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Mind-Body Synergy: How the Resistance Training Improved Cognitive Functioning in Male Medical College Athletes and Non-Athletes

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ABSTRACT

Traditionally, mind-body synergy manifest harmonious relationship between physical and cognitive processes whereas resistance training has emerged as a powerful tool for enhancing brain function in both athletes and non-athletes This article explores the prevailing concept of resistance training as a tool for cognitive enhancement in both athletic and non-athletic It also discuss (1) cognitive benefits of resistance training across both athletic and non-athletic populations (2) exploring insights into the physiological and psychological mechanisms that underpin this mind-body synergy (3) especially focus medical college graduates in strop color-word test for determining executive functioning, working memory and attention status among male students. The sixty male college students have been selected for data collection procedure in which half performed resistance exercises or half are sedentary life-style during studying period in medical institutions. Strict eligibility criteria are followed while convenient selection of students. Both groups of students (n=30) undergoes strop color word tests individually and results are computed on their reading basis on tests tasks (WR, CN, CW) during 45 second time period. The Score are computed through independent sample t-test by SSPS software (version.18). The students having regular RT shows improved scores in CW test denoting higher executive functioning, **attention regulation, and working memory**. Therefore, the consistent resistance training is associated with improved cognitive flexibility and reduced interference effects. The cognitive domains (goal-directed behavior, problem-solving, and maintaining focus) and physiological changes (increased brain-derived neurotrophic factor (BDNF), improved insulin sensitivity, and hormonal modulation) are critical in academic, professional, and high-pressure learning settings.

Keywords: Resistance training, Cognitive, Executive function, Attention, Word reading, Color number, Color word, Brain derived neurotrophic factor.

1. Introduction

Recent neuro-scientific findings promote dynamic relationship between mental and physical states. Physical activities like dance, juggling, and racquet sports enhance cognitive function by activating brain regions. Resistance training facilitates neuroplasticity, while contemplative disciplines like yoga and mindfulness cultivate present-moment awareness and embodied cognition which forcibly enhancing psychological resilience and cognitive function (Team, 2024) The Psychophysiology and neuroscience developments take place due to investigation of mind –body integration. The diminutions of devices and developments of new algorithms enable scholars to study psychophysiology features underpinning the athletes' experts' behavior. The heart-brain communication can self-regulation and attention control in athletes. Also this relationship can help athletes learning up/down, regulate peripheral and center physiological response linked to sports performances (Filho & Basiovitch, 2021).

The researchers investigated comparison of the high-intensity interval training (HIIT) with moderate intensity continuous exercise on memory and inhibitory control domains of cognition. This results into short-term memory improvements with both type of subjects training execution (Kao et al., 2018). Similarly, in another study professionals' mind-body disconnects can lead to illness and burnout if uncontrolled. Meditation, yoga, and tai chi target mind-body processes to increase synergy. More wellbeing can be fostered. Meaningful, meditational, and kinesthetic processes can improve wellbeing in higher education (Henning et al., 2018).

The physical exercises and cognitive function are linked and co-existed sound relationship. The executive functioning and type-level of college students' sports were thoroughly examined. By utilizing three-way quasi experiment study, it is proved that non-athletes' performances are inferior from athletes' counterpart on tests of such executive functioning (Jacobson & Matthaeus, 2014). The effects of high- and low-intensity exercise on brain wave activity and functional connectivity in elite athletes were examined. Low-intensity exercise improves cognitive and attentional processing, but high-intensity exercise affects brain connections and performance permanently. This redirects the Neurofeedback and Physical Fitness Synergy Theory, which states that combining neurofeedback and exercise improves mental and physical health. This integrated approach could enhance physical performance and mental health (Yusuf et al., 2024). A study by Di Corrado et al. (2021) emphasized the significance of integrating mental and physical training for optimal performance. It highlights four themes: (i) mental toughness, (ii) emotional states, (iii) the effects of personality traits, and (IV) Cognitive and psychophysiological characteristic associated with sports performance. Mental training aids athletes in developing and maintaining mental skills, while emotional states significantly impact sports performance. Understanding the interplay between mental training, emotional states, personality traits, and cognitive characteristics is crucial for optimizing performance.

Clinical trials studies of systematic review and misanalysis literature were reviewed on older adults healthy versus impaired status having distinctive cognitive patterns. These researches focused on resistance training manipulation with comparison to cognitive functioning. However, in cognitively healthy adults, there was improvement in the temporary span memory status (assessed through digit span of the WAIS III) (Coelho-Junior et al., 2022).

The body composition, physical performance, cognitive function, and plasma brain-derived neurotrophic factor (BNDF) levels were examined thoroughly in over-age adults by means of weight training coupled with cognitive tasks performances. The cognitive function associated with resistance training significantly improved physical performance (Castaño et al., 2022).

Researcher performed a therapeutic trial to analyses the effects of resistance training (RT) on cognition and physical functioning among older adults. Among community-dwelling older adults, short term resistance training comprises of 12 weeks was effective for improving cognitive and physical function (Santos et al., 2020).

Similarly, cognitive frailties were assessed through interaction of high speed resistance exercises on cognitive function and physical performance. The high-speed resistance exercise training approaches were effective in improving cognitive function and physical performance. To reduce their level of frailty and cognitive impairment, the study enables participants to identify older adults with cognitive frailty in the community and primary care setting for effective intervention to reduce their level of frailty and cognitive impairment (Yoon et al., 2018).

The study of researchers Coetsee & Terblanche (2017) compares resistance training effectiveness, aerobic interval training higher intensity, and moderate aerobic training with respect to cognition and physical functioning in healthy older adults. The interval training improves cardiovascular fitness, while moderate continuous aerobic and resistance training enhance executive cognitive function, information processing speed, and physical function.

With this aspect a comparison study in senior women were conducted with one and two resistance training performances. This time period training duration then compared with cognition functions. The selective attention and conflict resolution among subject of study improved through above duration time span resistance training (Liu-Ambrose, 2010).

Soga et al. (2018) examined the effects of resistance training on executive function, inhibitory control, working memory, and cognitive flexibility. It suggests resistance training improves executive function inhibition, but the frequency, duration, and intensity of resistance training are uncertain.

In 2018 the Mixed Methods Appraisal Tool (MMAT) was developed iteratively using literature reviews, expert input, and field testing to improve clarity, uniformity, and usability. For cognitive performance research, valid, well-defined, and population-suitable measuring methods like neuropsychological examinations are essential. In qualitative and mixed-methods designs, the instrument helps researchers evaluate participant responses and synthesize qualitative and quantitative data on cognitive outcomes. The MMAT allows comparative evaluation across many study types and improves methodological rigor and transparency, making it ideal for systematic reviews in cognitive functioning-focused fields like neuropsychology, education, and exercise science.

The study of Liu-Ambrose et al. (2010) effectively utilized Stroop test. The set shifting and working memory are calculated through Trail Making Tests (parts A and B) and verbal span forward-backward tests respectively. The resistance training groups measured through stroop test showed improved performance quantitatively.

The study of van de Rest et al. (2014) reveals the effect of resistance-type exercise training with or without protein supplementation on cognitive functioning in frail and pre-frail elderly people. A neuropsychological test battery focused on the cognitive domains: episodic memory, attention and working memory, information processing speed, and executive functioning. The resistance-type exercise training in combination with protein supplementation improved information processing speed. Exercise training without protein supplementation was beneficial for attention and working memory.

Cotemporary researches' advancement in neuroscience emphasizes the sound linkage between physical activity and cognitive function. Physical activities like resistance training, yoga, and aerobic exercise stimulate brain regions that enhance executive functions, emotional regulation, and attention control. This mind-body synergy promotes neuro-plasticity, psychological resilience, and improved well-being. Mostly these research and literature reviews focused on elder adults and women subjects' participants with rarely based on educational and athletic settings.

However, previous source of literature and scientific works reaffirmed the notion that resistance training, alone or combined with cognitive tasks, improves executive functions. This functioning is in form of selective attention, working mindfulness, and cognition flexibility. The effects of these functioning are measurable through neuropsychological tools such as the Stroop test and digit span tasks. Researchers and literature findings elucidated that resistance training positively impacts physical and cognitive health in older adults with cognitive frailty. These findings support a growing body of literature advocating for integrated physical-cognitive interventions to optimize brain health and performance.

The fields of sports science and neuroscience were explored with research work of physical activity and cognition function association in children's performances (Khan & Hillman, 2014). A strong emphasis lied on aerobic exercise which used as a means to enhance attention, memory, and executive functioning in adults (Raichlen & Alexander, 2017).

Undoubtedly, resistance training facilitated neurobiological changes, including elevated brain-derived neurotrophic factor (BDNF) levels, improved cerebral blood flow, and favorable hormonal responses. This would collectively contribute to enhanced cognitive performance, particularly in executive functions such as inhibition, decision-making, and working memory. These effects are well-documented in older adults, while their implications for young adults, especially university students, remain under-researched.

Furthermore, athletes are specifically found to outperform non-athletes in cognitive domains, largely due to regular physical training. The existing studies frequently emphasize elite or professional athletes and aerobic-based training. These researches surpass the cognitive effects of resistance training among student athletes in rigorous academic environments like medical colleges. A validated tool to measure attention and inhibitory control-The Stroop Color Word Test, has been used in some exercise-cognition studies. The application of this test to resistance-trained versus untrained male medical students is rare. The literatures have limited access and focus on resistance training with respect of cognitive intervention due to persistent gap. This isolated intervention, may underrepresent young adult academic populations, and possibly a lack of comparative cross-sectional analyses between athletes and non-athletes in especially medical college education settings.

The current study is timely relevant because of these study gap. This study would contribute precisely to flourishing field of exercise-cognition research by investigating how resistance training influences cognitive functioning in male medical college athletes and non-athletes. It intends to determine whether resistance training serves as a viable cognitive enhancement strategy among students in intellectually challenging settings.

2. Methodology

The male undergraduate college students of age ranging from 21 to 23 were recruited during college sports days, by using a college sports volunteers (non-athletes) and sports participates(Athletes), through distribution of information flyers, and by local information meetings. Potentially eligible medical students were screened through General screening test. The Allama Iqbal Medical College Ethical Committee Board approved the study and informed written consent was taken from eligible study subjects.

Study Design

The transverse comparative research work was carried out at a single point in time. The two groups of athlete and non-athlete are categorized on basis of resistance training performing. The observation procedure implied to segregate college hostel medical college male students. The one time trials explored the effects of resistance exercises on cognition function in male college students. The primary motive was to measures cognitive functioning between two groups of medical college male students based on strop color word test procedure.

Sample size was calculated through and Convenience non-probability sampling technique selected which solely based on availability ease and participation consent, rather than through a random or systematic method. After carefully consideration of study parameters, a sample size of 30 subjects per group was considered adequate.

After inclusion, 60 subjects participated in a study with distinctively into students who do not do resistance training (non-athletes) and students who do regular routine resistance training with at least two session/week (athletes) in college fitness center located in gymnasium. Both the groups were undergoing cognitive strop color word testing procedure in two days.

Exclusion & inclusion criteria

The Allama Iqbal Medical College students aged 21–23 years were enrolled in this study. The different sports clubs enrolled students are athletes while those who did not participate and enroll in any college sports club are non-athletes. Both groups have no history of any illness or psychiatric disorders. Athletic training (resistance training) must have part and parcel of selected athletes group while non-athletes have no any sort of involvement in weight training during this specified period.

The students who have current injuries and chronic illness are excluded in this study.

Resistance training program

The students of athletes group are undergoing at least two session/week resistance training. This program includes Warm up sessions of 5-minutes. The number of set may comprise of Leg press and leg-extension (3 set) & chest press, lat pulldown, Pec-dec and vertical row (2 set others body weight and machine weight bearing selected exercises of students. Also the repetitions per set/ workload/1-Repitition Maximum (1-RM) are 25% (15-20 repetitions) and 50% of 1-RM (10–15 repetitions). The rest and recovery duration between set and exercises are 2 minutes and 3 minutes respectively. The Overall 1-RM goal is to improve body muscles hypertrophy which is only implied on athletes' college male students.

Executive functioning measurements

The procedures for assessing, evaluating and measuring executive function were usually carried through following tests: (a) to measures immediate, delayed memory and retrieval of newly acquired verbal material the Word Learning Test is used (Brand and Jolles, 1985). (b) to measures attention forward test of the Wechsler Digit Span Task is used and the backward test of the Wechsler Digit Span Task is used to measures working memory (Wechsler, 1981). (c) to measures sensorimotoric speed and concept shifting interference (executive function) Trail Making Test Version A and B are used respectively. (Reitan, 1958). (d) to measures selective attention and susceptibility to behavioral interference stroop color-word test is used. (Stroop, 1935). (e) to measures semantic memory and language Verbal Fluency Test is extensively used (Lezak et al., 2004).

STROP COLOR-WORD TEST

Procedure

This test primarily used for accuracy, reaction time and interference which aids in determination of cognitive performance and executive function. The components: selective attention and conflict resolution among medical college male students were undergoes this test procedure. For the Stroop test (Scarpina & Tagini, 2017), there commonly used following three 3 conditions. (a)Participants were instructed to loudly read out words printed in black ink. (b) Read out thoroughly the color of colored. (c) hand over a page with color words printed in incongruent colored inks (eg, the word blue printed in red ink). Then, the participants were asked to name the ink color in which the words are printed (while ignoring the word itself). There were 80 trials for each condition, and the time interval participants took to read each condition recorded in separate sheet. The calculation recorded was based on ability to selectively attend and control response output. This was based on the time difference between the 3rd condition and the 2nd condition. A smaller time difference indicates better selective attention and conflict resolution. A paper and pencil format is easiest way for calculation of scores within stipulated time duration in second.

Scoring

$$\mathbf{IT = CWtime - CNtime}$$

Where

- **(IT in sec) = Interference time calculation**
- **CW** = Color-word score (interference condition)
- **WR** = Word reading score
- **CN** = Color naming score

DATA COLLECTION AND ANALYSIS

The study participants completed the Stroop Color-Word Test, and their performance was assessed across three conditions: Word Reading (WR), Color Naming (CN), and Color-Word (CW) interference. The mean scores (MS) and standard deviations (SD) for each group also are presented in Tabular formation

Table 1: - Stroop Test Scores in Medical Student Athletes (n=30)

Duration: 45 seconds per task

Sr.No	Measure	Mean (± SD)	Interpretation
1	**Word Reading (WR)**	71.4 ±	High speed reading of color words in

		6.4words	black ink
2	**Color Naming (CN)**	69.4 ± 1.6words	Slightly slower naming of color blocks
3	**Color-Word (CW)**	62.3 ± 3.4words	Marked interference effect when ink ≠ word
4	**Interference Score (IS)**	27.9 ±4.2words	Higher cognitive control

Table 2: - Stroop Test Scores in Medical Student Non-Athlete (n=30) Duration: 45 seconds per task

Sr.No	Measure	Mean (± SD)	Interpretation
1	**Word Reading (WR)**	68.9 ± 6.5 words	Slightly slower than athletes in baseline reading
2	**Color Naming (CN)**	66.9 ± 3.7 words	Reduced speed of color processing
3	**Color-Word (CW)**	60.5 ± 3.6 words	Greater cognitive interference
4	**Interference Score (IS)**	26.9 ± 4.0 words	Lower cognitive control

The performance comparison assessed precisely in separate which listed below.

Table 3: Comparison for Performance Athletes Vs Non-Athletes

Sr.No.	Group	WR	CN	CW	IS
1	**Athletes**	71.4 ± 6.4words	69.4 ± 1.6words	62.3 ± 3.4words	27.9 ±4.2words
2	**Non-Athletes**	68.9 ± 6.5 words	66.9 ± 3.7 words	60.5 ± 3.6 words	26.9 ± 4.0 words
3	**Differences**	2.5 ±1.0words	2.5 ±2.1words	1.8 ±0.2words	1.0±0.2words

Independent sample t-test is used for comparing two independent groups (athletes vs. non-athletes). The continuous variable (reaction time or accuracy) is dependent.

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper

WR	Equal variances assumed	.683	.412	3.238	58	.002	5.10000	1.57511	1.94708	8.25292
	Equal variances not assumed			3.238	57.289	.002	5.10000	1.57511	1.94625	8.25375
CN	Equal variances assumed	22.046	.000	7.044	58	.000	5.10000	.72400	3.65076	6.54924
	Equal variances not assumed			7.044	41.356	.000	5.10000	.72400	3.63823	6.56177
CW	Equal variances assumed	.621	.434	4.526	58	.000	3.73333	.82485	2.08221	5.38446
	Equal variances not assumed			4.526	56.908	.000	3.73333	.82485	2.08153	5.38513
IS	Equal variances assumed	.834	.365	1.904	58	.062	1.95900	1.02879	-.10035	4.01835
	Equal variances not assumed			1.904	56.924	.062	1.95900	1.02879	-.10118	4.01918

Table 4: Independent Samples Test

Therefore,

The $P < 0.05$, which proved that null hypothesis (H_0), is rejected. Resultantly, there is a statistically significant difference between the two groups.

3. Results

Athletes manifested higher score amongst all three Stroop conditions compared to their non-athlete counterparts. Precisely, athletes read an average of 71.4 ± 6.4 words in the Word Reading condition, while non-athletes read 68.9 ± 6.5 words. The athletes named 69.4 ± 1.6words colors, whereas non-athletes named66.9 ± 3.7 words colors in the Color Naming condition. The largest performance difference: athletes completed 62.3 ± 3.4words items, while non-athlete completed only 60.5 ± 3.6 words items which were recorded in the Color-Word Interference. This task is primarily reflecting executive functioning and cognitive control among participants.

The interference score (IG) advocates the athlete group (27.9 ±4.2) compared to non-athletes (26.9 ±4.0). This score is calculated using the Golden formula (Golden, 1978) which indicates better inhibitory control and resistance to cognitive interference in athletes. The less cognitive flexibility and greater interference effect represents lower (more negative) IG scores. Thus the less negative score in athletes suggests superior executive functioning (Scarpina & Tagini, 2017).

The consistent advantage in cognitive task performance among athletes further explains from visual representation of the group differences. These persistent prior literature reassuring that improve cognitive outcomes (attention, processing speed, and inhibitory control) is closely related to regular physical activity engagements (Idowu & Szameitat, 2023; Dhahbi et al., 2025).

4. Discussion

The results indicated that student athletes consistently outperformed non-athletes across all test components: Word Reading (WR), Color Naming (CN), and the more cognitively demanding Color-Word (CW) interference condition. These findings suggest that regular engagement in athletic activity is associated with enhanced executive functioning. The same result was elucidated by the Santos et al., 2020 but they used a randomly, comparative trial to analyze the resistance training (RT) effectiveness on cognition and bodily function among older adults.

Athletes group of students showed higher mean scores in WR and CN, indicating faster basic processing speed and attentional capacity. Their superior performance in the CW interference condition, along with a less negative interference score (IG), suggests better inhibitory control. These results align with previous metanalysis study showing that physical activity in older adults can enhance executive cognitive domains ((Coelho-Junior et al., 2022)

The physical activity is evident to increase cerebral blood flow, upregulate neurotrophic factors such as brain-derived neurotrophic factor (BDNF), and support neuroplasticity. The study of Castaño et al., 2022 proved that physical performance increased with subjects having verbal fluency cognitive training combined with resistance training in pre and post intervention period. Our study implied cross-sectional approach and give same sound results like this study.

The athletes have been consistently reported for their cognitive improvements in numerous literature settings. These athletes require rapid decision-making and adaptability under pressure. These skills are closely related to stroop task performances. The current study finding supports the work of Jacobson and Matthaeus (2014) which proved that collegiate athletes outperformed non-athletes in tasks assessing inhibitory control and working memory. Similarly, Kao et al. (2018) demonstrated that better stroop interference control were associated to higher fitness levels in young adults.

The high speed resistance training in female to improve cognitive functioning (Yoon et al., 2018) was deduced effective results of improvements. Similarly, the research study of Coetsee & Terblanche, 2017 compares the effects of resistance training, high-intensity aerobic interval training. Also they compared this with moderate continuous aerobic exercises on cognition and motor functioning in healthy over-aged adults by grouping subjects into four types. Overall, these studies showed same consists results that cognitive functioning improved due to intervention of resistance exercises.

The resistance training effectiveness was explained with tone exercises and balance training. The executive cognition functions were also combined and discussed. The selective attention and conflict resolution among subject of study improved through one year’s weekly two different time span resistance training schedules (Liu-Ambrose, 2010). Soga et al., 2018 examined the effects of resistance training on executive function, inhibitory control, working memory, and cognitive flexibility. It suggests resistance training improves executive function inhibition, but the frequency, duration, and intensity of resistance training are uncertain.

Undoubtedly, some limitations should be acknowledged in this study. The cross-sectional design precludes causal inferences. The individuals with superior cognitive abilities are more likely to engage in competitive sports. The sample size limits generalizability while adequate to preliminary analysis. Additionally, the participants' classification as "athletes" was based on self-report rather than structure supervised training volume or objective performance. This could possibly introduce variability.

This study provides further evidence that athletic activity participation is entirely linked to enhanced cognitive control among young adults. These adults consistently study under pressures demanding academic settings such as medical education. The importance of integrating structured physical activity into medical curricula is highly recommended. This is not only for physical health of students but also to support cognitive performance and academic resilience.

5. Conclusion

The study demonstrated that male undergraduate medical athletes have superior cognitive performances in all components of the strop color-word test as compared to their non-athletes' college students. This result suggests regular resistance training participations are positively associated with enhanced executive functioning especially in selective attention, processing speed and inhibitory control domains. Furthermore, the outcome underscores the potential value of promoting structured supervised resistance training program considering the cognitive demands of medical education and clinical decision-making approach. The students may not improve their academic achievements but also develop imperative cognitive skills for their future professional practice by supporting cognitive resilience through weight bearing exercises.

6. Recommendations

1. The longitudinal and interventional designs should be considering in future exploring causal relationship, pathways and examination the neural mechanism underpins cognitive functioning.

2. Future research study should be highly recommended which could incorporate objective measures of physical fitness and athletic engagement. This could provide deeper insight into the relationship between resistance training and executive function in academically high-performing populations.

3. Academic institutions must encourage students' regular participations at least 2-3 sessions/per week to significant improvement in cognitions (memory, attention and executive function).

4. Additionally, future research must have designed training schedules according to fitness level of athletes to ensure effectiveness in cognition developments.

5. Others standardized cognitive assessments tests must have implemented in future research study before and after training interventions to measure cognitive gains.

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