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Research Study

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### A study on efficacy of hand coordination and strengthening exercises to improve handwriting among high school students

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#### ABSTRACT

##### Background and objective

Handwriting is a complex activity which requires blending of cognitive, kinaesthetic, perceptual and motor components. The final output of handwriting depends on joint position sensation, strength and flexibility of muscles and the posture of the writer. During school time, many of the teachers address the handwriting difficulties among school students. The purpose of this study is to find out the effects of hand coordination and strengthening exercises to improve handwriting speed, hand grip strength and manual dexterity among high school students.

##### Methods

30 subjects were selected based on the inclusion and exclusion criteria, then divided equally into two groups: Group A (Experimental Group: n=15) received hand coordination and strengthening exercises along with handwriting practice and ergonomic guidelines and Group B (Control group: n=15) received handwriting practice and ergonomic guidelines. Structured exercise program was held for five days a week (for 40 minutes) for 5 weeks. Writing speed, hand grip strength, and manual dexterity were measured at the beginning and fifth week after intervention using Handwriting Speed Test (HST), Hand held Dynamometer and Box and Blocks Test (BBT).

##### Results and discussion

The results were analysed using paired and independent t-test. The significance level kept as  $p < 0.05$ . In case of handwriting speed, there was significant difference between the pre-test and post-test HST scores in both experimental and control groups,  $p < 0.001$ ,  $p < 0.01$  respectively. In the group comparison of HST, the obtained  $p$  value was  $0.0389$  ( $p < 0.05$ ), hence there was significant difference in post-test scores between the two groups. The mean difference 12.66 shows that the improvement is more significant in Experimental group.

In the handgrip strength, there is significant difference between pre-test and post-test scores in the two groups,  $p < 0.001$ ,  $p < 0.05$  respectively. In the group comparison, the obtained  $p$  value was  $0.0312$  ( $p < 0.05$ ), hence there was significant difference in post-test scores between the experimental and control groups. The mean difference 0.87 shows that the Experimental group showed more significant improvement.

In case of manual dexterity, there is significant difference existing between the pre-test and post-test scores in both experimental and control groups,  $p < 0.001$ ,  $p < 0.01$ . When the two groups were compared, the obtained  $p$  value was  $0.0114$  ( $p < 0.05$ ) and hence there was significant difference in post-test scores between both the groups. The mean difference 7.0 shows more significant improvement in the Experimental group. Although both groups showed improvement, the scores in the experimental group is significantly higher than that of the control group.

## Conclusion

The study concluded that, there is improvement in handwriting speed, handgrip strength and manual dexterity in experimental as well as in control group. But the Experimental group shows significantly higher improvement in all the three parameters when compared to the control group.

**Keywords:** Handwriting speed; Hand coordination exercises; Hand strengthening exercises; Manual dexterity; Handgrip strength

## INTRODUCTION

Proficient handwriting is an important aspect of education and academic performance of a child. Handwriting is a crucial skill to produce fluent writing for communicating and expressing the ideas<sup>(1)</sup>. Handwriting is a complex activity which requires blending of cognitive, kinaesthetic, perceptual and motor components. All these components must be fully functional to achieve an effective writing<sup>(2)</sup>. Factors affecting handwriting performance can be intrinsic (lack of fine motor control, improper visual-motor integration) or extrinsic (sitting position, chair-desk height, blackboard position, environmental lighting)<sup>(3)</sup>.

Handwriting is often judged and seen as reflection of an individual's intelligence and capabilities. Often lower marks are assigned to children with poor handwriting and higher marks to those with legible handwriting despite similar content<sup>(4)</sup>. The effect of gender is also an important consideration in handwriting development. Often Girl's handwriting is more legible than boy's handwriting. Also girls write faster<sup>(5)</sup>.

According to teacher estimates, approximately 11% to 12% of females and 21% to 32% of male school aged children have handwriting difficulties<sup>(6)</sup>. The main reasons for slow handwriting are delay in information processing, difficulty with spelling, improper motor coordination and adoption of a labour intensive writing style<sup>(7)</sup>. Writing researchers stated that slow handwriting can lead to loss of motivation and evasion of school work (Hedderly, 1992). It can affect note taking during lectures and completing written assignments<sup>(8)</sup>.

Assessment of handwriting speed is an important aspect of handwriting performance. The Handwriting Speed Test (HST; Wallen, Bonney & Lennox, 1996) is a standardized assessment developed to provide an objective and reliable assessment of handwriting speed for school students in years 3 to 12. It consists of a handwriting sample form, student information and record form and a comprehensive test manual. The handwriting sample form has the sentence "The quick brown fox jumps over the lazy dog" at the top. This sentence contains all the letters of alphabet and is familiar to all students. Students are asked using standard administration instructions, to copy this sentence as many times as they can in a 3 minute time. Total letters completed are counted using the specific scoring criteria and it is divided by three to achieve a letters-per-minute score<sup>(9)</sup>.

Hand grip measurement is being used worldwide due to the ease in application and portability of the dynamometer<sup>(10)</sup>. Grip strength of the hand indicates the overall muscle strength that is measured by using a handheld dynamometer, which is considered as the gold standard<sup>(11)</sup>. It is measured in kilograms or pounds. Three consecutive

attempts are made and the average of these three is taken as the result<sup>(12)</sup>.

The Box and Blocks test was designed by Ayres and Holsler to evaluate gross manual dexterity for adult cerebral palsy patients (Smith, 1961). The Box and Block test consisted of a wooden box 53.7 cm by 25.4 cm which was divided into two equal compartments by a 15.2 cm high partition. The subject was instructed to transfer as many 2.5 cm cubes as possible from one compartment to another in one minute. The subject's score is the number of cubes transferred in one minute<sup>(13)</sup>.

Sitting with a good posture for writing increases stability and provides a sturdy foundation for written output and can increase attention and focus. Sitting with poor posture can put stress on muscles, joints and ligaments. When children have unstable posture, they end up using excess energy to maintain their stability and balance. This can affect how they function and decrease their ability to complete fine motor tasks, school work and even to listen<sup>(14)</sup>.

## METHODOLOGY

### Study setting

- Govt. Vocational Higher Secondary School, Irumpanam
- Govt. Higher Secondary School, Panampilly Nagar

### Sample Size

- n=30
- 15 in each group (Group A and Group B)

### Inclusion Criteria

- Age, 13- 15 years
- Both genders
- HPSQ Score less than 14
- Students who can write more than 15 words in 1 minute
- Right hand dominance
- School going children with regular attendance

### Exclusion Criteria

- Learning disability
- Cognitive impairments
- Visual and hearing defect
- Recent trauma to upper limb
- Congenital or acquired structural and functional impairments to upper limb

- Poor intelligence
- Absenteeism

### Sampling Procedure

The total study duration was 5 weeks. 30 students, both male and female, age 13-15 years were recruited from the two high schools through convenient sampling according to the inclusion and exclusion criteria. The study was conducted at the two centres during different study period.

The subjects were divided into two groups:

- Group A (Experimental Group) – Hand coordination and strengthening exercises along with handwriting practice and ergonomic advice – 15 subjects
- Group B (Control Group) – Handwriting practice and ergonomic advices – 15 subjects

## METHODS

### Outcome Measures

- Handwriting Speed Test (HST): To assess the handwriting speed of student
- Hand Held Dynamometer: To measure handgrip strength
- Box and Blocks test: To assess unilateral gross manual dexterity

### Methods of Data Collection

#### Materials Used

- Clay
- Rubber band
- Plastic knife
- Smiley ball
- Cloth pieces
- Zip lock
- Stopwatch
- Handheld dynamometer
- Box and Blocks Test Apparatus
- Handwriting sample forms
- Pens and pencils

### Intervention Procedure

#### Control Group

The students were made to sit in their respective chairs in the classroom. A detailed class were taken to them about the importance of handwriting speed in their academics. They were taught about some conventional

handwriting practice techniques. They were given different writing sheets to practice handwriting. The students were taught proper seating posture for writing. The ergonomic advices were provided by the therapist. The child’s posture at their table or desk should follow the “90-90-90 angle rule”. The position of child in relation to the chair and table:-

- The child’s body should be facing the table with their elbows in line with the desktop at 90 degrees
- They should be seated with their back hinged at the hips slightly forward towards the desk
- Their paper should be stabilized with their non-dominant hand
- Their arm and wrist should be resting on the table
- Their paper should be tilted up to the right if they are right handed and to the left if they are left handed
- Their paper should be angled between 30-45 degrees for left handed writers and between 20-45 degrees for right handed writer

### Experimental Group

The students were made into a group and they were taught about the importance of hand exercises for improving their handwriting speed. Gave them a brief idea about the exercises using materials like clay, zip lock, cloth pieces, smiley balls and rubber bands. Demonstrated them the types of hand strengthening exercises using these materials. There were seven different types of exercises including exercises using clay (Finger hooks, Power grip, Finger extension, Finger scissors, Finger pinch, Finger spread, Thumb press, Thumb adduction, 3 jaw chuck pinch, cutting the clay with plastic knife, rolling the balls of the clay between the tips of thumb, index finger and middle finger). The other exercises were pinching and sealing the zip lock for 10 times, smiley ball squeezing exercises for 10 times, rubber band exercises (finger extensions, finger lift, wrist extension, finger bend), clapping using both hands for 10 times, reciprocal flexion and extension movement of fingers for 10 times, crumbling a piece of cloth for 10 times. All these exercises were done by each student in every session. There were 5 sessions a week for continuous 5 weeks. Each session lasted for about 40 minutes.

## RESULTS

The present study was designed to explore the effectiveness of hand strengthening and coordination training among high school students to improve handwriting.

**Table 1- Mean age in Group A and Group B**

	Mean Age	Standard Deviation	Minimum	Maximum
<b>Experimental group</b>	13.8	0.86	13	15
<b>Control group</b>	13.87	0.83	13	15

The age group taken for the study was between 13-15 years and the mean age for the experimental group was 13.8 with a standard deviation of 0.86 and the mean age for the control group was 13.87 with a standard deviation of 0.83.

**Table 2- Mean Height, Weight, BMI in Group A and Group**

Group	Gender	Height (cm)	Weight (kg)	BMI
Experimental	Male	157±5.66	54.15±4.45	21.93±0.88
	Female	149.13±5.51	46.25±5.23	20.74±1.09
Control	Male	157±3.42	55.86±4.88	22.64±2.02
	Female	148.5±7.01	48.75±7.01	22±1.64

**Statistical analysis of HST using t test**

**Mean, SD and t value to compare Pre test Post test HST in Group A**

**Table 3- paired t test for handwriting speed in Group A**

Test	Mean	SD	Mean Improvement	n	t	df	p-value
Pre-test	112.07	17.18	17.06	15	6.64	14	$p < 0.001$
Post-test	129.13	17.01					

Since the *t-value* 6.64 shows  $p < 0.001$ , there is a significant difference existing between the pre-test and post-test Handwriting Speed Test scores among high school students in the experimental group. This proves the effect of

hand strengthening and coordination exercises with handwriting practice and ergonomic advices to improve the handwriting speed.

**Mean, SD and t value to compare pre test post test HST in Group B**

**Table 4- paired t test for handwriting speed in group B**

Test	Mean	SD	Mean Improvement	n	t	df	p-value
Pre-test	110.93	14.62	5.54	15	4.22	14	$p < 0.01$
Post-test	116.47	14.93					

Since the *t-value*, 4.22 shows  $p < 0.01$ , there is a significant difference existing between the pre-test and post-test Handwriting Speed Test scores among high school

students in the control group. This proves the effect of handwriting practice and ergonomic advices to improve the handwriting speed.

**Mean, SD and t value to compare pre test HST between Group A and Group B using t test**

**Table 5- Unpaired t test for pre test HST score between Group A and Group B**

Group	Pre-test Mean	S.D.	Difference in mean	n	t	df	p-value
Experimental	112.07	17.18	1.14	30	0.195	28	$p = 0.85$
Control	110.93	14.62					

Since the *t-value* 0.195, shows  $p\text{-value} > 0.05$ , there is no significant difference in pre-test handwriting speed scores between the experimental and the control groups .So we can consider the groups as homogenous in the baseline level.

**Mean, SD and t value to compare the post test HST scores between Group A and Group B using t test**

**Table 6- Unpaired t test for post test HST scores between Group A and Group B**

Group	Post-test Mean	S.D.	Difference in mean	n	t	df	p-value
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<b>Experimental</b>	129.13	17.01	12.66	30	2.17	28	$p < 0.05$
<b>Control</b>	116.47	14.93					

Since the *t-value*, 2.17 shows *p-value* < 0.05, there is a significant difference in post-test handwriting speed scores between the experimental and the control groups. The scores in the experimental group are significantly higher

than that in the control group. Hence hand coordination and strengthening exercises is effective in improving handwriting speed among high school students.

**Statistical analysis of handheld dynamometer using t test**

**Mean, SD and t value to compare pre test post test handheld dynamometer in Group A**

**Table 7- Paired t test for handgrip strength in Group A**

Test	Mean	SD	Mean improvement in grip strength	n	t	df	p-value significance
<b>Pre-test</b>	14.21	1.2	0.91	15	5.26	14	$p < 0.001$
<b>Post-test</b>	15.12	1.05					

Since the *t-value*, 5.26 shows  $p < 0.001$ , there is a significant difference existing between the pre-test and post-test grip strength among high school students in the

experimental group. This proves the effect of hand strengthening and coordination training with handwriting practice and ergonomic advices to improve the grip strength.

**Mean, SD and t value to compare pre test post test handheld dynamometer in Group B**

**Table 8- Paired t test for handgrip strength in Group B**

Test	Mean	SD	Mean improvement in grip strength	n	t	df	p-value
<b>Pre-test</b>	14.07	1.02	0.19	15	2.96	14	$p < 0.05$
<b>Post-test</b>	14.25	1.05					

Since the *t-value*, 2.96 shows  $p < 0.05$ , there is a significant difference existing between the pre-test and post-test grip strength among high school students in the control

group. This proves the effect of handwriting practice and ergonomic advices to improve the grip strength.

**Mean, SD and t value to compare pre test handheld dynamometer between Group A and Group B using t test**

**Table 9- Unpaired t test for pre test handgrip strength scores between Group A and Group B**

Group	Pre-test Mean	S.D.	Difference in mean	n	t	df	p-value
<b>Experimental</b>	14.21	1.2	0.14	30	0.36	28	$p = 0.72$
<b>Control</b>	14.07	1.02					

Since the *t-value* 0.36, shows  $p-value > 0.05$ , there is no significant difference in pre-test grip strength scores between the experimental and the control groups. So we can consider the groups as homogenous in the baseline level.

**Mean, SD and t value to compare post test handheld dynamometer between Group A and Group B using t test**

**Table 10- Unpaired t test for post test handgrip strength scores between Group A and Group B**

Group	Post-test Mean	S.D.	Difference in mean	n	T	df	p-value
<b>Experimental</b>	15.12	1.05	0.87	30	2.259	28	$p < 0.05$

<b>Control</b>	14.25	1.05
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Since the *t-value* 2.259, shows *p-value* < 0.05, there is a significant difference in post-test grip strength scores between the experimental and the control groups. The scores in the experimental group are significantly higher than that

in the control group. Hence hand coordination and strengthening exercises is effective in improving grip strength among high school students.

**Statistical analysis of BBT using t tests**

**Mean, SD and t value to compare pre test post test BBT in Group A**

**Table 11- Paired t test for manual dexterity in Group A**

Test	Mean	SD	Mean improvement in manual dexterity	n	t	df	p-value
Pre-test	70.33	5.39	9.0	15	6.41	14	<i>p</i> < 0.001
Post-test	79.33	6.9					

Since the *t-value*, 6.41 shows *p* < 0.001, there is a significant difference existing between the pre-test and post-test manual dexterity among high school students in the experimental group. This proves the effect of hand strengthening and coordination training with handwriting practice and ergonomic advices to improve manual dexterity.

**Mean, SD and t value to compare pre test post test BBT in Group B**

**Table 12- Paired t test for manual dexterity in Group B**

Test	Mean	SD	Mean improvement in manual dexterity	n	t	df	p-value
Pre-test	69.33	7.68	3.0	15	3.65	14	<i>p</i> < 0.01
Post-test	72.33	7.25					

Since the *t-value*, 3.65 shows *p* < 0.01, there is a significant difference existing between the pre-test and post-test manual dexterity among high school students in the control group. This proves the effect of handwriting practice and ergonomic advices to improve manual dexterity.

**Mean, SD and t value to compare pre test BBT between Group A and Group B using t test**

**Table 13- Unpaired t test for pre test manual dexterity scores between Group A and Group B**

Group	Pre-test Mean	S.D.	Difference in mean	n	t	df	p-value
Experimental	70.33	5.39	1.0	30	0.412	28	<i>p</i> = 0.68
Control	69.33	7.68					

Since the *t-value* 0.412, shows *p-value* > 0.05, there is no significant difference in pre-test manual dexterity scores between the experimental and the control groups. So we can consider the groups as homogenous in the baseline level.

**Mean, SD and t value to compare post test BBT between Group A and Group B using t test**

**Table 14- Unpaired t test for post test BBT scores between Group A and Group B**

Group	Post-test Mean	S.D.	Difference in mean	n	T	df	p-value
Experimental	79.33	6.9	7.0	30	2.71	28	<i>p</i> < 0.05
Control	72.33	7.25					

Since the *t*-value 2.71, shows *p*-value < 0.05, there is a significant difference in post-test manual dexterity scores between the experimental and the control groups. The scores in the experimental group are significantly higher than that in the control group. Hence hand coordination and strengthening exercises is effective in improving manual dexterity among high school students.

## DISCUSSION

Handwriting is a complex activity which requires blending of cognitive, kinaesthetic, perceptual and motor components. All these components must be fully functional to achieve a proficient writing. Handwriting speed is a crucial step in the student's achievement regardless of ability. Academic note taking and writing exams within the given time is an important skill in education. In some competitive exams or regular school exams, a particular method is followed for assessing the ability of the student, wherein one's knowledge is tested within a particular time. When the tempo of writing slows down or it is interrupted constantly, students fail to express their ideas through words. All these points out to the importance of handwriting speed in a student's academic life.

There are only limited screening questionnaires to assess handwriting among school children. The HPSQ represents a first step that can be used by therapists to identify and treat handwriting deficiency. The tool demonstrated good internal consistency ( $\alpha = .90$ ). Test-retest reliability for the score revealed an intra class correlation coefficient (ICC) of .84 and inter rater reliability of ICC=.92 for the total questionnaire score. Here in this study I have taken the HPSQ (Handwriting Proficiency Screening Questionnaire) as the inclusion criteria for selecting the students for the study.

Nilukshika KVK et al, 2012<sup>(2)</sup> stated that upper limb exercises can be used to improve handwriting speed among undergraduate students. It is said that the extension of study on to different populations and with specific exercise programmes can be done in future. To that end, I choose high school students and improving their handwriting speed by using hand coordination and strengthening exercises.

Pre and post test measurements were done before and after the interventions. The outcome measures used are Handwriting Speed Test (HST), handheld dynamometer and Box and Blocks Test. The results were analysed using *t*-test. Paired *t*-test was used to compare the results within the group and independent *t*-test to compare results between the groups. Significance level kept as *p* value < 0.05.

In case of the Handwriting speed, it was found that in paired *t* test, the results showed improvement in both groups. In the independent *t* test, since the *t*-value 2.17, shows *p*-value < 0.05, (*p*=0.0389) there is a significant difference in post-test handwriting speed scores between the experimental and the control groups. The mean difference, 12.66 shows the difference between mean in two groups 129.13 & 116.47 respectively. The scores in the experimental group were significantly higher than that of the control group.

Strengthening of intrinsic muscles of hand can improve handwriting speed. During resistive training, muscles undergo an isotonic contraction. i.e., increase in intramuscular tension along with the change in length of

muscle. As intramuscular tension increases, there is gradual increase in muscle power leading to hypertrophy. Due to hypertrophy of muscle there is improvement in endurance and strength of muscle. The intervention was planned that it directly targeted on the components which are required for good handwriting. The result goes in hand with Singh, I (2009) who concluded that hand exercises are important in strengthening the muscles involved in handwriting<sup>(15)</sup>. The improvement in this study can be supported by the evidence in the literature that, intervention to improve handwriting would result in greater gains than no intervention at all<sup>(16)</sup>.

In case of the hand grip strength, in paired *t* test, both groups have shown improvement. In the independent *t* test, since the *t*-value 2.259, shows *p*-value < 0.05, (*p*=0.0312) there is a significant difference in post-test grip strength scores between the experimental and the control groups. The difference, 0.87 shows the difference between mean in two groups, 15.12&14.25 respectively. The scores in the experimental group were significantly higher than that in the control group.

The intervention targeted mainly at the grip strength which is essential for the static and dynamic pencil grasp. An increase in tripod grip strength will prevent slipping of the pencil and helps to improve handwriting and speed of writing. This was supported by the study done by Falk et al in 2010 that, grip force dynamics play a key role in determining the handwriting quality of students<sup>(17)</sup>. There are differences between the grip strengths of males and females. It is more in males than females. It can be due to differences in the gender specific muscle fibres or increase in muscle mass. Researches said that a child needs strong muscles in the hands to grasp the writing equipment and to manipulate it for functional use<sup>(18)</sup>. The intervention consisted of exercises to improve grip strength and motor coordination also. Fine motor skills involve the use of the small muscles of the hand that enable movement and functions such as handwriting and grasping small objects. However, the direct association of handgrip strength with that of pinch grip strength in improving handwriting is yet to find out.

In case of manual dexterity, the paired *t* test, there was improvement in both the groups. But more significant improvement in scores was shown in the experimental group. This can be concluded by the independent *t* test which said that, since the *t*-value 2.71, shows *p*-value < 0.05 (*p*=0.0114), there is a significant difference in post-test manual dexterity scores between the experimental and the control groups. The difference, 7.0 shows the difference between mean in two groups 79.33 & 72.33 respectively.

The strengthening exercises included activities such as manipulating clay, rolling the balls of clay between the tips of the thumb, middle and index finger, pinching and sealing a zip-lock, rubber band exercises and ball squeezing provides resistance to smaller muscles of hand. All these exercises make use of the muscles of the thenar eminence which is considered as the "skilled triad" of the hand. Hence, the in-hand manipulation skills help to improve the fine motor skills as well as grip strength. Previous studies in this area have revealed that the production of functional handwriting depends on the complex interplay of number of abilities, including skilful fine motor coordination and precise force regulation<sup>(19)</sup>. Tom Have stated that box and block test is reliable and valid tool for measurement and

training of fine motor coordination as well as manual dexterity function<sup>(20)</sup>.

The students in control group were given handwriting practice and taught appropriate writing postures and ergonomic advices. The ergonomics and the writing posture are the extrinsic factors related to handwriting and the ergonomics play a very important role. Body posture is considered to have an important influence on the efficiency of writing process and product<sup>(21)</sup>. Hence, students in Group B also showed improvement in their handwriting. Sovik et al (1991) concluded the effects of different writing tasks on student's writing speed and accuracy. Practicing is the act of rehearsing behaviour or engaging in an activity again and again, for the purpose of improving or mastering it. In simple words, "practice makes perfection". As like everything in life, the key to successfully improve one's penmanship is consistent practice. Hence, students in Group B also showed improvement in their handwriting.

Lastly all the activities included were of playful nature which the students might have enjoyed and thus led to their maximum participation and resulted in significant improvement in the group which received intervention.

### Strength of the study

- Number of participants were equal in both groups
- Only 30 subjects were taken, easy to conduct within proper time
- Participants independently committed to the exercise sessions and were regularly present.
- Cost effective programme

### Limitations of the study

- As the measurements were taken manually, this may introduce human error, which could threaten the reliability of the study.
- The quality of handwriting was not assessed.
- Both genders were included which may affect the outcome measures.
- Right hand dominant subjects were included.

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### Future research

- The sample size of the study can be increased; hence it may lead to better results.
- The treatment duration of the study can be increased.
- Can be administered in children with cerebral palsy, autism and ADHD.
- A follow-up study could ensure the long-term effect of the treatment programme.

### CONCLUSION

From the above study, it was obtained that there is significant difference among the experimental and control groups when the values were analysed. The study concluded that the analysis of handwriting speed, handgrip strength and manual dexterity shows improvement within the group as well as between the groups. But the Experimental group shows significantly higher improvement in all the three parameters when compared to the control group.

Hence, I conclude that a well-planned 5 weeks of exercise intervention programme including hand coordination and strengthening exercises along with handwriting practice and ergonomic advice is effective in improving handwriting among high school students.

### CONFLICT OF INTEREST

None

### SOURCE OF FUNDING

Self

### ETHICAL CLEARANCE

Approved by the Institutional Ethical Committee of Medical Trust Hospital on 8<sup>th</sup> May 2019. Ref. no. MTH/MPT/EC/1198/19

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