



EFFICACY OF GRIP STRENGTH, COORDINATION AND ENDURANCE TRAINING FOR HAND TO IMPROVE THE HANDWRITING OF SCHOOL GOING CHILDREN.

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BACKGROUND: Handwriting is an important skill for school aged children who need to produce fluent and legible writing for expressing, communicating and recording. Nowadays, handwriting is used as a predictor of one's personality. There are several therapeutic interventions to improve handwriting in school going children. Among them strengthening, endurance and coordination exercises training have been individually proven to be beneficial in improving handwriting in school going children. But, there are no evidences found comparing the effect of both. Hence, the purpose of the study is to compare the effect of "grip strength, endurance and coordination training in hand writing quality and speed improvement." **METHODOLOGY:** An Experimental study design, with four groups: Group A, Group B, Group C and Group D. 80 subjects of school going children grade 1 and 2. Subjects with age group of 6-8 years. **GROUP A:** Strength training (n=20) **GROUP B:** Endurance training (n=20) **GROUP C:** Co-ordination training (n=20) **GROUP D:** Control (n=20) Handwriting quality and speed was assessed by using MHT (minnesota handwriting test) and HST (handwriting speed test) before and after 4 weeks of intervention to evaluate & compare the effectiveness of the treatment protocol. **RESULT:** Result were statistically analysed using paired and unpaired t-test and ANOVA by using SPSS version 25.0 excel 2019, there was significant improvement in group C in handwriting quality (MHT) as compared to group A, group B, group D. But in handwriting speed (HST) improvement there was significant difference in group A as compared to group B, group C and group D. **CONCLUSION:** The study concluded that coordination training is more significant to improve handwriting quality but to improve handwriting speed, strength training shows significant effect. **KEYWORDS:** Strength training, Endurance training, Coordination training, Minnesota handwriting test, Handwriting speed test, handwriting proficiency screening

INTRODUCTION:

Writing is an art and the most special character that is to be an essential skill in daily life. Handwriting comprises of both engrave and running. hand and is vastly different from formal manuscript or typography because each person's handwriting is unique and different, it can be used to verify a document's writer.¹ The deterioration or changes of a person's handwriting is also a symptom or result of certain diseases. The ethnicity to produce clear and Similar handwriting is also known as dysgraphia. It is estimated that between 13/100 and 27/100 of school aged children experience handwriting difficulty.² Rehana Bharthu et al (2017) state that a variety of skills, as well as skilled fine motor coordination needed for functional handwriting. Grip power, motor control, and hand endurance are the most common components involved in handwriting. Grip force is the force applied by an individual's thumb and finger to the

barrel of a writing instrument. Fine motor skills include handwriting and gripping, which are initiated by small muscles in the body.³ The standard writing speed is between 10 and 20 words per minute. If the number of words written is between 5-8wpm considered as handwriting speed is severely affected.⁴ For schoolchildren, the most important skill is handwriting, which is needed to produce legible and fluent writing for expressing, documenting, and communicating. Hand writing is one of the most important factors to predict personality. 31-60% of school day children spend in performing fine motor task and handwriting.³ Children who have trouble writing can't often finish assignments on time, can try to use as few words as possible, and, most importantly, can't pay attention to cognitive content while concentrating on the mechanical aspect of writing. Many research in occupational therapy and physiotherapy have been conducted to improve handwriting in children by creating a changed setting.³ Many researchers found that school going children facing so many problems like after writing few words they get tired.⁵ So many factors effects handwriting like age, gender, and body size, as well as extremity, general health, writing surface, and instrument, all affect hand grip ability which effect handwriting quality and speed. If all of these components are absent, the writing will suffer. Grip strength, dexterity, and agility are all improved with resistive hand exercises. Gender is also most important factor in handwriting evaluation. we can see more legible writing in girls than boys handwriting. And girls write faster than boys. Left handers are slower than the right handers.⁶ Vaibhav kadaskar et al (2020) evaluate that there was significant correlation between palmer pinch grip strength and handwriting among school going children. He concluded that if palmer pinch strength is less then poor is handwriting and if palmer strength is good or more then the handwriting is good/legible.⁷ Marie-lsurre kaiser PhD et al (2009) found that there was significant correlation between coordination of hand and handwriting. The quality of trace like curving in letters and too long joining, unsteady traces were significantly relationship with the quality of handwriting (correction of letter forms).⁸

FOUR MATURE AND EFFECTIVE GRASP PATTERNS FOR PRACTICAL WRITING:

Dynamic tripod (DT): The most widely recommended pencil grasp for handwriting is the dynamic tripod (DT). The 1st, 2nd and 3rd digits of hand together work as tripod in this grasping. Movement of fingers originating from IP joints and of forearm and hand are in little amount and well-coordination which are possible with the DT grip. This understanding grows between the ages 4 and 6 and it can be corrected till the age of 14years.⁹

Lateral (thumb) tripod (LT): 2nd most common pattern for grasping. In LT grip adduction of thumb is done against lateral aspect of 2nd digit and it frequently crosses the top of writing instrument.⁹

Dynamic quadrupod (DQ): it is similar to the DT gripping. it includes the thumb and three fingers. In 2nd grade, this is a classic pattern for grasping.⁹

Lateral (thumb) quadrupod (LQ): it is alike LT excluding 4 digits which makes contact with the writing instrument with 2nd, 3rd, and 4th digits which starts motion with pencil.⁹

The Minnesota handwriting test (MHT), developed by Reisman (1993), it is standard documental test which is sensitive to little alteration in performance of children's manuscript handwriting. It was used for children to identify difficulty in handwriting in grade 1st and 2nd 10 Children are asked to copy word from a pre-printed sample of words at the top of writing sheet.^{11,12} The Handwriting speed test (HST) was developed by Wallen et al in New South Wales, Australia to provide a quick and convenient, but also objective and reliable, norm-referenced assessment of speed of hand for school going students of 1st to 12th in Australian system. The test was developed to help occupational therapist and other screen whole classes of students for handwriting difficulties and evaluate the individual students speed.^{13,14} HPSQ (handwriting proficiency screening questionnaires) tool was used for evaluation assessment of handwriting in school going children and it is appropriate for clinical and academics uses.^{15,16} In this study we are going to compare strengthening training, endurance training and coordination training to find out which one is more effective in improvement of handwriting quality and speed of handwriting.

INCLUSION CRITERIA

- School going children
- Age group 6-8year
- Both genders.
- Willing to participate
- Minimum up to 8 wpm (words per minute)
- Who are willing to participate

EXCLUSION CRITERIA

- Children with cognitive developmental disorder
- Dysgraphia
- Dyslexia
- Attention deficit hyperactivity disorder.
- Congenital structural and functional impairment of upper limb
- Acquired functional and structural impairment of upper limb
- Absenteeism on initial and final days of assessment
- Irregularities in attending the exercise program

METHODOLOGY:

After Ethical approval the student were selected with the help of teachers according to the HPSQ and who fulfills the inclusion criteria. Consent form were received after explaining the intervention from all the parents. The following evaluation tool were used for measurement. ▪ HPSQ (handwriting proficiency screening questionnaires), MHT (Minnesota handwriting test), HST (handwriting speed test). After selection students were divided into four group (Group A (n=20) [strength training], Group B (n=20) [endurance training], Group C (n=20) [coordination training] and Group D (n=20) [control group]). Pretest were done using MHT and HST. Instruct the student to sit in desk and ask to copy "The quick brown fox jumped over the lazy dogs." And features of handwriting was done by spacing, legibility, form, size and alignment and HST were assessed according to the words per minute written by the students. After pretest evaluation students treated with sets of strengthening training, endurance training, and coordination exercise training. Session are of 6 days per week, for 30-45min every day for 4weeks. After 4weeks post-test were taken of all the four groups using MHT and HST.

GROUP A (STRNGTHENING TRAINING)

- Instruct the children to manipulation clay, putty, dough and resistance material and asked children for doing full grip, finger extension, finger spread, finger scissor, finger pinch, scissor spread, thumb extension, thumb press, thumb adduction, and thumb pinch strengthening, cutting materials with scissor or a plastic knife also strengthens muscles. Asked to children to place a rubber band around knuckles than instruct to open and close hand /fingers . Ball squeezing exercise: asked student to squeeze ball..

Number of sessions: 1 session per day. 6ays per week, number of weeks: 4 week,

number of repetitions: 10 repetitions per exercise

GROUP B (ENDURANCR TRAINING):

1. Praying exercise

- Instruct to children to sit in your desk. . The body is relaxed and in neutral position. shoulder is over hips. Bring palms up toward face keeping elbows together-press palm into each other to create resistance and strengthening. Posture check- keep head over shoulder back and down (as opposed to forward slouch). On an inhale slide elbow along desk away from each other until the forearms are on the desk in front of you. Keep palm together, heels of hands are also pressed together. Press into the palms and feel the stretch through the arms and right up into the back. On an exhale, draw the elbows toward each other while hands move up off the table (keeping firmly pressed together)• Feel the opening occurring in the back, between the shoulder blades. Allow the forearms and elbows to move towards touching each other. When finished, roll out the shoulder, releasing any tension and elbow to move towards touching each other

2. Straight finger flexion (finger exercises): instruct to children to flex your finger straight than neural position than again flexion up to 10 repetitions.

- number of session: 1 session per day
- number of days: 6 days per week
- number of weeks: 4 weeks
- number of repetitions: 10 repetitions per exercise

COORDINATION EXERCISES (GROUP-C)1

1. Instructed the students to transfer the wooden blocks as many as possible in 1minutes in one big box. The subjects scored according to the number of balls transferred in 1minute.

2. Asked the student to do reciprocal movements to finger like

- make a fist
- preform finger stretch
- than claw stretch
- squeezing ball for pinch strengthener
- thumb flex
- thumb touch (thumb touches one by one with all other fingers)

All these trainings perform with 10-10 repetition

Number of session: 1 session per day

Number of days: 6 days per week

Number of weeks: 4 weeks

Number of repetitions: 10 repetitions per exercise

CONTROL GROUP (GROUP-D)

This group was under observation and instructed don't do any exercises or any activity that play role in improvement in strength, endurance and in coordination. But included in pre and post-test had been done.

STATISTICAL ANALYSIS

The collected data were analyzed using statistically package of social sciences (SPSS) version 25.0 excel 2019. The parametric test was used in statistical analysis because the distribution of data was normal. Demographic values were compared within and between the groups using paired t-test, unpaired t-test & ANOVA. Statically significant was set at $p < 0.05$.

RESULT:

In this study 80 students with age of 6-8 years having handwriting quality and speed issue were included. There were 32 were male and 48 were female.

TABLE 1.1 AGE AND GENDER DISTRIBUTION:

	GROUP A (n=20)	GROUP B (n=20)	GROUP C (n=20)	GROUP D (n=20)
AGE	12.38± 0.512	12.38± 0.512	12.38± 0.512	12.38± 0.512
GENDER M / F	2 / 18	12 / 8	7 / 13	11 / 9

TABLES 1.2: COMPARISON OF BETWEEN GROUPS (MHT)

OUTCOME (MHT) (Minnesota handwriting test)	PRE-mean	POST-mean	t-value	MEAN ± SD	p-value
STRENGTHENING TRAINING GROUP-A	15.70	18.25	-8.40	2.550±1.356	<0.05
ENDURANCE TRAINING GROUP-B	12.05	14.65	-6.61	2.600±1.759	<0.05
COORDINATING TRAINING GROUP-C	15.15	20.85	-5.95	5.700±4.281	<0.05
CONTROL GROUP-D	14.25	15.55	-4.21	1.300±1.380	<0.05

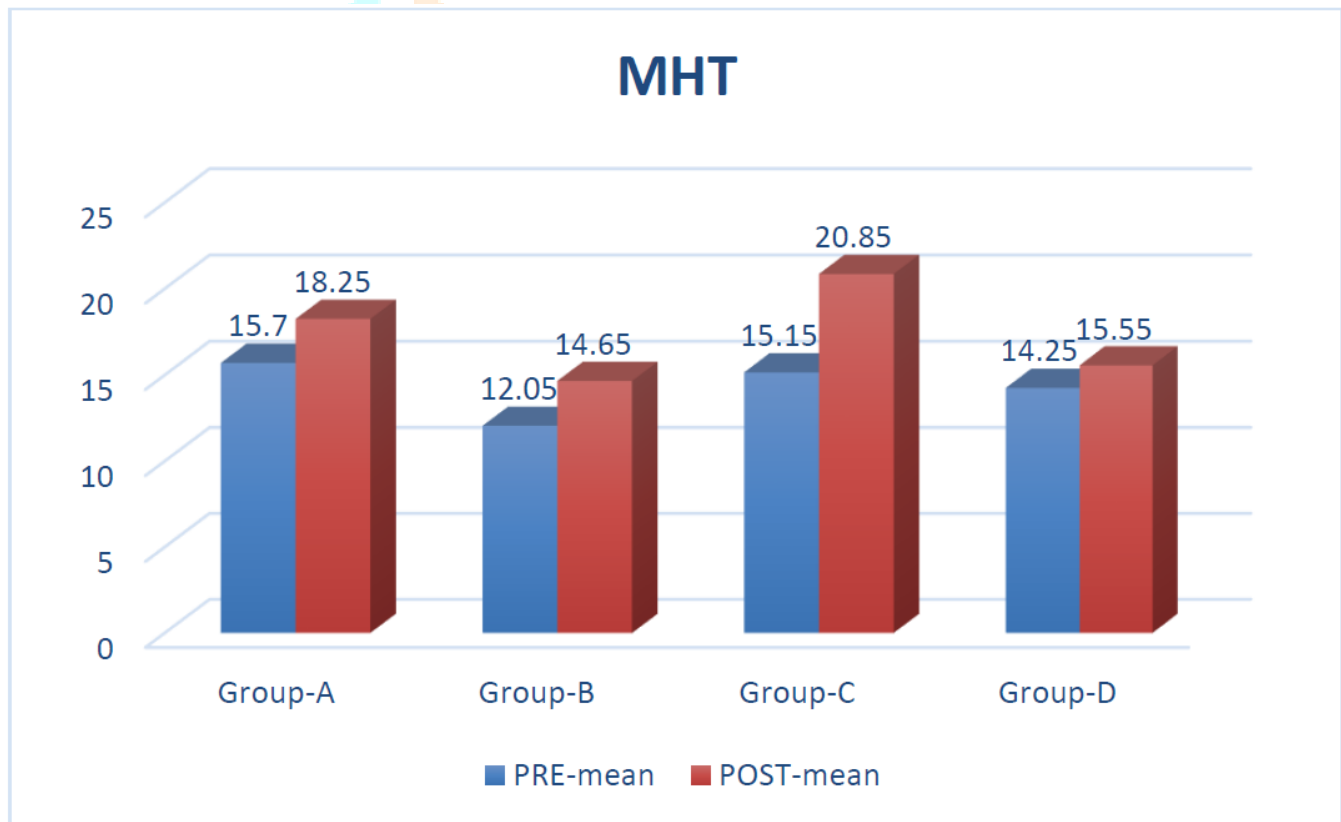
GRAPH 1.1: COMPARISON OF BETWEEN GROUPS (MHT)

Table no. 1.2 shows between the groups comparison. Unpaired t-test and ANOVA was used and p value <0.05 which is showing statistical significance difference between GROUP A (STRENGTH TRAINING), GROUP B (ENDURANCE TRAINING), and GROUP C (COORDINATION TRAINING) in improvement of handwriting quality. But group C was greater effect on quality improvement rather than group A, group B and group D.

TABLES 1.3: COMPARISON OF BETWEEN GROUPS (HST)

OUTCOME(HST) (handwriting speed test)	PREmean	POSTmean	MEAN±SD	t-value	p-value
STRENGTHENING TRAINING GROUP A	3.55	8.40	4.850±1.182	-18.35	<0.05
ENDURANCE TRAINING GROUP- B	3.60	7.75	4.150±1.348	-13.76	<0.05
COORDINATION TRAINING GROUP- C	4.00	8.65	4.650±1.387	-14.99	<0.05
CONTROL GROUP- D	4.00	3.85	0.150±1.461	0.45	0.65

GRAPH 1.2: COMPARISON OF BETWEEN GROUPS (HST)

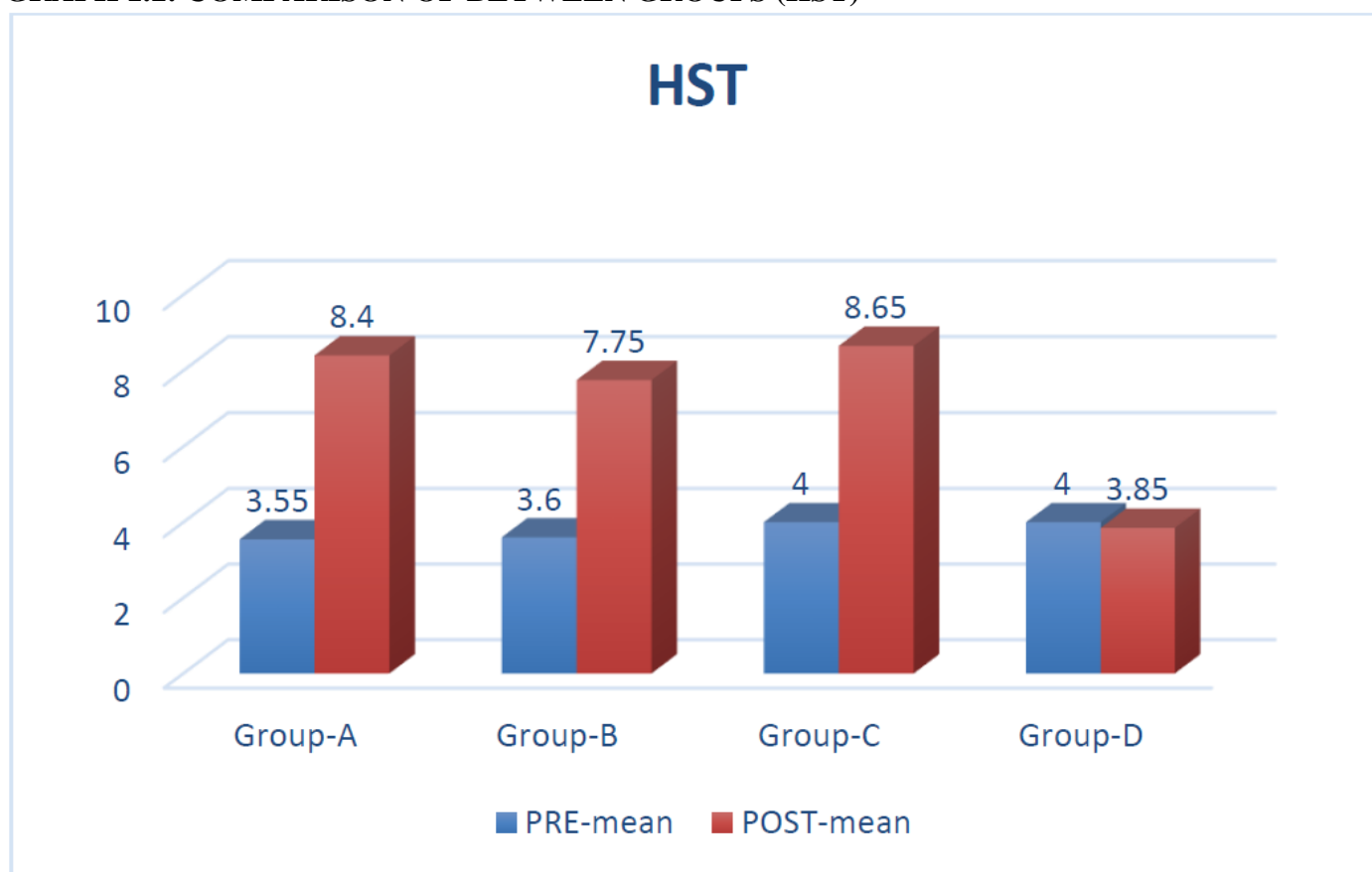


Table no. 1.3 shows between the groups comparison. Unpaired t-test was used and p value <0.05. So statistically proven that there was significant difference between GROUPS A (STRENGTH TRAINING), GROUP B (ENDURANCE), and GROUP C in improvement of handwriting speed. But group A shows greater effect rather than group B, group C, and group D in speed improvement and group D didn't show significant difference.

DISUCSSION:

The main aim of the study is to determine the effect of strength training, endurance training and coordination training on handwriting quality and speed improvement. 80 school going children were selected of grade 1st and 2nd in between age 6-8years according to HPSQ and other inclusion criteria. Selected 80 students were divided into four groups. Group A (n=20) received strengthening training, Group B (n=20) received endurance training, Group C (n=20) received coordination training session, and Group D (n=20) was control group each session is of 30-45min per day, 6 days per week, up to four weeks. Handwriting quality was measured with the help of MHT (Minnesota handwriting test) and handwriting speed is measured with the help of HST (handwriting speed test). Pre and post assessment were taken before and after the treatment with the help of MHT and HST. The exercises were set such a

way so that children can perform training with full of enjoyment and user friendly and which was done under the supervision. So there was very least chances of exercise error and harms. After statistical analysis of pre and post data result of this study showed that all three training are effective to improve quality of handwriting and speed in school going children. But, coordination training is more effective in handwriting quality improvement as compared to endurance and strength training. But strength training is more effective to improve handwriting speed as compared to endurance and coordination training. Y Praveen kumar, sharma harishankar Shweta et al (2013) examined the effectiveness of forearm, hand and wrist exercise on handwriting speed. They done their study with 100 students and handwriting speed, pinch grip strength and coordination was assessed pre and post exercise training. They concluded that these exercises improve handwriting speed.

5 Conclusion of this study supports my study In this study quality of handwriting was measured by MHT group A (strength training) pre mean score of MHT=15.70 and post mean score of MHT= 18.25. So, mean difference is 2.55. In group B (endurance group) pre mean score of MHT= 12.05 and post mean score of MHT= 14.65. So mean difference is 2.6. In group C (coordination training) pre mean score of MHT=15.15 and post mean score of MHT=20.85. So, mean difference is 5.70. And group D (Control group) pre mean score of MHT=14.25 and post mean score of MHT= 15.55. So, mean difference is 1.3. There is significant difference in all groups $p < 0.05$. In this study component of MHT (Minnesota handwriting test) was also compared between groups and found that legibility, form, alignment, size and spacing improvement was greater in group C (coordination group) as compared to group A (strength training), group B (endurance training) and group D (control group).

10,24 In this study speed of handwriting was measured by HST group A (strength training) pre mean score of HST=3.55 and post mean score of HST= 8.40. So, mean difference is 4.85. In group B (endurance group) pre mean score of HST= 3.60 and post mean score of HST= 7.75. So mean difference is 2.6. In group C (coordination training) pre mean score of HST=4.00 and post mean score of HST=8.65. So, mean difference is 4.65. And group D (Control group) pre mean score of HST=4.00 and post mean score of HST= 3.85. So, mean difference is -0.15. There is significant difference in all groups $p < 0.05$ except group D. Rehana bharthu, ahamed thajudeen et al (2017) provided strengthening and coordination training for 4 weeks, 6 days per week 10 repetition/exercise each day. They concluded that a well-orchestrated physiotherapeutic session can amend the handwriting quality in students.

3 Nilukshika KVK et al (2012) assess the effectiveness of UL exercises on hand speed. Protocol was of five days per weeks. At the beginning speed of writing, UL coordination and strength of palmer pinch grip was measured and after 2 and 4 weeks it was measured again.

17 Strengthening of hand (forearm and intrinsic muscles) increase speed of writing. Muscle goes in an isotonic contraction that is increase in intramuscular tension along with change in length of muscle and there is gradual increase in muscle power leading to hypertrophy.

25 Changes in nervous system resulting in reduction in nerve conduction velocity, sensory activity, rate and magnitude of reflex response and arousal threshold. Decrease in motor coordination and function is also due to impairment of sensory process and effect hand functions.

18 H. S. R. KAO (2007) they assess the effect of hand finger exercise on human handwriting performance. They concluded that performance pace was significantly accelerated under the exercise conditions.

20 Strength provide good gripping during pencil grasp this prevent slipping of pencil. Strength training is highly effective in handwriting speed improvement. These strength exercise works on 'skilled triad' of hand that is thenar eminence muscles.

29,36 In this study we found that quality of handwriting was highly improved by coordination training than the strengthening and endurance training. Similar studies done in past showed that VMI i.e the capability to see and copy fairly to gently related to skill and handwriting. So the exercises to amend the ocular-motor control and ocular perceiver-hand coordination availed to amend.

37,38,39 There was some evidence that shows strengthening training, endurance training and coordination training are effective to improve handwriting quality and speed but there is no study done that which one is more effective in school going children. So the present study conducted to evaluate the more effective training on handwriting quality and speed.

5,40. Statistically and clinically all the four groups showed significant effect, but in improvement of quality of writing group C (coordination training) was observed greater improvement than strength training and endurance training. And in improvement of speed of writing group A (strength training) was observed greater improvement than endurance training and coordination training.

CONCLUSION:

This study showed a significant difference in efficacy of Group C (COORDINATION TRAINING) to improve handwriting quality compared to Group A (strength training), Group B (endurance training) and Group C (control group). Group A (STRENGTH TRAINING) is more effective to improve handwriting speed than the other four groups. So study concluded that Co-ordination training is more effective to improve quality and strengthening training is more effective to improve speed..

LIMITATIONS AND FUTUTE RECOMMENDATIONS

LIMITATIONS

1. Training protocol is of short duration.
2. There were only 1st and 2nd grade students were taken.
3. Due to covid study done with less subject.

FURTHER RECOMMENDATIONS

1. This study can also be done in adults and other population.
2. It can be done with large sample sizes.
3. This study can also be done on college going students.
4. Exercise protocol may be used for any other neurological disease having writing difficulty or having bad quality & less speed.

REFERENCES

1. Huber, Roy A.; Headrick, A.M. (April 1999), Handwriting Identification: Facts and Fundamentals, New York: CRC Press, p. 84, ISBN 978-0-8493-1285-4
2. SHAO-HSIA CHANG (2009). Characterization of motor control in handwriting difficulties in children with or without developmental coordination disorder
3. Rehana Bharthu, Ahamed thajudeen (2017). Efficacy of grip strength and hand coordination training in improvement of handwriting in school children.
4. Y Praveen , sharma harishankar shweta , menachery john angha (2013). Effect of forearm ,hand and wrist exercise on writing speed in health science students of Nagpur.
5. Gokulakrishnan J, Franklin J (2020) A Study on Upper Limb Strengthening Exercises on Hand writing Speed for Undergraduates. J Physiother Res Vol.4 No.3:3
6. Vengata subramani manoharan, Subramanian ganesh sundaram, Jacob.isaacjason (2015). Factor affecting hand grip strength and its evaluation :A systemic review.
7. Vaibhav Kadasar, Tejas Borkar. (2020), A study of evaluate the correlation between pinch grip and handwriting among school going children in rural areas, international journal of research and review, February 2020. Vol.7; no.2
8. Marie-Laure kaiser, PhD, Jean-Michel Albaret, PhD,2 and Pierre-André Doudin, PhD (2009). Relationship Between Visual-Motor Integration, EyeHand Coordination, and Quality of Handwriting, Journal of Occupational Therapy, Schools, & Early Intervention, Vol. 2, No. 2, July 2009: pp. 1–21
9. Heidi schwellnus , heather carnahan , azadeh kushking , helene polatajko ,Cheryl missiuna , tom chau (2012). Effect of pencil grasp on the speed and egibility of handwriting in children.
10. Reisman, J.E(1993). Development and reliability of the research version of the Minnesota handwriting test. Physical & Occupational Therapy in Pediatrics, 13, 41–55.
11. Reisman, J. (1999). Minnesota Handwriting Assessment. London, UK: Harcourt Assessment.
12. Minnesota Handwriting Assessment(MHA) , pearson assessment, 19500 Bulverde road, San Antonio, TX.78259. published, 1999
13. Wallen, M., Bonney, M., & Lennox, L. (1996). The Handwriting Speed Test. Adelaide: Helios Art and Book Co. Google Scholar
14. Handwriting speed assessment distributed by Patoss. The professional association of teachers of student with specific learning difficulties.
15. Ayres, A. J. (1989). The sensory integration and praxis tests. Los Angeles, CA: Western Psychological Services.
16. Sara Rosenblum, Liat Gafni-Lachter (2016). Handwriting Proficiency Screening Questionnaire for Children (HPSQ–C): Development, Reliability, and Validity. The American Journal of Occupational Therapy. Downloaded From: <http://ajot.aota.org/> on 03/03/2016 Terms of Use: <http://AOTA.org/term>.
17. Nilukshika KVK, Nanayakkarawasam PP, Wickramasinghe VP. (2012), Effect of upper limb exercise on writing speed

, indian journal of physiotherapy and occupational therapy, April June 2012.Vol. 6, no.2

18. Shields RK ,et al.phys Ther (1999).effect of repetitive handgrip training on endurance ,specificity and cross-education Randomized controlled trial.

19. P kamalanathan, shabreen banu H.(25th june 2017) effect of upperlimb strengthening exercise on handwriting speed in undergraduade students.

20. Henry S. R. Kao. (2006) Shufa: Chinese calligraphic handwriting (CCH) for health and behavioural therapy. International Journal of Psychology 41:4, pages 282-286.

21. Syed Nasir Hussain et al (2019). Developing handwriting skill of students at early childhood education level. Pakistani journal of social science, vol 39

22. American Psychiatric Association. (1994). Diagnostic and Statistical Manual of Mental Disorders(4th ed.). Washington, DC: Author.

23. Chandan kumar et al (2012). Effectiveness of physiotherapy for the handwriting problem of school going children

24. Amundson, S. J. (1995). Evaluation tool of children's handwriting. Homer, AK: OT KIDS.

25. Anandhi D, Gokila D, Sivakumar VPR. Comparison of Functional Tasks Exercise Versus Resistance Exercise to Improve Grip Strength and Hand

Function in Elderly Population. J Physiother Res. 2018, Vol.2 No.1:5

26. Duursma SA (2006) A functional task exercise programme was better than a resistance exercise programme in elderly women. J Am Geriatr Soc 10: 109.

27. Vreede PL (2003) Functional tasks exercise improves daily function in older women, Doctoral dissertation, Utrecht University. J Am Geriatr Soc 53: 12-20.

28. Carvalho Bastone A, Jacob Filho W (2004) Effect of an exercise program on functional performance of institutionalized elderly. J Rehabi Res Develop 41:659

29. [10:54 PM, 3/26/2021] Gunjan Chauhan: Tseng MH, Cermak SA. The influence of ergonomic factors and perceptual-motor abilities on handwriting performance. Am J Occup Ther 1993;47(10):919-26

30. Graham S, Harris KR, Fink B. Is handwriting causally related to learning to write? Treatment of handwriting problems in beginning writers. J Educ Psychol 2000;92(4):620-33

31. Boyle C. An analysis of the efficacy of a motor skills training programme for young people with moderate learning difficulties. Int J Spec Educ 2007;22:11-24.

32. Naider-Steinhart S, Katz-Leurer M. Analysis of proximal and distal muscle activity during handwriting tasks. Am J Occup Ther 2007;61(4):392-8.

33. Cheung, W. S. C. (2007). Factors affecting the Chinese handwriting performance of children in Hong Kong. Unpublished Ph.D. Thesis. The Hong Kong Polytechnic University.

34. Tseng, M. H., & Murray, E. A. (1994). Differences in perceptual motor measures in children with good and poor handwriting. Occupational Therapy Journal of Research, 14, 19–36.

35. Dennis, J. L., & Swinth, Y. (2001). Pencil grasp and children's handwriting legibility during different-length writing tasks. American Journal of Occupational Therapy, 55,175–183. <http://dx.doi.org/10.5014/ajot.55.2.175>

36. Graham, S., Weintraub, N., & Berninger, V. W. (1998). The relationship between handwriting style and speed and legibility. Journal of Educational Research, 91, 290–297. <http://dx.doi.org/10.1080/00220679809597556>

37. Stevens, A. C. (2008). The effects of typical and atypical grasps on endurance and fatigue in handwriting. Unpublished master's thesis, Texas Woman's University, Denton.

38. Tseng, M. H. (1998). Development of pencil grip position in preschool children. OTJR: Occupation, Participation andHealth, 18, 207–224.

39. Rigby, P., & Schweltnus, H. (1999). Occupational therapydecision-making guidelines for problems in written productivity. Physical and Occupational Therapy in Pediatrics,19, 5–27. http://dx.doi.org/10.1080/J006v19n01_02

40. Maeland, A. F. (1992). Handwriting and perceptual–motor skills in clumsy, dysgraphic, and “normal” children. Perceptual and Motor Skills, 75, 1207–1217.