DISCUSSION

7.0 DISCUSSION

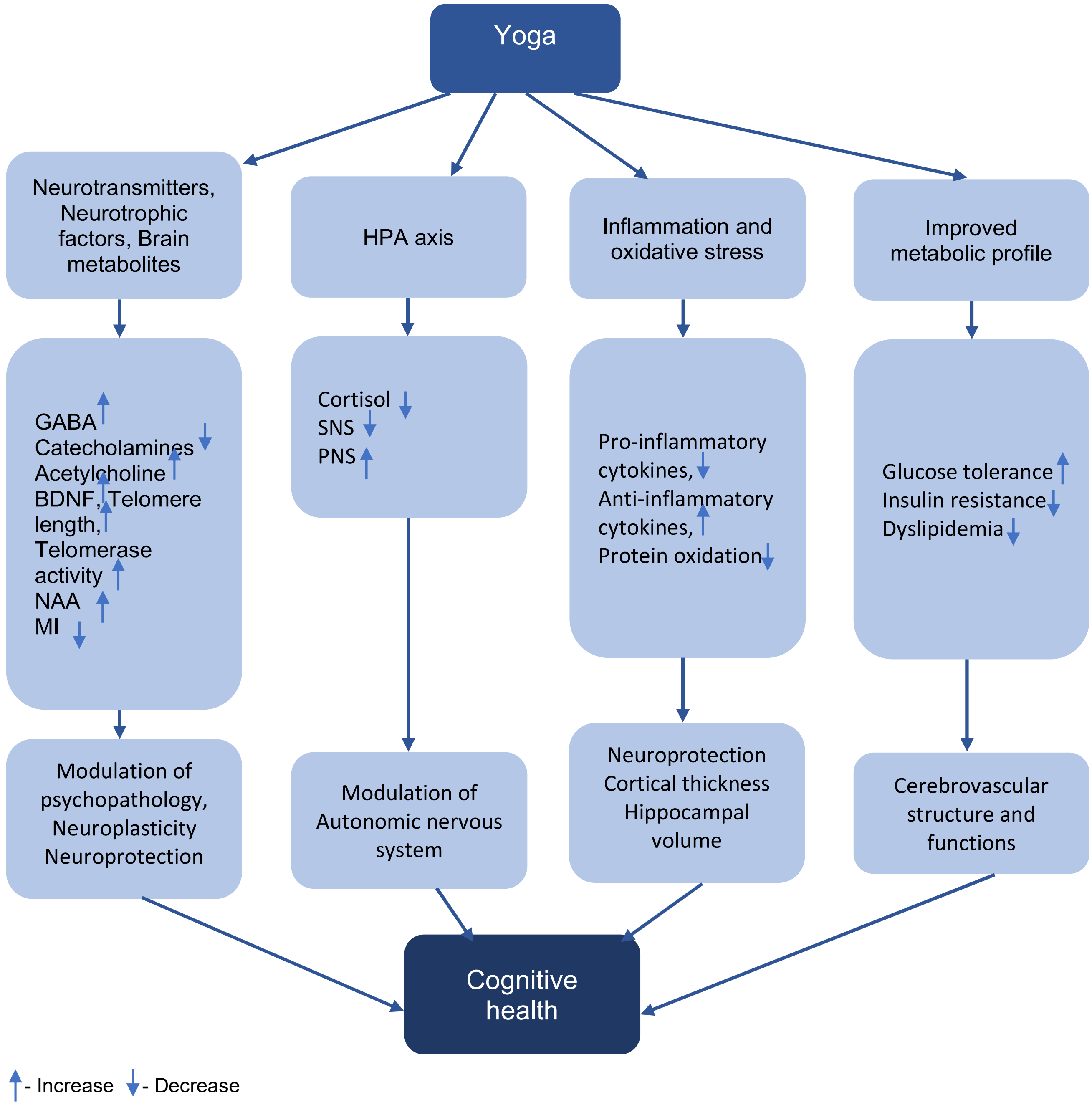
The present study assessed working memory performance and PFC oxygenation following twelve weeks of yoga practice in T2DM patients. During the post-intervention assessment, the yoga group showed a significant improvement in working memory performance in terms of accuracy and reaction time in the high task load conditions (2-back); however, no improvement in performance was observed in the low task load conditions (0 and 1-back), whereas the control group did not show any improvement in any task conditions. Similar to our findings, earlier studies have shown that yoga enhances working memory performance (Satish & Lakshmi, 2016) in T2DM patients and healthy older adults (Gothe et al., 2014; Hariprasad et al., 2013). Also, yoga was found to improve the manipulation and maintenance subconstructs of working memory in young healthy individuals (Brunner et al., 2017). There was a significant increase in OxyHb in the dlPFC and vlPFC regions during the 2-back task at post-intervention in the yoga group, whereas no change in the control group. T2DM patients have decreased activation in frontal cortex regions with increasing task load. According to our study, yoga facilitates a higher level of activation in T2DM patients during high working memory load. Further analysis revealed that improvement in behavioural outcomes correlated with the change in oxygenation during the post-intervention assessment. The change in oxygenation in the dlPFC region was positively correlated with accuracy and negatively correlated with reaction time in working memory performance. But, in the vlPFC region, the change in oxygenation was not associated with either accuracy or reaction time. Working memory performance is largely dependent on functions such as updating, monitoring, and manipulating newly acquired information, for which dlPFC plays a vital role. This might be a plausible reason for the correlation of an increase in oxygenation in the dlPFC region with working memory performance. Earlier studies indicated that the dlPFC plays a crucial role in modulating WM performance when cerebral resources are challenged, while vlPFC plays a role in functions such as practicing and maintaining internal representations, which has a lesser influence on working memory performance (Hillary et al., 2006).

When compared to pre-intervention, the change in oxygenation in the entire PFC region was also significantly higher and associated with improved behavioural outcomes during the 2-back task condition at post-intervention. There was a slight decrease, though not significant, in oxygenation compared to pre-intervention, during all task conditions at mid-intervention in the yoga group. The possible reason could be that participants were in a kind of stressful period in getting adjusted and stabilized with yoga practices during this period. The significant effect of yoga intervention was seen only after mid-intervention, either a change in oxygenation or working memory performance, indicating a possible influence of the duration of yoga intervention. However, to validate this aspect, further study is needed with a focus on the dose-response relationship of yoga practice. In an earlier study by Gothe et al., long-term yoga practitioners showed lower dlPFC activation during the encoding phase of a working memory task without any difference in performance when compared to non-practitioners (Gothe et al., 2018). Age and duration of illness in T2DM patients influence cognitive functions (Biessels et al., 2008). Research findings suggest more efficient hemodynamics in the PFC region during working memory in females (Li et al., 2010). In our study, as the intervention and control group groups did not differ in age, gender and duration of illness statistically, we assume our findings might not be influenced by these factors.

To our knowledge, this is the first study that has examined the effects of yoga on working memory performance and associated PFC oxygenation in individuals with T2DM. Several other mind-body and exercise intervention studies have looked at PFC oxygenation during different cognitive tasks. Similar to the results of our study, a four-week exercise intervention in obese participants showed an increase in executive task performance associated with higher OxyHb concentration in the left vlPFC and bilateral dlPFC during the executive function task (Xu et al., 2017).In another study, a twenty-four-week Tai Chi intervention resulted in a higher Stroop task score with no significant change in OxyHb concentration in the PFC (Wang et al., 2013). Eight weeks of Baduanjin mind-body (BMB) training seemed to be more effective than a relaxation exercise program in enhancing executive control of college students, with increased OxyHb in the left PFC during the incongruent trials (T. Chen et al., 2017). In summary, most of these studies indicate enhanced PFC oxygenation during cognitive tasks following the intervention.

Our study observed an improved HRV in the yoga group associated with a reduction in mean heart rate, an increase in HF and a decrease in LF power components post-intervention. Along similar lines, earlier studies also have shown the effectiveness of yoga in increasing the parasympathetic tone associated with a reduction in LF, increase in HF and reduction in LF/HF ratio (Zou et al., 2018). In our study, although the yoga group showed improvements in working memory performance parameters, accuracy and reaction time did not correlate with HRV parameters. Earlier study showed that a higher resting state HRV is linked with better cognitive performance (Forte et al., 2019). Yoga practice has a downregulating effect on the sympathetic nervous system and HPA axis and may improve cognitive performance (Gothe et al., 2016). The study on sustained attention and working memory showed that the group with higher HRV was linked to better performance compared to the group with lower HRV(Hansen et al., 2003). The Rumination score was significantly reduced in the yoga group indicating the role of yoga in alleviating depressive symptoms, along similar lines to earlier studies (Cramer et al., 2013). Also, the reduction in rumination scores is positively correlated with the improvement in reaction time during the high task load condition indicating a potential role of rumination on working memory performance. Even though there was no statistically significant correlation between a reduction in rumination and an improvement in accuracy, there was a trend toward an influencing relationship. The earlier study on neural correlates of sustained attention and cognitive control in subjects with depressive symptoms showed that levels of depression and reflection, a form of rumination, were not significantly associated with accuracy or reaction time in the sustained attention task, however, there was a negative impact of high levels of reflection on the efficiency with which cognitive resources are applied during the task (Owens et al., 2021). This study found no effect of yoga intervention on PTQ scores. Both PTQ and RRS are based on core characteristics of repetitive negative thinking i.e., repetitiveness, intrusiveness and difficulties to disengage. In our study, we hypothesized that yoga would have a similar effect on RRS and PTQ. However, our results indicate no change in perseverative thinking due to yoga intervention. The RRS is mainly focused on the thought process which is content driven and disease specific. However, unlike the RRS, PTQ is mainly determined by the structure of the thought process, such as repetitiveness, intrusiveness and difficulties disengaging. This might explain the difference in the effect of yoga in our study on RRS and PTQ. The yoga intervention in our study could not bring about a change in the structure of the thought process but could affect the content driven aspect of thinking. Further study would be needed, to validate our assumption, with more specific yoga intervention to change the structure of the thought process itself.

Many plausible mechanisms have been proposed by which yoga improves cognitive functions. Studies show that yoga practice mitigates age-related and neurodegenerative declines by positively affecting brain structure and functions (Gothe et al., 2019). The higher level of cardiorespiratory fitness due to yoga practice (Büssing et al., 2012) positively influences cerebrovascular structure and function (Davenport et al., 2012), resulting in higher levels of cortical activity. Chronic stress associated with health conditions like T2DM leads to prolonged activation of the hypothalamic-pituitary-adrenal (HPA) axis, which in turn results in high levels of cortisol having detrimental effects on brain function and contributing to cognitive deficits over a period (Sapolsky et al., 1986). The study shows that yoga has a downregulating effect on the sympathetic nervous system and HPA axis which moderates the stress response and improves working memory performance (Gothe et al., 2016). Yoga practice has been shown to increase neuroplasticity which may contribute to improved cognitive function (Eyre et al., 2016; Gard et al., 2014). Also, yoga practices have an antidepressant effect that is correlated with elevated serum Brain Derived Neurotrophic Factor (BDNF) levels and improved neuropsychological functions, indicating a neuroplastic effect of yoga (Halappa et al., 2018). A significant role for inflammation has been identified in the pathogenesis of type 2 diabetes (T2DM) and insulin resistance (Badawi et al., 2010). Studies have shown that yoga reduces inflammation, including lowering levels of pro-inflammatory cytokines (Derry et al., 2015; Kiecolt-Glaser et al., 2010) and increasing levels of anti-inflammatory cytokines (Kiecolt-Glaser et al., 2012). As a result of yoga's anti-inflammatory effects, cognitive function may be improved (Derry et al., 2015). A study has shown that yoga has a neuroprotective effect by stabilizing brain metabolites like N-acetyl aspartate (NAA) and myoinositol (MI) in T2DM (Nagothu, Reddy, Rajagopalan, et al., 2015). Cholinergic transmission plays a crucial role in cognitive function, particularly in attention, memory, and learning (Hasselmo & Sarter, 2011). A study by Hassan et al.(2018) showed that several combinations of neurotransmitters and neurotrophins released during yoga and meditation have a neuroprotective action on Cholinergic Transmission (Hassan et al., 2018). Studies have confirmed the role of dopamine in cognitive function and alterations of the dopaminergic system in diabetes patients (Pignalosa et al., 2021). In this scenario also, yoga might have a neuroprotective role that requires investigation. In summary, the approach of integrated yoga appears to help in establishing a homeostatic effect on the inner imbalances as portrayed in the traditional yoga texts (Iyengar, 1995). Figure 15. represents the summary of plausible mechanisms of action of yoga in improving cognitive health in T2DM patients.



BDNF- Brain Derived Neurotrophic factor, GABA - Gamma aminobutyric acid, HPA - Hypothalamic-pituitary-adrenal, MI- Myoinositol, NAA- N-acetyl aspartate, PNS – Parasympathetic nervous system, SNS-Sympathetic nervous system

Figure 15. Schematic representation of plausible mechanisms of action of yoga