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Effect of yoga program on executive functions of adolescents dwelling in an orphan home: A randomized controlled study

Satya Prakash Purohit*, Balaram Pradhan [a]

Division of Yoga and Humanities, SVYASA Yoga University, #19, Eknath Bhavan, Gavipuram Circle, 560 019, Bengaluru, India

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ABSTRACT

Executive function (EF) is important for physical and mental health of children. Studies have shown that children with poverty and early life stress have reduced EF. The aim of the study was to evaluate the effect of Yoga program on the EF of orphan adolescents. Seventy two apparently healthy orphan adolescents randomized and allocated into two groups as Yoga group (n = 40; 14 girls, age = 12.69 ± 1.35 yrs) and Wait List Control (WLC) group (n = 32, 13 girls, age = 12.58 ± 1.52 yrs). Yoga group underwent three months of Yoga program in a schedule of 90 min per day, four days per week whereas the WLC group followed the routine activities. They were assessed by Stroop Color-Word Task, Digit Symbol Substitution Test (DSST), Digits Span Test and Trial Making Test (TMT) at the beginning and end of the program.

The repeated measures ANOVA showed significant difference in time and group interactions ($p < 0.05$) for all subtests of Stroop Color-Word Task and Digit Span Test and part-A of TMT whereas there were no significant difference found in DSST and TMT (part-B).

The post-hoc test with Bonferroni adjustment also showed significant improvements ($p < 0.001$) within the Yoga group in all test scores while in wrong score of DSST did not exhibit significant reduction. Whereas the WLC group, showed significant improvement ($p < 0.05$) in Stroop Color, Color-Word score, net score of DSST, Digit Span forward and Digit Span Total.

Three months Yoga program was found useful for the young orphan adolescents in improving their executive functions.

1. Introduction

Globally two hundred million children failed to reach their potential in cognitive development because of interrelated factors like poverty, inadequate care and poor health.[1] Orphans are among such disadvantaged children living in the community with poverty, severe grief and easily subjected to abuse, negligence and exploitation.[2] Prevalence of orphans was 143 million worldwide,[3] 72 million in South and East Asia,[4] and 20 million in India.[5]

Adverse childhood events have a negative effect on latter life cognitive performance.[6] Socio-economic conditions of one's early life or childhood are positively correlated with intelligence, academic achievement and other developmental outcomes in later life.[7,8] Previous studies with older Post Institutionalization (PI) children have shown reduced performance on cognitive flexibility,[9] working memory performance,[9–11] and inhibitory control.[11–13] It is also reported that PI children have attention deficits and hyperactivity symptoms, which persist into adolescence.[14,15]

The higher order of cognitive processes, such as cognitive flexibility, working memory, and inhibition control which allow individuals to engage in planning, to be conscious and goal-directed problem solving are called Executive Function (EF).[16,17] In children, EF is related to emotion regulation,[18] conscience and moral development,[19] also math and literacy ability.[20] EF is very important factor for physical and mental health,[21] making friendship,[22] and for success in school.[23,24] Furthermore EF predicts school readiness,[20] later academic performance.[25] Developments in such cognitive functions are important in early life because deficiency in these functions caused at childhood predict similar problems in the

* Corresponding author. Tel.: +91 080 2263 9961, +91 7676745174 (mobile).
E-mail addresses: purohit.satya@gmail.com (S.P. Purohit), balaramp13@gmail.com (B. Pradhan).

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[a] Tel.: +91 080 2263 9961, +91 9483711185(mobile).

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later years.[21,26] It is believed that the higher order cognitive functions may play an important role in balancing emotional arousal, cognitive processing,[27] and reducing the impact of adverse circumstances.[28]

Various activities are suggested to improve children's EF. The best evidences exist are computer based training programs for enhancing memory and reasoning,[29,30] task-switching computer-based training,[31] traditional martial arts,[32] aerobics,[33] and Yoga.[34] Yoga is an ancient Indian science and the way of life which includes practice of specific postures, breathing regulation, and meditation.[35] Earlier studies on Yoga including physical postures, Yogic breathing, meditation and guided relaxation technique have been shown its efficacy in improving delayed recall of spatial information and verbal memory,[36] in reducing planning and execution time,[34] and cognitive processes[37] in adults. It is also proved that there was an improvement in cognitive performance of 7–9 year-old school children from a socioeconomically disadvantaged background in South India after three months of Yoga.[38] Yogic life style has also a positive impact in planning ability.[39] There is also evidence of the positive impact of Yoga on cognitive functions in children with attention deficit and hyperactive disorder.[40–43] In addition, Yoga is an effective method to improve various cognitive functions of remote memory, mental balance, attention, concentration, attention span, processing speed, attention alternation ability, delayed and immediate recall, executive functions, verbal retention, and recognition tests in healthy young subjects.[44,45]

However, recent reviews stated that most of the Yoga studies on children were open, unblinded, small sample sizes, short interventions. Also many of the randomized studies have not mentioned the process of randomization or have used inappropriate statistical analysis.[46,47] Thus, understanding the effect of Yoga on cognitive functions of orphans may be necessary in providing avenues for promoting the mental strength to overcome various tragedies in their upcoming life. In sum, the present study was intended to evaluate the effect of Yoga on cognitive performances of young orphan adolescents.

2. Material and methods

2.1. Participants

Out of 135 registrants, 80 were chosen for the study based on the inclusion and exclusion criteria. Children were eligible for inclusion by following criteria: a) orphan(s) of any type, b) aged between 11 and 16 years, c) boys and girls, d) apparently healthy without any chronic illness, physical, or mentally handicap. The study was conducted between September 2014 and November 2014 in an orphanage, within a suburban area of Bangalore.

2.2. Ethical clearance

The study was approved (RES/IEC-SVYASA/32/204) by the Institutional Ethics Committee of SVYASA (Swami Vivekananda Yoga Anusandhana Samsthana) University. Both signed informed consent from the institution head and signed informed assent from all participants were obtained, upon explaining the study details.

2.3. Design

It was a randomized wait-list controlled pre-post study. After the initial process of screening, participants were randomized by a statistician using a random number table from www.randomizer.org and assigned into two groups: Yoga group and Wait List Control (WLC) group. The Yoga group underwent the Yoga program for 3-months whereas the WLC group underwent routine activity.

2.4. Blinding

The statistician (who did the randomization and analyzed the data) and the researchers (who carried out the allocation & assessments) were blinded.

2.5. Intervention

The Yoga group received a combined approach of Yoga activities of 90 min, 4 days per week, for 3-months. Later the same intervention was served to WLC for the same duration. The Yoga program was conducted by two certified Yoga teachers from SVYASA (one with a master's degree in Yoga and other with a post-graduation diploma in Yoga therapy). The principle and concept of an integrated approach of the Yoga program was based on the research works of SVYASA.[48] The details of the intervention (Yoga program) are given in Table 1.

2.6. Assessments

The socio-demographic data was collected from the office of the orphan home as it was collected as a routine documentation by them. The final demographic data after post assessment in Yoga group was taken on 40 participants where the males were 14(35%), female were 26(65%), whereas in WLC male were 13 (40.6%), female were 19 (59.4%) out of 32 participants. The cognitive functions tests (Table 2) were collected by the research staffs of SVYASA during the prior and following weeks adjacent to the intervention period for all recruited participants. The investigators were available to clear all possible doubts and provide unbiased guidance during the assessment. There were four executive function tests, included in the study, as detailed below.

2.6.1. Stroop color and word test[49]

The children's version Stroop test measures the EF, which involves in both word and color naming responses. The test was in the form of a booklet containing three pages of word and color conditions. The first page tests how fast the participant can read words; name the colors in the second page; name which color the words were printed in, ignoring the name of the word in the third page. The test extracts three basic scores, namely Stroop Word (STROOP_W) score, Stroop Color (STROOP_C) score and Stroop Color-Word (STROOP_CW) score. The task was administered individually and test instructions were explained before starting the test. Errors of the participants were indicated and asked to be corrected by the examiner before continuing. The participants were given 45 s for each page and the time taken to complete the task was recorded by using a stop watch.

2.6.2. Trial making test (TMT)[50]

This test was used to access the visual search, scanning, processing speed, mental flexibility, and EF. It has two parts, part-A (TMT_A) and part-B (TMT_B). In TMT_A, participants have to draw lines sequentially connecting 25 encircled numbers distributed on a sheet of paper; And in TMT_B the task is similar except the participant must alternate the sequence between numbers and letters (e.g. 1, A, 2, B, 3, C, etc.). The score on each part represents the amount of time required to complete the task. Participants were administered part A and B of the TMT and Total time in seconds for both part A and B was recorded.

2.6.3. Wechsler intelligence scale for children[51]

It was used in order to assess working memory and mental tracking processes. Both forward and backward spans were

Table 1
List of practices in the yoga program.

Order no.	Intervention components	No. of rounds	Approx. time (Total 90 min)	Schedule
1	Yogic prayer, Session on basic concepts of yoga and instructions for the class		10 min	4 days/week (Wednesday, Thursday, Saturday and Sunday)
2	**Preparatory practices:** a) Warm up: jogging, jumping, hopping, forward & backward bending, side bending, twisting b) Loosening: for toes, ankle, knee, hips, fingers, wrist, elbow and neck c) Stretching with breathing exercises: hands in and out, hands stretch, ankle stretch, hip stretch, backstretch, tiger stretch (spinal ups- down), supine straight leg raising, cycling, lumber stretch, rocking and rolling	One each	10 min	4 days/week (Wednesday, Thursday, Saturday and Sunday)
3	**Sun salutation** (*Suryanamaskar*)	10–12	10 min	4 days/week (Wednesday, Thursday, Saturday and Sunday)
4	**Asana** (Postures): A. Standing postures a) Half waist rotation posture (*Ardhakati Chakrasana*) b) Foot palm posture (*Padahastasan*) c) Half wheel posture *(Ardha chakrasana*) d) Triangle posture (*Trikonasana*) e) Tree posture (*Vrikshana*) f) Eagle posture (*Gasudasana*) B. Sitting postures a) Diamond (*Vajrasana*) b) Rabbit posture (Shasahankasana) c) Sleeping diamond posture (*Suptavajrasana*) d) Camel posture (*Ustrasana*) e) Posterior stretch (*Paschimotasana*) f) Spinal twist posture (*Ardhamatsyendrasana*) g) Cow face posture (*Gomukhasana*) C. Prone posture: a) Cobra posture (*Bhujangasana*) b) Grasshopper posture (*Salabhasana*) c) Bow posture (*Dhanurasana*) d) Shoulder stand (*Sarvangasana*) e) Plow posture (*Halasana*) D. Supine postures a) Fish posture (*Matsyasana*) b) Boat posture (*Naukasana*)	1 each	20 min (around 1 min each posture)	4 days/week (Wednesday, Thursday, Saturday and Sunday)
5	Deep relaxation technique (DRT)	1	10 min	4 days/week (Wednesday, Thursday, Saturday and Sunday)
6	**Pranayama (voluntary regulation of breath)**: a) Breathing with forceful exhalation with passive inhalation (*Kapalabhati*-3 types) b) Breathing with rapid inhalation & exhalation (*Bhastrika*) c) Slow & rhythmic alternate nostril breathing (*Nadisodhana*) d) Exhalation, with a honey bee sound (*Bharamari*) e) *Ujjayi* (Hissing in thought while exhaling)	1 each	15 min	4 days (Wednesday, Thursday, Saturday and Sunday)
7	**Concentration Techniques:** a) Eye exercises (*Netra shakti vikasana*) b) Practice to improve collective motivation (*Dhruti shakti vikashaka*) c) Activity to improve intellect (*Dhi shakti vikasaka*) d) *Trataka* e) Palming	1 each	15 min	2 days/week (Wednesday and Saturday)
8	**Yogic games** (games for memory, awareness and creativity)		15 min	2 days/week (Thursday and Sunday)

calculated. For Digits Span Forward (DS_F), the participant was supposed to repeat digits of the strings exactly as read by the examiner. Two trials were administered of each string length. In Digits Span Backward (DS_B), the procedures are identical to DS_F except that the participant was required to repeat the string of digits in a reverse order. Scoring for each correctly reproduce digit span was scored as “one” and otherwise as “zero”. The total score (DS_T) was calculated in addition of the DS_F and DS_B scores.

2.6.4. Digit Symbol Substitution Test (DSST)[51]

DSST was used in order to access various cognitive components as scanning, matching, switching, and writing operations which are reflective of several higher cognitive functions such as perception, encoding and retrieval processes, transformation of information stored in active memory and decision making.[52] It has a worksheet with a specified row of six different symbols matched with six different digits with pairs, which were to be canceled and had a working section consisting of different pairs arrange randomly in 22 rows and 14 columns. Participants were asked to cancel the correct pairs as much as possible in 90 s with any possible strategy. The total number of canceled pairs in the test (DSST_T), wrong targets (DSST_W) and net scores (DSST_N) (total attempted-wrongly attempted) was calculated for the analysis.

2.7. Data analysis

Data were analyzed using the Statistical Package for Social Science (Version 18.0). Gender categorical variables were analyzed

Table 2
Comparison of the tests executive functions of yoga and wait-list control group.

	Yoga (n = 40)				WLC (n = 32)				Group*time interaction
	Pre		Post		Pre		Post		
	Mean ± SD	95% C.I. (LB to UB)	Mean ± SD	95% C.I. (LB to UB)	Mean ± SD	95% C.I. (LB to UB)	Mean ± SD	95% C.I. (LB to UB)	
STROOP_W	62.18 ± 22.36	54.95 to 69.40	73.18 ± 21.67***	65.84 to 80.51	69.44 ± 23.59	61.36 to 77.52	72.06 ± 25.13	63.86 to 80.27	.001
STROOP_C	48.65 ± 10.57	45.20 to 52.10	54.95 ± 11.86***	51.13 to 58.77	53.47 ± 11.38	49.61 to 57.33	56.22 ± 12.44*	51.95 to 60.49	.017
STROOP_CW	27.90 ± 7.12	25.67 to 30.13	33.43 ± 8.71***	30.75 to 36.10	32.78 ± 6.99	30.29 to 35.27	34.50 ± 8.20**	31.51 to 37.49	.034
DSST_T	33.95 ± 8.40	31.31 to 36.59	39.05 ± 8.42***	36.20 to 41.90	33.22 ± 8.37	30.26 to 36.18	35.94 ± 9.77	32.75 to 39.13	.201
DSST_W	2.13 ± 2.03	1.53 to 2.72	1.85 ± 2.62	1.17 to 2.53	1.72 ± 1.69	1.05 to 2.38	1.31 ± 1.42	0.55 to 2.08	.843
DSST_N	31.83 ± 8.52	29.16 to 34.49	37.20 ± 8.94***	34.20 to 40.20	31.22 ± 8.38	28.24 to 34.20	34.63 ± 10.22*	31.27 to 37.98	.327
DS_F	7.03 ± 1.51	6.58 to 7.47	9.40 ± 2.05***	8.82 to 9.98	8.19 ± 1.31	7.69 to 8.69	9.00 ± 1.50*	8.36 to 9.64	.002
DS_B	3.28 ± 1.18	2.86 to 3.69	4.70 ± 1.57***	4.24 to 5.16	3.56 ± 1.46	3.10 to 4.02	4.06 ± 1.32	3.55 to 4.58	.011
DS_T	10.30 ± 2.20	9.60 to 11.00	14.20 ± 3.05***	13.34 to 15.06	11.69 ± 2.28	10.90 to 12.48	13.03 ± 2.25**	12.07 to 13.99	.000
TMT_A	46.28 ± 15.27	41.81 to 50.75	37.25 ± 10.40***	33.23 to 41.26	41.45 ± 12.69	36.44 to 46.45	43.92 ± 15.18	39.43 to 48.42	.000
TMT_B	89.98 ± 32.80	78.66 to 101.30	72.50 ± 21.10***	63.99 to 81.00	95.99 ± 39.45	83.33 to 108.65	86.65 ± 32.90	77.14 to 96.16	.242

STROOP_W = Stroop Word, STROOP_C = Stroop Color, STROOP_CW = Stroop Color Word, DSST_T = Digit Symbol Substitution Total Score, DSST_W = Digit Symbol Substitution Wrong Score, DSST_N = Digit Symbol Substitution Net Score, DS_F = Digit Span Forward, DS_B = Digit Span Backward, DS_T = Digit Span Total, TMT_A = Trial Making Test A, TMT_B = Trial Making Test B, YG = Yoga Group, WLC = Wait-List Control Group.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; pre compared with post.

using Chi squared test. The Independent Sample 't' test was used to check the difference between groups for demographic measures. Analysis of repeated measure followed by Bonferroni post-hoc was performed for all the cognitive functions and Anthropometric outcome measures.

3. Results

The trial profile of the study is shown in Fig. 1. There were no dropouts from Yoga group but eight from WLC. Among eight, two were sick, two were suspended during the post assessment due to their behavioral issues and other four were not willing to complete the task. There were 40 data from Yoga group and 32 from the WLC were available for the final analysis. The baseline mean age between groups was matched ($p = 0.78$, Independent 't' test). The distribution of gender ($p = 0.624$, Chi^2 test) was not significantly different between the two groups.

Repeated measures of ANOVA showed that there were no significant differences between the groups mean score of baseline ($p > 0.05$) for all the cognitive functions tests except Stroop_CW, DS_F and DS_T.

There were significant difference ($p < 0.001$) found in times (pre-post) score for STROOP_C [F (1,70) = 39.165, $p < 0.001$], STROOP_W [F (1,70) = 32.540, $p < 0.001$], STROOP_CW [F (1,70) = 16.880, $p < 0.001$]; DSST_T [F (1,70) = 17.968, $p < 0.001$], DSST_N F (1,70) = 19.366, $p < 0.001$]; DS_F [F (1,70) = 44.796, $p < 0.001$], DS_B [F (1,70) = 29.228, $p < 0.001$], DS_T [F (1,70) = 64.221, $p < 0.001$]; TMT_A [F (1,70) = 5.113, $p < 0.001$] and TMT_B [F (1,70) = 15.100, $p < 0.001$].

The group by time interaction showed (Table 2) significant differences ($p < 0.05$) in STROOP_C, STROOP_W, STROOP_CW; DS_F, DS_B, DS_T; TMT_A. This suggests performance of the Yoga group is better than WLC, whereas there were no significant differences found in, DSST_T, DSST_W, DSST_N, and TMT_B.

Within the Yoga group, post-hoc test with Bonferroni adjustment showed (Table 2) significant improvements ($p < 0.001$) in score for STROOP_C (12.95%), STROOP_W (17.69%), STROOP_CW (19.98), DSST_T (15.02%), DSST_N, (16.89%), DS_F (33.81%), DS_B (43.51 %), DS_T (37.86 %), TMT_A, (19.52%) and TMT_B (19.43%). There was no significant improvement in DSST_W (12.94 %).

Within WLC group, post-hoc test with Bonferroni adjustment showed (Table 2) significant improvement in STROOP_C ($p < 0.05$, 5.14%), STROOP_CW ($p < 0.01$, 5.24%); DSST_N ($p < 0.05$, 10.91%), DS_F ($p < 0.05$, 9.92 %), DS_T ($p < 0.01$, 11.50 %), whereas there were no significant improvement in STROOP_W (3.78 %), DSST_T (8.18 %), DSST_W (23.64 %), DS_B (14.04 %), TMT_A (5.98 %), TMT_B (9.73 %).

4. Discussion

The present study was intended to study the effect of three months of Yoga as compared to a WLC group on the CF of orphan adolescents. The effect of the Yoga program provides evidence on improving cognitive functions in orphan adolescents. The result showed that the EF of the yoga group improved significantly ($p < 0.05$) in the following domains; STROOP_W, STROOP_C, STROOP_CW, DS_F, DS_B, DS_T, TMT_A, and TMT_B whereas WLC group exhibited improvement STROOP_C, DSST_N, DS_F, DS_T as compared to their baseline. The group by time interaction analysis showed significant differences ($p < 0.05$) in STROOP_C, STROOP_W, STROOP_CW; DS_F, DS_B, DS_T; TMT_A. This suggests performance of the Yoga group is better than WLC.

Present study demonstrated that yoga has moderate effect (g = 0.29) on overall cognition, executive functions (g = 0. 27), attention and processing speed measures (g = 0.34). These effect sizes are comparable with a recent meta-analysis study of randomized controlled trials on Yoga,[53] where the overall observed effect size of Yoga on cognition was (g = 0.33), executive function (g = 0.27), attention and processing speed (g = 0.29).

Earlier findings of studies on Yoga were aligned with the present study in Stroop,[54] DSST,[55] DSF and DSB,[56–59] TMT.[45,58] Two recent studies have demonstrated 12 weeks of yoga sessions were positively associated with acute increase in thalamic GABA levels, improvement in mood and anxiety scales,[60] and reduction in depressive symptoms.[61] When yoga postures performed with a gap in between, provides relaxation to body, then ultimately enhances cognition. Previous studies on yoga techniques which consisted of sequence of yoga postures interspersed with relaxation techniques, found improvement in selective attention,[62] and inhibition of the cortical region.[63] *Suryanamakara,* an important part of intervention given, performed with rhythmic breathing develop internal awareness which might have influenced the cognitive outcome measures in the present study.

Yoga breathing techniques have influence on brain cortex area. For example, high frequency yoga breathing practice (*Kapalabhati*) enhances blood flow to pre frontal cortex,[64] and cortical electrical activity measured through electroencephalogram.[65] Pre-frontal

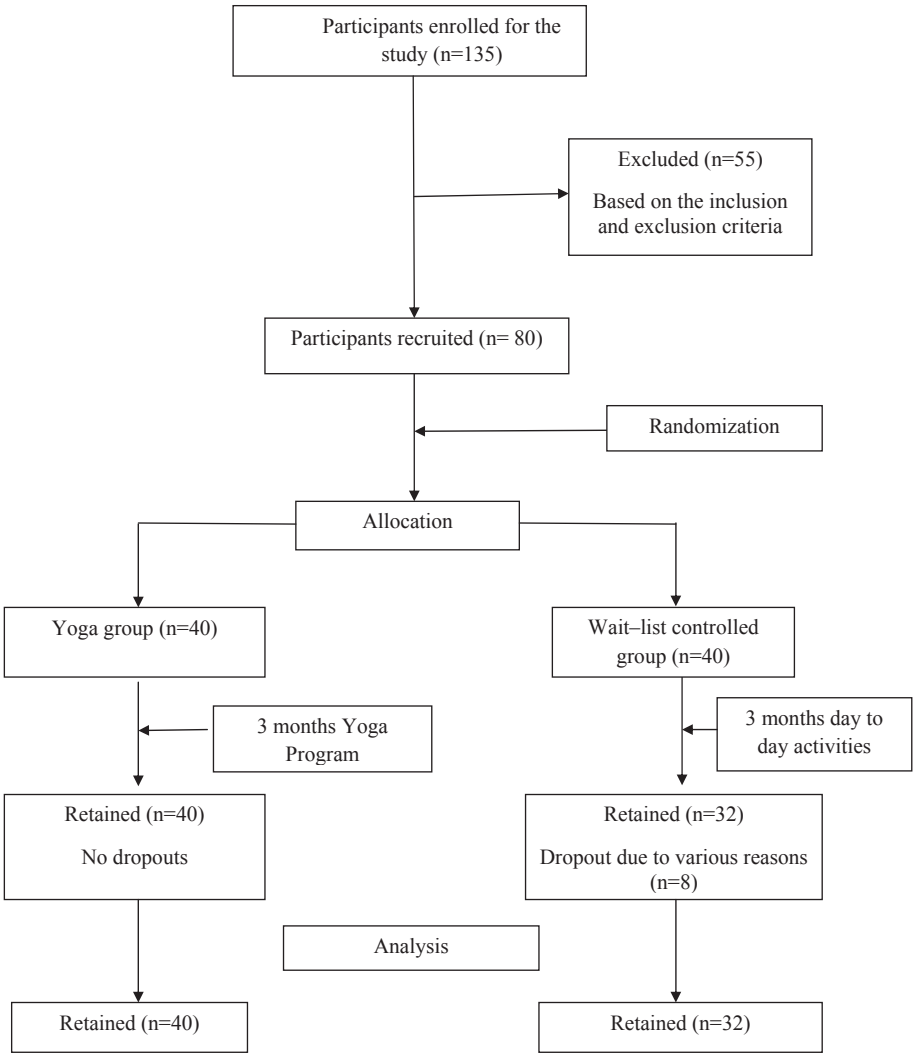

Fig. 1. Trial profile.

cortex is associated with memory, attention, and EF.[66,67] Yoga breathing (*Pranayama*) regulated the autonomic functions by dominating sympathetic[68–70] or parasympathetic tone[71,72] based on the types of techniques. Different yoga breathing techniques were found to be important contributors for significant improvement in various cognitive domains.[57,73,74] *Kapalabhati* and *Bhastrika Pranayama* had influence on auditory working memory, and central neural processing and sensory-motor performance.[75] *Bhramari Pranayama* may enhance inhibition response and cognitive control in healthy participants.[76]

Trataka is a yogic technique in which a person practices focusing and defocusing on a chosen object.[48] This improves the concentration of mental thought process which channelizes action toward given task/test. A recent study on *Trataka* for one month showed there were beneficial effects by enhancing cognitive functions tests and TMT_B in elderly participants.[58] The mechanisms in *Trataka* practice involve *Dharana* (focusing) and *Dhyana* (defocusing) which also contributes in enhancing cognitive measures.

Strengths of the study arise from randomized design with use of well-validated measures of EF while the raters and statistician were blinded and the main limitation of the study includes, it was conducted on adolescents belonging to one orphanage and the results were not able to rule out the effect of diet and other school activities. Improvement observed in WLC group may be due to test-retest effect, uncontrolled physical activities in schools, time and growth effect.

The study can be improvised in design by further reducing the age range of participants, developing a Yoga Module especially for orphans and also comparing the Yoga intervention with other kinds of complementary alternative therapies such as Ayurveda, Naturopathy for promotion of positive health for orphans.

5. Conclusion

Evidence for the effectiveness of three months yoga on EF was demonstrated in this study, which may be a useful tool for the young orphans, to be practiced for cognitive health on a daily basis. The sustained effect of Yoga on EF seen in the present study may have potential implications on learning, classroom behavior and in handling the adverse circumstances and stand as a preventive measure for mental health problems.

Conflict of interest

None declared.

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