most cases recover quickly, however some are at risk of becoming chronic cases of pain and disability [2]. The strain on the health care system from LBP is significant as it is a common reason why individuals seek medical attention [2]. In addition, if early detection and treatment for LBP is not done, the effects on the individual could be severe as disability may occur [5] resulting in many consequences, including an inability to work or care for oneself [6].

A risk factor of LBP is weakness and lack of control of the deep trunk musculature [6] including the Transversus Abdominus

(TrA) and Lumbar Multifidus (LM) [7]. The segmental stability of the spine is provided by co-contraction of the LM and TrA to keep the spine in a neutral posture [7]. In those with LBP, alteration in muscle activity of the TrA and LM have been observed [7].

Mobility and stability of the lumbopelvic region can be ensured by the increased segmental stabilization from effective activation of TrA and LM muscles [6], which will improve outcomes in individuals with LBP. Segmental stabilization and strengthening exercises effectively reduce pain and functional disability in individuals with LBP compared to a strengthening program alone through increased muscle activation of the TrA [6]. TrA thickness increased when performing the following exercises: a side bridge, the Abdominal Drawing in Maneuver (ADIM) during a crunch, and the quadruped exercise which involves upper and lower extremity lifts in opposition [8].

Current research and evidence based guidelines for management of LBP have suggested that exercises for strength and mobility are useful [9]. Various types of yoga have been used as a treatment method for LBP as an alternative therapy to traditional exercise [10]. Yoga is currently increasing in popularity as a potential treatment for LBP [11]. In the United States, more than half of patients with LBP use complimentary treatments and yoga is among the most common complementary treatment used [2]. Approximately 20% or 15 million Americans report having practiced yoga at least once exclusively for LBP relief [2,12,13]. Yoga is an ancient form of health promotion involving physical activity postures (asana), breathing techniques (pranayama), and relaxation methods and meditation (dyana) to improve mind-body awareness [2,10,14]. Progressions through posture sequences and meditation in yoga aims to challenge joint flexibility, muscle strength and balance [11]. Yoga has demonstrated both musculoskeletal and psychological benefits through traditional poses adjusted for those with LBP [10,15,16].

Activation patterns of five hip and trunk muscles during 11 common yoga poses have been examined and it was concluded that specific core muscle firing depends on trunk and pelvic positions in those poses [17]. The high plank, low plank and upward facing dog can be used to effectively activate the external oblique, one of the core muscles, however intrinsic musculature was not assessed [17].

To date, no studies have examined specific spinal stabilizing muscle changes from a yoga intervention for LBP patients. The aim of this study is two-fold. First, to determine the effectiveness of a 4-week yoga intervention on the timing of muscle activation and activation ratio of the TrA and LM among all participants. Second, to determine the effectiveness of a 4-week yoga intervention on the Visual Analogue Pain Scale (VAS) and functional disability levels as measured by the Oswestry Disability Index (ODI) among LBP participants. It is hypothesized that both groups of participants in the yoga intervention, regardless of their LBP status, will experience an increase in TrA and LM muscle thickness and faster timing of activation. LBP participants will also improve outcome scores for pain and functional disability.

Methods

Study Design

The design of this study was a controlled laboratory study. The independent variables were time of measurements being taken (pre and post) and group (participants having Low Back Pain (LBP) or being healthy (free of LBP)). The dependent variables were VAS and ODI scores, and TrA and LM timing of activation and thickness measured with diagnostic ultrasound. This study was approved by the Institutional Review Board and all participants signed informed consent.

Participants

Twenty-five participants volunteered to be in the study, 9 males and 15 females. Demographics are presented in Table 1. Exclusion criteria was <18 years of age and >30 years of age at the start of the study, have performed yoga in the last year, new LBP treatments started 30 days prior to the intervention, sustained any injury to the body in the last six weeks, could not use stairs and/or get up from the floor unaided, pregnant, have a history of spinal surgery or abdominal surgery, have serious spinal abnormalities (radiculopathy, nerve root compression, spondylosis, spondylolisthesis, tumor, spinal infection, kyphosis or widespread neurological disorder), have had a chronic systemic or connective tissue disease, have a balance disorder, score > 40% on ODI, or have a shoulder or knee pathology. Inclusion criteria for the low back pain group include the following: having 3 or more episodes of LBP in the past year that resulted in limited Activities of Daily Living (ADL) or more then five times in their lifetime, have an ODI score between 2-40%, be English speaking, have back pain for less than six weeks during an episode, have a mean pain intensity equal to or greater than 1/10 at the time of testing. Healthy participants could not have had any injury to the body in the past 6 weeks, including no history of LBP, and an ODI score could not be higher than 0%.

	Gender (M/F)	Age (years)	Height (cm)	Weight (kg)
Healthy (n=10)	(M=3 / F=7)	22 ± 4.24years	170.4 ± 17.89cm	66.9 ± 23.09kg
LBP (n=14)	(M=6 / F=8)	23.5 ± 7.78years	173.1 ± 23.35cm	93.1 ± 30.79kg
(mean ± SD) **Participant #1 removed for being an outlier				

Table 1: Demographics of Participants.

Instrumentation

Ultrasound imaging

Ultrasound imaging was obtained using a Terason t3000 M-series portable ultrasound system (Teratech, Burlington, MA) with an 8-15MHz linear array. It was used to measure TrA and LM

muscle activation and onset of the muscle contraction. Intra-rater reliability was established prior to data collection (ICC=97).

Pain - Visual Analogue Scale

The VAS consists of a 100mm line, where the scale ranges from left being no pain to right being unbearable pain. The participant places a vertical line to indicate his or her current level of pain. This distance from the left mark was measured in millimeters and recorded. Higher values indicate more pain. Reliability and validity of the VAS has been established for pain intensity in rehabilitation [18].

Functional Disability - Oswestry Disability Index

The ODI version 2.0 was used to assess the impact of LBP on daily activities.The score was calculated by adding the values of the individual questions to categorize the disability. Categories are broken down as zero to mild disability (0-20%), moderate disability (21-40%), severe disability (41-60%), incapacity (61-80%) and restricted to bed (81-100%) [19]. This outcome measure has been recommended to detect meaningful changes in disability status in ADL [20]. The ODI allows investigation of many domains of an individual's life and can be used for individuals with any scale of LBP from mild to severe. It has been proven as a valid and reliable measure for LBP patients [19].

Procedures

Participants arrived for testing wearing comfortable athletic clothing of their choice. Anthropometric measurements of height and mass were recorded as well as a demographic survey to collect age and sex. All participants completed the ODI, to ensure the healthy participants had a score of zero and to take baseline measures for the LBP group. VAS measurements were completed for the LBP group.

The Abdominal Drawing-In Maneuver (ADIM) was taught to all participants prior to ultrasound imaging. The ADIM was used to measure core muscle thickness by ultrasound imaging. The participant was instructed to lie supine with knees flexed to 90° in the hook lying position for measures of the TrA and in the prone lying position for the LM measurement. This position was the starting and resting position. The participant was instructed to "breath in and then out and draw your belly button to your spine" to perform the contracted position [21]. Six ultrasound images were taken of TrA and LM each, three at resting and three contracted images. Resting muscle images was taken prior to contracted images. Participants were allowed to practice the ADIM three times with clinician feedback on proper form before imaging was collected [21]. A 10 second movie clip was also recorded during active glenohumeral flexion to 180 degrees to assess when the muscles "turned on" or initiated activation.

The intervention lasted 4 weeks with participants required to attend two yoga sessions per week. Each session lasted 30 minutes with 10 minutes of breathing, mediation, relaxation, stretching, and 20 minutes of yoga pose exercise. Questionnaires were distributed at the end of each session asking participants to subjectively describe how they were feeling, rate their muscle soreness and LBP levels on a scale from 0-10.

The yoga instructor was certified by the Yoga Alliance and had experience instructing individuals with LBP. The yoga style taught was Hatha yoga. The yoga poses were demonstrated and modified to the abilities of each individual to prevent injury (Appendix A). The instructor provided verbal feedback to the participants to assist them in achieving the postures with proper alignment, mechanics and breathing. The yoga series taught emphasized core activation and allowed participants to modify each pose as needed. A large emphasis was placed on using props for support and assistance in postures as needed. Twenty-four to ninety-six hours after the conclusion of the yoga intervention, participants reported to the athletic training facility for ultrasound imaging and completion of the ODI and VAS scores. The primary investigator who performed ultrasound imaging was not told of the participants' LBP status.

Session 1	Session 2
Centering / Dirgha Pranayama	Centering/Dirgha + Ujjayi
Torso Circles	Torso circles
Q Moon Stretches	Sun Breaths
Seated flowing twist	Window Wipers
Cat/Cow	Deer Flow with hold in twists
Wag tail	Cat/Cow
Child's pose	Down dog
Tadasana (Pelvis Neutral)	Standing forward fold
½ Sun Salutation	Ragdoll
Ragdoll Hold	Tadasana
Ardhachandrasana flow (half moon pose)	Standing forward fold with block (Co-contraction)
Lay down	Moonflowers
Knees to chest	Sunflowers
Lazy knee-down twist	Wide leg forward fold
Savasana	Hip rocking with wide legs
	Supported Bridge
	Knees to chest
	Savasana
Session 3	Session 4
Centering on back (option for reclining B angle) – connecting to earth	Centering
Pelvic rocking	Torso circles

Moving to bridge (lifting one vertebrae at a time, slowly building to full bridge, 5-8 breath hold, 3 breaths down to release)	Q moon stretches
Windshield wipers	Seated twists
Udarakarshanasana (3 mins per side) (supine T twist)	Seated knees to chest
Supine Bridge with Block to supported shoulder shand	Cat/Cow with hands behind knees
Knees to chest (option to rock)	Patdimothanasana (long seated forward fold)
Savasana (option to move to supported bridge)	Wide leg (compass prep)
	Cat/Cow
	Downward dog
	Chair with block
	Standing forward fold
	Table
	Savasana
Session 5	Session 6
Centering	Cobra/Spinal extension tutorial
Sun Salutation	Centering
Stating series (Warrior 1 à Warrior 2 à Reverse Warrier à Triangle)	Sun Salutation
Wide leg forward fold with hip rocking)	Standing series (Warrior 1 (with small backbend) à warrior 2 à reverse warrior à triangle)
Standing series on opposite side	Bound angle (engagement, and folding)
Tree	Udarakarshanasana (supine T twist)
Pigeon	Knees to chest
Udarakarshanasana (supine T twist)	Savasana
Savasana	
Session 7	Session 8
Centering – Standing	Centering
Sun salutations	Sun Salutations (5x)
Standing Series (both sides) (Lunge à reverse side angle à warrior 2 à triangle	Standing series (Lunge à Warrior 1 à warrior 2 à reverse warrior à triangle)
Repeat standing series in opposite order	Wide leg forward fold
Pigeon posture breakdown (option to come in from table or downward dog)	Repeat standing series on opposite side
Downward Dog	Tadasana
Plank Kriya	Standing series 2 (Lunge à reverse side angle à bound lunge with lizard modification)
Table	Repeat on opposite side
Bridge Flow	Moon flowers 5x
Supported Bridge	Sunflowers 5x
Supported Shoulder Stand	Yoga squat flow 5x
Knees to chest	Yoga squat hold for 5 breaths (option for crow)
Bent knee spinal twists (supine)	Tadasana
Happy Baby	Downward dog
Savasana	Eifel tower
	R knee to R elbow
	Float between hands
	R knee to L elbow
	Pigeon (option for twisted pigeon) – repeat on L
	Knees to chest
	Udarakarshanasana (Supine T-twist)
	Savasana

Appendix A: Yoga Postures Performed.

Data Reduction

A second investigator calculated the TrA and LM activation ratio by dividing the contracted muscle thickness by the resting muscle thickness. Use of the activation ratio standardizes the activation observed to the resting level and allows for comparison across participants [22].

The timing of activation was calculated by dividing the number of image frames that were collected over the 10-second interval. The frame where the TrA or LM started to contract was multiplied by the number of seconds each frame was collected at. This was the reported time that the muscle started contracting. The ultrasound software was used to convert the time of that frame into seconds [22]. The images were coded so that they did not indicate LBP status.

Statistical Analysis

Statistical analysis was performed using SPSS (IBM SPSS Statistics for Windows, version 21.0; IBM Corp, Armonk, NY). Separate 2 x 2 analysis of variances (ANOVA) were applied to compare muscle activation ratios and timing of activation between the healthy and LBP patients. Paired samples t-tests where used to assess differences in VAS and ODI scores between the LBP group. Alpha was set a priori at 0.05. Effect sizes were calculated by Cohen's d to be interpreted for meaningfulness and clinical significance.

Results

There were no significant differences between groups for TrA (p>.101) and LM (p>.437) timing and activation after 4 weeks of yoga. ODI was significantly different (p=.049), but the effect size confidence interval crossed zero (CI -0.55-0.94). VAS was not significantly different (p=.239), but the effect size was strong (0.87 (0.11-1.63)). Results are presented in Tables 2-4.

	ODI Baseline†	ODI Post-Int.†	Effect Size	VAS Baseline	VAS Post-Int.	Effect Size
LBP (n=14)	6.0 ± 3.8%	5.2 ± 4.1%	0.2 (weak) (CI -0.55-0.94)	13.0 ±12.7 mm	6.4 ± 7.6 mm	0.87 (strong) (CI 0.11-1.63)
Abbreviations: LBP: Low Back Pain; ODI: Oswestry Disability Index; VAS: Visual Analogue Pain Scale (mean ± SD); † ODI Pre-post significant difference (p=.049). VAS Pre-post difference (p=.239).						

Table 2: ODI and VAS Scores Following a 4-week Yoga Program Among LBP Participants.

	TrA Activation	TrA Activation	TrA Timing	TrA Timing
	Baseline	Post-Int.	Baseline	Post-Int
Healthy (n=10)	1.63 ± .28	1.45 ± .25	2.17 ± .41 s	2.05 ± .42 s
LBP (n=14)	1.80 ± .58	1.73 ± .47	2.25 ± .63 s	2.20 ± .52 s

Table 3: Transverse Abdominis Activation and Timing Following a 4-week Yoga Program.

	LM Activation	LM Activation	LM Timing	LM Timing
	Baseline	Post-Int.	Baseline	Post-Int.
Healthy (n=10)	1.08 ± .11	1.05 ± .03	2.11 ± .32 s	2.21 ± .30 s
LBP (n=14)	1.08 ± .09	1.07 ± .05	2.09 ± .52 s	2.26 ± .28 s
Abbreviations: TrA: Transversus Abdominis; LM: Lumbar Multifidus				

Table 4: Lumbar Multifidus Activation and Timing Following a 4-week Yoga Program.

Activation (mean ± SD) is the ratio of the muscle thickness change from a resting to a contracted position during the abdominal draw in maneuver and calculated as a contracted state/resting rate ratio

Timing was calculated as the point when the muscle began to contract when the arm was brought overhead after a three second wait period.

Discussion

This controlled laboratory study was conducted to evaluate the effectiveness of a 4-week yoga intervention on core musculature, pain and functional disability among healthy and LBP participants. In particular, we were interested in determining if and how yoga may be effective at improving LBP outcomes. The results found that participants with LBP experienced pain relief, but there was no changes found with functional disability, muscle activation and muscle timing. No serious adverse events were reported from the yoga sessions from any of the participants.

While the difference in ODI scores were significant, the effect size confidence interval crossed zero, and as such the change may not be meaningful. The average baseline ODI scores were less than 10%, indicating a population with minor disability. The minimal detectable change has been reported as 15-16% [23,24]. Since the average ODI scores at baseline were less than 10% and are below the minimal detectable change, this indicates that a change in the scores would not cause a significant difference in a clinical setting. A floor effect may have resulted, where there was not much room for improvement in scores.

Pain on the other hand, showed a strong effect size. Pain decreased by about half in our LBP participants. However, this should be taken with caution. The average baseline VAS scores were below 20mm (2 out of 10). Our population was not in considerable pain during the study and may not be generalizable to a more painful population.

Core muscle ultrasound imaging of the TrA and LM showed no significant changes over the 4-week intervention. Neural changes may have occurred causing an increase in muscle fiber recruitment. Short-term strength training increases the output of motor neurons to the targeted muscles of the training [25]. The neural transmission is altered by strength training through motor neurons controlling the muscles therefore facilitating undetectable strength changes [26]. Before force generation or muscle thickness is observed there needs to be more efficacy of the motor neural junctions (synapses) and more excitability of the motor neurons [25] which may have occurred in our study. More time may have been needed for the body to adapt to the neural changes and increase muscle thickness.

Adherence to the yoga intervention was excellent at 96% with all but one participant completing the minimum of 7 of the 8 classes conducted (68% completed all 8 sessions). The high attendance rate to each of the eight sessions may be attributed to the sense of community that was developed over the 4 weeks among participants. Slade et al [27]. demonstrated that individuals are more likely to engage in exercise programs and activity that consider their fitness levels, health status and exercise experi-

ence. The yoga classes in this study were beginner level targeted to participants who never performed yoga before and was tailored to participants having LBP. This may be the reason we saw an increased adherence to the yoga intervention. The yoga classes were instructed in a group setting, which afforded participants to become familiar with each other and to the instructor of the class. The small class size and intimate and personal setting was conducive for participants to develop a sense of accountability, which increased adherence to participation. Participants were able to gain socialization and support from the group intervention providing them a positive experience to manage their LBP.

Prior yoga studies for LBP have used a variety of yoga styles. The use of hatha yoga is the most common practiced type for LBP in real-world environments, as well as therapeutic setting [28]. Our study was conducted at the discretion of the yoga instructor to mimic everyday yoga classes addressing the needs of the participants. In this case the classes had a LBP treatment focus using a passive hatha yoga style initially then progressed the class to become more active style of yoga, with one breath associated to each movement, if the participants were responding well. The yoga teacher began the 4-week intervention with two weeks (4 sessions) of gentle hatha yoga to introduce the first-time participants to the foundations of yoga including posture, breathing, mobility, stretching, core engagement, relaxation and listening to one's body. The last two weeks (4 sessions) were more active yoga classes incorporating standing postures and sun salutations linking one breath to one movement. Currently there has been no research to suggest one type of yoga is more effective than another for providing relief of LBP. The yoga sessions involved total body activity and not isolated core muscle training. All of yoga postures performed were instructed the focus on correct posture and alignment and participants were not specifically cued to activate their core muscles during all poses. The lack of repetitive cueing to activate the TrA and LM or use of specific core muscle exercises may explain the lack of change observed in the TrA and LM muscles.

A unique aspect of this study was the use of ultrasound imaging to examine the core musculature of the TrA and LM to see if we could provide reasoning to why participants may be seeing improvements in their LBP symptoms and daily functioning. A potential limitation to the lack of change seen in the musculature or effect on outcome measures was that the classes were only 30 minutes in total. The 30-minute classes included a mindfulness and breathing warm-up for 5 minutes and resting corpse pose called savasana, used for relaxation and meditation, at the end of each session for 5 minutes allowing for approximately 20 minutes of yoga postures including instructional demonstrations. The short duration of the classes may have influenced the inactivity of the core to not show any significant changes in the timing or activation of the musculature. Ward, et al. [28] found large variation in frequency and duration of yoga classes from 40 to 120 minutes with the average being 75 minutes and the frequency being 1 to 6 times per week. Higher frequencies of classes were reported with shorter duration of 60 minutes or less. It was most common for yoga classes to be conducted one time per week in most intervention protocols [28]. Duration of the yoga intervention varied from 2 weeks to 24 weeks with the most common being 12 weeks, occurring in 5 studies [3,29-32]. This suggests that a longer duration study may be required to see benefits on core musculature and outcome measures.

Research conducted has demonstrated that individuals with LBP possess a delay in core activation of the TrA and LM that may lead to spinal instability. In the participants of this study a delayed timing of activation was not observed in the LBP group which may be explained by the age of the target population and the low-grade LBP that they were experiencing. The ODI scores were (6.02 ± 3.83%) placing them in the minimal disability category allowing them to go about daily activities where no treatment or conservative treatment can be used. The LBP baseline scores on the ODI and VAS indicated that the symptomatic participants did not experience LBP to a severe enough level to cause large alterations in their daily activities to be reflected in their subjective measures. Utilizing a young population did not demonstrate differences either, however in future studies a more functionally disabled population would be recommended.

We may compare the results of this study to the 6-week study by Galantino et al [12]. who had 22 participants undergo 60-minute hatha yoga classes twice weekly. This study was similar to our study however was two-weeks longer and focused only on hatha yoga. Galantino et al [12]. found no statistical significance in their ODI ($p=0.170$) or flexibility measures ($p=.534$) between the control and intervention groups. They did find that the depression outcome (Beck Depression Inventory) improved significantly ($p=.008$). Their improvements in the ODI score were from 24.98% to 21.15% among the yoga group ($n=11$) showing that their LBP group was more symptomatic then the participants in our study ($n=14$) whose ODI scores decreased 6.0% to 5.2%.

Some limitations that may have affected the results of our study could have been the small sample size of 25 participants, where only half had LBP. The youthful age of the participants in our study was the target to see if LBP could be intervened from a younger age as a prevention tool for re-occurrence. All previous literature utilized adults older than our target age range, in their mid-40's [12,30-33]. Also, the location of the yoga classes (off campus) and the timing of the yoga class (middle of the day at 11:30am) may have limited the number of participants able to participate.

Future studies should examine flexibility measures as well as psychological outcomes regarding depression (Beck depression inventory), mood or journaling (best part of the experience, look

forward to most about yoga, difficult thing to be involved with the group, impact of the instructor) to provide a more comprehensive examination of the effects of yoga. The intervention should be of longer duration and the follow-up periods should be extended to see the long-term effects if LBP returned or was prevented among the affected participants. The outcome measures for future studies should examine all dimensions of health surrounding LBP addressing the mind, body and spirit that is affected by LBP.

Conclusion

This controlled laboratory study, despite its limitations, demonstrated promising results for a 4-week yoga intervention for individuals with LBP. It provides potential for long-term effects on core musculature to be examined alongside LBP outcomes to prevent recurrence if timing and activation can be improved. Future studies should examine all dimensions of human wellness, including mind, body and spirit. Group exercise has demonstrated success through a strong adherence when all individuals were beginners to yoga, and the classes were targeted for younger individuals with LBP. The improvements in the report of subjective pain should support more studies to examine the objective reasons for yoga effectiveness, and be included as a complimentary method to traditional exercise or physical therapy treatment.

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