RESULTS

6.0 RESULTS

The CONSORT flowchart shows the trial profile (Figure 2). Out of 102 participants who were screened, 82 were eligible and 54 volunteered to participate in the trial with randomization to yoga or a waitlist control group. At the end of the trial, 25 participants were available in each group for analysis.

6.1 BASELINE CHARACTERISTICS

Table 5. shows the demographic and clinical characteristics of the participants. The yoga group and waitlist control group participants did not differ statistically in any of the parameters.

Table 5. Baseline characteristics of participants

	Yoga (n = 25)	**Control (n = 25)**	**P value**
	Mean±SD/Median /Ratio/Count	Mean±SD/Median /Ratio/Count	
Age (Years)	52.5 ± 8.7	52.6 ± 8.5	0.79
Sex (Male: Female)	18:7	19:6	
Education (Years)	15.7 ± 1.3 15.0†	14.8 ± 2.8 15.0†	0.31^{+}
BMI (Kg/m^2)	25.1 ± 3.1	25.8 ± 3.4	0.75
Handedness (Right: Left)	25:0	25:0	
Family history of T2DM (Yes: No)	18:7	17:8	
Duration of T2DM (Years)	9.5 ± 7.2 8.0†	8.3 ± 5.6 6.0†	0.66^{+}
HbA1c (%)	8.0 ± 1.7 8.0†	8.0 ± 1.2 8.0†	0.69^{+}
Hypertension (Yes:No)	7:18	6:19	
Systolic blood pressure (mmHg)	120.6±14.2 120.0†	123.6±14.9 122.0†	0.36^{+}
Diastolic blood pressure (mmHg)	75.7±9.3 76.0†	78.0±7.5 80.0†	0.38^{+}
Smoking			
Never	25	23	
Occasional	0	1	
Regular	0	1	
Alcohol consumption			
Never	22	21	
Monthly once	3	3	
Weekly once	0	1	
Regular	0	0	
Medication (Insulin: Non-Insulin)	0:25	1:24	
MoCA score	27.4 ± 1.1 27.0†	27.1 ± 1.1 27.0†	0.49^{+}
Symptom Checklist R-90 Score	0.46 ± 0.33 0.43†	0.54 ± 0.41 0.46†	0.61^{+}

BMI-Body Mass Index, HbA1c – Glycated hemoglobin, MoCA- Montreal Cognitive Assessment. † - Median value, '+' – Non-parametric tests

6.2 BEHAVIOURAL OUTCOMES

Table 6. and Figure 8. summarizes the behavioural results. The accuracy values were log-transformed since they were negatively skewed in all n-back task conditions. For the accuracy measure, a mixed ANOVA indicated a significant interaction effect between time, condition and group, $F(4,192) = 2.54$, $p = 0.041$, partial $\eta 2 = 0.05$ and a non-significant between-subjects effect, $F(1,48) = 2.16$, $p = 0.15$, partial $\eta 2 = 0.04$. The groupwise analysis showed a significant interaction effect between time and condition in the yoga group, $F(4,96) = 3.6$, $p = 0.009$, partial $\eta 2 = 0.13$. A post hoc pairwise comparison indicated improved accuracy in the yoga group for the 2-back task condition between post and pre-intervention with a geometric mean difference of 3.15%, 95% CI [2.33,3.96], $p = 0.001$, and between post and mid-intervention with a geometric mean difference of 2.03%, 95% CI [1.32,2.75], $p = 0.013$. For the reaction time measure, the analysis showed a significant interaction effect between time, condition and group, $F(2.6,126.1) = 2.99$, $p = 0.04$, partial $\eta 2 = 0.06$, epsilon = 0.66, and a non-significant between-subjects effect, $F(1,48) = 1.07$, $p = 0.31$, partial $\eta 2 = 0.02$. The groupwise analysis showed a significant interaction effect between time and condition in the yoga group, $F(2.5,59.0) = 4.2$, $p = 0.013$, partial $\eta 2 = 0.15$, epsilon = 0.61. A post hoc pairwise comparison indicated decreased reaction time in the yoga group for 2-back task condition between pre and post-intervention, with a mean difference of -100.8 ms,95% CI [-166.6, -35.1], $p = 0.002$, and between mid and post-intervention with a mean difference of -69.3 ms, 95% CI [-116.4,-22.1], $p = 0.003$.

Table 6. Accuracy and Reaction time scores of n-back tasks

Accuracy (in %)

	Yoga (n = 25)			Control (n = 25)		
n-back task	**Pre**	**Mid**	**Post**	**Pre**	**Mid**	**Post**
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
0 - back	94.5 ± 7.5	95.6±4.1	95.7±3.2	94.2±6.7	93.5±6.6	95.4±5.0
1 - back	96.6 ± 4.3	97.2±2.5	96.0±3.5	95.7±3.9	95.5±3.6	95.6±4.7
2 - back	90.2± 5.6	91.3±4.9	93.7±3.8*+	88.0±7.7	88.4±6.6	88.7±7.4

Reaction Time (in milliseconds)

	Yoga (n = 25)			Control (n = 25)		
n-back task	**Pre**	**Mid**	**Post**	**Pre**	**Mid**	**Post**
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
0 - back	572.2±76.1	561.5±63.9	541.6±60.3	607.7±112.1	590.2±85.3	575.1±88.5
1 - back	660.2±91.0	641.9±79.2	630.9±81.6	691.8±110.3	670.9±99.3	660.6±92.7
2 - back	844.8±151.2	813.2±145.6	743.9±112.6*+	810.3±135.8	801.9±126.2	790.2±135.3

'*' – denotes significant compared to Pre, $p < 0.05$, '+' – denotes significant compared to Mid, $p < 0.05$

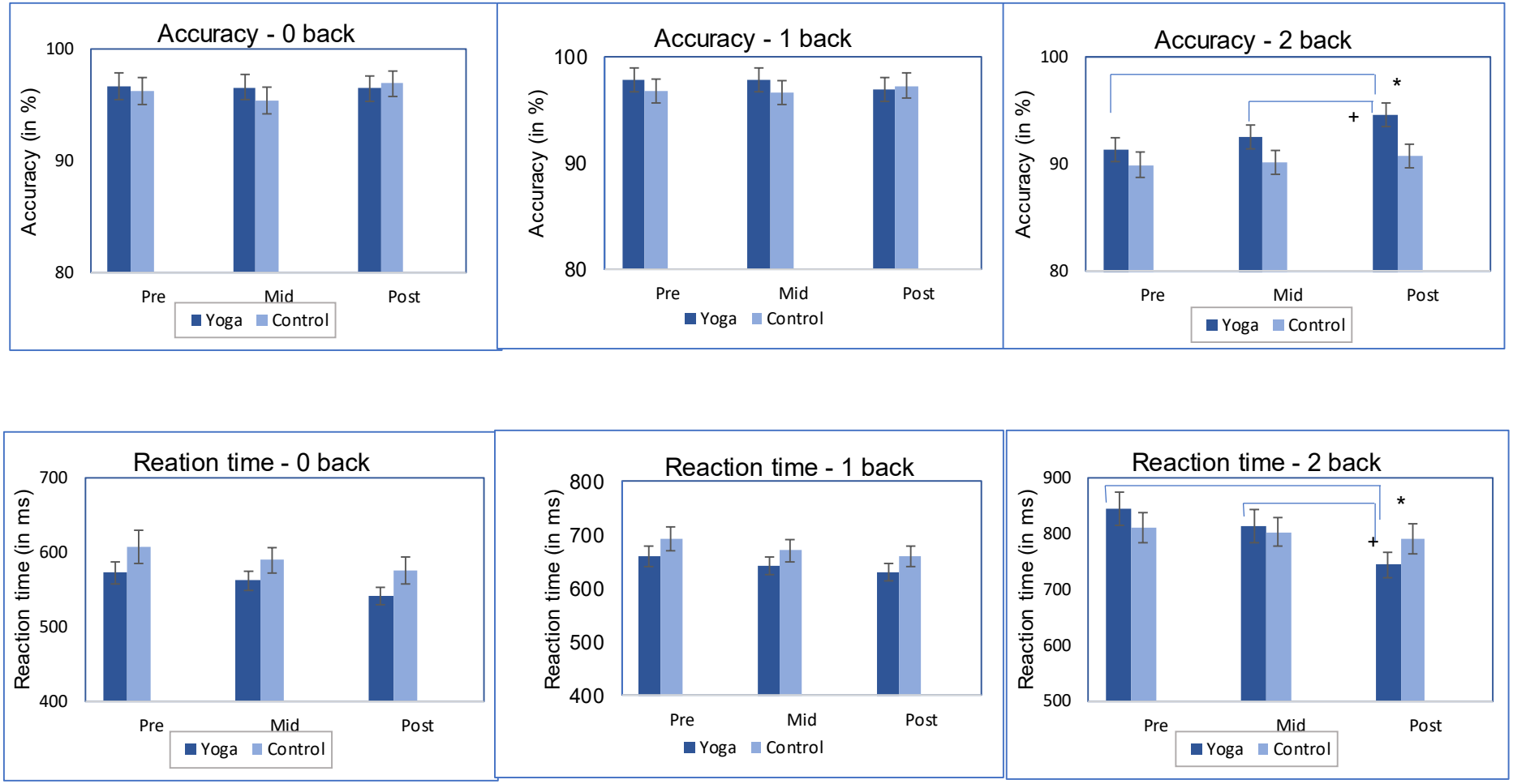

Figure 8. Accuracy and Reaction time scores of n-back tasks (Mean±SE). Performance of 0-,1- and 2-back tasks of both yoga and control groups were assessed during Pre, Mid and Post-intervention. The yoga group showed improvements in post-assessments compared to Pre and Mid- assessments. '*' – denotes significant compared to Pre, $p < 0.05$, '+' – denotes significant compared to Mid, $p < 0.05$

6.3 PFC OXYGENATION

Table 7. summarizes the result of the analysis of OxyHb (β coefficients) in different ROI during the n-back task conditions. For the dlPFC region, the analysis showed a significant interaction effect between the group, time and condition, F (3.3,160.3) = 4.29, p = 0.004, partial η^2 = 0.08, epsilon = 0.76 and a non-significant between-subjects effect, F (1,48) = 3.76, p = 0.058, partial η^2 = 0.07. The groupwise analysis showed a significant interaction between time and condition in the yoga group, F (2.6,62.0) = 4.98, p = 0.005, partial η^2 = 0.17, epsilon = 0.65, but not in the control group, F (2.8,66.4) = 0.52, p = 0.66, partial η^2 = 0.02, epsilon = 0.69. The *post hoc* pairwise comparisons showed a significant increase in OxyHb in the yoga group during the 2-back task condition between post and pre-intervention mean values, with a difference of 95.6, 95% CI [0.23,191], p = 0.049, and between post and mid-intervention mean values, with a difference of 151.8, 95% CI [32.3,271.3], p = 0.010.

For the vlPFC region, the analysis showed a significant interaction effect between the group, time and condition, F (3.0,143.2) = 2.96, p = 0.035, partial η^2 = 0.06, epsilon = 0.74. The groupwise analysis indicated a significant interaction between time and condition in the yoga group, F (4,96) = 3.85, p = 0.006, partial η^2 = 0.14, but not in the control group, F (2.8,67.3) = 1.28, p = 0.29, partial η^2 = 0.05, epsilon = 0.7. The *post hoc* pairwise comparisons showed a significant increase in OxyHb during the 2-back task condition, between post and pre-intervention mean values, with a difference of 53.4, 95% CI [7.8,98.9], p = 0.018, and between post and mid-intervention mean values with a difference of 99.4, 95% CI [34.4,164.3], p = 0.002.

For vmPFC & OFC, dmPFC(BA9) and dmPFC(BA6/8) regions, the analysis showed a non-significant interaction effect between the group, time and condition and between-subjects effect. Also, there were no significant main effects for either time or condition.

For the entire PFC region, the analysis showed a significant interaction effect between the group, time and condition, F (4,192) =2.67, p = 0.034, partial η^2= 0.05. There was no significant between-subjects effect, F (1,48) = 2.0, p = 0.168, partial η^2 = 0.04. The groupwise analysis showed a significant interaction effect between time and condition in the yoga group, F (4,96) = 4.0, p = 0.005, partial η^2 = 0.14. The *post hoc* pairwise comparisons showed a significant increase in OxyHb, during the 2-back task condition, between post and pre-intervention mean values with a difference of 50.3, 95% CI [4.5,96.2], p = 0.028, and between post and mid-intervention mean values with a difference of 92.8, 95% CI [24.3,161.3], p = 0.006. The control

group did not show any significant interaction effect between time and condition (Figure 9 and Figure 10).

6.3.1 ASSOCIATION BETWEEN PFC OXYGENATION AND BEHAVIOURAL OUTCOMES

Pearson's correlation analysis was done to check the association between the behavioural outcomes and the difference in oxygenation change at post-intervention assessment (Figure 11). The analysis showed that change in oxygenation in the dlPFC region was positively correlated to accuracy, $r(23) = 0.65$, $p<0.001$ and negatively correlated to reaction time, $r(23) = -0.47$, $p = 0.017$, in 2-back task condition between pre- and post-intervention. In the vlPFC region, the analysis showed that change in oxygenation was neither correlated to reaction time, $r(23) = -0.11$, $p = 0.592$, nor to accuracy, $r(23) = 0.24$, $p = 0.250$, in 2-back task condition between pre- and post-intervention. Further, the analysis indicated that change in oxygenation in the entire PFC region was positively correlated to accuracy, $r(23) = 0.53$, $p = 0.006$ and negatively correlated to reaction time, $r(23) = -0.38$, $p = 0.061$, in 2-back task condition between pre- to post-intervention and mid to post-intervention respectively.

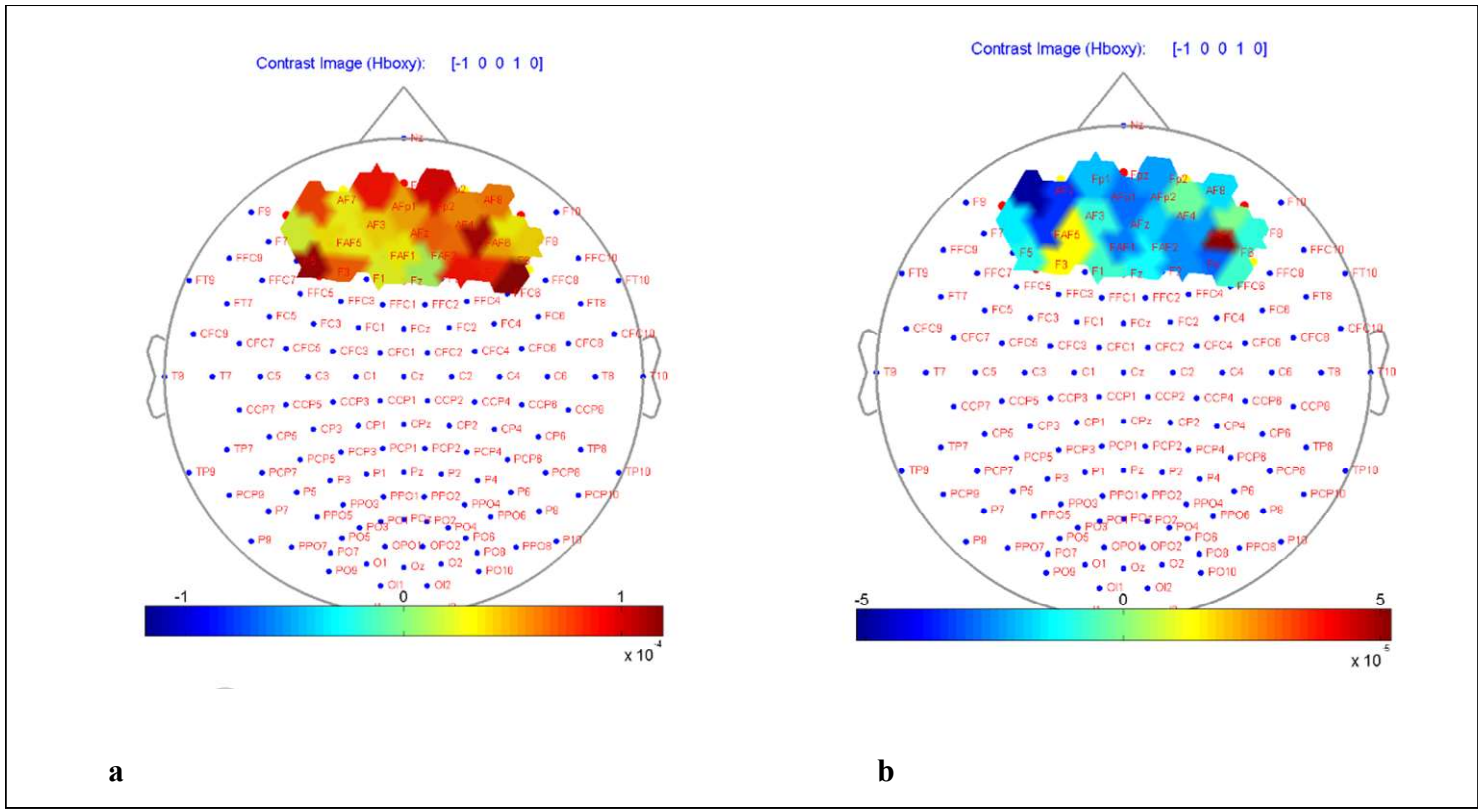

Figure 9. Topoplot of Prefrontal cortex (PFC) oxygenation (beta coefficients) averaged across all the participants during 2-back task condition at post-intervention assessment. a) Yoga group. The oxygenation changes relative to resting condition is higher (Red colour) in high task load condition b) Control group. The oxygenation changes relative to resting condition is lesser in (Blue colour) in high task condition (compared to yoga group)

Table 7. Beta coefficients of OxyHb[b] during n-back task conditions

		Yoga (n = 25)			Control (n = 25)		
Condition	**ROI**	**Pre**	**Mid**	**Post**	**Pre**	**Mid**	**Post**
		(Mean ± SD)	(Mean ± SD)	(Mean ± SD)	(Mean ± SD)	(Mean ± SD)	(Mean ± SD)
0-back	**dlPFC**	5.0±102.7	-5.9±108.3	37.4 ±67.8	-20.7±76.9	3.3±102.3	8.6±143.6
	dmPFC(BA9)	-3.6±76.4	-10.9±99.7	27.2±69.7	-23.3±85.8	-13.6±85.5	-10.5±126.9
	dmPFC(BA6/8)	-1.7±35.9	12.1±39.6	16.1±35.2	15.8±42.1	14.9±49.5	28.3±56.4
	vlPFC	-23.3±81.7	-24.3±82.0	16.0±94.3	-2.0±76.6	14.7±77.0	-0.6 ±147.3
	vmPFC & OFC	-11.7±80.3	-16.7±93.2	33.8±105.5	-17.3±91.9	-7.8±86.2	-1.0±155.9
1-back	**dlPFC**	7.9±89.1	1.03±94.8	44.5±98.7	-26.7±95.8	-27.0±132.5	-7.3±88.3
	dmPFC(BA9)	10.5±65.1	-7.5±88.2	28.3±93.2	-24.4±87.5	-20.2±100.8	-16.9±76.1
	dmPFC(BA6/8)	15.4±44.4	20.7±36.8	5.6±74.4	7.3±39.7	5.1±61.9	10.7±62.1
	vlPFC	1.3±85.6	-22.8±98.8	18.3±108.1	2.6±87.4	-13.2±104.5	-6.6±109.2
	vmPFC & OFC	5.4±78.9	-19.7±104.4	34.7±118.6	-6.4±88.0	-24.9±132.3	-17.5±126.8
2-back	**dlPFC**	8.6 ± 94.1	-47.5±113.0	104.4±177.0*+	-30.1±72.2	-13.6±105.7	-11.8±114.4
	dmPFC(BA9)	16.7±70.8	-16.2±103.0	46.6±77.2	-29.8±73.9	-17.0±81.9	-15.5±100.0
	dmPFC(BA6/8)	18.8±43.8	8.9±54.1	13.0±36.8	8.5±52.5	10.6±34.2	20.5±61.9
	vlPFC	-5.9 ± 86.9	-51.9±94.8	47.5±81.7*+	4.8±65.9	0.6±71.4	-20.6±118.1
	vmPFC &OFC	8.3±83.7	-42.5±93.5	68.0±77.6	-9.2±66.8	-14.6±83.3	-24.8±134.8

BA- Brodmann area, dlPFC- dorsolateral prefrontal cortex, OFC- orbitofrontal cortex, vlPFC- ventrolateral prefrontal cortex, vmPFC- ventromedial prefrontal cortex, ROI- Region of interest. '*' –Significant compared to Pre values, $p < 0.05$, '+' - Significant compared to Mid values, $p < 0.05$, [a] – values x 10^{-6} , [b] – relative to resting condition during respective assessment.

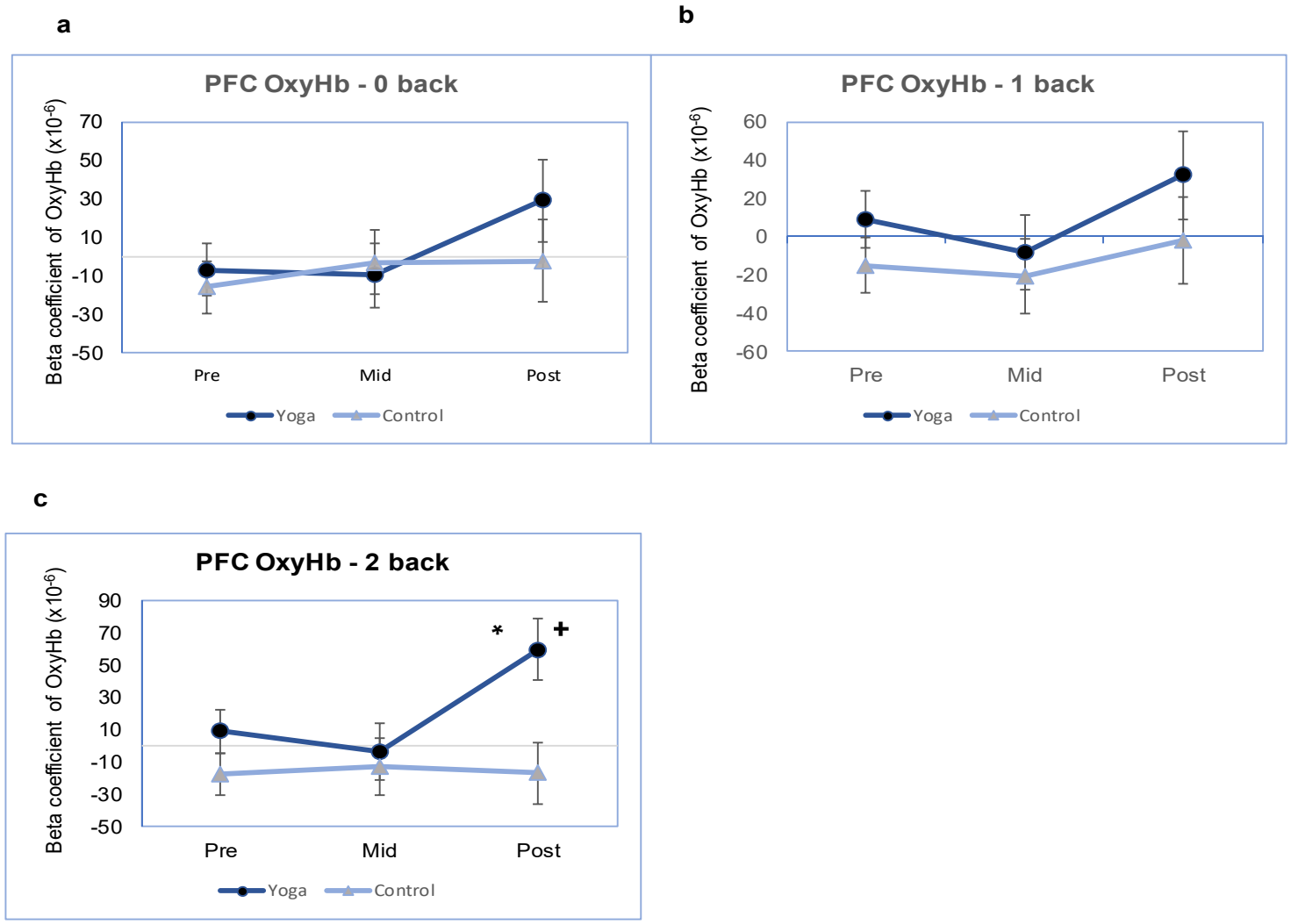

Figure 10. PFC oxygenation changes (OxyHb relative to resting condition) during n-back task condition in yoga and control groups (Mean±SE): a) 0-back task. No significant changes in oxygenation in both the groups b) 1-back task. No significant changes in oxygenation in both the groups c) 2 -back task. Significant changes in oxygenation during Post-intervention assessment in the yoga group. * Significant compared to the Pre value, $p < 0.05$, + Significant compared to the Mid value, $p < 0.05$. PFC- Prefrontal cortex

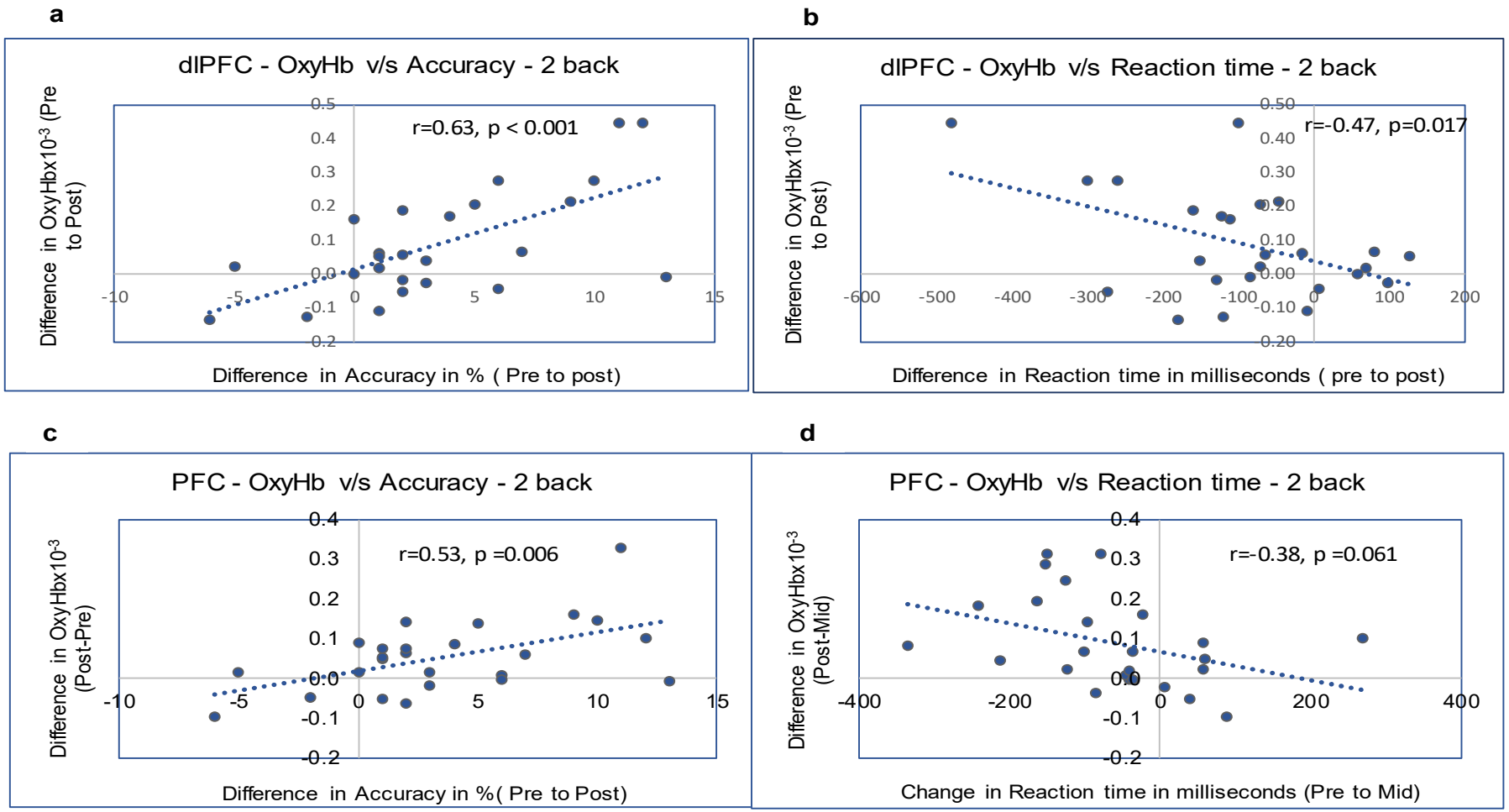

Figure 11. Association between the difference in oxygenation (pre- to post-intervention) and the improvement in behavioural outcomes (n-back task accuracy and reaction time from pre- to post-intervention) in 2-back task condition. a) and b) In the dlPFC region c) and d) In the entire PFC region. PFC- Prefrontal cortex, dlPFC – dorsolateral PFC, OxyHb – Oxygenation (beta coefficients)

6.4 HEART RATE VARIABILITY

A two-way mixed ANOVA was conducted separately to examine the effects of the intervention on mean HR, RMSSD, SDNN, LF, HF and LF/HF ratio. Table 8. And Figure 12. summarizes the results.

6.4.1 Mean HR

There was a significant interaction effect between the intervention group and time, F (1.8,85.4) = 4.15, p = 0.023, partial η2 = .08, epsilon = 0.8 and a non-significant between-subjects effect, F(1,48) = 0.8, p = 0.38, partial η2 = .02 for mean HR. The groupwise analysis showed that in the yoga group, there was a significant effect of time, F (2,48) = 16.7, p < 0.001, partial η2 = 0.41. The pairwise comparison indicated a decreased HR value at post-intervention compared to pre- and mid-intervention with a mean difference of 7.0, 95% CI [-9.5, -4.4], p < 0.001 and 6.1, 95% CI [-10.1, -2.2], p = 0.002 respectively. There was no significant effect of time in the control group, F (1.5,35.2) = 0.43, p = 0.6, partial η2 = 0.02, epsilon = 0.7.

6.4.2 RMSSD

There was a non-significant interaction effect between the intervention group and time, F(1.8,84.3) = 1.62, p = 0.46, partial η2 = 0.02, epsilon = 0.9 and a non-significant between-subjects effect, F (1,48) = 0.07, p = 0.8, partial η2 = 0.001 for RMSSD.

6.4.3 SDNN

There was a non-significant interaction effect between the intervention group and time, F(1.8,84.3) = 0.8, p = 0.20, partial η2 = 0.03, epsilon = 0.9 and a non-significant between-subjects effect, F(1,48) = 0.11, p = 0.74, partial η2 = 0.002 for SDNN.

6.4.4 LF

There was a significant interaction effect between the intervention group and time, F(2,96) = 6.5, p = 0.002, partial η2 = 0.12 and a non-significant between-subjects effect, F(1,48) = 0.27, p = 0.61, partial η2 = 0.006 for LF. The groupwise analysis showed that in the yoga group, there was a significant effect of time, F (2,48) = 4.9, p = 0.011, partial η2 = 0.17. The pairwise comparison indicated a decreased LF value at post-intervention compared to pre- and mid-intervention with a mean difference of 10.7, 95% CI [-21.0, -0.3], p = 0.041 and 10.6, 95% CI [-20.5, -0.6], p = 0.034 respectively. There was no significant effect of time in the control group, F (2,48) =1.6, p = 0.20, partial η2 = 0.06.

6.4.5 HF

There was a significant interaction effect between the intervention group and time, $F(2,96) = 5.5$, $p = 0.005$, partial $\eta 2 = 0.10$ and a non-significant between-subjects effect, $F(1,48) = 0.26$, $p = 0.61$, partial $\eta 2 = 0.005$ for HF. The groupwise analysis showed that in the yoga group, there was a significant effect of time, $F(2,48) = 5.2$, $p = 0.009$, partial $\eta 2 = 0.18$. The pairwise comparison indicated an increased HF value at post-intervention compared to pre- and mid-intervention with a mean difference of 10.7, 95% CI [0.23, 21.1], $p = 0.043$ and 11.3, 95% CI [1.1, 21.5], $p = 0.03$ respectively. There was no significant effect of time in the control group, $F(2,48) = 0.6$, $p = 0.60$, partial $\eta 2 = 0.02$

6.4.6 LF/HF Ratio

There was a non-significant interaction effect between the intervention group and time, $F(2,96) = 2.6$, $p = 0.08$, partial $\eta 2 = .05$ and a non-significant between-subjects effect, $F(1,48) = 0.14$, $p = 0.71$, partial $\eta 2 = 0.003$ for LF/HF ratio.

The correlation analysis showed that none of the improved autonomic parameters at post-intervention were associated with any improvements in behavioural outcomes, either accuracy or reaction time.

Table 8. Heart rate variability during rest

	Yoga (n = 25)			Control (n = 25)		
	Pre	**Mid**	**Post**	**Pre**	**Mid**	**Post**
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Mean HR (beats/ min)	82.6±9.6	81.8±12.4	75.7±9.8*†	83.7±12.9	82.1±12.6	82.2±12.1
SDNN (in ms)	21.1±8.4	19.8±7.0	20.1±5.5	21.7±9.9	21.7±10.5	19.6±7.5
RMSSD (in ms)	15.8±7.1	17.0±6.3	17.0±5.7	17.1±8.9	15.9±7.4	15.5±6.3
LF nu	68.5±12.9	68.5±14.9	57.9±17.8*†	66.0±17.3	65.3±17.6	69.6±17.9
HF nu	31.2±12.8	30.6±15.0	41.9±17.4*†	32.9±18.2	33.6±18.5	31.1±19.1
LF/HF	2.9±1.9	3.2±2.2	2.3±1.7	2.5±1.7	2.6±1.9	3.1±2.8

ms – milliseconds, nu – normal unit, " ∗ " – Statistically significant compared to Pre, $p < 0.05$,
" † " – Statistically significant compared to Mid, $p < 0.05$,

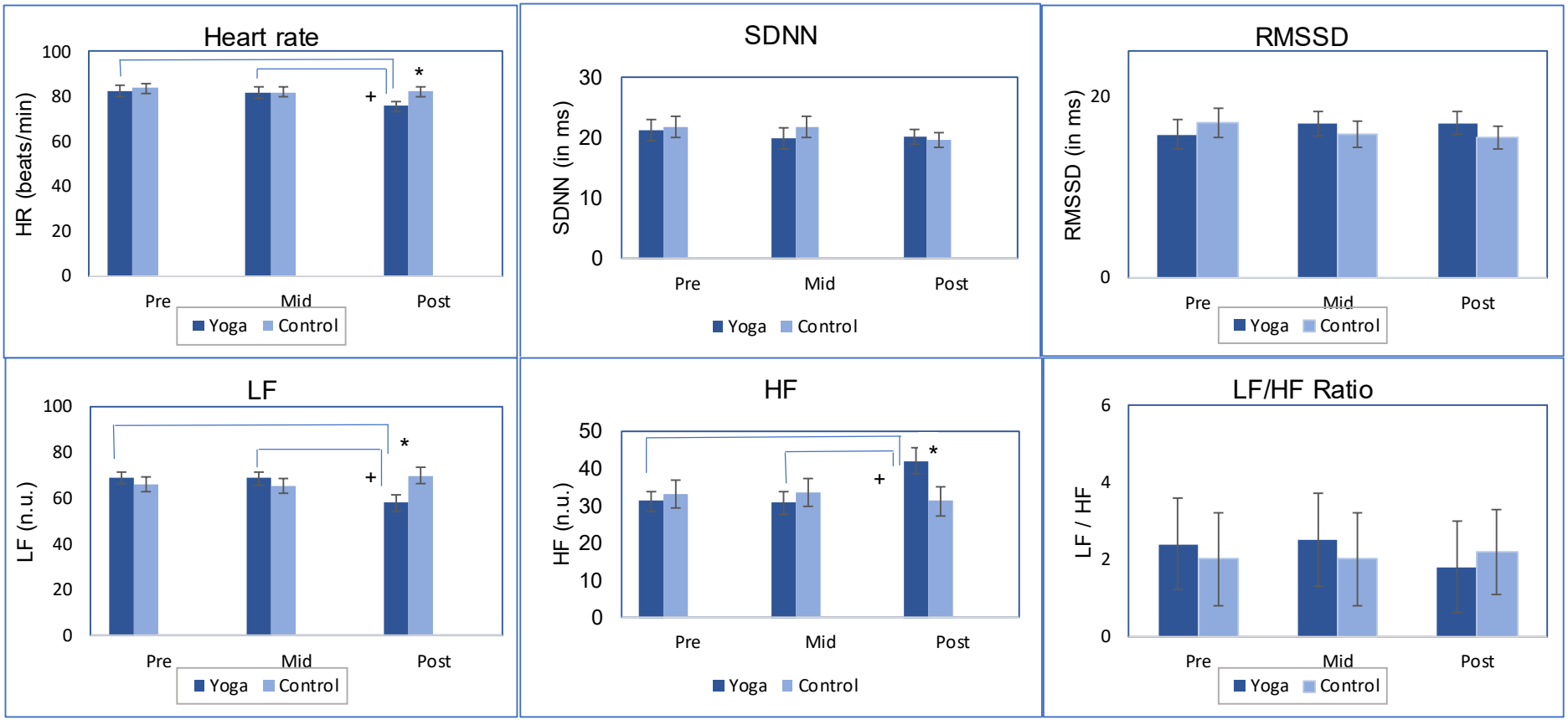

Figure 12. Heart rate variability during rest (5 mins of resting condition) (Mean±SE). Significant decrease in Heart rate and LF component in yoga group at post-intervention assessment. Significant increase in HF component in yoga group at post-intervention assessment. ms – milliseconds, nu – normal unit, " ∗ " – Statistically significant compared to Pre, $p < 0.05$, " + " – Statistically significant compared to Mid, $p < 0.05$

6.5 RUMINATION RRSPONSE SCALE (RRS) SCORE

The two-way mixed ANOVA was conducted to analyze the effect of the intervention on rumination scores. The result showed a significant interaction between the intervention and time on rumination score, $F(2,96) = 3.4$, $p = 0.04$, partial $\eta^2 = 0.07$ and a non-significant between-subjects effect, $F(1,48) = 1.3$, $p = 0.25$, partial $\eta2 = 0.03$. The groupwise analysis showed that in the yoga group, a significant effect of time on rumination score, $F(1.3,32.2) = 5.7$, $p = 0.02$, partial $\eta^2 = 0.19$, epsilon = 0.7. The pairwise comparison indicated a decrease in rumination score at post-intervention compared to pre-intervention, with a mean difference of -4.72, 95% CI [-8.5, -1.0], $p = 0.011$. Whereas in the control group, there was no significant change, $F(1,8) = 0.03$, $p = 0.96$, partial $\eta^2 = 0.001$. A Pearson's correlation showed a significant, moderate positive correlation between the decrease in rumination scores (at post-intervention) and the improvement in reaction time (at post-intervention) compared to pre-intervention, $r(25) = 0.65$, $p < 0.001$, with the decrease in rumination scores explaining 42% of the variation in improving the response time. However, there was no significant correlation between rumination scores and the accuracy measure, $r(25) = -0.35$, $p = 0.09$. Table 9, Figure 13. and Figure 14. summarize the result of the analysis. In this study, RRS had a good internal consistency with Cronbach $\alpha = 0.84$ to 0.93.

6.6 PERSEVERATIVE THINKING QUESTIONNAIRE (PTQ)

The two-way mixed ANOVA was conducted to analyze the effect of the intervention on PTQ scores. The result showed a non-significant interaction effect between the intervention group and time on PTQ score, $F(2,96) = 1.4$, $p = 0.26$, partial $\eta2 = 0.03$ and a non-significant between-subjects effect, $F(1,48) = 0.34$, $p = 0.6$, partial $\eta2 = 0.007$. In this study, PTQ had a good internal consistency with Cronbach $\alpha = 0.90$ to 0.96. Table 9 and Figure 13. summarizes the result.

Table 9. RRS and PTQ scores

	Yoga (n = 25)			Controls (n = 25)		
	Pre	**Mid**	**Post**	**Pre**	**Mid**	**Post**
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
RRS						
	42.0±9.6	38.6±8.5	37.2±7.8*	42.1±10.4	42.4±12.1	42.1±9.7
PTQ						
	25.4 ± 10.2	24.08±10.8	23.3±10.2	26.3±13.3	25.8±13.2	26.5±14.0

'*' – denotes significant compared to Pre, $p < 0.05$.

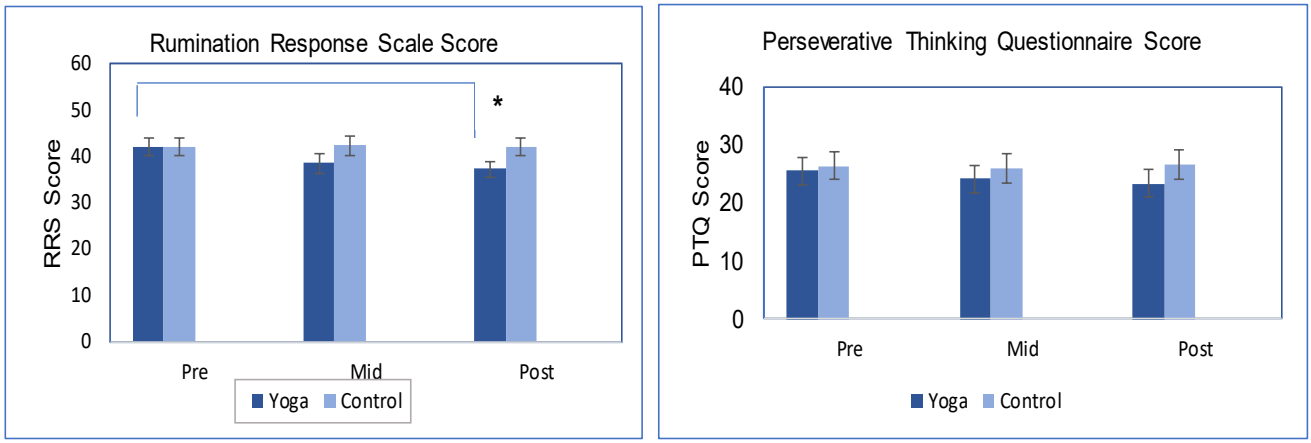

Figure 13. RRS and PTQ scores (Mean ± SE). '*' – denotes significant compared to Pre, $p < 0.05$. RRS – Rumination Response Scale, PTQ – Perseverative Thinking Questionnaire

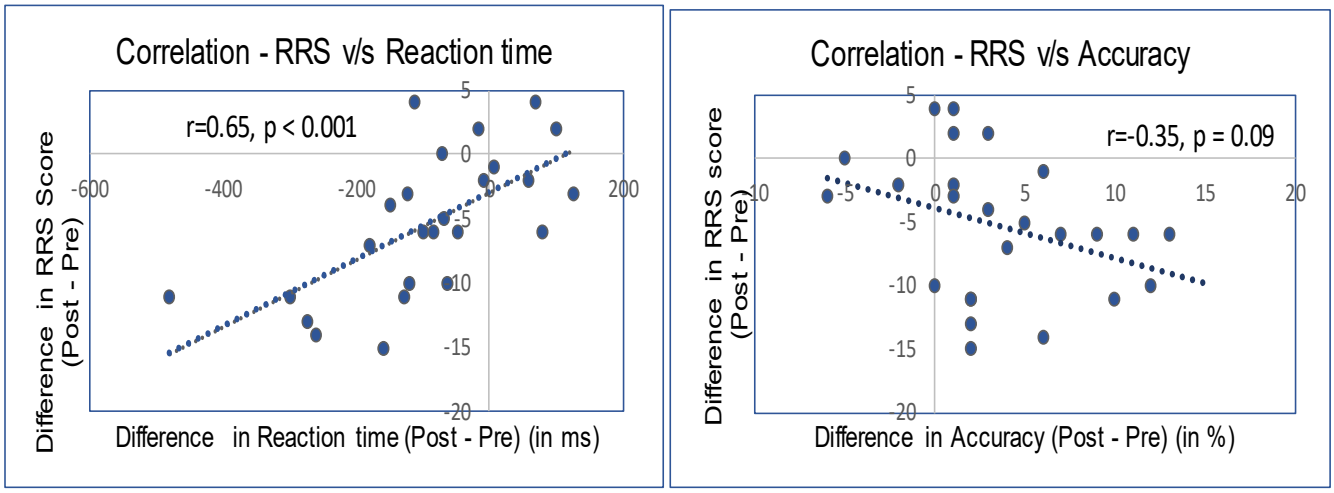

Figure 14. Association between the difference in RRS score (Pre to Post) and the improvement in behavioural outcomes (n-back task accuracy and reaction time from pre- to post-intervention in 2-back task condition). RRS – Rumination Response Scale