

### **Kertas Asli/Original Articles**

## **The Effectiveness of Occupational Therapy Handwriting Intervention for Children with Motor Coordination Issues: A Systematic Review** (Keberkesanan Terapi Cara Kerja Bagi Intervensi Tulisan Tangan Terhadap Kanak-kanak Dengan Masalah Koordinasi Motor: Tinjauan Literatur Sistematis)

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#### ABSTRACT

*Handwriting difficulty is one of the main issues among school children, especially for those with motor coordination issues. The aim of this systematic review is to evaluate the effectiveness of occupational therapy interventions in handwriting components for children with motor coordination issues. Current research articles were systematically searched according to the PRISMA guidelines. Two hundred and sixty-eight (n=268) research articles were identified; however, only ten (n=10) were eligible to be evaluated for this study. Studies were appraised by using McMaster Critical Review Form-Quantitative Studies. Descriptive synthesis was executed due to the heterogeneity of included studies. The review found various types of intervention conducted by occupational therapists to have a positive effect on handwriting performance components among children with motor coordination issues. Types of intervention used were visual, motor, perceptual, sensory, activity of daily living skills, training device and assistive technology and specific handwriting programs. Most handwriting intervention showed effectiveness to improve handwriting performance in motor function, visual and perceptual components. Future research should focus on homogeneity of Occupational Therapy (OT) intervention to improve handwriting performance by using specific handwriting programmes and similar standardised evaluation instruments. Practitioners of OT intervention should consider collaboration with teachers, parents and other health professionals to expedite effectiveness of intervention in handwriting performance components.*

*Keywords: Handwriting skills; occupational therapy intervention; motor coordination issues; systematic review*

#### ABSTRAK

*Masalah kemahiran tulisan tangan adalah salah satu isu utama kanak-kanak di sekolah terutama kanak-kanak sekolah yang mempunyai masalah koordinasi. Tinjauan sistematik ini adalah bertujuan untuk menilai keberkesanan intervensi terapi cara kerja dalam komponen tulisan tangan untuk kanak-kanak yang mempunyai masalah koordinasi motor. Artikel penyelidikan terkini telah diperolehi secara sistematik mengikut garis panduan PRISMA. Dua ratus enam puluh lapan artikel penyelidikan (n=268) dikenal pasti namun hanya sepuluh artikel (n=10) yang layak untuk dinilai dalam kajian ini. Kajian yang telah dipilih dinilai dengan menggunakan McMaster Critical Review Form-Quantitative Studies. Tinjauan sistematik ini dianalisis secara deskriptif kerana kajian yang dipilih mempunyai ciri-ciri heterogen. Hasil penilaian mendapati terdapat pelbagai jenis intervensi terapi cara kerja yang memberi impak positif terhadap kemahiran tulisan tangan kanak-kanak dengan masalah koordinasi motor. Jenis intervensi yang digunakan ialah kemahiran visual, motor, persepsi, sensori, aktiviti pengurusan kehidupan, latihan penggunaan alat, penggunaan alat bantuan berteknologi dan penggunaan program tulisan tangan yang spesifik. Kebanyakan intervensi tulisan tangan menunjukkan keberkesanan meningkatkan kemahiran tulisan tangan dalam komponen kefungsi motor, visual dan persepsi. Kajian pada masa akan datang perlu berfokus kepada ciri-ciri homogen dalam intervensi terapi cara kerja bagi meningkatkan kemahiran tulisan tangan melalui program tulisan tangan yang spesifik dengan menggunakan instrumen pengukuran standard yang sama. Ahli terapi cara kerja perlu mengambil kira kerjasama dengan guru, ibu bapa dan professional kesihatan lain untuk meningkatkan keberkesanan intervensi terapi cara kerja dalam komponen kemahiran tulisan tangan.*

*Kata kunci: Kemahiran tulisan tangan; intervensi terapi carakerja; masalah koordinasi motor; tinjauan sistematik*

## INTRODUCTION

### Motor coordination issues

Motor coordination issues also known as Developmental Coordination Disorder or dyspraxia (American Psychiatric Association 2013). Motor coordination issues should be diagnosed differently with motor impairment due to other medical condition such as cerebral palsy, Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD), dyslexia and dysgraphia. According to APA (2013), motor coordination issues affect approximately 5-6% of school-aged children. However, children with motor coordination issues seldomly get proper diagnosis because of the reliance that these issues are not severe to give long-term impact in life and the thought that these issues disappeared as the child grows (Cairney 2012).

Motor coordination issues are related with handwriting performance. In addition to that, children with motor coordination issues were reported to experience slower development in handwriting ability compared to typical children, hence they require specific and special intervention (Volman, Van Schendel & Jongmans 2006; Waelvelde et al. 2012). Therefore, children with motor coordination issues have motor skills problems which impact their handwriting skills performance, especially in school-related tasks.

### Handwriting skills

Handwriting skills is fundamental in the early stage of educational activities (Taverna et al. 2020a). Handwriting skills were included in the 30-60% of task in schools for children (McHale & Cermak 1992). However, some children might experience challenges and difficulties in acquiring this skills (Smits-Engelsman, Niemeijer & Van Galen 2001). Handwriting skills performance involves perceptual motor function (Volman, Van Schendel & Jongmans 2006), fine motor skills (Smits-Engelsman et al. 2013), visual motor integration (Brossard-Racine et al. 2008; Duiser et al. 2020; Resta & Eliot 1994), cognitive function and speed of handwriting (Biotteau et al. 2019; Volman, Van Schendel & Jongmans 2006). Handwriting difficulties could be considered one of the important factors in learning problems that affect children in academic and school-related tasks (Milone 2007). In the relevant literature, the reported prevalence of children having handwriting difficulties across the world ranges between 5-35% (Brossard-Racine et al. 2012; Duiser et al. 2020; Feder & Mejnemer 2007; Medwell & Wray 2007; Overvelde & Hulstijn 2011; Volman, Van Schendel &

Jongmans 2006). The effect of handwriting difficulties was reported to be associated with poor academic performance (Barnett et al. 2009; Feder & Mejnemer 2007; Rosenblum 2019), low self-esteem (Biotteau et al. 2019; Rosenblum 2019), low motivation (Brossard-Racine et al. 2008; Waelvelde et al. 2012; Whalen, Henker & Finck 1981), reduced life skills (Resta & Eliot 1994) and behavioural problems (Sandler et al. 1992; Waelvelde et al. 2017). Children with motor coordination issues have deficits in motor coordination, executive function, gait and postural control and some aspects of sensori-perceptual function that definitely will affect their handwriting abilities (Wilson et al. 2013). Hence, there is strong connection that children with motor coordination issues might have handwriting difficulties.

### Occupational therapy intervention

Children with handwriting issues often been referred for occupational therapy intervention. The needs of occupational therapy intervention are very much encouraged to support children for school readiness and academic purposes (Chiu et al. 2008) especially in school related task such as handwriting skills. Occupational therapy intervention has been credited with having a positive effect on handwriting skills (Jongmans et al. 2003; Ratzon, Efraim & Bar 2007). Occupational therapy intervention targeting handwriting ability has been deemed successful in improving certain essential skills, including visual motor integration skills (Berninger et al. 2008; Volman, Van Schendel & Jongmans 2006), cognitive skills (Waelvelde et al. 2017), motor skills (Denton, Cope & Moser 2006; Roberts, Derkach-Ferguson & Siever 2014; Waelvelde et al. 2017), behavioural skills (Furman 2006), as well as increasing the involvement of parents and teachers in the intervention process (Polatajko, Fox & Missiuna 1995; Waelvelde et al. 2017). There was abundance of studies on motor, visual and perceptual skills that enhance handwriting performance. However, there were little studies to support behaviour approach to be effective in improving handwriting skills performance. Furthermore, involvement of parents and teachers (McGuire, Crowe & Law 2004; Polatajko, Fox & Missiuna 1995; Waelvelde et al. 2017) could escalate handwriting skills performance but there was limited evidence on this intervention approach. A very recent study had suggested that OT intervention in handwriting should be integrated with the school curriculum and carried out in the school setting for optimum benefits for students with handwriting issues (Kadar et al. 2020). Therefore, this review was planned to examine these effects of intervention that contribute to handwriting performance.

The main objective of this study was to review the effectiveness of various occupational therapy intervention in treating handwriting difficulties among children with motor coordination issues. The focus was on experimental study design including randomised controlled trial (RCT) and pre and post study on occupational therapy intervention in handwriting skills. It is vital to systematically review the most current and evidence-based occupational therapy interventions or programmes used to treat handwriting problems among children with motor coordination issues. This information is very important to evidence the most effective OT intervention in terms of duration, frequency and type of intervention used to enhance handwriting skills among children with motor coordination issues.

## METHODOLOGY

### SYSTEMATIC LITERATURE REVIEW STRATEGY

The Preferred Reporting Items for Systematic Reviews (PRISMA) framework and guideline is used as the methodology of this systematic review. The Population Intervention Comparison Outcome (PICO) format was utilised as the search strategy with the keyword terms summarised in Table 1.

Table 1: Search string

Database	Scopus	Sage Journal
Search string	TITLE-ABS-KEY ("occupational therapy") AND (intervention OR treatment) AND ("handwriting skills" OR "handwriting performance" OR "handwriting") AND ("developmental coordination disorder") AND (effectiveness OR effect)	("occupational therapy") AND (intervention OR treatment) AND ("handwriting skills" OR "handwriting performance" OR "handwriting") AND ("developmental coordination disorder") AND (effectiveness OR effect)

The research question developed for this study is “What is the impact of occupational therapy intervention strategies or programmes in improving handwriting skill performance among children with motor coordination issues?”. The databases used were Scopus, Sage Journals and a manual search through suggestion from Mendeley search articles. The manual search was completed through suggestions from Mendeley database. There are four phases which are identification, screening, eligibility and inclusion

based on PRISMA. The PRISMA flow diagram is presented in Figure 1. The process of developing the search string used the Boolean Operator on Scopus, Sage Journals and manual search database. The result from this phase was 268 articles. The screening process was carried out based on inclusion and exclusion criteria to find suitable literatures for this study. Articles that did not meet the determined criteria were excluded. Additionally, duplicate articles in the database were removed accordingly.

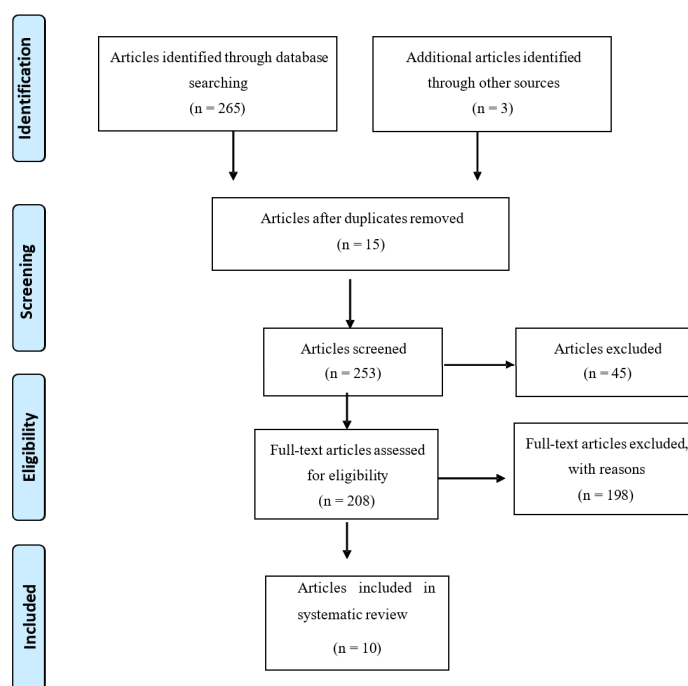


Figure 1. PRISMA flow diagram

## INCLUSION CRITERIA

The method for this systematic review was based on the PICO format which included the population of study, type of intervention, comparison of treatment, outcomes and study design. The nature of study selected should have at least an intervention in handwriting skills for children with motor coordination issues who have handwriting difficulties. Firstly, the population included in this study is children with motor coordination issues or DCD. Secondly, the type of intervention selected must focus on occupational therapy intervention in handwriting skills difficulties provided by a qualified occupational therapist. Thirdly, the outcome of the study must focus on the effectiveness of specific handwriting intervention to improve handwriting skill performance in terms of handwriting legibility and quality among children with motor coordination issues. Finally, the study design was narrowed to experimental design only. The systematic review focused on research articles published within the years 2011-2020 and which were required to be in English. The studies selected were required to use at least one standardised and validated outcome measures in handwriting skills performance such as Test of Visual Perceptual Skills 3rd edition (TVPS-3), Movement Assessment Battery for Children version 2

(MABC-2), Evaluation Test of Children's Handwriting (ETCH), Beery Visual Motor Integration (Beery-VMI), Developmental Test of Visual Perception version 2 (DTVP-2) and other standardised handwriting outcome measure namely Chinese Handwriting Evaluating Questionnaire (CHEQ).

## EXCLUSION CRITERIA

Articles that were published prior to 2011 were excluded, including those from grey literatures such as proceedings, chapters in books or book series. The exclusion criteria for the population were children other than motor coordination issues or DCD such as dyslexia or dysgraphia and articles written in languages other than English. The articles were also excluded if the intervention was done by professionals other than occupational therapist, as well as studies that used non-standardised outcome measures. Then, the researcher reviewed selected articles and removed any articles that did not meet the criteria based on the study. Justifications of the inclusion and exclusion criteria is to ensure the selected articles purely reflect the main objective of this study and to maintain the uniform criteria in the selected articles for review.

Table 2: Summary of inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Publication timeline	2011-2020	2010 and before
Document type	Research article	Conference proceeding, chapters in book, book series and other formats
Language	English	Non-english
Nature of the study	i. Randomised Controlled Trial (RCT) ii. Pre and post experiment	Other method than i-ii
Type of intervention	Occupational therapy intervention	Not done or not monitored by occupational therapist
Type of participant	Children with motor coordination issues such as: i. Developmental Coordination Disorder (DCD) ii. Visual perceptual problem iii. Handwriting difficulties	i. Typical children ii. Dyslexia iii. Dysgraphia
Outcome measure of effectiveness	Any standardised and validated assessment in handwriting such as: i. Beery Visual Motor Integration (Beery VMI) ii. Movement Assessment Battery for Children 4th edition (MABC-4) iii. Test of Visual Perceptual Skills-4 (TVPS-4) iv. DTVP	Other non-standardised assessment or no outcome measures

## APPRAISING METHODOLOGICAL QUALITY

To evaluate the methodological quality of the included studies, a modified McMaster Critical Review Form – Quantitative Studies (Law et al. 1998) was used. Three reviewers (2nd, 3rd and 4th author) assessed the research

articles independently by using the form. This form assessed eight components including study purpose, literature review, study design, sample, outcomes, intervention, results and conclusion and implications of research study. The instrument used YES or NO rating for 14 specific components such as (1) statement of study

purpose, (2) design of study, (3) relevant literature review, (4) detailed description of the sample, (5) justification of sample, (6) reliability and (7) validity of outcome measures, (8) detailed description of intervention, (9) avoidance of contamination during the study, (10) result report in statistical significance, (11) appropriateness of method analysis, (12) report of clinical importance, (13) drop-outs report and (14) appropriateness of conclusion given in the study. The overall score for each research article was generated for comparison. The data extraction from this study was developed systematically based on the search results, methodology quality, study characteristics, participants characteristics, the outcome of effectiveness of handwriting intervention on participants and type of intervention (refer to Table 3).

The level of evidence was assessed using The National Health and Medical Research Council (NHMRC) Additional Levels Of Evidence And Grades For Recommendations For Developers Of Guidelines (Coleman et al. 2009). Level of evidence is the hierarchy of evidence according to the type of research questions, appropriateness of research

design and relevancy of diagnosis, prognosis, aetiology and screening processes of articles. The criteria for each level for this review is based on intervention which is Level 1 (a systematic review of level II studies), Level II (randomised controlled study, pseudorandomised control trial, comparative study with controls), Level III (comparative study without controls) and Level IV (case series or pre and post-test outcomes). Level of evidence in the included articles for this review ranged from Level II to IV. Five articles were randomised control trials studies with clearly defined clinical presentation of participants (level II evidence) (Coutinho et al. 2017; Farhat et al. 2016b; Mcglashan et al. 2017; Tse, Thanapalan & Chan 2014a; Waelvelde et al. 2017), two articles were pre-post quasi experiment studies with reference standard of comparator groups participants (level III evidence) (Snappchilds, Mon-williams & Bingham 2012; Thornton et al. 2016) and three articles were pre-post studies without comparator group (level IV evidence) (Baldi, Nunzi & Brina 2015; Dunford 2011; Kaiser 2013).

Table 3: Study characteristic

Author(s) and year	Study design	Sample size and age group	Comparator	Intervention used	Outcome measures	Changes in outcome measures	Effectiveness of intervention in handwriting skills (visual, motor or perceptual skills)
Dunford 2011	Pre-post	7 children 7-11 years old DCD	None	Goal-oriented approach combining motor learning and cognitive strategies  Duration: 8 sessions of 50-min over 2 weeks.	MABC COPM Harter's Scale of Perceived Competence/Harter Pike's Pictorial Scale of Perceived Competence Clinical observations.	Significant improvements in the COPM and MABC.  No changes in Harter's scores.	Not mention Motor skills improved
Snapp-Childs, Mon-Williams & Bingham 2012	Pre-post (quasi experiment)	16 children 7-8 years old DCD	Compared with typical children	Sensorimotor approach training using magnetic	Beery VMI DTVP Wide Range Assessment of Visual Motor Abilities: pegboard/fine motor subtest).	Both groups of children improved.  Significant improvement of scores in children with DCD	Yes Motor Perceptual *involve motivation (increase self-confidence)
Kaiser 2013	Pre-post	45 children 5-11 years old DCD	None	Combined approach of handwriting, fine-motor skills, balance, sensory and perceptual skills and self-confidence.  Duration: 16 weekly session of 45 to 60 minutes.	M-ABC COPM	Significant improvements in the M-ABC	Yes Motor (manual dexterity) *self-confidence increase
Tse, Thanapalan & Chan 2014	RCT	88 children 9-11 years old Handwriting problems	Compared with typical children	Visual perceptual training  Duration: 30 minutes OT task	Developmental Test of Visual Perception (DTVP-2)	Increased handwriting legibility scores in treatment group	Yes Visual Perception
Baldi & Nunzi 2015	Pre-post	3 male children 9-10 years old Handwriting problems	None	Handwriting Task Program (HTP)  Duration: Biweekly for 13 weeks	Concise Evaluation Scale for Children's Handwriting (assessed) Visual Motor Integration Test (VMI) (pre and post)	Improved handwriting legibility	Yes Motor Visual Perceptual *involve parents

*continue...*

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Thornton et al. 2016	Pre-post (quasi experiment)	20 children 8-10 years old DCD	Control group undergo regular activity	Cognitive Orientation to Daily Occupational Performance (CO-OP)  Duration: 10 weeks group- based intervention	MABC Handwriting Speed Test COPM Goal Attainment Scale	Improved in all outcome measures for intervention group	Yes Motor *increase over time *increase participation
Farhat et al. 2016	RCT	41 children 6-10 years old DCD	3 groups: Experimental, training DCD Control, non- training DCD Control, non-training typical	Group-based task oriented on motor physical skills  Duration: 8-week	MABC MAT THD 5JT Handwriting Performance Test	No significant changes in control group Improved MABC scores  Significant improvements in MAT, THD and 5JT  Significant improvement in handwriting quality and speed	Yes Motor skills improve
Coutinho et al. 2016	RCT	20 children 4-12 years old Visual motor deficit	Control group undergo traditional OT intervention targeting on visual motor skills	iPad application on visual motor integration skills  Duration: 40 minutes weekly for 10 weeks	Beery VMI M-FUN	No significant results for Beery VMI score	Not mention But increase visual and motor skills over time
McGlashan et al. 2017	RCT	21 children 8-10 years DCD	Control group with no online game given	Online interactive typing intervention  Duration: 2 online games over 4 weeks	MABC-2	No effect of intervention	No But might increase in visual and motor skills over time  Handwriting skills require visual, tactile and proprioceptive input, suggested sensory processing to improve handwriting skills.
Waelvelde et al. 2017	RCT	31 children 7-8 years old	Similar group with consecutive intervention	"I Can!" Handwriting Programme (self-regulative and behavioural approach)  Duration: 7 weeks	Systematic Screening of Handwriting Difficulties test VMI MABC-2 OMT	Improve handwriting quality Significantly improve handwriting speed in intervention group	Yes Motor skills improve *involve parents and teachers

## RESULTS

### SEARCH RESULTS

The database searchers identified 268 studies (n=268) in the identification phase. During the screening phase, 15 duplicates articles removed (n=15). From this point, 253 studies (n=253) were screened for title and abstract. Then, 45 studies (n=45) were excluded because the title and abstract did not meet the objective of this study. Following that, 208 studies (n=208) progressed to be eligible in this study. Those studies were reviewed in full text. After detailed analysis of each article, 198 were then excluded (n=198), for the following reasons: do not meet the study design (n=106); intervention stated not related to occupational therapy intervention such as physiotherapy or classroom intervention (n=54); written in language other than English (n = 18); unable to access full text article (n =17) and involve dyslexia, dysgraphia and children with developmental disabilities which were different diagnosis with motor coordination issues in this focus of review study (n=3). Upon final screening, ten studies were found to be eligible and were included in the appraisal process to be evaluated for their methodological quality. Therefore, the final number of articles included in this study for review was ten (n=10). The details of each phase demonstrated in a flowchart (see Figure 1).

Table 4 summarizes the critical appraisal scores of all selected articles. The methodological quality was described

in detail according to the critical appraisal point. All 10 articles have stated clearly the purpose of their studies. All 10 articles presented relevant literature reviews according to the context of study. The study design in the selected articles were mainly randomized controlled trials (RCT) (n=5) and pre- and post-test experiments (n=5). All of the studies used the sample number between 3 to 88 children with motor coordination issues. All articles comprehensively describe their sample. Only 3 articles justified their sample. Six articles used reliable outcome measures, while the other 4 articles did not address the reliability of the outcome measures applied. All articles mentioned that the outcome measures used are valid in their research. Eight studies clearly describe about the intervention used. Four studies declared that they avoid contaminations during study while one study did not. The remaining 5 studies stated that they did not address the avoidance of contamination during the study conducted. Similarly result appeared for the co-intervention avoidance except for one study by Farhat et al. (2016) who did not address the co-intervention avoidance. All 10 studies report their results in statistical significance. All studies demonstrated relevant method analysis accordingly. Nine studies mentioned about the importance of their report clinically while only one study did not clearly explain this. Seven studies did not report any withdrawal of participants during their study while the other 3 studies reported the drop-outs from the participants. All studies pertinently conclude their results of study.



Table 4: Critical appraisal scores

Study	1	2	3	4a	4b	4c	5a	5b	6a	6b	6c	7a	7b	7c	7d	8	Total	%
Dunford 2011	Y	Y	Pre-post	7	Y	N	NA	Y	Y	Y	Y	Y	Y	Y	N	Y	11	79
Snapp-Childs, Mon-Williams & Bingham 2012	Y	Y	Pre-post	16	Y	NA	Y	Y	Y	NA	NA	Y	Y	NA	N	Y	9	64
Kaiser 2013	Y	Y	Pre-post	45	Y	N	Y	Y	N	NA	NA	Y	Y	Y	N	Y	9	64
Tse, Thanapalan & Chan 2014	Y	Y	RCT	88	Y	N	NA	Y	N	NAD	NAD	Y	Y	Y	N	Y	8	57
Baldi & Nunzi 2015	Y	Y	Pre-post	3	Y	N	Y	Y	Y	NAD	NAD	Y	Y	Y	Y	Y	11	79
Thornton et al. 2016	Y	Y	Pre-post	20	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	13	93
Farhat et al. 2016	Y	Y	RCT	41	Y	Y	NA	Y	Y	Y	NA	Y	Y	Y	N	Y	11	79
Coutinho et al. 2016	Y	Y	RCT	20	Y	N	Y	Y	Y	NAD	NAD	Y	Y	Y	Y	Y	11	79
McGlashan et al. 2017	Y	Y	RCT	21	Y	Y	NA	Y	Y	N	N	Y	Y	Y	Y	Y	11	79
Waelvelde et al. 2017	Y	Y	RCT	31	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	12	86

McMaster items to be scored: 1. Was the purpose stated clearly?; 2. Was relevant background literature reviewed?; 3a. What was the study design?; 4a. Sample number; 4b. Was the sample described in detail?; 4c. Was the sample size justified?; 5a. Were the outcome measures reliable?; 5b. Were the outcome measures valid?; 6a. Intervention was described in detail?; 6b. Contamination was avoided?; 6c. Cointervention was avoided?; 7a Results were reported in terms of statistical significance?; 7b. Were the analysis method/s appropriate?; 7c. Clinical importance was reported?; 7d. Drop-outs were reported?; and 8. Conclusions were appropriate given study methods and results?; Y = yes, N = No, NA = not addressed.

## EFFECTS OF STUDY CHARACTERISTICS

Study characteristics includes the detailed information about the authors, study design, sample size and age group, comparator, intervention used, outcome measures, changes in outcome measures and effectiveness of intervention in handwriting components. The characteristics of the selected articles have been presented in Table 4. All ten articles were focused on occupational therapy intervention to improve handwriting skills among children with handwriting skills issues.

The selected articles were a mixture of studies sought from different authors from different countries around the world such as United Kingdom (n=2) (Dunford 2011; Mcglashan et al. 2017), United States of America (n=1) (Snapp-childs, Mon-williams & Bingham 2012), China (n=1) (Tse, Thanapalan & Chan 2014), Canada (n=1) (Coutinho et al. 2017), (n=1) Switzerland (Kaiser 2013), Italy (n=1) (Baldi, Nunzi & Brina 2015), Australia (n=1) (Thornton et al. 2016), Tunisia (n=1) (Farhat et al. 2016a), and Belgium (n=1) (Waelvelde et al. 2017). The widespread studies could represent the broader perspective of handwriting intervention among children with motor coordination issues.

The participants in the selected articles were children, ranging from 4-12 years old with difficulties in motor skills or handwriting skills. The participants in this systematic review had Developmental Coordination Disorder (DCD) (n=6), handwriting problems (n=3) and visual motor problem (n=1). All participants had motor coordination skills difficulties that might impact their handwriting skills ability. In most selected articles, participants with cognitive and/or any physical impairments such as visual or hearing problems were excluded. In terms of gender, two studies (n=2) had reported that the participants recruited in their studies were male only (Baldi, Nunzi & Brina 2015; Thornton et al. 2016), a study (n=1) mentioned their study included both male and female (Kaiser 2013) while others did not specify gender in the recruitment. Gender specification would be beneficial information in this review because motor coordination issues are often found in male compared to female children with suggested ratio between 2:1 to 7:1 (De Waal, Pienaar & Coetzee 2018). However, a more recent study by Cairney, Kwan, Hay & Faught (2012) revealed that gender difference was not significant in motor coordination prevalence population.

From the review, three studies (n=3) did not have any comparator group (Baldi, Nunzi & Brina 2015; Dunford 2011; Kaiser 2013), three studies (n=3) made comparison to typically developing children (Farhat, Hsairi, Baati, Smits-engelsman et al. 2016; Snapp-childs et al. 2012; Tse et al. 2014) and four other studies (n=4) compared the effectiveness of intervention tested with other control

treatment. The presence of comparator groups is very crucial to account for differences in intervention provision. Without comparator groups, there is poor possibility to examine intervention effect on handwriting performance (Black et al. 2020).

An important main concern was the possibility of contamination of intervention (6b). Only 5 studies (n=5) clearly explained the avoidance of intervention contamination (Dunford 2011; Farhat et al. 2016a; Thornton et al. 2016; Waelvelde et al. 2017; Wuang et al. 2018), while others did not address the issue. Another concern was that the possibility of co-intervention during the studies was not clearly addressed. This would impact on the effectiveness result of intervention given. Four studies (n=4) showed the effectiveness of the intervention used to improve handwriting without indicating the possibility of having cointervention (Dunford 2011; Thornton et al. 2016; Waelvelde et al. 2017; Wuang et al. 2018). Other than that, only three studies (n=3) had justified the sample size used (Farhat et al. 2016a; Mcglashan et al. 2017; Thornton et al. 2016).

## EFFECTS OF INTERVENTION

The interventions used in the selected articles were not restricted to conventional methods like face-to-face session but comprised modern and emerging interventions using technology and smart application on devices to improve handwriting performance for children with handwriting issues. Mode of delivery for intervention in nine of the studies (n=9) was practising direct intervention facilitated by therapist or assisted therapist and only one study (n=1) allowed online intervention delivered by parents at home, monitored by the therapist which also considered as occupational therapy intervention (Mcglashan et al. 2017). The types of intervention used had been categorized into conservative OT therapeutic approach using visual, motor, perceptual, sensory and activity of daily living skills training (n=7); device and assistive technology approach (n=1) and specific handwriting program (n=2).

Frequency of duration varied from once a day to four times per week, in intervention periods that lasted from two to sixteen weeks. There were 5 studies (n=5) provided 8 weeks and more for intervention period. There were 3 studies (n=3) provided less than 7 weeks intervention period and two studies (n=2) did not state the duration of intervention period given during their studies. Based on the intervention period, it was clear that the longer intervention period, the higher chance of the intervention being effective. Most of the interventions were applied individually on a one-on-one basis, except for one study (n=1) that employed group-based intervention (Farhat et

al. 2016a). Additionally, two studies (n=2) combined more than one intervention target component such as combining motor with cognitive skills (Dunford 2011) or combining motor skills with sensory, perceptual and self-confidence skills (Kaiser 2013). Table 4 provides an overview of the intervention outcomes and effectiveness.

#### EFFECTS OF OUTCOME MEASURE

The outcome measures used in each article were mostly standardised assessments to measure handwriting skills, motor function skills and visual perceptual skills. The handwriting skills outcome measures were Handwriting Speed Test, Evaluation Tools of Children's Handwriting (ETCH), Chinese Handwriting Evaluating Questionnaire (CHEQ), Systematic Screening of Handwriting, and Handwriting Performance Test. The outcome measures used for motor function skills were the Movement Assessment Battery for Children (MABC) and M-Fun, while visual perceptual skills were assessed by the Test of Visual Perceptual Skills (TVPS), Developmental Test of Visual Perception (DTVP) and Beery Visual Motor Integration Test (Beery VMI). There were a few studies that used occupational models of performance such as the Canadian Occupational Performance Measure (COPM) (Dunford 2011; Kaiser 2013; Thornton et al. 2016). All of the measures used in the selected articles were standardised and provide valid evidence to measure handwriting skills. Outcome measures were aimed to identify which intervention succeed and fulfil the desired results after intervention provided (Wilson, Kane & Falkenstein 2008). The use of valid and reliable outcome measures was very significant to monitor and evaluate definite changes of scores to represent effectiveness of intervention. As a result, outcome measures used should be linked with the handwriting intervention delivered in order to appraise specific occupational goal.

#### EFFICACY OF OCCUPATIONAL THERAPY HANDWRITING INTERVENTION

Table 4 summarises the outcome of occupational therapy handwriting intervention in handwriting performance, visual, perceptual, motor function and other outcomes of intervention. Essentially, three interventions (n=3) did not improve handwriting skills performance. There were using (1) a combination of motor and cognitive approach (Dunford 2011); (2) an iPad application (Coutinho et al. 2017); and (3) an online interactive typing intervention (Mcglashan et al. 2017). From these interventions, it is reported that there were increases in motor skills function over time, even though it was not significant during their

intervention period. In summary, 70% of all interventions (n=7) used in this review had shown effectiveness specifically in handwriting skills performance. The efficacy of intervention had impact on specific skills related to handwriting such as motor, visual and perceptual skills. In addition to that, effectiveness of intervention also can be seen through children's motivation, participation and parent's involvement that is discussed later in this review.

#### INTERVENTION IMPACT ON MOTOR, VISUAL AND PERCEPTUAL SKILLS

There are three primary outcomes from this review: motor function, visual and perceptual skills. Motor function focused more on ability to control movement and postures during handwriting activities. Visual perceptual skills enable action and interpretation through seeing. These skills are directly related to occupational therapy intervention to improve handwriting skills. For motor function skills, seven out of ten studies (n=7) (70%) found that their intervention had escalated handwriting performance. Those interventions were (1) a combination motor and cognitive approach (Dunford 2011); (2) a sensory motor approach using a magnetic device (Snapp-childs, Mon-williams & Bingham 2012); (3) a combination of handwriting, motor, sensory and perceptual skills approach (Kaiser 2013); (4) a Handwriting Task Programme (HTP) (Baldi, Nunzi & Brina 2015); (5) Cognitive Orientation to Daily Occupational Performance (CO-OP) (Thornton et al. 2016); (6) a group-based task based on motor physical skills (Farhat et al. 2016a); (7) an iPad application on visual motor skills (Coutinho et al. 2017); (8) online interactive typing (Mcglashan et al. 2017) and (9) the I Can! Handwriting Programme (Waelvelde et al. 2017). About 50% (n=5) of the interventions showed increased visual skills among the participants, whereas only 30% (n=3) had a positive effect on perceptual skills. This is because only three studies (n=3) mentioned about effect of the selected intervention on perceptual skills through the outcome measures assessed during the study.

#### INTERVENTION IMPACT ON CHILD'S MOTIVATION, PARTICIPATION AND PARENTS' INVOLVEMENT

There are three other outcomes from the interventions that showed a positive impact on the participants: (1) child motivation, (2) child participation and (3) involvement of parents. The studies used sensory motor approach using a magnetic device (Snapp-childs, Mon-williams & Bingham 2012) and sensory perceptual skills approach (Kaiser 2013) that increased child motivation to continue the treatment.

An intervention using CO-OP (Thornton et al. 2016) had built up participation among the children in the activity. The review gathered information on motivation and participation through qualitative observations and interviews. It is an interesting finding that two studies that used handwriting intervention programmes had an impact on the parents' involvement in enhancing the effectiveness of the intervention (Baldi, Nunzi & Brina 2015; Waelvelde et al. 2017).

## DISCUSSION

Generally, occupational therapy intervention has impacted favourably on handwriting skills among children with motor coordination issues. This systematic review would suggest that no specific occupational therapy intervention which could be said to be the best and most effective to improve handwriting skills (Engel et al. 2018). Handwriting skill performance may improve due to several factors such as time, other indirect intervention outside OT session, life routine and others. However, this review can conclude that the characteristics of an effective OT intervention to improve handwriting performance would be based on: (1) time frame, (2) age range, (3) type of intervention, (4) targeted outcomes and (5) involvement of other support during an intervention. To make an occupational therapy intervention effective for handwriting performance among children with motor coordination issues, involvement of others such as parents, teachers or health professional should be taken into consideration. The presence of these people may accelerate success of an intervention. Collaboration with teachers, parents and health professionals in an occupational therapy intervention should be activated through specific guides to increase the effectiveness of an OT intervention; for example, a clinical practice guideline for health professionals, a home programme for parents or a curriculum-based OT intervention for teachers (Engel et al. 2018; Kadar et al. 2020).

### INTERVENTION CHARACTERISTICS THAT DEMONSTRATED HIGHEST EFFICACY

This systematic review focuses on the effectiveness of occupational therapy intervention on handwriting skills performance among children with motor coordination issues. There were studies which suggested that the effectiveness of an intervention on handwriting skills can be seen over time (Coutinho et al. 2017; Thornton et al. 2016). It means that handwriting skills performance might improve as the child grows. Previous study suggested that there were eight characteristics of an intervention to be

effective, (1) severity of diagnosis, (2) setting (either in school, centre or at home), (3) approach of intervention, (4) length of intervention (in weeks), (5) frequency of intervention (per week), (6) type of intervention, (7) risk of bias and (8) intervention dose (in minutes) (Yu, Burnett & Sit 2018).

The use of an intervention programme could be the medium to accelerate the handwriting skills performance within a time frame between 6 to 16 weeks of weekly sessions (Baldi et al. 2015; Farhat et al. 2016; Kaiser 2013; Thornton et al. 2016; Waelvelde et al. 2017). It is suggested that the most ideal length of intervention for an occupational therapy intervention to become effective is 6-7 weeks with intervention dose at least 40-50 minutes per session (Waelvelde et al. 2017; Wuang et al. 2018). To support, another systematic review on curriculum-based handwriting programmes suggests twice weekly for at least 20 sessions is the most effective (Engel et al. 2018). To summarise this, most literatures concluded that effective handwriting intervention length ranged from 8 to 48 sessions with intervention dose between 20 to 60 minutes per session. These very high intensity and duration of intervention might be very demanding for occupational therapy practice. Moreover, children, parents and teachers might show up distress to this demanding service. Consequently, a recent study by Brevoort (2018) has evident that handwriting intervention can be effective with at least 15 minutes of 15 therapy sessions with 3-5 times a week. Hence, this low intensity, high frequency and short duration handwriting intervention could be practiced to manifest effectiveness of handwriting intervention.

From this review, it is also proposed that participant age range could play a significance factor for an intervention to become effective. Therefore, it is strongly recommended that the smaller age range the higher effectiveness impact after an intervention given. Most studies in this review that used small range of age, for example 7-11 years or 9-10 years has mostly demonstrated significance improvement in outcome measures. Hence, this imply that handwriting intervention has the highest degree of effectiveness among children between 7-10 years old.

Most of the studies used different standardised assessments in handwriting skills such as visual perceptual skills and motor function by analysing the scores before and after the intervention. This means standardised assessment reflects the approach and type of intervention applied during respective studies. From this review, motor function, visual, and perceptual skills are the most important skills components assessed for handwriting performance. Occupational therapists need to apply evidence-based interventions that have substantial impact in motor skills especially fine motor (Piller & Torrez 2019).

If a motor function skills deficit is not treated, it may persist to impact on participation in academic performance, life skills and the emotions of an individual with DCD (Talsaban et al. 2012). Visual motor function is another skill that is strongly linked to a handwriting task, as without vision, handwriting could not be carried out. It is supported that educational activities in school environment can have beneficial impact on visual motor coordination by scores (Taverna et al. 2020b). In addition, handwriting skills acquire visual and perceptual skills. Visual and perceptual skills involve letter formation, letter reversals, spacing, size, slanting of letters and alignment (Lam et al. 2011; Shih et al. 2018; Tourigny 2016). These components are very considerably important to produce a good handwriting piece.

The approach of intervention plays significant factor to the effectiveness in improving handwriting skills. From this review the approach of using modern technology device and application did not encourage handwriting performance (Coutinho et al. 2017; Mcglashan et al. 2017). This might be due to the positive relationship of intervention approach and handwriting performance. The practice of right intervention approach contributed to explicit impact in handwriting skills. Consequently, it is strongly suggested that handwriting intervention approach should contained established evidence-based methods namely multisensory, motor, cognitive, task-oriented approaches and therapeutic practice (Jones & Candler 2011). Therefore, in reflecting that, most occupational therapy practitioners often combined relevant intervention strategies required for handwriting skills for example sensory play, visual perceptual motor skills, adapted writing skills and as well as collaboration with teachers and parents.

This review unveiled that certain handwriting intervention had impact on child's motivation and participation in an affirmative way. Motivation could be associated with behaviour that drives an individual to participate in handwriting activities (Grünke 2019). Motivation to take part in handwriting activities could be manifested through interesting play and movement in order to provide effect of intervention. Specific handwriting intervention programme might elicit individual interest, thus increase their motivation to perform handwriting practice (Lai 2011). In previous studies had discussed that plan of action used in handwriting intervention programme could improve engagement and encourage participation in learning processes (Lai 2011). Therefore, it is highly recommended that effective handwriting intervention should implement more than one strategy in order to flourish motivation, behaviour and participation among children.

This review also proposed that handwriting intervention had impact on parents' commitment positively. Many studies supported that engagement from parents had shown positive relationship in an intervention thus lead to increase child's quality of life (Whittingham et al. 2016). Therefore, parents' involvement proved high compliance to home programmes provided by occupational therapist to expedite handwriting performance. It can be derived that following a handwriting intervention programme, parents became more alert to support their children at home through functional activities related to handwriting skills. Hence, it is suggested that handwriting intervention should promote home programme as monitoring evidence to increase effectiveness of intervention strategies. Occupational therapist should include consultative approach such as brief explanation and guidance in handwriting activities for parents to regard their commitment.

## LIMITATIONS

There are limitations in this systematic review. The databases used are limited to specific publication companies such as Scopus and Sage Journals. Therefore, future studies should include more databases like Medline and CINAHL for a more rigorous article-searching strategy. The articles studied were lacking in a high level of evidence with strong RCT study design. Despite this, due to inaccessibility, some of the most suitable articles could not be included in this review. As this review focused on OT intervention, there was a huge heterogeneity of the type of interventions to influence handwriting performance among children with motor coordination issues. Many of the studies fail to provide adequate information on the justification of sample, contamination of intervention and co-intervention bias.

## CONCLUSION

In general, occupational therapy intervention had greatly impact on the student's handwriting skills. This review revealed that occupational therapy service focuses on visual perception skills, fine and gross motor skills and sensory motor skills. These skills provided through occupational therapy intervention are vital to support the process of teaching and learning handwriting in a classroom environment. A study that has investigated the effects of occupational therapy services in handwriting performance claimed that the handwriting legibility increased in group of students who receives occupational therapy compared to the group of students who did not receive the service

(Case-Smith 2002). Moreover, that study also reported that providing occupational therapy service benefited the students with Developmental Coordination Disorder (DCD) in motor skills performance hence impacted in increased school participation and academic engagement. Therefore, the effectiveness of the OT handwriting intervention exhibited direct impact on motor, visual and perceptual skills, child's motivation and participation in the handwriting task as well as parent's involvement.

#### IMPLICATIONS FOR CLINICAL PRACTICE

In clinical practice, all studies were heterogeneous, and the results should be interpreted with caution if claiming effectiveness in improving handwriting skills performance for children with motor coordination issues. However, there were five studies in this review (Level II evidence) that provide intervention along with comparison group to measure the effectiveness of provided handwriting intervention to the targeted group. This suggested that effectiveness of intervention could be compared between two groups of different intervention/without intervention provided. It is believed that therapeutic intervention with the right number of therapy sessions could benefit the handwriting skills performance among children with motor coordination issues such as Developmental Coordination Disorder (DCD) and handwriting problems. It is also suggested that specific therapeutic intervention should be incorporated in the meaningful occupation of children such as the school curriculum to maximise its effectiveness (Kadar et al. 2020). It is strongly recommended that an OT intervention should consider engagement of other support from the surroundings of the children with motor coordination issues to expedite the effectiveness of intervention, such as providing a clinical practice guideline for health professionals, a home programme for parents or a curriculum-based OT intervention for teachers (Engel et al. 2018; Kadar et al. 2020).

#### IMPLICATIONS FOR FURTHER RESEARCH

The OT intervention techniques that have no evidence of improvement in handwriting skills should be avoided by occupational therapists, as they might not benefit the children's handwriting skills performance. This review only focused on average number of participants less than hundreds of children with mixture of RCT and pre-post study design. Therefore, further study is needed with larger number of participants with strong study design using RCT to prove its effectiveness. This review covered various handwriting intervention from conventional to modern

method of application, wide range of outcome measures from motor skills to perception skill and broad age range (7-10 years old). Hence, it is suggested that future research should focus on homogeneity of OT intervention applied to improve handwriting performance by using specific handwriting programmes, equivalent outcome measures and similar diagnosis of children with smaller age range. It is also interesting to recommend future research to examine the relationship of handwriting skills performance with genders among children with motor coordination issues.

#### IMPLICATIONS FOR OCCUPATIONAL THERAPY PRACTICE

The findings of this review suggest the following recommendations for occupational therapy practice intervention and research:

1. Motor function, visual and perceptual skills are directly related to occupational therapy intervention to improve handwriting skills.
2. Other outcomes from OT interventions that showed a positive impact on handwriting skills are child motivation, involvement of parents, child behaviour and child participation.
3. Effective OT intervention to improve handwriting performance would be based on time frame, type of intervention, targeted outcomes and involvement of other support during an intervention.
4. OT intervention should consider engagement of other support from the surroundings of children with motor coordination issues to expedite the effectiveness of intervention, such as providing a clinical practice guideline for health professionals, a home programme for parents or a curriculum-based OT intervention for teachers.

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