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Upper extremity strength and motor speed in children with visual impairment following a 16-week yoga training program

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Abstract.
BACKGROUND: Yoga's benefits on various aspects of health for sighted children is substantially supported by the literature. This study aimed to extend those fidings to children with visual impairment.
OBJECTIVE: The aim of the study was to measure changes in upper extremity strength and motor speed in children with visual impairment following 16-weeks of yoga training.
METHODS: This was a two arm pre post, single blind, waitlist-controlled study. Eighty-three (yoga [$n = 41$], control [$n = 42$]) participants (aged 9–16 years) enrolled, 6 dropped out from the trial. Demographic characteristics were not significantly different between the two groups. The following variables: upper extremity muscle strength; elbow flexion and elbow extension, pinch strength and motor speed were evaluated bilaterally using a handheld dynamometer, pinch dynamometer and finger tapping board respectively at baseline and after the 16-week intervention. SPSS-20 was used for statistical analysis.
RESULTS: Significant improvements in all variables ($P < 0.05$) were observed in the yoga group for both limbs but no significant changes were observed in the control group.
CONCLUSION: The study suggests that yoga may be considered an effective option to improve muscle strength and motor function in children with visual impairment.

Keywords: Muscles strength, motor speed, visual impairment, children, yoga

1. Introduction

Physical activity plays a vital role in maintaining muscle strength, an imperative predictor of function, mobility, independence and activities of daily living (ADL). Individuals with visual impairment (VI) spend a relatively low percentage of the day physically active, usually of insufficient duration and intensity to improve overall health status [1]. Various aspects of fitness are significantly lower in children with VI compared to their age-matched sighted peers [2–7] which is associated with their loss of independence. To perform their ADL the VI are usually dependent on caregivers or assistants [8] thus incurring additional expenditure.

The upper extremities are essential for the performance of many important tasks and also most ADL; dressing, writing, combing, and most housework. Their strength, endurance and coordination are essential components of motor speed [9], an important measure of both cognitive and physical function [10]. The upper extremities are commonly used for tasks such as reaching and grabbing, which may involve multiple coordinated steps of precise motor control [11]. Enhancing upper extremity strength can therefore play an important role in improving daily

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activity. Various studies have demonstrated deficiencies in upper extremity strength in individuals with VI [12,13], but only limited effort has been given to develop rehabilitative interventions aimed at their specific needs. Strategies to improve upper extremity functions would play vital roles in keeping those with VI active and independent throughout their lives.

Yoga, a traditional Indian approach to right living, promotes human health holistically which has increasingly been gaining popularity in western countries [14]. It may generally be described as a practice which integrates four elements: postures, breath control, meditation, and relaxation. It may be regarded as a muscle strengthening and conditioning exercise program [15], better than exercise at improving a variety of health-related measures [16]. A growing number of studies provide good evidence that yoga can lead to improvement in musculoskeletal strength [17–20] and finger tapping speed, a common assessment of motor function [21–23]. Yoga's positive effects on autonomic arousal [24], balance [25], and proprioception [26] in individuals with VI are well-documented, but on muscle strength and motor speed have not been reported on similar populations. To fill these gaps, we assessed upper extremity strength and motor speed in children with VI following a specific yoga intervention for 16-weeks, designed to meet the requirements of our participants, in consultation with a panel of five independent yoga experts.

2. Methods

2.1. Participants

Eighty three children with VI aged 9–16 years were enrolled by convenience sampling from the Ramana Maharishi Academy for the Blind (residential school) in Bangalore, South India. They were divided into two groups: yoga ($n = 41$), and control ($n = 42$). All were in good general health, independent in walking, able to communicate and follow testing procedures. They had right hand dominance, assessed using the Edinburgh handedness inventory [27].

Approval for the research was obtained from the SVYASA's Institutional Ethics Committee in accordance with the Declaration of Helsinki, and reviewed by Institutional Review Board. Written informed consent was obtained from the school administration, parents or guardians and each participant after explaining the experimental procedure in detail.

2.2. Inclusion criteria

Participants, who had (a) Congenital blindness (b) Visual acuity less than 20/200, field of vision limited to 20° (legally blind) [28] (c) aged 9 to 16 years (d) able to understand both English and the regional Indian language (Kannada) (e) no prior exposure to yoga, and (f) agreed to provide written informed consent, were included in the study.

2.3. Exclusion criteria

Children with (a) left hand dominance (b) multiple impairments, (c) any injury restricting practice of yoga, (d) and deformity in the upper extremities, (d) and deficit in other sensory systems, (e) additional physical disabilities were excluded from the study.

2.4. Design

This was a nonrandomised, single-blind, waitlist control trial, with the two groups matched on age, gender, height, weight and degree of blindness. Both groups were assessed at baseline and after 16 weeks. The yoga group participated in one hour of yoga practice, five days per week, while the control group spent the same amount of time in ostensibly comparable activities, learning dance, preparing hardboard, or playing games.

2.5. Intervention

The yoga program was conducted by an experienced yoga trainer with more than four years of yoga teaching experience to children with VI with the help of two other certified yoga instructors. For better learning, the yoga group ($n = 41$) was divided into four subgroups of 10 or 11 students each. Classes were conducted separately for each group in different sessions of 60 min duration. The program lasted 16 weeks and the practices are listed in Table 1. All participants were provided with paper cut-out models of some yoga postures to give them an idea about the same through touch and feel method. Audio cassettes with detailed instructions of all practices were also given. Individual care was taken to ensure that they could understand, feel and perform each practice accurately.

Control group participants were requested to maintain their routine activities and not to begin yoga or any mind-body program during the course of the study. At the end of the training period, they received the yoga program.

Table 1
List of yoga practices

Type of practice	Duration	Name of the practices
Breathing Practices	5 mins	Hands in and out breathing
		Ankle stretch breathing
		Sasankasana breathing
		Tiger breathing
Loosening Practices	10 mins	Jogging and Jumping
		Forward & backward bending
		Twisting
		Surya Namaskar (Sun salutation)(12 rounds)
Yogasanas	20 mins	
Standing-Asanas		Ardhakati Cakrasana (Half waist sliding pose)
		Ardha Cakrasana (Half wheel bend pose)
		Padahastasana (Hand to foot pose)
		Trikonasana (Triangle pose)
		Parivritta Trikonasana (Twisted triangle pose)
Sitting-Asanas		Vajrasana (Thunderbolt pose)
		Paschimottanasana (Back stretching pose)
		Ustrasana (Camel pose)
		Vakrasana (Half spinal twist)
Prone-Asanas		Bhujangasana (Cobra pose)
		Salabhasana (Locust pose)
		Dhanurasana (Bow pose)
		Makarasana (Crocodile pose)
Supine-Asanas		Sarvangasana (Shoulder stand pose)
		Halasana (Plough pose)
		Matsyasana (Fish pose)
Pranayama	15 mins	Kapalabhati (Frontal brain cleansing)
		Vibhagiya pranayama (Sectional breathing)
		Nadisuddhi pranayama (Alternate nostril breathing)
		Bhramari pranayama (Humming bee breathing)
Relaxation/Dharana & Dhyana	15 mins	Instant, Quick, and Deep Relaxation Techniques/ Nada-anusandhana
		A+U+M Chanting (each 9 rounds)
Total	60 mins	

2.6. *Assessments*

2.6.1. *Anthropometric measures*

The participants were instructed to stand in upright position in light clothes with bare feet. Height was measured to the nearest centimetre using a non-stretchable measuring tape (Gilick Anthropometric tape60" Model J00305, Lafayette Instrument, USA). The weight and Body Mass Index (BMI) were taken using In Body R20 composition analyzer (Gymcompany). The physical and functional assessment of the upper limb with inspection, palpation and active movement to check the integrity of the musculoskeletal and neuro-functional system was carried out before commencement of the test.

2.6.2. *Upper extremity muscle strength*

Elbow muscle strength

The maximum isometric muscle strengths (peak force, in kg) of the Elbow Flexion (EF) and Elbow Extension (EE) were measured bilaterally using the Lafayette Manual Muscle Test System (Model 01165, Lafayette Instrument Company, Indiana, USA) with standardized measurement procedures [29] and dynamometer placements [30]. Participants were instructed to pull or push against the device as firmly as they could in each direction, as the investigator counteracted that force for 5 seconds per trial. The instrument was calibrated before each participant was tested. Three consecutive trials were conducted, with a 10 seconds rest between trials. Maximum peak force of the three trials was recorded for analysis.

2.6.3. *Pinch strength (PS)*

PS was assessed bilaterally, using Jamar hydraulic hand and pinch dynamometers (Lafayette Instruments, Model No. J00111, Indiana, USA). During the evaluation, participants were seated in a chair without armrests, feet resting fully on the ground and hips against the back of the chair. The arm remained parallel to the body, shoulder adducted, elbow flexed at 90° and forearm in neutral position, wrist between 0° and 30° of

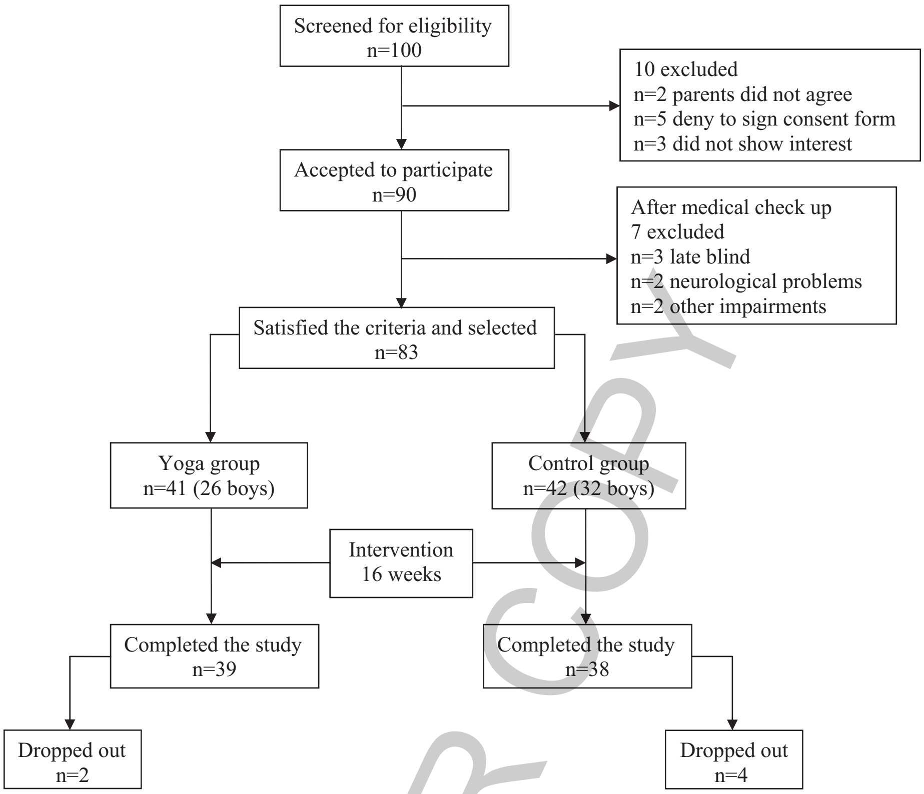

Fig. 1. Trial profile of the study.

extension and 0° to 15° of ulnar deviation. This position has demonstrated the highest reliability coefficients [31]. Three consecutive measurements of each hand (total 6 trials) were performed for PS, alternating between the dominant and non-dominant sides, with minimum intervals of 30 sec between them to avoid muscle fatigue. Maximum values obtained from the three trials were recorded for statistical analysis. Pre and post measurements were made by the same examiner.

2.6.4. *Finger Tapping Test (FTT)*

The FTT is a neuropsychological test that assesses motor speed and motor control [32]. It was measured using an apparatus consisting of an 18 inch fiber-resin board with two rectangular metal plates on either end, 11 inches apart (Lafayette Instruments, Model No. 32012, Indiana, USA). The apparatus has a metal stylus connected to it, and contacts between the stylus and the two metal plates are registered on an impulse counter.

The instrument was fixed to an adjustable-height flat table positioned at the midline and waist level. Participants were instructed to use their right hand to hold the stylus as a pen is held and tap on the steel plate using index finger (not the whole hand or wrist) which was on the right side of the board, and to use their left hand for the board on the left side. After being familiarized with the conditions with one practice trial, they were instructed to tap as rapidly as possible for 10 sec for five consecutive trials in each hand alternatively [32]. Average scores of the 5 trials were used in the analysis, for each hand.

Participants were given an opportunity to become comfortable with the tasks before commencing the final test. They were provided the trail sessions for each test until they became familiar to the process. Verbal instruction and tactile modelling were used to help them. For accurate testing, it was important for the participants to understand the protocol fully.

2.7. *Statistical analysis*

SPSS 20.0 software (IBM Corporation, USA) was used to analyze the data. Continuous variables were reported as mean ± standard deviation (SD) and categorical variables were reported as number and percentage. Paired samples t-test was used for within-group com-

Table 2
Demographic characteristics

Variables		Yoga ($n = 39$)	Control ($n = 38$)	P-value
Gender	Male	24 (61.5)*	30 (78.9)*	$P = 0.095$
	Female	15 (38.5)*	8 (21.1)*	
Degree of blindness	Total	31 (79.5)*	29 (76.3)*	$P = 0.737$
	Light perception	8 (20.5)*	9 (23.7)*	
Age (years)		12.21 ± 1.90**	13.08 ± 2.13**	$P = 0.061$
Height (cm)		144.51 ± 12.38**	149.50 ± 14.22**	$P = 0.105$
Weight (kg)		34.51 ± 12.43**	40.03 ± 14.67**	$P = 0.079$
Body mass index (kg/m^2)		16.67 ± 3.49**	17.33 ± 4.17**	$P = 0.450$

*n (%), chi square test and **Mean ± SD, independent t' test.

Table 3
Comparative changes in outcome variables for yoga and control groups

Variables	Group	Pre	Post	Post-Pre	% Change
EF_RH	Yoga	6.08 ± 0.77	6.43 ± 0.53***	0.35^a	5.76
	Control	6.26 ± 0.76	6.08 ± 0.51	−0.18	−2.88
EE_RH	Yoga	4.94 ± 0.94	5.95 ± 0.77***	1.01^a	20.45
	Control	5.41 ± 1.13	5.62 ± 0.88	0.21	3.88
EF_LH	Yoga	6.00 ± 0.68	6.36 ± 0.54***	0.36^b	6.00
	Control	6.07 ± 0.83	6.13 ± 0.59	0.06	0.99
EE_LH	Yoga	4.64 ± 0.95	5.75 ± 0.80***	1.11^a	23.92
	Control	5.31 ± 1.31	5.59 ± 0.89	0.28	5.27
PS_RH	Yoga	2.62 ± 1.00	3.64 ± 1.01***	1.02^a	38.93
	Control	3.17 ± 1.09	3.11 ± 1.16	−0.06	−1.89
PS_LH	Yoga	2.44 ± 1.10	3.00 ± 1.03***	0.56^b	22.95
	Control	2.92 ± 1.12	3.01 ± 1.13	0.09	3.08
FTT_RH	Yoga	56.35 ± 9.63	61.93 ± 6.55***	5.58^b	9.90
	Control	60.57 ± 9.06	61.02 ± 6.64	0.45	0.74
FTT_LH	Yoga	52.32 ± 9.22	56.76 ± 5.73***	4.44^c	8.49
	Control	54.84 ± 9.25	55.65 ± 6.71	0.81	1.48

Legend: LH = Left Hand; RH = Right Hand; EF = Elbow Flextion; EE = Elbow Extention; PS = Pinch Strength; FTT = Finger Tapping Test. $^{***}P < 0.001$ within pre and post comparisons (paired t test) $^aP < 0.05$, $^bP < 0.01$, $^cP < 0.001$, change in mean difference comparison between groups (ANOVA, group time interaction).

parison. Repeated measures ANOVA (time x group) were used to determine significant differences relative to the intervention. The significance level was fixed at $P < 0.05$ for all studied variables.

3. Results

Of the eighty three participants enrolled, 77 participants completed the trial (Fig. 1). Demographic characteristics of the two groups are presented in Table 2. Baseline characteristics were similar in both yoga and control group. There was no significant difference between the two groups ($P > 0.05$).

Results of paired t-test assessing within group pre to post intervention changes are given in Table 3. EF; left hand ($P < 0.001$), right hand ($P = 0.001$) and EE; left hand ($P < 0.001$), right hand ($P < 0.001$), PS; left hand ($P < 0.001$), right hand ($P < 0.001$) and FTT; left hand ($P < 0.001$), right hand ($P < 0.001$) significantly increased in the yoga group. In contrast, the control group did not demonstrate any significant within group changes or trends.

Repeated measures ANOVA (time x group) interaction found that there was significant differences in pre-to-post intervention for all variables EF; left hand ($P = 0.002$), right hand ($P < 0.001$) and EE; left hand ($P < 0.001$), right hand ($P < 0.001$), PS; left hand ($P = 0.002$), right hand ($P < 0.001$) and Finger tapping; left hand ($P = 0.004$), right hand ($P = 0.035$).

4. Discussion

The yoga group showed greater improvement in muscle strength and motor speed compared to the control group, confirming the research hypothesis. Details are as follows.

The upper extremity strength was evaluated bilaterally through PS and elbow strength in two different positions; flexion and extension. No other study has been published using these variables to compare upper extremity strength in children with VI. Limited interventional studies on children with VI have shown that some practices; goal ball [33,34], motor training program [35], rope jumping [36], and indoor rowing exercise [37] have shown positive improvement in upper extremity strength. In support of these, our results demonstrate significant improvements in PS for both hands in children who practiced yoga compared to controls, who continued normal daily activities. As an alternative to hand grip strength (HGS) for assessing muscle strength [38], PS may provide a comparison with these studies. Our results are in accordance with previous studies that found yoga significantly improved HGS in normal children [20,39]. This is in contrast to a previous yoga study [40] which did not find significant improvement in HGS in children aged 8–13 years following a three month yoga program. This disparity can be attributed to many factors, including differences between intervention and population characteristics.

The current study found that yoga increased muscle strength bilaterally for both EF and EE in children with VI, while the control group did not show any improvement. Few studies exist concerning the use of physical activity as training protocols for individuals with VI, though those differ on the basis of intervention used and variables assessed, with the present study. A study on goal ball players with varying degrees of VI reported that upper limb EF and EE is superior in them after 6 hours per week training compared with non-goal ball players [33]. In contrast similar goal ball training did not yield improvements in the shoulder-stretch test [34].

The mechanisms by which yoga provides beneficial effects on muscular strength still need to be determined. Suryanamaskar, combination of 12 different postures stimulates skeletal muscles during isometric contraction, which may have helped to achieve optimal intensity to increase muscular strength [20]. In addition, yoga practice helps maintain proper posture and spinal alignment, which also exerts beneficial effects on muscular strength. Moreover, yoga practices improve flexibility, which can improve efficiency of muscles.

The FTT is a common assessment of motor speed. The yoga group increased finger taping speed in both hands, while no improvement was observed in the control group, which tends to rule out the possibility that the increase was due to a practice effect. Previously yoga practice has been observed to result in improved tapping speed in healthy volunteers [22], male participants [23] and in those using computers for more than 5 hours per day [21]. Motor speed depends on muscle strength, endurance and co-ordination [9]. Despite possible limitations in interpreting our findings, the yoga group's improvement suggests that yoga practice may improve muscle tone, enhancing muscle function generally and reducing muscle fatigue.

Although some participants found difficulty with certain yoga postures at the beginning of the intervention, class attendance was consistently high. No adverse events were reported. Therefore, our results suggest that yoga may offer an effective, safe alternative training modality for health enhancements in children with VI.

The study has a few notable strengths: participants were very willing to volunteer for the study; they remained highly motivated throughout, missing no classes. Also, to the best of our knowledge, this is the first time upper extremity strength and motor speed have been evaluated before and after a yoga intervention for children in the VI population.

The study's limitations include lack of randomization, which may have led to selection bias and confounding factors between groups decreasing comparability. Generalization of its outcomes may be limited as the study group were residential students enrolled in a special educational institution for children who are VI.

5. Conclusion

Results of this study revealed that a 16 week yoga program can produce beneficial changes in upper extremity muscular strength and motor speed for children with VI. High attendance rates and encouraging results mean that yoga programs could be implemented in all schools for visually challenged children to improve their fitness levels. Further investigation with longer follow-up (e.g., 6 months) for different age groups, including adults young and old with VI should be considered. Such programs would offer insights into long-term benefits of yoga practice.

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Conflict of interest

The authors declared no conflicts of interest.

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