A J Journal of Medical Sciences

AJ Journal of Medical Sciences

REVIEW ARTICLE

A Scoping Review of Research Analyzing the Effects of Head Position and Grip Pressure on Handwriting Legibility and Fluency in Children

Bindu Ninan[1*], Royline Fathima Pinto[2], Meghashree Shetty[2], Lakshmi [2]

[1]*Assistant Professor, Tejasvini Physiotherapy College, Kudupu, Mangalore- 575028, Karnataka, India*
[2]*Lecturer, Tejasvini Physiotherapy College, Kudupu, Mangalore- 575028, Karnataka, India*

ARTICLE INFO

Article history:
Received 03-11-2025
Accepted 02-12-2025

* *Corresponding author.*
Bindu Ninan
binduninan78@gmail.com

https://doi.org/10.71325/ajjms.v2i4.25.86

ABSTRACT

Background: Students, especially young ones, predominantly rely on handwriting. Children spend 31 to 60% of their school day performing handwriting and other fine motor tasks, and difficulty in this area can interfere with academic achievement. The purpose of the review was to consolidate the evidence for the association between grip pressure and head position on handwriting fluency and legibility in young children. **Method:** A thorough literature search for RCTs was conducted using keywords such as handwriting, composition, head position, grip pressure, and young children across PubMed Central, Google Scholar, EBSCO, ProQuest, and Clinical Key databases with "AND", "OR", and "NOT" boolean operators. Six research articles met the criteria and were found to be appropriate for the review. **Study Selection:** Randomised clinical trials were included if they were full-text English articles with dependent variables like head position, fluency, grip pressure and Legibility as outcome measures. Exclusion criteria comprised articles which did not meet the inclusion criteria, those with direct access denied and those that did not align with the keywords. **Results:** Analysis of the included Randomised Controlled Trials (RCTs) highlighted two main conclusions. First, a major limitation across the literature is the lack of a single, universal outcome measure, despite the use of diverse tools like handwriting scales and digital applications. Second, despite this assessment heterogeneity, a consistent positive correlation was found between neck posture and handwriting legibility. Conclusion: Future efforts must prioritise developing a comprehensive, standardised assessment tool for crucial ergonomic factors (head position, grip pressure) in schools, enabling early identification and intervention to improve handwriting and associated psychosocial outcomes.

Keywords: Handwriting; Composition; Head position; Head control; Grip pressure; Young children

INTRODUCTION

Handwriting is a fundamental, essential skill for school-aged children, promoting academic progression and participation[1-3]. As a pivotal component of success, handwriting deficits often lead to academic underachievement, typically assessed through students' performance on writing tasks[4-6]. It remains a foundational competence supporting various school tasks, including mathematics and text composition, even in a digital environment[7-9].

Effective handwriting requires the orchestration of perceptual, cognitive, motor, and linguistic skills[10-12]. Studies suggest a visual and sensorimotor coupling of letter shape, noting that writing movements (like tracing letter outlines) have aided subjects with reading difficulties[13-16].

Transcription, a fundamental subprocess in cognitive writing models, converts linguistic ideas into a physical product by integrating spelling and handwriting/typing. Its automation frees up working memory for higher-level functions, thereby enhancing compositional quality[17-19]. Additionally, children require muscle/nerve control and eye-hand coordination and must ultimately recognize writing's utility for expressing thoughts[20].

Handwriting development progresses from skill acquisition (5–6 years) to functional mastery (9–10 years)[21]. Since written tasks consume over half of instructional time, the 10-30% prevalence of Handwriting Difficulties (HD) is a serious educational issue. HD causes poor legibility and fluency in timed assessments, strongly correlating with academic underachievement and long-term negative effects on self-esteem, attainment, behavior, and attitude[22-26]. Learning difficulties further impair legibility through struggles with letter formation, spacing, word size, writing, and alignment[27].

Kinesthesia/proprioception is the non-visual, non-auditory ability to sense the position, amplitude, and direction of body movements[28]. This crucial sensory input influences handwriting by affecting pencil grip, writing pressure, boundary maintenance, and directional letter formation[27].

During early development, novice writers often struggle with modulating pressure on the writing tool[29]. This motor control challenge is complicated by ergonomic factors - body posture, pencil grip, positioning, and grip consistency that affect handwriting[11, 30, 31]. Precise pencil pressure control is essential; excessive force causes rapid muscle fatigue and diminished writing endurance[32].

Notably, there are two types of relevant pauses: pen stops —the pen is immobile on paper, and pen lifts pen movements in the air to initiate subsequent pen movements[33]. Furthermore, poor writers typically exert more pressure on paper which might impede smooth pen movements and impair handwriting development[34, 35].

Handwriting is primarily driven by the forearm, powered by the shoulder, with minimal finger/wrist motion, fine motor control ensures fast, precise, legible results[15, 36]. Moreover, body posture and the angular positions of the upper limb joints (shoulder to hand) influence maximal grip strength and, consequently, handwriting performance. Notably, head flexion and positioning correlate directly with legibility and fluency[11, 31, 37, 38].

Research on handwriting proficiency often isolates influencing factors, ignoring the interplay of crucial ergonomic variables. A significant gap is the lack of a comprehensive review linking the combined effect of head position and grip pressure to a child's legibility and fluency. This scoping review aims to synthesize the literature on this relationship, advocating for the holistic integration of head posture and grip strength analysis in paediatric therapy.

METHODOLOGY

1) Search and Selection Guidelines

A highly sensitive and systematic search was conducted across five electronic databases: PubMed, Google Scholar, ProQuest, Clinical Key, and databases accessible via the EBSCO platform (e.g., CINAHL). The literature search was performed between August 1, 2024, and September 30, 2025. The search strategy combined core terms (Handwriting, Composition, "head position", "Grip pressure", "Grip Strength", Children) using Boolean operators (AND/OR). The initial inclusion criteria focused on English-language, Randomized Controlled Trials (RCTs) published within the last year.

2) Study Selection

The study selection focused on empirical trials investigating the impact of biomechanical factors (such as head position and grip pressure) on children's handwriting, encompassing studies of typically developing school-aged children as well as comparative trials involving children with cognitive, motor, or learning difficulties. While the initial focus was on RCTs published within the most recent year, the evidence base was expanded to include highly relevant RCT reference articles from the previous years due to the limited initial yield of recent trials on this specific topic, thereby maximizing the comprehensiveness of the evidence synthesis.

3) Extraction of Data and Quality Evaluation

Data were independently retrieved and extracted by two reviewers using a standardized form based on predefined criteria. Any disagreements between reviewers were resolved through discussion and consensus. The methodological quality of the included studies was systematically evaluated by documenting critical risk of bias components. This evaluation was likely performed using a recognized tool (e.g., the Cochrane Risk of Bias tool, RoB), assessing domains such as: eligibility requirements, adequacy of randomization and blinding, allocation, concealment, baseline group similarity, variation in co-interventions, use of intention-to-treat analysis, and patient attrition (loss to follow-up).

4) Summary of Quantitative Data

The quantitative data extracted for analysis focused on both process-based and product-based handwriting outcomes. Process and kinematic outcomes included measures of automaticity and fluency, specifically the

Number of Inversions in Velocity (NIV), alongside other key metrics such as grip pressure, pen stops, and pen lifts.

Writing Chronometric Measures were also captured, including Reaction Times (RTs), Inter-Letter Interval means (ILIs), and Whole Response Duration (WRD). The Experimental Protocols from which this data was drawn encompassed diverse graphomotor tasks, such as Tracing Single Semicircles, Tracing Composite Figures, and Repetitive Handwriting of a Cursive Letter.

Instrumentation relied on a Digital graphic tablet (Wacom{R}Intuos 4 XL) with a cordless pen to capture both on-surface and in-air handwriting, utilizing customized acquisition software (LabHand 0.7) for precise determination of pen position and pressure.

Legibility was primarily assessed using the Handwriting Legibility Scale, often incorporating the 9-point scale from the Test of Legible Handwriting (TOLH; Larsen & Hammill, 1989), and the Penmanship Objective Evaluation Tool (POET) was also utilized for product assessment.

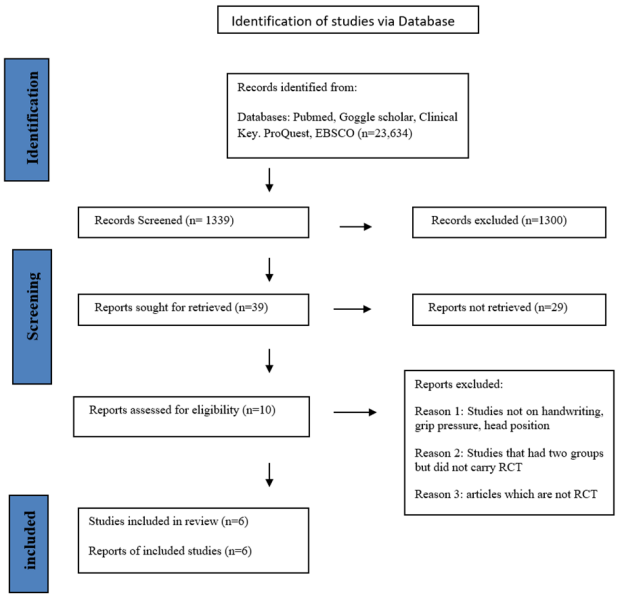

Fig. 1: **Flow diagram of the study process**

RESULTS

Six randomized control trials were included for the literature analysis. All the analyzed studies showed different levels of changes following interventions.

Sl No	Author(s)	Findings
1.	Poon *et al*., (2010)	Computerized training program focusing on visual perception and visual-motor integration training appeared to be effective in enhancing the handwriting time among children with handwriting difficulties
2.	Džepina *et al*., (2005)	Kinematic handwriting analysis, when combined with machine learning techniques, offers a promising tool to support objective recognition of psychomotor speed, providing insight into psychomotor retardation in youth with depression.
3.	Sundaramurthy *et al*., (2012)	The highest maximal grip strength obtained at H-N rotated to left, showed that for accurate assessment and rehabilitation, the H-N should be positioned opposite to the tested extremity which could be due to the influence of ATNR
4.	Lopez & Douret, (2021)	The results conclude that the absence of visual feedback (and thus visual control) in children results in decreased letter quality and increased strokes duration, dysfluence (discontinuity of movement), letter size, and pen pressure.
5.	Cerni & Job, (2023)	Different pattern of processing for handwriting, the automatized process for our participants, and for typing, for which stronger lexical and sublexical effects emerged.
6.	Truxius *et al*., (2024)	Importance of considering different kinematic aspects when investigating typically developing beginning handwriters.

DISCUSSION

Previous research has established a connection between handwriting quality and body posture[31]. In line with this, our scoping review focused specifically on investigating the effect of head position and grip pressure on handwriting legibility and fluency in children.

Handwriting is a multifaceted task that requires the integration of motor, sensory, perceptual, praxis, and cognitive functions. An essential motor aspect involves the precise control of pencil pressure and pressure of the lead on the paper, as excessive pressure on the pen when writing can cause muscle fatigue. A survey of 2000 German teachers revealed that sustained writing was a problem for >60% of children in elementary or secondary

school, most often based on handwriting-associated cramps (73%) and incorrect pencil grip (68%). Another study by Lin *et al.,* observed that children exhibit difficulties in pressure adjustment when learning graphomotor skills[28].

"A follow-up study on writing posture and writing movement of young children" by Blöte and Van der Heijden (1988) demonstrated that forward and upright posture was considered as important discriminating factor in the writing behavior of children between 5-7 years. Grip posture is another discriminating factor wherein grip is classified as tripod grip when there is more flexion on the index finger secondly a grip that are less distal than the tripod posture, there is no opposition of thumb and index and the pencil rests on the second phalanx of the middle finger instead on the third and lastly a grip that is more distal than the tripod grip, tip of the middle finger sometimes the ring finger lies on the pencil shaft[39].

The developmental trajectory of handwriting behavior has long been recognized as a process of shifting motor strategies, moving from high effort to increased efficiency. De Ajuriaguerra *et al.,* (1979) famously delineated this process into two primary, sequential tendencies. The initial phase is characterized by a paradoxical combination: a seemingly relaxed, low forward lean in the body posture (including a lowered head, likely for enhanced visual-perceptual feedback) co-occurs with marked heightened muscular tension and constrained, awkward progression in the primary movers of the hand and arm. This suggests that the generalized body relaxation is offset by localized, intense effort at the writing interface[40].

Conversely, the transition toward motor maturity and fluency is marked by the establishment of an optimized kinematic base. This is evidenced by an expansion of the functional writing area on the desk, the partial resting of the forearm on the support surface for enhanced proximal stability, and a transition from a parallel to an oblique forearm alignment. Critically, the second tendency aligns with the increased frequency and successful adoption of the mature dynamic tripod grip, indicating a shift toward a more stable, yet highly mobile, fine motor configuration necessary for sustainable, efficient handwriting[40].

Additionally our review also tried to analyze the correlation between motor involvement and grip pressure on handwriting which is supported by a study of Raut *et al.*, (2021) Assess the correlation between scapular muscle endurance and handwriting legibility assessed by using Scapular Muscle Endurance Test (SMET) and the Handwriting Legibility Scale (HLS) respectively in school children they found a significant positive correlation: as participants' scapular muscle endurance scores increased, their handwriting legibility concurrently improved[40].

Furthermore, in a study by Gesell *et al.,* (1947) established a foundational tenet of motor development, positing that the smooth acquisition of fine motor skills is fundamentally dependent on the concurrent maturation of gross motor (large muscle) skills. This developmental progression typically adheres to a cephalo-caudal (head-to-toe) pattern and, more relevant to skill progression, a proximal-distal pattern, where control motor moves from the central body parts (trunk and shoulder girdle) outward to the extremities.

Moreover, the above study was supported by Alizadehkhaiyat *et al.,* (2011) conducted a study on 16 healthy subjects (9 male and 7 female) to study the Activity and fatigue of the shoulder muscles in a controlled hand grip they used Electromyography of scapulothoracic muscles during grip task the results showed that grip increases the activity of both muscles[41].

A highly relevant recent intervention by Wang *et al.,* (2024) utilized the WriteUpRight system to regulate children's handwriting posture through an Error Amplification (EA) Strategy. This study demonstrated that the WriteUpRight system is a promising tool for the unobtrusive regulation of both head roll angle and head-screen distance. The intervention not only yielded significant improvement in these postural factors but also led to a significant improvement in the kinematic dimensions of handwriting[38]. This evidence strongly supports the objectives of the current review by demonstrating that head position regulation can indirectly yet significantly enhance the biomechanical factors, dexterity, and dynamics of a child's handwriting performance.

A study on the usability of the SensoGrip system by Rettinger (2024) reinforces the findings of our review. The SensoGrip is a pressure-measuring pen that provides personalized, real-time feedback on pressure modulation. The study concluded that this system effectively helps children with handwriting difficulties adjust their pressure application during a task. This evidence directly supports our review's objective that maintaining proper grip pressure is a crucial factor influencing handwriting quality and performance in young children[31].

Several studies have presented computer-based handwriting assessments that utilize spatial and temporal measurements, as well as assessing pen-tip force via tablet systems (Alamargot & Morin, 2015; Bisio *et al.,* 2016; Chang & Yu, 2014; Lee *et al.,* 2016).

Over the last four decades, numerous tests have been created to diagnose and assess handwriting difficulties. These evaluations typically gauge overall handwriting quality in two ways: by rating the legibility of a final, static writing sample or by scoring pre-defined criteria

like letter form, size, spacing, line-straightness, pencil grasp, pencil pressure, and body posture.

A study in a traditional pen-and-paper handwriting test used by healthcare professionals is limited by several factors. Its effectiveness is compromised by time-consuming scoring, subjectivity in evaluation, and a lack of precise dynamic measures such as pen tilt and pressure. Moreover, the use of standardized text leads to limited ecological validity, and the process often causes delays between initial concern and expert assessment[42].

Despite the availability of existing tools, such as established handwriting scales and digital apps for posture analysis, the field of handwriting assessment faces critical limitations. The core issue is the lack of a universal assessment standard that comprehensively integrates the three crucial biomechanical factors: head position, table distance, and grip pressure. This is compounded by many students' unawareness of how to modulate the correct grip pressure and the limited research that simultaneously evaluates the combined effects of all these factors. These deficiencies collectively emphasize the urgent need for more efficient and accessible assessment methods. Therefore, this review advocates for shifting handwriting evaluations into school settings to facilitate early identification and intervention in a familiar, effective environment.

CONCLUSION

This scoping review, investigating the effects of head position and grip pressure on children's handwriting, revealed a critical finding: a positive correlation exists between regulating these two biomechanical factors and significant improvements in handwriting fluency and legibility. Crucially, these physical gains were shown to have a direct positive impact on students' self-esteem and self-confidence. However, despite the acknowledged importance of these factors and the availability of various scales and digital applications, the analysis identified a major gap: there is currently no universal, "gold standard" assessment that comprehensively integrates and evaluates head position and grip pressure across the reviewed Randomized Controlled Trials (RCTs).

LIMITATION

The primary challenge in this field is the absence of standardized assessment methods for all critical physical factors (e.g., head posture, grip pressure). This methodological gap introduces significant variation (heterogeneity) across studies, hindering reliable comparison and meta-analysis. Crucially, the evidence base suffers from a scarcity of high-level research; Randomized Controlled Trials (RCTs) specifically examining the causal impact of head position on handwriting are extremely rare. The available literature is predominantly correlation or observational which, while suggesting associations, fails to establish clear cause-and-effect (causality). This foundational limitation prevents the development of precise, evidence-based intervention protocols for clinical practice.

DISCLOSURE

Conflict of Interest: None.

Funding: Nil.

References

1. Prunty MM, Pratt A, Raman E, Simmons L, Steele-Bobat F. Grip strength and pen pressure are not key contributors to handwriting difficulties in children with developmental coordination disorder. *British Journal of Occupational Therapy*. 2020; 83 (6) :387-396 . Available from: https://doi.org/10.1177/0308022619885046
2. Amundson SJ. Handwriting: evaluation and intervention in school settings. In: Case-Smith J, Pehoski C, editors. Development of Hand Skills in the Child. Rockville, MD: American Occupational Therapy Association; 1992. p. 63–78.
3. Engel-Yeger B, Nagauker-Yanuv L, Rosenblum S. Handwriting Performance, Self-Reports, and Perceived Self-Efficacy Among Children With Dysgraphia. *The American Journal of Occupational Therapy*. 2009; 63 (2) :182-192 . Available from: https://doi.org/10.5014/ajot.63.2.182
4. Graham S, Berninger VW, Abbott RD, Abbott SP, Whitaker D. Role of mechanics in composing of elementary school students: A new methodological approach.. *Journal of Educational Psychology*. 1997; 89 (1) :170-182 . Available from: https://doi.org/10.1037//0022-0663.89.1.170
5. Graham S, Berninger V, Weintraub N, Schafer W. Development of Handwriting Speed and Legibility in Grades 1–9. *The Journal of Educational Research*. 1998; 92 (1) :42-52 . Available from: https://doi.org/10.1080/00220679809597574
6. Graham S, Harris KR, Fink B. Is handwriting causally related to learning to write? Treatment of handwriting problems in beginning writers.. *Journal of Educational Psychology*. 2000; 92 (4) :620-633 . Available from: https://doi.org/10.1037//0022-0663.92.4.620
7. Dinehart L, Manfra L. Associations Between Low-Income Children's Fine Motor Skills in Preschool and Academic Performance in Second Grade. *Early Education & Development*. 2013; 24 (2) :138-161 . Available from: https://doi.org/10.1080/10409289.2011.636729
8. Malpique AA, Pino-Pasternak D, Roberto MS. Writing and reading performance in Year 1 Australian classrooms: associations with handwriting automaticity and writing instruction. *Reading and Writing*. 2020; 33 (3) :783-805 . Available from: https://doi.org/10.1007/s11145-019-09994-z
9. Sovik N, Arntzen O, Teulings HL. Interactions among overt process parameters in handwriting motion and related graphic production. *Journal of Human Movement Studies*. 1982;8:103-22.
10. Abbott RD, Berninger VW. Structural equation modeling of relationships among developmental skills and writing skills in primary- and intermediate-grade writers.. *Journal of Educational Psychology*. 1993; 85 (3) :478-508 . Available from: https://doi.org/10.1037//0022-0663.85.3.478

11. Parush S, Levanon-Erez N, Weintraub N. Ergonomic factors influencing handwriting performance. *Work*. 1998; 11 (3) :295-305 . Available from: https://doi.org/10.3233/wor-1998-11306
12. Bartolomeo P, Bachoud-Lévi AC, Chokron S, Degos JD. Visually- and motor-based knowledge of letters: evidence from a pure alexic patient. *Neuropsychologia*. 2002; 40 (8) :1363-1371 . Available from: https://doi.org/10.1016/s0028-3932(01)00209-3
13. Seki K, Yajima M, Sugishita M. The efficacy of kinesthetic reading treatment for pure alexia. *Neuropsychologia*. 1995; 33 (5) :595-597, 599-609 . Available from: https://doi.org/10.1016/0028-3932(94)00138-f
14. Longcamp M, Zerbato-Poudou MT, Velay JL. The influence of writing practice on letter recognition in preschool children: A comparison between handwriting and typing. *Acta Psychologica*. 2005; 119 (1) :67-79 . Available from: https://doi.org/10.1016/j.actpsy.2004.10.019
15. Longcamp M, Boucard C, Gilhodes JC, Velay JL. Remembering the orientation of newly learned characters depends on the associated writing knowledge: A comparison between handwriting and typing. *Human Movement Science*. 2006; 25 (4-5) :646-656 . Available from: https://doi.org/10.1016/j.humov.2006.07.007
16. Alves RA, Limpo T, Fidalgo R, Carvalhais L, Pereira LÁ, Castro SL. The impact of promoting transcription on early text production: Effects on bursts and pauses, levels of written language, and writing performance.. *Journal of Educational Psychology*. 2016; 108 (5) :665-679 . Available from: https://doi.org/10.1037/edu0000089
17. Olson DR. Towards a psychology of literacy: on the relations between speech and writing. *Cognition*. 1996; 60 (1) :83-104 . Available from: https://doi.org/10.1016/0010-0277(96)00705-6
18. Hayes JR, Flower L. Identifying the organization of writing processes. *In: Gregg LW, Steinberg ER, editors. Cognitive processes in writing*. 1980; :3-29 . Available from: https://doi.org/10.4324/9781003580126-15
19. Serpa-Andrade LJ, Pazos-Arias JJ, López-Nores M, Robles-Bykbaev VE. Sensorised Low-Cost Pencils for Developing Countries: A Quantitative Analysis of Handwriting Learning Progress in Children with/without Disabilities from a Sustainable Perspective. *Sustainability*. 2020; 12 (24) :10682 . Available from: https://doi.org/10.3390/su122410682
20. Li-Tsang CW, Wong AS, Leung HW, Cheng JS, Chiu BH, Tse LF, *et al*. Validation of the Chinese Handwriting Analysis System (CHAS) for primary school students in Hong Kong. *Research in Developmental Disabilities*. 2013; 34 (9) :2872-2883 . Available from: https://doi.org/10.1016/j.ridd.2013.05.048
21. Li-Tsang CW, Li TM, Yang CN, Cheung PP, Au KY, Chan YP, *et al*. Evaluation of a group-based sensorimotor intervention programme to improve Chinese handwriting of primary school students. *Heliyon*. 2023; 9 (2) :e12554 . Available from: https://doi.org/10.1016/j.heliyon.2022.e12554
22. Gosse C, Dricot L, Van Reybroeck M. Evidence of graphomotor dysfunction in children with dyslexia: A combined behavioural and fMRI experiment. *Cortex*. 2022; 148 :68-88 . Available from: https://doi.org/10.1016/j.cortex.2021.11.021
23. Poon KW, Li-Tsang CW, Weiss TP, Rosenblum S. The effect of a computerized visual perception and visual-motor integration training program on improving Chinese handwriting of children with handwriting difficulties. *Research in Developmental Disabilities*. 2010; 31 (6) :1552-1560 . Available from: https://doi.org/10.1016/j.ridd.2010.06.001
24. Fancher LA, Priestley-Hopkins DA, Jeffries LM. Handwriting Acquisition and Intervention: A Systematic Review. *Journal of Occupational Therapy, Schools, & Early Intervention*. 2018; 11 (4) :454-473 . Available from: https://doi.org/10.1080/19411243.2018.1534634
25. Yeung PS, Ho CS, Chan DW, Chung KK. Writing motivation and performance in Chinese children. *Reading and Writing*. 2020; 33 (2) :427-449 . Available from: https://doi.org/10.1007/s11145-019-09969-0
26. Feder KP, Majnemer A. Handwriting development, competency, and intervention. *Developmental Medicine & Child Neurology*. 2007; 49 (4) :312-317 . Available from: https://doi.org/10.1111/j.1469-8749.2007.00312.x
27. Fisher AG, Murray EA, Bundy AC. Sensory integration: Theory and practice. Philadelphia: FA Davis; 1991.
28. Lin YC, Chao YL, Wu SK, Lin HH, Hsu CH, Hsu HM, *et al*. Comprehension of handwriting development: Pen-grip kinetics in handwriting tasks and its relation to fine motor skills among school-age children. *Australian Occupational Therapy Journal*. 2017; 64 (5) :369-380 . Available from: https://doi.org/10.1111/1440-1630.12393
29. Rasyad M, Muslim E. Biomechanical ergonomic evaluation of handwriting performance in left-handed students when using writing armchair. *AIP Conference Proceedings*. 2019; 2193 :050008 . Available from: https://doi.org/10.1063/1.5139381
30. Rosenblum S, Goldstand S, Parush S. Relationships Among Biomechanical Ergonomic Factors, Handwriting Product Quality, Handwriting Efficiency, and Computerized Handwriting Process Measures in Children With and Without Handwriting Difficulties. *The American Journal of Occupational Therapy*. 2006; 60 (1) :28-39 . Available from: https://doi.org/10.5014/ajot.60.1.28
31. Rettinger L, Schönthaler E, Kerschbaumer A, Hauser C, Klupper C, Aichinger L, *et al*. Evaluating the Experiences of Occupational Therapists and Children Using the SensoGrip Pressure-Sensitive Pen in a Handwriting Intervention: Multimethods Study. *JMIR Rehabilitation and Assistive Technologies*. 2024; 11 :e51116 . Available from: https://doi.org/10.2196/51116
32. Truxius L, Maurer MN, Sägesser Wyss J, Roebers CM. The internal structure of handwriting proficiency in beginning writers. *PLOS ONE*. 2024; 19 (1) :e0296096 . Available from: https://doi.org/10.1371/journal.pone.0296096
33. Di Brina C, Niels R, Overvelde A, Levi G, Hulstijn W. Dynamic time warping: A new method in the study of poor handwriting. *Human Movement Science*. 2008; 27 (2) :242-255 . Available from: https://doi.org/10.1016/j.humov.2008.02.012
34. Rosenblum S, Livneh-Zirinski M. Handwriting process and product characteristics of children diagnosed with developmental coordination disorder. *Human Movement Science*. 2008; 27 (2) :200-214 . Available from: https://doi.org/10.1016/j.humov.2008.02.011
35. Day JM, Bush H, Nitz AJ, Uhl TL. Scapular Muscle Performance in Individuals With Lateral Epicondylalgia. *Journal of Orthopaedic & Sports Physical Therapy*. 2015; 45 (5) :414-424 . Available from: https://doi.org/10.2519/jospt.2015.5290
36. Fong PW, Ng GY. Effect of Wrist Positioning on the Repeatability and Strength of Power Grip. *The American*

Journal of Occupational Therapy. 2001; 55 (2) :212-216 . Available from: https://doi.org/10.5014/ajot.55.2.212

37. Wu FG, Luo S. Design and evaluation approach for increasing stability and performance of touch pens in screen handwriting tasks. *Applied Ergonomics*. 2006; 37 (3) :319-327 . Available from: https://doi.org/10.1016/j.apergo.2005.06.010
38. Wang C, Tozadore DC, Bruno B, Dillenbourg P. WriteUpRight: Regulating Children's Handwriting Body Posture by Unobstrusively Error Amplification via Slow Visual Stimuli on Tablets. *Proceedings of the CHI Conference on Human Factors in Computing Systems*. 2024; :1-13 . Available from: https://doi.org/10.1145/3613904.3642457
39. Blote AW, Van der Heijden PG. A follow-up study on writing posture and writing movement of young children. *Journal of Human Movement Studies*. 1988;14:57-74.
40. Raut S, Golhar SP. Correlation between scapular muscle endurance and handwriting legibility in school children: Correlational study. *International Journal of Applied Research*. 2021; 7 (7) :354-358 . Available from: https://doi.org/10.22271/allresearch.2021.v7.i7e.8805
41. Alizadehkhaiyat O, Fisher AC, Kemp GJ, Vishwanathan K, Frostick SP. Shoulder muscle activation and fatigue during a controlled forceful hand grip task. *Journal of Electromyography and Kinesiology*. 2011; 21 (3) :478-482 . Available from: https://doi.org/10.1016/j.jelekin.2011.03.002
42. Pasco D, Gustafsson E, Burget L, Asselborn T, Dillenbourg P, LaMue C, *et al*. Rapid in-class assessment of handwriting using a digital tablet: Multidimensional analysis of gender and socioeconomic status. *Computers & Education*. 2025; 232 :105311 . Available from: https://doi.org/10.1016/j.compedu.2025.105311