

Effect of Dual-Task Training on Executive Function in Healthy Children Aged 10–15 Years Using the Stroop Test: A Pre-Post Intervention Study

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Publication Date: 2026/10/14

Abstract:

➤ Background:

Executive function, attention, working memory and inhibitory control continue to develop during childhood and are important for learning and daily activities. Dual-task training combines motor and cognitive demands and may influence executive processing.

➤ Methods:

This quasi-experimental pre-post intervention study included 43 healthy children aged 10 to 15 years recruited by convenience sampling from a primary school in Jalgaon. Participants completed Stroop testing before and after a structured dual-task training program involving walking with backward spelling, word recall and counting backward through weekdays. Training was delivered for 30 minutes per session, three times per week for four weeks according to the methodology and intervention description in the project. Descriptive statistics were reported as mean and standard deviation, and a paired t-test was used for pre-test and post-test comparison.

➤ Results:

The mean Stroop Interference score increased from 4.135 ± 1.964 at pre-test to 7.049 ± 2.428 at post-test, with a statistically significant difference at p less than 0.0001.

➤ Conclusion:

The findings indicate that the dual-task training program was associated with significant improvement in Stroop performance in the participating children. Further controlled studies with larger samples and multiple cognitive outcome measures are warranted.

Keywords: Dual-Task Training; Executive Function; Children; Stroop Test; Cognitive-Motor Training; Physiotherapy.

How to Cite: Gauri Gawande; Ashishkumar Patil; Kalpana Deshmukh (2026) Effect of Dual-Task Training on Executive Function in Healthy Children Aged 10–15 Years Using the Stroop Test: A Pre-Post Intervention Study.

International Journal of Innovative Science and Research Technology, 11(10), 512-517.

<https://doi.org/10.38124/ijisrt/26oct460>

I. INTRODUCTION

Cognition function can be defined as ‘variety’ of brain-Mediated Function and Processes, that allow to us to Perceive ‘Evaluate, Store, Manipulate and use Information from External (e.g. environment) and internal (e.g. experiences, Memory) Sources and then respond to this information. Cognitive function can (be divided into six domains: Memory, attention’ perception ‘executive function, language, and psychomotor function. It is evident that

cognitive function influences children’s and adolescents’ ability to learn and may subsequently affect their academic achievement at school. Therefore, this population has received considerable attention in the literature. (1) Executive functions make possible mentally playing with ideas; taking the time to think before acting; meeting novel, unanticipated challenges and staying focused. Core Executive functions are inhibitory control, working memory, and cognitive flexibility (including creatively thinking “outside the box,” seeing anything from different perspectives, and quickly and

flexibly adapting to changed circumstances). Executive functions (EFs) are essential skills that support mental and physical well-being, academic and life success, as well as cognitive, social, and psychological development. Inhibitory control, a core component of executive function, refers to the ability to regulate attention, thoughts, emotions, and behaviour by suppressing automatic or inappropriate responses. It enables individuals to resist impulses, habitual behaviours, and environmental distractions and to respond in a more appropriate and goal-directed manner. Thus, inhibitory control allows individuals to modify their responses and consciously regulate their behaviour rather than acting automatically based on habitual patterns (2) Executive attention is commonly discussed in relation to attention and working memory. It refers to the higher-level control of attention that enables individuals to direct and maintain their focus toward relevant goals, select appropriate responses, plan actions, resist distractions and temptations, and shift effectively between tasks. It also involves top-down regulation of attention, allowing individuals to focus on relevant environmental stimuli while suppressing attention to irrelevant information. Attention as a resource for storage and processing, a shared resource for perceptual attention and memory maintenance, and a resource for the control of attention. (3) Working memory plays a key role in supporting children's learning over the school years, and beyond this into adulthood. It is proposed here that working memory is crucially required to store information. A child with a poor working memory capacity will struggle and often fail in such activities, disrupting and delaying learning. Working memory refers to the cognitive system responsible for temporarily storing and manipulating information. It serves as a mental workspace that supports complex cognitive activities requiring both information processing and temporary storage, such as mental arithmetic. However, working memory has a limited capacity, and excessive processing or storage demands may result in the loss of information. For example, solving a mental arithmetic problem, such as multiplying two numbers without using paper, a calculator, or other external aids, requires the individual to temporarily retain and manipulate the numbers in working memory. (4) Cognitive functions are brain-based abilities essential for performing tasks ranging from the simplest to the most complex. They involve the processes that enable us to learn, remember, solve problems, and maintain attention. Specifically, this paper focuses on the brain functions related to perception, attention, and memory. (5)

➤ Dual Task Training

In dual task training involves a combination of two motor tasks with different goals or single motor task combined with a cognitive task. This paradigm is generally used to study the ability to perform simultaneous tasks in different populations, providing useful information of enhancing learning processes in children. Cognitive and motor aspects of a secondary task both can be helpful in selecting optimal task parameters to be used in. (6) Dual task training has been used in manifold ways to improve cognitive-motor performance in different age groups. Dual task training is assumed to improve both, single task motor and cognitive performance, but particularly, performance

under dual tasking conditions. Further, Dual Task interventions have been shown to be beneficial for motor skill learning and cognitive performance single task motor cognitive performance as well as academic achievements in children under dual tasking condition. (7) The interdependence of motor and cognitive function comes from the cognitive-motor interference researches using dual task condition cognition-motor interference refers to phenomenon in which carrying out simultaneously a motor and cognitive task interference with performance of one or both task. (8) The ability to coordinate two tasks increases our efficiency in daily life. These tasks targeted at children's executive function component : inhibition, switching, and updating skills There are multiple situations in which we perform two tasks simultaneously such as when we talk to a friend while walking through town combining several concurrent task is typical behaviour in children lives. However, even though we are continuously performing two tasks simultaneously. (9)

➤ STROOP Test

The development of cognitive control and its relation assessed by Stroop test (10) The Stroop Colour and Word Test (SCWT) is a widely used neuropsychological tool applied in both experimental and clinical settings. It measures the ability to inhibit cognitive interference, which occurs when the processing of one aspect of a stimulus disrupts the simultaneous processing of another aspect. (11)

➤ Need of Study

Children aged 10–15 years undergo important development of attention, working memory and cognitive control. During this period, attention and working memory, which are core components of executive function, continue to mature and are essential for academic learning, problem solving and everyday activities. Attention allows children to focus on relevant information and ignore distractions, while working memory enables them to hold and manipulate information in mind, both of which are critical for successful learning and higher-order cognitive processes. Previous studies have shown that dual-task training, which combines motor and cognitive tasks, can enhance cognitive functions in children with different age group. However, there is limited specific evidence regarding its effect on executive function, particularly in the 10–15-year age group. Most existing studies have used multiple techniques to assess both motor and cognitive outcomes, whereas the present study aims to evaluate the effect of a single, structured dual-task training program on executive function.

➤ Aim and Objectives

- Aim: To Study the effect of Dual task training on executive function in healthy children aged 10 to 15 years using the Stroop Test.
- ✓ To assess STROOP interference performance before dual-task training in children aged 10 to 15 years.
- ✓ To assess STROOP interference performance after dual-task training in children aged 10 to 15 years.

- ✓ To compare pre-test and post-test Stroop interference scores following dual-task training in children aged 10 to 15 years.

➤ Hypothesis

Dual task training will have significant effect on executive function in children aged 10 to 15 years.

- Null hypothesis: Dual task training will have no significant effect on executive function in children aged 10 to 15 years.

➤ Inclusion And Exclusion Criteria

• Inclusion Criteria

- ✓ Participants willing to attend all sessions.
- ✓ Children with age group between 10 to 15 years of age.
- ✓ Both gender male and female.

• Exclusion Criteria

- ✓ Children who are not willing to participate in full duration of the training or testing session.
- ✓ Children with visual or hearing impairments.
- ✓ Children with neurological psychiatric, developmental disorders and musculoskeletal disorders.

➤ Outcome Measure

STROOP TEST Stroop test has excellent inter-rater correlation ($icc = 0.926$). Reliability– 0.88 Validity– 0.57 The Stroop colour-word test is considered one of the gold standards of attentional measures and is one of the most widely used instruments in clinical and experimental neuropsychological settings. Among the different standardized versions, the test proposed by Golden (1978) is one of the most extensive, this version features a three-page test booklet. On the first page, the words “red,” “green,” and “blue” are printed in black ink and repeated randomly in columns. On the second page, the item “XXXX” appears repeatedly in columns, printed in red, green, or blue ink. On the third page (referred to as the interference page, henceforth Stroop colour-word or SCW), the words “red,” “green,” and “blue” are printed in red, green, or blue ink, but the words and the colours in which they are printed never match. The subject must look at each page and move down the columns, reading words or naming the ink colours as quickly as possible. The test yields three direct scores, based on the number of items completed on each of the three stimulus sheets in 45 s. In addition, interference ($CW - [(WR * CN) / (WR + CN)]$);

II. MATERIALS AND METHODOLOGY

➤ Materials

- Pen
- Paper
- Stroop test
- Timer

- Consent form
- Patient evaluation sheet

➤ Methodology

- Study Design – Quasi Experimental
- Study Type – Pre–Post intervention study
- Sample Technique – Convenience sampling
- Study Population – Primary school children aged 10-15 years
- Study Duration – 6 months • Study Setting –Primary school Jalgaon.
- Sample size – $43 n = (Z_1^2 \times S^2) / d^2$ M Your guess of Population M 0.53 S Standard deviation of M 0.05 $1 - \alpha$ Set Level of Confidence (value <1.0) 0.95 Z_1 Z Value associated with confidence 1.96 D Absolute precision 0.015 N Minimum sample size 43

➤ Procedure

Ethical clearance was taken from institutional Ethical Committee of Dr. Ulhas Patil College of Physiotherapy, Jalgaon prior to the commencement of the study. Study was undertaken at Primary School Student. Participants were included by screening based on inclusion and exclusion criteria as mentioned earlier. A brief demographic data of all participants was obtained and written consent was taken from all participants. All participant is underwent to pre-test assessment as performing outcome measure

All procedure was explained to the participant participants underwent dual task training (walking with backward of week days or spellings of words) for 4 weeks After completion of the intervention, all participant underwent post -treatment assessment using outcome measure The pre and post – treatment findings were recorded and subjected to statistical analysis using GraphPad Prism software.

➤ Intervention

First, the participants were selected through convenience sampling. All participants were novice in terms of skill level, taking the tests, and performing the tasks as they had no background of being familiar with the procedure. Prior to the tests and tasks, the participants were given some information on the procedure. After receiving the initial information, the examiner provided the participants with information on the process involved in the test and dual-task trainings. Next, all participants attended the pre-test session at an indoor hall to take the Stroop test and post-test session after Dual task training. Dual task training session in dual task training consists cognitive and motor both, cognitive task is backward spelling of word and motor task in walking in straight line. ask children to do walking with backward spelling, simultaneously. And the period of training session is 30 min per session 3 times per week for 4 weeks. after training again will take Stroop test.

- Training session Warmup– 5 min hand tapping arm swings Wrist circle, Raise arm overhead.

- Dual task training– 20 to 25 min walking with spelling proper names backward (name: London, backward: nodnol), recalling order of words (Ball– cat– sun– tree), Counting down week days (Friday– Thursday– Wednesday– Tuesday Monday)
- Choose appropriate word London, Teacher Animals ask the children to walk at normal pace and spell the word backward Timing = 3 to 4 trails 30 sec and 30-60 rest between each trail total duration 4 to 6 min
- Recall the words while walking while walking gives a list of 3-5 words (ball, cat, sun, tree) and repeat in correct order. Timing = 3 to 4 trails 30 sec and 30 to 60 sec rest between each trail total duration 4 to 6 min
- Countdown weekdays while walking “Sunday, Saturday, Friday.....” Timing = 3 to 4 trails 30 sec and 30 to 60 sec rest between each trail total duration 4 to 6 min

➤ Statistical Analysis

Data were entered and analyzed using GraphPad Prism software. Descriptive statistics were used to summarize the pre-test and post-test Stroop Interference (IG) scores. Results were expressed as mean $\pm$ standard deviation (SD).

A paired t-test was used to compare the pre-test and post-test IG scores within the intervention group.

The paired t-test showed a statistically significant difference between pre- test and post-test scores. The p-value is <0.0001 .

III. RESULTS

Table 2. Descriptive statistics for age: Age (Mean $\pm$ SD), 12.33 $\pm$ 1.13 years; 10 to 12 years, 58%; 13 to 15 years, 42%.

The table and pie chart show that the mean age of the participants was 12.33 $\pm$ 1.13 years. Among the participants, 58% were aged 10–12 years, while 42% were aged 13–15 years. Therefore, the majority of participants belonged to the 10–12 years age group.

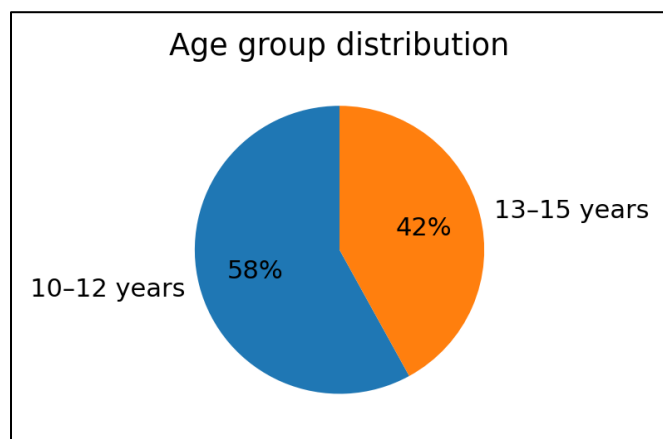


Fig 1 Age Group Distribution.

Table 3. Gender distribution: Male, n = 23 (53%); Female, n = 20 (47%); Total, n = 43 (100%).

The study included a slightly higher proportion of male participants (53%) compared with female participants (47%). The distribution is relatively balanced, with only a 6-percentage-point difference between males and females.

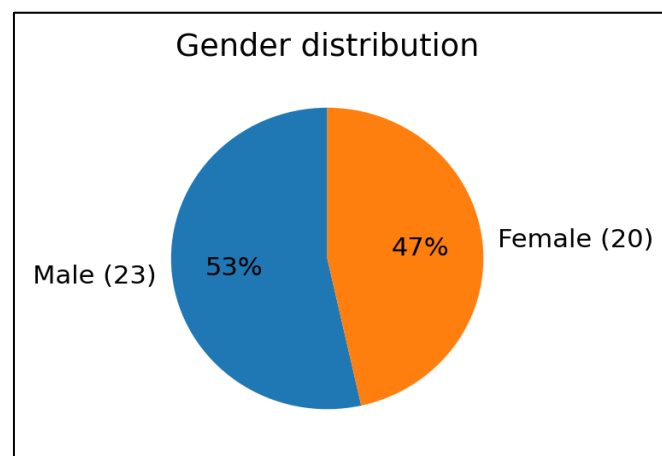


Fig 2 Gender Distribution.

Table 4. Stroop Test Interference Score: Pre-test, 4.135 $\pm$ 1.964; Post-test, 7.049 $\pm$ 2.428; p-value, <0.0001 .

The mean IG Score increased from 4.135 $\pm$ 1.964 at pre-test to 7.049 $\pm$ 2.428 at post-test. This change was statistically significant ($p < 0.0001$), indicating a significant improvement/change in Stroop test performance following the intervention.

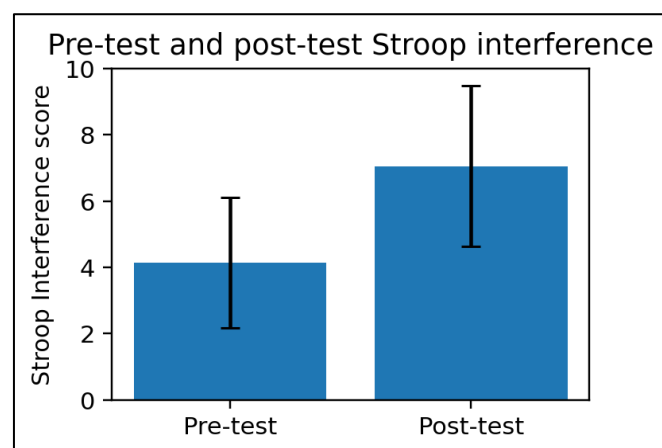


Fig 3 Pre-Test and Post-Test STROOP Interference Score.

IV. DISCUSSION

The present study investigated the effect of an 4-week cognitive-motor dual-task training program on cognitive performance in children aged 10–15 years using the Stroop Color and Word Test. The intervention combined a motor component, mainly walking, with cognitive tasks such as backward spelling, recalling words in sequence, and counting backward through the days of the week. The training was performed for 30 minutes per session, 3 times per week for 8 weeks. The Stroop Interference (IG) score was used to evaluate the change in performance before and after the intervention. In the present study, the mean IG score increased from 4.135 $\pm$ 1.964 at pre-test to 7.049 $\pm$ 2.428 at

post-test. The paired t-test demonstrated a statistically significant difference between pre-test and post-test scores ($p < 0.0001$). Therefore, the observed change indicates improvement in Stroop performance following the intervention, according to the scoring direction used in this study. The Stroop test assesses the ability to manage interference between competing stimulus dimensions and is particularly related to inhibitory control and executive processing. Clinically, the improvement in IG can be reasoned through the nature of the intervention. During dual-task training, the children were required to maintain walking while simultaneously processing and responding to a cognitive task. This creates simultaneous demands on attention, working memory, response selection and inhibitory control. Repeated practice may therefore improve the child's ability to allocate attentional resources and manage competing task demands. The 2022 scoping review similarly reported that cognitive-motor dual-task interventions may improve cognitive and/or physical functions in children and adolescents, although improvements were not consistent across all intervention

The improvement may also be explained by the working-memory demands of the intervention. In the present protocol, children had to retain information, manipulate it and produce an appropriate response while walking. For example, backward spelling requires the child to hold the word in working memory while mentally reversing its sequence. Similarly, recalling a sequence of words requires temporary storage and retrieval, whereas counting backward through weekdays requires continuous updating and attentional control. Working memory is important for coordinating complex cognitive activities and multitasking. Hoshyari et al. reported that dual-task training was associated with improvement in working memory in children, with both cognitive-motor and motor-motor dual-task groups showing better working-memory performance than the single-task group (6). The findings can also be understood from the developmental perspective. Children continue to develop attentional control, task switching and the ability to maintain and manipulate information in working memory throughout childhood and adolescence. The findings of Perri     et al. (2021) support the use of Stroop interference as an outcome related to working memory. Therefore, changes in Stroop interference following dual-task training may reflect changes in these cognitive processes involved in managing competing information.” (21) The Stroop result is also clinically relevant because the incongruent Color–Word condition requires the child to inhibit the more automatic tendency to read the word and instead identify the ink color. Scarpina and Tagini describe this as a conflict between an automated process and the required response, making the Stroop task useful for examining cognitive interference and executive control. (11) The present findings are broadly consistent with previous evidence on cognitive- motor dual-task training in children. Hoshyari et al. found improvements in working memory following dual-task training in children. Similarly, the scoping review by Wollesen et al. found that several interventions in children and adolescents demonstrated improvements in cognitive functions, although the authors emphasized substantial variation between training protocols

and outcomes. Thus, the present findings add to the evidence that a structured cognitive-motor dual-task approach can be associated with measurable changes in cognitive performance in school-aged children. (6)(7) From a physiotherapy perspective, the clinical reasoning is that the intervention did not train cognition in isolation. Walking provided a continuous motor demand, while the concurrent cognitive activities required attention, working memory, response inhibition and updating. Repeated simultaneous practice may have challenged the child to distribute attentional resources between the motor and cognitive components. With practice over 8 weeks, the children may have become more efficient in managing these competing demands, which was reflected by improved Stroop interference performance. Overall, the statistically significant pre-to-post change in Stroop Interference score suggests that the 4-week cognitive-motor dual-task training program was associated with improved Stroop performance in the children included in this study. The clinical rationale is supported by the repeated practice of simultaneous motor and cognitive processing, which may have challenged attention, working memory and inhibitory control. These findings are in agreement with previous research suggesting potential cognitive benefits of cognitive-motor dual-task training in children, while recognizing that the existing literature is heterogeneous and that further controlled studies are required to determine the specific mechanisms and long-term effects.

V. CONCLUSION

The present study concluded that the 4-week cognitive-motor dual-task training program significantly improved Stroop performance in children aged 10–15 years. Significant improvement was observed in the Stroop Interference (IG) score. Therefore, the cognitive-motor dual-task training program can be considered a useful physiotherapy approach for improving executive function, particularly attention, inhibitory control, and interference control, in children aged 10–15 years.

VI. LIMITATIONS

- The study included children aged 10–15 years, which may limit the generalizability of the findings to younger or older age groups.
- The study used a single-group pre-test–post-test design, with no separate control group for comparison.
- The study focused on the Stroop Interference (IG) score, so the findings may not represent changes in all cognitive functions or academic performance.

FUTURE SCOPE

- Future studies can be conducted with a larger sample size to improve the generalizability of the findings.
- The effectiveness of dual-task training can be studied using a randomized controlled trial with a control group.
- Future studies can use multiple cognitive outcome measures along with the Stroop test to assess attention, working memory, executive function, and processing speed.

CLINICAL IMPLICATIONS

The findings support consideration of structured cognitive-motor dual-task activities within physiotherapy programs for school-aged children. Physiotherapists may incorporate safe walking-based cognitive tasks that challenge attention, working memory, response inhibition and interference control, while monitoring the child's ability to perform both components. Such training may be useful as an adjunct approach for executive-function-related goals in children, although controlled studies are needed before making broader clinical recommendations.

➤ Funding

No funding was received for this study.

➤ Conflict of Interest

The authors declare no conflict of interest.

ACKNOWLEDGMENT

The authors acknowledge the support of Dr. Ulhas Patil College of Physiotherapy, Jalgaon, and the participants who cooperated with the study.

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