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Balance Promotes Cognition: An Experimental Study with Balancing Asana in Early Adolescent Children

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ABSTRACT

Introduction: Asana, the main component of yogic physical practice, is sure to promote motor skills and cognitive functions in normal and special needs children. Neural connectivity of vestibular organ with cognitive areas of the higher brain through the cerebellum and the locus coeruleus of the pons and induce neurotrophic factors, e.g., BDNF (brain-derived neurotrohphic factor) may transform balance motor skills to cognitive abilities with regular practice of asana. This open a scope of the role of Balancing Asana (BA) on cognition. So, the present study built on this premise of the mechanism of BA and cognition. Thus, a set of BA was introduced to children, and their balance and cognitive function were examined.

Methods: Forty school children between 10 and 13 years were randomized as BA and control groups(n=20 each; mean age 11.4 ± 1.2 years). The children were assessed for cognition to the Stroop color-word task for children and balance the Bass stick test. After the pretest, the BA group practiced a set of BA 30 minutes daily, five days a week for six weeks,while the control group continued with their usual routine. Both groups were assessed at the end of six weeks.

Results: Within-group and between-group results showed that the BA group significantly improved the Stroop color tasks ($p<0.001$) and Bass stick test balance ($p<0.001$) compared to a control group with larger effect sizes.

Conclusion: Our findings demonstrated that BA impacts vestibular connectivity, which helps in inducing balance and improving balancing skills, thereby enhancing children's cognitive ability.

KEYWORDS

• Balancing Asana • Vestibular Organ • Cerebellum • Balance • Cognition

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INTRODUCTION

Childhood is a crucial period for the rapid development of physical fitness and cognitive function.[1] Additionally, Yogic techniques have been shown to promote health, wellness and mental well-being across various age groups of children.[2-4] Asana, the fundamental component of yogic physical activity, is believed to improve aerobic capacity, muscular strength, endurance, and balance[5-6] by enhancing core muscle stability connected to the spine, pelvis, legs, and shoulders.[7-8] Research indicates that regular asana practice positively influences cardiovascular health,[9-10] cognitive function and academic performance[11-13] in children.The potential benefits of asana have generated interest in research focusing on both typically developing and special needs children in concerning cognition and motor skills.[14-15] Studies demonstrate that enhancing motor skills through asana[16-17] is linked with cognitive function.[18] The mechanism of yogic exercise influences the higher brain center responsible for memory and cognition.[12;16-18]

To explore how asana improves cognitive functions, the authors sought to identify possible mechanisms supported by existing literature about the cognitive benefits derived from asana practice. Broadly, yogic asanas are categorized based on different movements and positions. One primary category is balancing asana (static balance). Balancing asanas (BA) involve various movements by shifting the center of gravity.[19] Regardless of whether performed standing, sitting, or supine, BA stimulates the vestibular, neuromuscular and proprioceptive systems[20-21] The perception of body movement and static balance in achievingthefinal posture is processed through vestibular detection of inertial motion combined with proprioceptive and visual signals.[22] Consequently, BA stimulates the vestibular system. The semicircular canals and otolith organs of the peripheral vestibular system are located in the inner ear.[23] While achieving the final position of BA, it senses motion, navigation, and spatial orientation.[24-25] Anatomically, the vestibular organ connects with the cerebellum and pons via the vestibular nucleus.[26-27] Neuroanatomical studies reveal that the cerebellum serves as a bidirectional pathway linked to the dorsolateral prefrontal cortex, inferior frontal gyrus, and anterior cingulate cortex ofthe cerebral cortex, which regulate cognitive functions.[28-31] Thus, normal vestibular stimulation is some what essential for cognitive functions in children, such as spatial memory, navigation, and attention.[32-34] Neurological studies indicate that the locus coeruleus(LC) in the pons plays a vital role in numerous higher brain functions, including cognition and memory.[35] Furthermore, the vestibular system is interconnected with the dorsal raphe and the LC in the pons. The LC has a direct connection with the hippocampus and amygdala.[36] Therefore, BA transmits vestibular stimulation to the cerebellum, which then responds to the LC in the pons. In the hippocampus, place cell activity and theta rhythm can be modulated solely by vestibular stimulation.[37] Theta rhythm in the hippocampus enhances cognitive functions such as spatial orientation and spatial memory.[38-39] Occasionally, achieving a higher level of asana leads to a state of sukhaavastha or non-duality. Reaching this elevated mental state may promote theta rhythm in the hippocampus. Increasing literature also supports the neurochemical and neurophysiological changes that arise through asana practice. Neurochemical components such as neurotrophic factors e.g., brain-derived neurotrophic factor (BDNF) or insulin-like growth factor 1 (IGF-1), metabolites (e.g., lactate), and neurotransmitters (e.g., serotonin) play a crucial role in neuronal development and cognitive function.[40–42] Neurotrophic factors facilitate neural connectivity, which is a mechanism that may elucidate the relationship between BA and cognition.

Therefore, the present study was based on the premise of the mechanisms linking of BA and cognition. A set of BA was thus introduced to children, and their balance and cognitive function were assessed.

MATERIAL AND METHODS

1. Design

It was a randomized pre-post-control trial that compared balance and cognition following the practice of a set of BA. A comparison was made both within the group and between the groups.

2. Participants

For this study, 40 students from Popular High Schoolin Imphal, Manipur, studying in grades five to seven Subjects were randomly assigned to two groups using a computerized random method. The ages of the subjects ranged from 10 to 13 years (group mean and SD11.58 ± 2.02) with 53% being girl students. Inclusion criteria included healthystudents with regular attendance within the age group of 10-13 years. Exclusion criteria comprised any history of psychiatric or neurological disorders and color vision impairment. Signed informed consent was obtained from the principal of the school. The subjects were divided into two groups of 20 each: Group 1 (BA) and Group 2 (Control). Data was collected from both groups, referred to as pre-test data. Following this, Balancing Asana training was administered to the BA group for six weeks while the control group continued with their usual routine. After the training was completed, data was collected again from both groups as post-test data.

3. Assessments

The participants were assessed for cognition using the stroop test and balance with the Bass stick test.

The stoop color and word test (SCWT) is a neuropsychological test design to assess the ability to inhibit cognitive interference.It is also considered a cognitive control task.[43] The SCWT was developed by John Ridley Stroop in 1935. In this task, subjects must read three tables as quickly as possible. The first card (set. 1) requires reading words, the second (set. 2) involves reading the color of the word and the third card (set. 3) asks the participants to name the color of the ink in which a printed word is displayed. The Stroop test measures cognitive functions such as attention, processing speed, cognitive flexibility and working memory. Participants were instructed to respond as quickly and accurately as possible. Score were recorded in seconds for all three sets.[44]

Bass stick test: The Bass stick test evaluates balance, in which participants alternate foot hopping and hold a static position. It measures the static balance of the subject by maintaining stability on a narrow surface while standing on the ball of the foot. This test is suitable for both sexes aged ten years and above. Scores are recorded in seconds.[45]

4. Administration of the training program

After completing the pre-test, the BA group under went six weeks of BA training, while the control group engaged in their daily activities. Training was conducted six days a week, from Monday through Saturday. Initially, subjects were given to have balancing asanas. The BA training module was as follows.

Table 1: Practice modules of BA and their Balancing Potential

Sl.No.	Name of the practice	Time
1	Starting prayer: Om sahanavavatu	2 min
2	Standing Loosening exercise	2 min
3	Tadasana (standing palm tree): balance is maintained by putting body weight on the big toes and partially on the other toes of both legs.	2 min
4	Triyakatadasana (standing swaying palm tree): balance is maintained by both legs by shifting the center of gravity to the left or right side by bending the upper body from the waist region with hand stretch interlocking position.	2 min
5	Vriksasana (standing tree pose): balance is achieved in a single leg by folding one leg at the knee and placing the sole on the inner thigh of the standing leg.	2 min
6	Natrajasana (standing dancer pose): Balance is maintained in a single leg, and another leg is held by the same hand by pulling up from the back.	2 min
7	Garudasana (standing eagle pose): balance is achieved in a single leg by typically raping another leg and both arms cross each other from at elbow joints.	2 min
8	Virabhadrasana (back bending warrior pose) balance is maintained in a single leg by bringing the body and another leg parallel to the ground.	2 min
9	Ardhanavasana (abdominal balancing half boat pose): balance is achieved by being in the prone position on the abdomen by lifting the upper trunk and legs towards the sky.	2 min
10	Parvatasana (sitting mountain pose): sitting in padmasana, then standing and balancing on both knees.	2 min
11	Prapadasana (sitting tip-toe pose): balance is maintained by squatting down onto toes with both heels in the air.	2 min
12	Relaxation: Savasana (corpse) pose.	5 min
13	Closing prayer: Sarve bhavantusukhinah	3 min
	Total =	30 min

5. Statistical analysis

The data collected from the pre and post-test was analyzedusing descriptive statistics. The significance level was set at 0.05, and all statistics were performed using Jamovi 2.2.1 free software. Cognition was compared with the values of three sets of Stroop tests and balance was assessed using the Bass Stick test. Descriptive statistics was applied to determine the characteristics of the pertaining data. Additionally, a paired sample t-test was employed to identify the significant difference between the means of the pre-and post-test cognition tasks and balance. In the between-group comparison, Stroop test sets one and two did not show normal distribution. The results of Shapiro-Wilk Normality Test indicatedthat low p-values violate the normality assumption. Therefore, for Stroop tasks set 1 and 2, the Welch's t-test was conducted. Other variables, such as Stroop task set 3 and the Bass stick test also utilized Independent Samples t-test.

RESULTS

Table 1: Comparison of Pre and Post test of BA Group on the three sets of Stroop test

Group	Mean ± SD	t-value	p-value	Cohen's d
SET1-Pre	6.05 ± 1.32	1.17	<0.001	1.17
SET1-Post	5.30±1.08			
SET2-Pre	8.50±1.50	2.67	<0.001	2.50
SET2-Post	6.90±1.29			
SET3-Pre	12.00±1.72	2.50	<0.001	2.67
SET3-Post	9.30±1.34			

Note: Result of Paired Samples t-test, Significant at 0.05, SET1 - first card, SET2 - second card, SET3 - third card.

Table 1 indicates a significant difference regarding the Stroop test for the BA group with t-values of 1.17, 2.67, and 2.50 and p-values (sig) of <0.001, <0.001, and <0.001, respectively found lower than the 0.05 level of significance demonstrating larger effect sizes.

Table 2: Comparison of Pre and Post-test of Control Group on the three sets of Stroop test

SET	Mean±SD	t-value	p-value	Cohen's d
SET1-Pre	5.85±1.27	0.294	0.204	0.29
SET1-Post	6.10±0.85			
SET2-Pre	8.70±1.46	0.000	1.000	0.00
SET2-Post	8.70±1.46			
SET3-Pre	11.75±1.55	0.188	0.412	0.18
SET3-Post	11.50±1.54			

Note: Result of Paired Samples t-test, Significant at 0.05, SET1- first card, SET2- second card, SET3- third card

Table 2 shows that there is no significant difference in the Stroop test ofthe control group with t-values of 0.29, 0.00, and 0.18, and corresponding p-values of 0.204, 1.000, and 0.412, all exceeding 0.05and indicating smaller effect sizes.

Table 3: Comparison of Pre and Post test of BA Group on Bass Stick Test

Variable	Mean±SD	t-value	p-value	Cohen's d
BST Pre	16.65±3.64	15.9	<0.001	3.56
BST Post	22.70±4.25			

Note: Result of Paired Samples t-test, Significant at 0.05, BST - Bass stick Test

In Table 3 a significant difference is observed in the Bass stick test for the experimental group with the t-value of 15.7 and p-value (sig) <0.001, both of which are below0.05 and reflect ahigh effect size as indicated by Cohen's d value of 3.56.

Table 4: Comparison of Pre Post test of Control Group on Bass stick test

Variable	Mean±SD	t-value	p-value	Cohen's d
BST Pre	15.10±5.20	4.97	<0.001	1.11
BST Post	16.65±5.09			

Note: Result of Paired Samples T-Test, Significant at 0.05, BST- Bass stick Test

Table 4 reveals a significant difference in the Bass stick test forthe control group with a t-value of 4.97 and a p-value (sig) <0.001, both lower than 0.05 and yielding a high effect size of Cohen's d value of 1.11.

Table 5: Comparison between BA and Control Groups on the three sets of Stroop test on their mean difference

Variable	t-value	p-value	Cohen's d
SET 1	4.20	<0.001	1.33
SET 2	6.84	<0.001	2.16
SET 3	6.23	<0.001	2.06

Note: SET 1 and 2 results of Welch's t and SET 3 student t-test, Significant at 0.05

Table 5 demonstrates a significant difference regarding the three sets of Stroop tasks between the BA and control group, with t-values of 4.20, 6.84, 6.23, and the p-values of (sig) <0.001, <0.001 and <0.001 and Cohen's d values of 1.33, 2.16 and 2.06.

Table 6: Comparison between Experimental and Control groups of Bass stick test on mean difference

Variable	t-value	p-value	Cohen's d
Bass Stick Test	9.15	<0.001	2.89

Lastly Table 6 indicatesa significant difference in the Bass

Stick Test while comparing between the BA and control groups with a t-value of 9.15 and p-value(sig) <0.001, both lower than 0.05, and a higher effect size represented byCohen's d value of 2.89.

DISCUSSION

The findings of this study reveal that six weeks of the BA program have an effect on improving the three sets of Stroop tasks and the Bass stick test. Forthe BA group, the results of the three sets of Stroop tasks analyzed using the paired sample 't' test showed a significant change between pre and post readings. Conversely, for the control group, from the same sets of Stroop tasks indicated no significant changes between pre and post readings. In the Bass stick test, the results of paired sample t-test that both groups demonstrated considerable changein their pre and post readings. Comparing the BA and control groups with the Studentt-test and Welch's t-test revealed substantial changes in the three sets of Stroop tests and the Bass Stick test. Therefore, according to statistical analysis, it was confirmed that the six-week BA program was effective in improving balance and cognition among children.

The Stroop task is based on three interrelated cognitive processes: inhibition, working memory, and cognitive flexibility.[43] Inhibition is the ability to resist and control one's attention and thoughts, which may be habitual or impulsive. Working memory involves retaining essential and pertinent information in mind simultaneously engaging in another task. Cognitive flexibility refers to the ability to switch quickly and easily between different tasks.[46] In this study, the BA program improved these three levels of cognitive processes compared to the control group. The findings also support one of the modules aimed at enhancing inhibition skills in individuals by transferring skills from training, specifically, from BA training to cognitive abilities.[47]

Another insight comes from neuroimaging studies using fMRI which have shown that the three components of cognitive function engage a network of brain regions, including the dorsolateral prefrontal cortex, inferior frontal gyrus, anterior cingulate cortex, supplementary motor cortex, pre-supplementary motor cortex, precuneus, and insula.[48] The supplementary motor cortex (SMA), pre-supplementary motor cortex (pre-SMA) and other areas are also involved in programming complex sequences of movements and coordinating bilateral movements.[49] In the present BA module, several Asanas such as Natarajasan, Guradadasana, Virabhadrasana, and Propadasana involve in bilateral complex sequences of movement in the final positions. This pathway may support the transformation of skills from BA asana training to cognitive abilities in the Stroopcolor-word task.

The study by Rogge *et al.* 2017 demonstrated that 12 weeks of balance training could induce structural plasticity in higher brain center such as the superior temporal cortex, visual association cortex, posterior cingulate cortex, and superior frontal sulcus. These areas facilitate higher cognitive functions such as memory and spatial cognition and are also involved in visual-vestibular self-motion processing. Our present study replicates the Rogge *et al.* 2017 findings.[50] The BA program induces neural connectivity through the vestibular pathway, which is reflected in improvements in balance and increased ability to inhibit cognitive interference in the Stroop task readings compared to the control group.

Generally, Asana, including the BA, is practiced with closed eyes and participants maintained the final posture with their eyes closed according to their individual ability. Studies have shown that achieving balance with closed eyes is more challenging than with eyes open.[51] In a review by Prosperini *et al.* (2013), the ability to balance with closed eyes was used to assess balance in patients with multiple sclerosis compared to those with open eyes. The result indicated that there was a greater degree of imbalance with closed eyes than with open eyes due to the absence of visual proprioception.[52] Silvas tested static balance among young women with open and closed eyes while wearing high-heeled shoes. The findings revealed that closed eyes were a contributing factor to maintaining static balance in standing posture.[51] Thus, practicing with eyes closed may also induced neural connectivity and improved balance. As a result, there may be improved cognition in children participating in the BA program compared to the control children.

The present study observed that BA improved motor skills by enhancing balance readings in the Bass stick test. Studies have demonstrated that motor skills and cognitive function are inter connected.[53-54] Children need to enhance their balancing motor skills through regular physical activity, which would, in turn, improve cognitive function.

In this study, we utilized BA to engage the vestibular, proprioceptive, and reticular formation systems. Regarding of children's balance skills, the cerebellar region plays a significant role in maintaining balance. A recent review the structural brain correlates with postural balance and training in humans revealed that a larger cerebellar gray matter volume is associated with better balance across various training programs for healthy and clinical populations.[55] Our findings regarding Bass stick test readings for static balance in healthy children may also support this concept. Another observation from the Bass stick test redings indicate that in the pre and post data, both the BA group and the control group showed improvements in balance. The reason for this could be that learning is a natural phenomenon in children[56] which they often observe and emulate from others' daily activities. However, between-group results revealed that BA enhances neural connectivity and significantly improves balance in BA children compared to their control children.

CONCLUSION

Based on the results obtained, the present randomized controlled trial demonstrated that balancing asanas positively impact vestibular connectivity, aiding in balance for children. The findings confirmed that enhancing balancing skills contributes to improved cognitive ability in children. Improvements in balance and cognitive tasksamong children participatingin BA may support the mechanisms underlying these benefits discussedat the beginning of this paper. Despitethe small sample sizes, this study provides significantopportunities for future research to examine the impact of various types of asanas on cognition. Future studies could be exploring simple forms of asana compared to complex sequencesregarding cognitive abilities. Additionally, this study could be replicated with children who have cognitive deficits or special needsutilizing neuroimaging methods.

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REFERENCES

1. Bidzan-Bluma I, Lipowska M. Physical Activity and Cognitive Functioning of Children: A Systematic Review. Int J Environ Res Public Health. 2018;15(4):800. doi:10.3390/ijerph15040800
2. Nanthakumar C. The benefits of yoga in children. J Integr Med. 2018;16(1):14-19. doi:10.1016/j.joim.2017.12.008
3. Eggleston B. The Benefits of Yoga for Children in Schools. The International Journal of Health, Wellness and Society; 2015;5(3):1-7. DOI:10.18848/2156-8960/CGP/v05i03/41125
4. Hagen I, Nayar US. Yoga for Children and Young People's Mental Health and Well-Being: Research Review and Reflections on the Mental Health Potentials of Yoga. Front Psychiatry. 2014;5:35. doi:10.3389/fpsyt.2014.00035
5. Bhowmik BG, Ray US. Improvement in muscular strength, body flexibility and balance by yogasana and with reduced detraining effects by yoga breathing maneuvers: A non-randomized controlled study. J Ayurveda Integr Med. 2024;15(1):100815. doi:10.1016/j.jaim.2023.100815
6. Omkar SN, Vishwas S, Tech B. Yoga techniques as a means of core stability training. J Bodyw Mov Ther. 2009;13(1):98-103. doi:10.1016/j.jbmt.2007.10.004; PMID: 19118798
7. Rathore M, Trivedi S, Abraham J, Sinha MB. Anatomical Correlation of Core Muscle Activation in Different Yogic Postures. Int J Yoga. 2017;10(2):59-66. doi:10.4103/0973-6131.205515; PMID: 28546675
8. Ni M, Mooney K, Harriell K, Balachandran A, Signorile J. Core muscle function during specific yoga poses. Complement Ther Med. 2014;22(2):235-243. doi:10.1016/j.ctim.2014.01.007; PMID: 24731894
9. Pandit DP, Upadhyah A, Goyal P, Sharma D. Effect of short term yoga on body weight, BMI, body fat percentage & blood pressure. Indian J Clin Anat Physiol. 2019; 6(2), 179-182. doi.org/10.18231/j.ijcap.2019.040
10. Ray US, Pathak A, Tomer OS. Hatha yoga practices: energy expenditure, respiratory changes and intensity of exercise. Evid Based Complement Alternat Med. 2011;2011:241294. doi:10.1093/ecam/neq046; PMID: 21799675
11. Prakash RS, Voss MW, Erickson KI, Kramer AF. Physical activity and cognitive vitality. Annu Rev Psychol. 2015;66:769-797. doi:10.1146/annurev-psych-010814-015249;

PMID: 25251492

12. Telles S, Singh N, Bhardwaj AK, Kumar A, Balkrishna A. Effect of yoga or physical exercise on physical, cognitive and emotional measures in children: a randomized controlled trial. Child Adolesc Psychiatry Ment Health. 2013;7(1):37. Published 2013 Nov 7. doi:10.1186/1753-2000-7-37; PMID: 24199742
13. Parajuli N, Pradhan B, Bapat S. Effect of yoga on cognitive functions and anxiety among female school children with low academic performance: A randomized control trial. Complement Ther Clin Pract. 2022;48:101614. doi:10.1016/j.ctcp.2022.101614; PMID: 35688056
14. Mohanty S, Pradhan B, Hankey A. Yoga Practices as an Alternative Training for Physical Fitness in Children With Visual Impairment. Adapt Phys Activ Q. 2019;36(4):431-446. doi:10.1123/apaq.2018-0167 ; PMID: 31509796
15. Purohit SP, Pradhan B. Effect of yoga program on executive functions of adolescents dwelling in an orphan home: A randomized controlled study. J Tradit Complement Med. 2016;7(1):99-105. Published 2016 Apr 20. doi:10.1016/j.jtcme.2016.03.001; PMID: 28053894
16. Jarraya S, Jarraya M, Nouira S. Effect of Yoga on Motor Skills and Self-Esteem in Kindergarten Children: A Randomized Controlled Trial. Int J Yoga Therap. 2022;32(2022): 10. doi:10.17761/2022-D-21-00060; PMID: 35997992
17. Ramakrishnan, R., & Sethu, S. Effects of Yogasanas practice on motor skills among school children. Children. 2018;14(4), 91-92.
18. M, Bhat A. Creative Yoga Intervention Improves Motor and Imitation Skills of Children With Autism Spectrum Disorder. Phys Ther. 2019;99(11):1520-1534. doi:10.1093/ptj/pzz115; PMID: 31765484
19. Taylor M J. "Yoga Therapeutics: An Ancient Practice in a Twenty-First Century Setting." Integrative Therapies in Rehabilitation. Routledge, 2024. 181-202.
20. Rao S, Pal R. "Exploring the Multidimensional Health Effects of Yogasana: A Comprehensive Overview." Yoga-Exploring the Health Benefits and Diverse Dimensions, Intech Open, 2024. DOI: 10.5772/intechopen.1005096
21. Delhaye BP, Long KH, Bensmaia SJ. Neural Basis of Touch and Proprioception in Primate Cortex. Compr Physiol. 2018;8(4):1575-1602. Published 2018 Sep 14. doi:10.1002/cphy.c170033; PMID: 30215864
22. Winter L, Huang Q, Sertic JVL, Konczak J. The Effectiveness of Proprioceptive Training for Improving Motor Performance and Motor Dysfunction: A Systematic Review. Front Rehabil Sci. 2022;3:830166. doi:10.3389/fresc.2022.830166 ; PMID: 36188962
23. Goldberg, Jay M., et al. The vestibular system: a sixth sense. Oxford University Press, 2011
24. Zwergal A, Grabova D, Schöberl F. Vestibular contribution to spatial orientation and navigation. Curr Opin Neurol. 2024;37(1):52-58. doi:10.1097/WCO.0000000000001230; PMID: 38010039
25. Diaz-Artiles A, Karmali F. Vestibular Precision at the Level of Perception, Eye Movements, Posture, and Neurons. Neuroscience. 2021;468:282-320. doi:10.1016/j.neuroscience.2021.05.028 ; PMID: 34087393
26. Hitier M, Besnard S, Smith PF. Vestibular pathways involved in cognition. Front IntegrNeurosci. 2014;8:59. Published 2014 Jul 23. doi:10.3389/fnint.2014.00059; PMID: 25100954
27. Dieterich M, Brandt T. Functional brain imaging of peripheral and central vestibular disorders. Brain. 2008;131(Pt 10):2538-2552. doi:10.1093/brain/awn042; PMID: 18515323
28. Epstein RA, Patai EZ, Julian JB, Spiers HJ. The cognitive map in humans: spatial navigation and beyond. Nat Neurosci. 2017;20(11):1504-1513. doi:10.1038/nn.4656 ; PMID: 29073650
29. Ventre-Dominey J. Vestibular function in the temporal and parietal cortex: distinct velocity and inertial processing pathways. Front IntegrNeurosci. 2014;8:53. doi:10.3389/fnint.2014.00053; PMID: 25071481
30. Koziol LF, Budding D, Andreasen N, et al. Consensus paper: the cerebellum's role in movement and cognition. Cerebellum. 2014;13(1):151-177. doi:10.1007/s12311-013-0511-x; PMID: 23996631
31. Baillieux H, De Smet HJ, Paquier PF, De Deyn PP, Mariën P. Cerebellar neurocognition: insights into the bottom of the brain. Clin Neurol Neurosurg. 2008;110(8):763-773. doi:10.1016/j.clineuro.2008.05.013; PMID: 18602745
32. Smith LJ, Wilkinson D, Bodani M, Surenthiran SS. Cognition in vestibular disorders: state of the field, challenges, and priorities for the future. Front Neurol. 2024;15:1159174. doi:10.3389/fneur.2024.1159174; PMID: 38304077

33. Smith PF, Geddes LH, Baek JH, Darlington CL, Zheng Y. Modulation of memory by vestibular lesions and galvanic vestibular stimulation. Front Neurol. 2010;1:141. doi:10.3389/fneur.2010.00141 ; PMID: 21173897

34. Wiener-Vacher SR, Hamilton DA, Wiener SI. Vestibular activity and cognitive development in children: perspectives. Front IntegrNeurosci. 2013;7:92. doi:10.3389/fnint.2013.00092; PMID: 24376403

35. Craigmyle NA. The beneficial effects of meditation: contribution of the anterior cingulate and locus coeruleus. Front Psychol. 2013;4:731. doi:10.3389/fpsyg.2013.00731; PMID: 24137145

36. Melnychuk MC, Dockree PM, O'Connell RG, Murphy PR, Balsters JH, Robertson IH. Coupling of respiration and attention via the locus coeruleus: Effects of meditation and pranayama. Psychophysiology. 2018;55(9): e13091. doi:10.1111/psyp.13091; PMID: 29682753

37. Aitken P, Zheng Y, Smith PF. The modulation of hippocampal theta rhythm by the vestibular system. J Neurophysiol. 2018;119(2):548-562. doi:10.1152/jn.00548.2017; PMID: 29167325

38. Li JY, Kuo TBJ, Hung CT, Yang CCH. Voluntary exercise enhances hippocampal theta rhythm and cognition in the rat. Behav Brain Res. 2021;399:112916. doi:10.1016/j.bbr.2020.112916; PMID: 32949643

39. Soltani ZH, Ghadiri T, Seyedi M, et al. Theta Oscillations Through Hippocampal/Prefrontal Pathway: Importance in Cognitive Performances. Brain Connect. 2020;10(4):157-169. doi:10.1089/brain.2019.0733; PMID: 32264690

40. Zühtü BY. 'The Potential Role of Exercise-Induced Neurotrophic Factors for Mental Health'. Mental Health - Preventive Strategies, Intech Open, 19 July 2023. Crossref, doi:10.5772/intechopen.106867

41. Sharma K, Pannu V, Sayal N, Bhalla A, Anand A. Effects of one month of Common Yoga Protocol practice appear to be mediated by the angiogenic and neurogenic pathway: A pilot study. Explore (NY). 2021;17(5):451-457. doi:10.1016/j.explore.2020.09.007; PMID: 33059980

42. Nicastro TM, Greenwood BN. Central monoaminergic systems are a site of convergence of signals conveying the experience of exercise to brain circuits involved in cognition and emotional behavior. Curr Zool. 2016;62(3):293-306. doi:10.1093/cz/zow027; PMID: 29491917

43. MacLeod CM. Half a century of research on the Stroop effect: an integrative review. Psychol Bull. 1991;109(2):163-203. doi:10.1037/0033-2909.109.2.163; PMID: 2034749

44. Golden CJ, Freshwater SM, Golden Z: Stroop Color and Word Test Children's Version for ages 5–14: A manual for clinical and experimental uses. U.S.A. Stoelting Co.; 2003.

45. Johnson BL, Nelson JK. Practical measurements for evaluation in physical education. (1979) 3rd edition, Burgess Publishing Company, Minneapolis. ISBN: 9780808710110, 0808710117

46. A. Executive functions. Annu Rev Psychol. 2013; 64:135-168. doi:10.1146/annurev-psych-113011-143750 ; PMID: 23020641

47. Thorell LB, Lindqvist S, Bergman Nutley S, Bohlin G, Klingberg T. Training and transfer effects of executive functions in preschool children. Dev Sci. 2009;12(1):106-113. doi:10.1111/j.1467-7687.2008.00745.x ; PMID: 19120418

48. TA, Laird AR, Ray KL, Dean YM, Glahn DC, Carter CS. Meta-analytic evidence for a superordinate cognitive control network subserving diverse executive functions. Cogn Affect BehavNeurosci. 2012;12(2):241-268. doi:10.3758/s13415-011-0083-5 ; PMID: 22282036

49. Nachev P, Kennard C, Husain M. Functional role of the supplementary and pre-supplementary motor areas. Nat Rev Neurosci. 2008;9(11):856-869. doi:10.1038/nrn2478; PMID: 18843271

50. Rogge AK, Röder B, Zech A, Nagel V, Hollander K, Braumann KM, Hötting K. Balance training improves memory and spatial cognition in healthy adults. Scientific reports. 2017; 7(1):5661. doi: 10.1038/s41598-017-06071-9; PMID: 28720898

51. Silva MB, Martinho Fernandes LFR, Caetano E Souza RH, Rosa de Sá AA, Naves ELM. Analysis of ankle muscle activity: A study on static balance with eyes closed and high-heeled shoes. Foot (Edinb). 2024. 60:102100. doi:10.1016/j.foot.2024.102100; PMID: 38810470

52. Prosperini L, Pozzilli C. The clinical relevance of force platform measures in multiple sclerosis: a review. Mult Scler Int. 2013;2013:756564. doi:10.1155/2013/756564 ; PMID: 23766910

53. VanderFels IM, TeWierike SC, Hartman E, Elferink-Gemser MT, Smith J, Visscher C.

The relationship between motor skills and cognitive skills in 4-16 year old typically developing children: A systematic review. J Sci Med Sport. 2015;18(6):697-703. doi:10.1016/j.jsams.2014.09.007; PMID: 25311901

54. O'Hagan AD, Behan S, Peers C, Belton S, O'Connor N, Issartel J. Do our movement skills impact our cognitive skills? Exploring the relationship between cognitive function and fundamental movement skills in primary school children. J Sci Med Sport. 2022;25(11):871-877. doi:10.1016/j.jsams.2022.08.001; PMID: 36064502

55. Surgent OJ, Dadalko OI, Pickett KA, Travers BG. Balance and the brain: A review of structural brain correlates of postural balance and balance training in humans. Gait Posture. 2019;71:245-252. doi:10.1016/j.gaitpost.2019.05.011; PMID: 31082657

56. Karadeniz S, Suveren C, Arslan Y, et al. Examination of basic motor skills in children and adolescents. Front Physiol. 2024;14:1346750. doi:10.3389/fphys.2023.1346750; PMID: 38481765