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AN INVESTIGATION INTO THE EFFECT OF A STETRO PENCIL GRIP ON THE WRITING AND PENCIL GRASP OF GRADE 2 CHILDREN WITH HANDWRITING DIFFICULTIES.

Esmie Smit

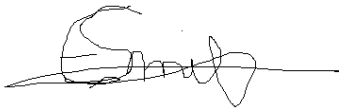
Research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the Master of Science in Occupational Therapy.

JUNE 2013

Johannesburg

Declaration:

I, Esmie Smit declare that this research report is my own work. It is being submitted for the degree of Master of Science in Occupational Therapy, in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.



_____

Esmie Smit

_____31_____day of _____May_____2013

Abstract:

The effectiveness of the Stetro pencil grip in 45 Grade 2 learners with handwriting difficulties was investigated. Monthly assessments considered descriptors including the position joints when writing, the position of the pencil in the hand, hand and arm movements, arm position and posture when writing as well as pencil grasp, the speed and quality of handwriting and tripod pinch strength.

The experimental participants used a Stetro pencil grip for two months after which it was removed for one month. The control participants wrote without a pencil grip. Statistically significant improvement was found for the experimental group in the efficiency of their pencil grasps and their use of their fingers when writing.

The quality and speed of writing and the pinch strength improved in both groups with the experimental group showing significant change in their index finger DIP position. The use of the Stetro pencil grip was effective in resolving inefficient pencil grasps in 70% of the experimental group.

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Nomenclature

Operational Definitions

Fine motor skills: the use of precise coordinated movements in such activities as writing, buttoning, cutting, tracing, or visual tracking (Mosby's Medical Dictionary, 2009). It is the ability to control small precise movements with the fingers, wrists and hands. A child's handwriting skills are dependent on the child's fine motor skills (Naidu, 2008).

Handwriting: Writing done with the hand. The writing characteristic of a particular person is unique (American Heritage Dictionary, 2009).

Legibility: Legibility is the degree at which glyphs and vocabulary are readable based on appearance; it is the ease of which writing can be read (Oxford Dictionary of English, 2010).

Motor engrams: Motor skill acquisition which occurs through modification and organization of muscle synergies into effective movement sequences. The learning process is reflected neurophysiologically as a reorganization of movement representations within the primary motor cortex. (Monfils, Plautz &, Kleim, 2005)

Pencil grasp: a method of holding instruments which is designed to enhance control and sensitivity, and consists of the tips of the thumb, index finger and middle finger holding the writing instrument. The ring finger provides the support. (O'Toole Miller-Keane, 2003)

Stetro pencil grip: The Pencil Grip works with the body's natural physiological action to place fingers in the proper position for gripping. It is a moulded plastic grip with indentations for tripod grasp (Free Kindergarten Worksheets Mini Books and Printables:, 2009).

Tripod Pencil Grip The pencil should be positioned so that there is equal pressure between the thumb, the side of the middle finger and the tip of the index

finger. All fingers are bent slightly. This is called a "tripod grip" or "tripod pencil grasp" (Stitzer, 2006).

Tripod pencil grasp with open web space: The pencil is held with the tip of the thumb and index finger and rests against the side of the third finger. The thumb and index finger form a circle (Agape Learning and Optometry Center, 2009).

Abbreviations

IP- interphalengeal

PIP – proximal interphalengeal

DIP - distal interphalengeal

CHAPTER 1:

INTRODUCTION

Writing is essential for children and adults to be able to communicate effectively in a non-verbal and non-demonstrative way. Handwriting is the tool that allows for expression of communication skills and for the personal expression of the child's literary skills (SENCo-Forum, 2002). Preminger et al, (2004) indicated that there is a prevalence of 5-20% for handwriting difficulties or dysgraphia in school going children affecting their ability to achieve these skills. Poor handwriting has also been associated with low self-esteem, poor motivation for participation in written and academic activities and frustration. Berninger, Vaughan, Abbott, Abbott, Rogan, Brooks, et al. further suggest that if handwriting has a poor appearance the writer is judged poorly by society (Berninger et al., 1997).

In 2007, Fitzgerald stated that preventing difficulty in handwriting in later years requires teachers to look at the needs that children have in their younger years and to support them in developing this skill. It is very important that the child develop a handwriting style that is adequate and accurate in the first few years at school, as Alston and Taylor (1987) indicated that motor skills, especially those related to writing habits, including pencil grasp, are resistant to change once they have been formed. (Alston & Taylor, 1987)

Adequate handwriting depends on the fluency and accuracy of the letters produced. This is associated with the fine motor development of the hand, the pen or pencil used and the effect of stress placed on the writing implement as well as the speed at which the writing occurs. Pencil grasp is another factor believed to affect handwriting. Even if it is only a small element of the handwriting, correct pencil grasp is very important for the early stages of writing development. It influences the dexterity and the speed of manipulation essential for adequate writing (Alston & Taylor, 1987).

Thus when children are referred to occupational therapy for handwriting difficulties, an inefficient pencil grasp is one of the problems that teachers and

occupational therapists regularly identify. Inefficient grasps include holding the pencil with a closed web space, the thumb over index and middle fingers, low in web-space, or with the thumb and index finger in parallel with each other (Stitzer, 2006).

Inefficient pencil grasps have also been associated with the following problems: slow work completion, excessive pressure when writing, poor spacing and organisation of written work, poor letter formation and reversals, pain in fingers, wrist and forearm and poor writing posture (Stitzer, 2006). If an inefficient pencil grasp is not addressed early, it is possible the child will develop some of these problems which will be exacerbated with the need to write more quickly in later years at school (Selin, 2003). Using a triangular plastic grip (Stetro pencil grip) on the pencil may improve poor handwriting, by adjusting the pencil grasp and placing the child's fingers in the natural physiological position for writing. This has been related to prevention of cramping and enhancing the writing action (Stitzer, 2006).

1.1 Statement of problem:

Difficulty with handwriting is one of the most common reasons for referral to occupational therapists (Ziviani, 1996). Children commonly present with dysfunctional or inefficient pencil grasps which may cause fatigue of the hand, cramping and even pain that will hinder the writing activity, (Ferrandino, 2007). In my personal experience as an occupational therapist in a mainstream schooling system is that at least 25% of the children in each class struggle with fine motor tasks including dysfunctional handwriting. Overvelde and Wouter Hulstijn (2011) found the prevalence of hand writing problems in Grade 2 to be 37%. (Overvelde & Hulstijn, 2011)

Numerous children with handwriting problems are referred by teachers to occupational therapy. This occurs due to handwriting problems alone (Stitzer, 2006).This referral results in a full assessment and therapy costs for the parents/legal guardians where treatment can continue over a number of months. The problems with children's handwriting have also been shown to improve markedly in the Grade 2 year so it is important to establish which children have

genuine problems and which children need support in class to improve their writing skill. (Overvelde & Hulstijn, 2011)

1.2 Purpose of the study:

The purpose of this research is therefore to establish, once the occupational therapist has identified pencil grasp as a problem affecting hand writing, what effect a classroom-based programme could have in correcting this problem. It is proposed that this intervention may be enough to avoid a full assessment and individual therapy programme for many of the children with handwriting difficulties. At the end of the study, if participants still have problems then they can and will be referred to an occupational therapist for further management.

The study examined the effect of a Stetro pencil grip on the handwriting of Grade 2 learners' who had difficulty with writing quality and speed. The investigation focused on whether the Stetro pencil grip could affect the functionality of the pencil grasp in terms of positioning the fingers in a tripod pinch and whether this pencil grasp was retained when the Stetro pencil grip was removed. The change in pencil grasp was also related to the quality and speed of writing as well as the strength of the learner's tripod pinch.

The ease of use of the Stetro pencil grip in the classroom over a period of up to three months was included in the study.

1.3 Justification of the study

Children referred for poor handwriting to occupational therapy are usually treated once a week for fine motor difficulties. The treatment can be drawn out and expensive for the families. This study evaluated the use of a Stetro pencil grip in classroom activities involving writing, with children identified as having incorrect pencil grasps. The purpose was to establish if the assistive device used in the classroom to correct pencil grasp would alleviate the need for expensive individual therapeutic intervention for some of these children allowing those with continuing problems to access the services they need.

1.4 Aim of the study

The study examined whether the use of a Stetro pencil grip in the classroom during writing activities played a role in the development of a tripod pencil grasp in Grade 2 learners presenting with inefficient dysfunctional pencil grasps. The effect of the pencil grasp used by an experimental and control group on observed descriptors of factors associated with pencil grasp, the scores on the Minnesota Handwriting Assessment for speed and quality as well as tripod grasp strength was also evaluated.

1.5 Objectives of the study:

1. To determine the dysfunction in the descriptors associated with pencil grasp and the descriptors of position and posture associated with writing as well as pencil grasp, speed and quality of handwriting and pinch strength in Grade 2 learners identified as having handwriting difficulties.
2. To determine the effectiveness of the Stetro pencil grip on these handwriting descriptors, the speed and quality of handwriting and pinch strength in Grade 2 learners identified as having handwriting difficulties.
3. To establish what change occurs in the descriptors associated with handwriting and pencil grasp as well as the speed and quality of handwriting and pinch strength in Grade 2 learners who do use a Stetro pencil grip for the first two months and those who do not use a Stetro pencil grip.
4. To determine whether any improvement made in the speed and quality of handwriting and pinch strength when using the Stetro pencil grip are retained once the pencil grip is no longer used.

1.6 Null Hypotheses:

There will be no difference in the descriptors associated with pencil grasp and the descriptors of position and posture associated with writing as well as the pencil

grasp of Grade 2 learners with handwriting difficulties, who do and do not use a Stetro pencil grip in a classroom programme.

There will be no difference in the speed and quality of handwriting and pinch strength of Grade 2 learners with handwriting difficulties, who do and do not use a Stetro pencil grip in a classroom programme.

If changes do occur in the speed and quality of handwriting and pinch strength of Grade 2 learners with handwriting difficulties who use a Stetro pencil grip in a classroom programme for two months, these will not be retained on removal of the Stetro pencil grip in the following month.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This literature review will consider the development of hand function as well as the development of handwriting. Factors related to handwriting including pencil grasp will be discussed. A review of the assessment of handwriting in terms of speed and quality as well as the remediation of pencil grasps and the use of pencil grips including the Stetro grip is also included.

Feder, Racine and Majnemer (2008) described the failure to attain handwriting competency during the school-age years as influencing a child's academic success and self-esteem. Handwriting is a complex occupational task which has many underlying component skills that may interfere with writing performance. They state that

> *"despite the widespread use of computers, legible handwriting remains an important life skill that deserves greater attention from educators and health practitioners."* (Feder et al., 2008, p68-88).

2.2 Development of Hand Function

Hand skills are vital to the child's interaction with the environment. Functional hand skills require object handling, almost all of which is accomplished with the hands (Case-Smith, 2005). The hand develops from birth and matures through various milestones. At birth, one has a strong grasp reflex but when the child start to retain objects in the hand this reflex matures. Between three and five months, the child develops a sustained voluntary grasp and the child starts using the fingers in the grasp. The child also starts developing a palmer grasp and the hand starts accommodating the objects in the hand. As the child start to transfer objects between his/her hands, tactile awareness will start to develop. At six months, the child should have a consistent palmer grasp and the radial-palmer grasp starts to develop.

Between seven and nine months, the child's grasp strength increases and there is integration of the radial-palmer grasp. This allows for the pinch grasp to develop. At the age of ten-twelve months, the child achieves the pincher grasp and progresses to the tip-pinch. The role of thumb opposition in the development of pinch grips is essential and must also be considered. When the opposition of the thumb against the fingers neither are nor used in pinch grips hand function can be impaired. Stability of the pinch is provided by the thumb (Selin, 2003).

Hand preference start to develop, from between 6 months and in hand manipulation and dexterity improve (Johnston et al, 2007). This is reliant on proprioceptive and sensory feedback as well as muscle action in the hand. The position of joints and visual input also play a role as does learning to use the intrinsic and extrinsic muscles of the hand in a co-ordinated way (Selin, 2003). This involves the differentiation of finger movement from those of the wrist and arm and the development of proximal stability to facilitate these distal movements.

> *"Functional use of the hand is more dependent on joint stability, than on joint mobility"* (Benbow, 1995, p 267)

The development of hand function as well as the fine motor skills is essential for writing and creative artistic activities. These fine motor skills are developed by other skills such as integration of early movement patterns (Fallon et al, 2002) and allow a child to perform to his/her potential in academic and physical tasks. The development of motor skills depends on an intricate set of cognitive and physical processes and result in targeted and precise actions. Basic motor skills include skills such as grasping and manipulation especially during infant and toddler stage and are refined enough at the age of five or six years for the child to write (Case-Smith, 2005). At two to three years a child has developed sufficient fine motor skills to use a writing tool and this component continues to develop until the age of five and six when the skill is developed enough for the child to learn formal handwriting (Brown, 2003).

According to Case-Smith (2005) in-hand manipulation related to fine motor skills has a significant association to handwriting skill (Case-Smith, 2005).

Developmental progression of pencil grasp between boys and girls follow similar trends (Schneck &. Henderson, 1990). Gross motor development is also important for fine motor skills as it provides the postural stability for the development of a relaxed, mature pencil grasp.

2.3 Development of handwriting

According to Case-Smith (2005), the functional skill of handwriting supports the academic task of writing and allows children to convey written information legibly and efficiently, while accomplishing written school assignments in a timely manner. Handwriting is a complex process of managing written language.

" *The development of a child's handwriting can provide clues to developmental problems that could hinder his/her learning because teachers depend on written work to measure how well a child is learning"* (American Occupational Therapy Association, 2001, p 1.

A child starts developing handwriting skills by playing, drawing and scribbling and this is an important unified process which occurs simultaneously with the development of language (Lu, 2000). Writing develops with neurodevelopmental skills such as grapho-motor, attention, language, and memory and higher–order cognition. In the writing process the grapho-motor skill is essential as it is the ability to use muscles in the fingers and hands to form letters and maintain a functional pencil grasp.

Graham, Harris and Mason (2005) indicate that handwriting is a flexible, goal-directed activity that is supported by cognitive processes and planning which together results in letter production, and revision (Graham et al., 2005). Handwriting however is reliant on motor skills that are predominantly learnt in childhood and although handwriting is important throughout a child's educational years, and as stated by Miller, Polatajko, Missiuna, Mandich and Macnab (2001) emphasis on its development occurs in primary school (Miller et al., 2001).

Studies by Dyson in 1983 suggested, writing of their names facilitated the development of writing with young children. Between 30-60% of the primary school child's class time is spent in fine motor or writing activities, with writing as

the predominant task (McHale & Cermak, 1992). Handwriting has a profound impact on learning and acceptance of ideas as suggested by Lamme and Farris (1994) (Lamme & Farris, 1994). In the handwriting readiness research of Marr et al. 2001 factors that influence can be divided into internal and external factors.

Overvelde and Hulstijn (2011) showed that there is maturation and improvement in the handwriting of children in Grade 2 and in their study children at risk of handwriting problems improved over a period of six months to equal normative scores for their writing. Those identified with dysgraphia also showed improvement and moved to the at risk category when tested on the Concise Assessment Method for Children's Handwriting (Overvelde & Hulstijn, 2011). The at risk and dysgraphic children showed significant and substantial improvement during Grades 2 in normal class work and this supported the work of Hamstra-Bletz and Blote (1993) who reported that only 10% of children with handwriting problems in Grade 2 still had writing problems in the subsequent grades. (Hamstra-Bletz & Blote, 1993).

2.3.1. Factors related to handwriting

Occupational therapists therefore consider both external and internal factors which affect handwriting including the environment, seated posture, strength and endurance, and kinaesthetic and motor planning skills which are all important for handwriting. Pencil grasp is especially important as it influences writing speed and legibility.

2.3.1.1 External Factors

The external factors include the instructional procedures, materials used and the environment during writing. These factors are outside the scope of this study and will not be reviewed.

2.3.1.2 Internal Factors

Lamme, 1979, outlined six prerequisites for handwriting three of which relate to the mechanics of writing. The first is small muscle development, and pinch grip strength (Lamme, 1979).

As a child develops a mature pencil grasp, holding the writing utensil between the distal phalanges of the thumb, index and middle fingers the intrinsic muscles of the hand develop strength and guide the handwriting movement (Selin, 2003). Finger movement is provided by strength in the lumbricals while strength in the interossei provide stability to the pencil grasp and provide pinch grip strength.

The thumb muscles are also required to co-contract in order to enhance the pinch strength and to stabilise the pencil (Summers, 2001).This is achieved by thumb opposition which relies primarily on the strength of opponens pollicis and adductor pollicis. The thumb moves through flexion and extension range of motion during handwriting and strength in the flexor and extensor pollicis muscles is therefore required. The flexor pollicis longus in conjunction with the opponens pollicis, are activated at the base of the thumb to maintain an open web space.

The second prerequisite is coordination. A number of studies have shown an association between eye-hand coordination and the quality of handwriting. Tseng and Murray (1994) found a significant correlation $r = .47$ ($p < .01$) between these variables. Poor fine motor control or co-ordination is related to writing problems in children in Grade 1 resulting in poor letter formation and size as well as poor placement of letters and words on the page (Tseng & Murray, 1994).

The ability to perform symmetrical and asymmetrical movements or bilateral integration is also necessary for coordinated movement when writing. Handwriting is an asymmetrical activity as the child write with the preferred hand while stabilizing the paper with the non-preferred hand (Feder & Majnemer, 2007). The preferred hand must be supported on the table (Selin, 2003).

In-hand manipulation is the third prerequisite and this allows for the pencil to be adjusted within the hand and for the linear movement of the pencil needed to reposition it in the hand after it is grasped, Translation is used in pushing the

fingers toward or away from the point of the pencil when writing. Rotation maybe used if the eraser on the back of the pencil is to be used (Feder & Majnemer, 2007).

Other internal factors addressed in this study relate to the mechanics of handwriting and therefore the first three of Lamme's prerequisites (Lamme, 1979) which are extended to include four other factors identified by Benbow, Hanft and Marsh (1992) which include gender, dominant hand use, midline crossing with the dominant hand and proper posture (Benbow et al., 1992).

In terms of gender differences previous research has found that girls often perform better than boys with regard to both their writing speed and legibility. According to Graham and Weintraub (1996), these gender differences may be due to both biological and environmental factors. Controversy still exists around this subject but it has been shown that girls have a more advanced progression of fine motor skills than boys, which may have an impact on their writing (Graham & Weintraub, 1996).

In the developmental stages of pencil grasp up to six years there is no significant difference between right- or left handed children. (Saida & Miyashita, 1979). Graham and Weintraub (1996) showed that right-handed children wrote faster than those who are left hand dominant. Some underlying causes for these differences may be the position of the paper that left-handed individuals use and quality of handwriting instruction given to left-handed children (Graham & Weintraub, 1996). Schneck in her study in 1991 found no association between good handwriting and handedness problems in establishing dominance being associated with poor handwriting (Schneck, 1991) ,

Selin (2003), noted that stability of the trunk is required for differentiated movements of the wrist and forearm to facilitate distal movements of the fingers (Selin, 2003). Pollock, Lockhart, Blowes, Semple, Webster, Farhat et al., 2009, also discussed the importance of the child's posture on the handwriting speed and end product. They describe the ideal posture for writing as

- "*Trunk aligned against the back of the chair to provide proximal*

stability

- *Head aligned with the trunk, which is optimal for visual scanning*
- *Seated on chair so that feet are firmly planted flat on the floor*
- *Forearms stabilized on the desk*
- *Wrist in a neutral position on the desk"* (Pollock et al., 2009, p 6)

According to Tseng and Cermak (1991), the visuo-motor, tactile kinesthetic and motor planning internal factors are more closely related to handwriting than visual perception (Tseng & Cermak, 1991). Dankert, Davies and Gavin 2003, define visuomotor skills as the ability to integrate image of letters of shapes with the appropriate response (Dankert et al., 2003). These skills are also linked to handwriting, as seen in research by Cornhill & Case-Smith, 1996 and Tseng & Murray, 1994, where they found a positive association between visuomotor skills and handwriting. These visuomotor skills include the ability to copy and reproduce the letters. (Cornhill & Case-Smith, 1996 and Tseng & Murray, 1994).

Kinaesthetic awareness plays a big role in handwriting as there is a temporal delay between the programming of the writing movement and actually seeing it on paper (Tseng & Cermak, 1991). Kinaesthetic awareness is defined by Cermak (1991), as the ability to judge, and adjust movements for the task at hand. It judges the force and accuracy of writing and holding the pencil, and during handwriting the body gives kinaesthetic feedback in order to sustain or adjust the movement. It plays a role in handwriting in terms of directionality of letters and size of the letters (Cermak, 1991).

Learning any new skill requires motor learning. It is the ability to plan, organise and execute a sequence of movements, thus influencing handwriting when learning new letters. Reversals occur often if motor planning is not appropriate (Levine, 1994).

Visual perception is a skill which allows the child to notice sizes, spacing and placement of letters. A child with visual-perceptual difficulties would be able to copy letters with accuracy but would not manage the detail in relation to the other details. (Dankert et al., 2003).Tseng and Murray (1994) indicated that by the time

a child can write, he/she should have fully developed a sense of visual shape discrimination. They also indicated that it is not all visual perception skills influence handwriting and research indicates that position in space specifically plays a role (Tseng & Murray, 1994).

One of the other internal factors related to hand writing is pencil grasp. Factors related to inefficient pencil grasp include slow speed in completion of tasks, heavy pressure, poor spacing and written organisation in work, poor letter formation and reversals, pain in fingers, wrist and forearm and a poor writing posture (Erhardt Developmental Products, 1994).

2.4 Pencil Grasp

2.4.1. Pencil Grasp in Handwriting

A good pencil grasp is one of the first steps in developing good handwriting skills. A good pencil grasp allows “the child to write quickly and smoothly while a tight or incorrect grasp can hinder writing” (Naidu, 2008).

2.4.2 Development of Pencil Grasp

At the age of 18 months the child will scribble with the pencil in a fist (cross palmer grasp) with the movements produced by the shoulder and trunk. Between the ages of two to three years the child will hold the pencil with the tip of the pencil on the thumb side and the index finger will start to straighten. The index finger will usually separate from the other three fingers and the grasp will be pressurised. The drawing movements will still be guided by the shoulder and the trunk (Selin, 2003).

By the age of four years most children can hold a pencil with the thumb in opposition to the other fingers. The ring and small finger at this stage start to flex and provide stability for the hand. As the stability improves the longitudinal arch develops. Gradually with more exposure and practice small finger movements at the metacarpophalangeal joints start to control the drawing/writing movements.

The movements are now limited to the fingers with the shoulder, elbow and wrist provide stability (Selin, 2003).

At the ages of five and six years the hand has matured, so that the child will have a mature pencil grasp. The mature pencil grasp is characterised by the hand that rests on the ulnar side, stabilised by the small and ring fingers on the page. The pencil is held in a relaxing manner with the thumb and index finger curved towards each other. The pencil rests against the base of the index finger (Selin, 2003). The intrinsic hand muscles control the writing actions while the wrist extension position will be used to moves the pencil from left to right. The shoulder, elbow and wrist stabilise the hand.

Schneck and Henderson, (1990) found that Grade 1 children use a variety of different pencil grasps in their drawings and colouring. There are different views as to whether a standard tripod grasp should be taught in the classroom or whether children should be allowed to use their own pencil grasps as long as they are able to produce efficient writing. The findings suggest that the children's own pencil grasps do not assist them when demands on writing speed and quality increase in higher grades (Schneck &. Henderson, 1990).

2.4.2.1 Efficient Pencil Grasps

Ferrandio, (2007), suggests there are two efficient or functional pencil grasps, the tripod grasp, where the thumb, index and middle fingers support the pencil or a quadrapod grasp where the thumb, index, middle and ring fingers hold the pencil. With both these grasps the fingers are able to move, which is the basic function essential to handwriting (Ferrandino, 2007).

According to Brown, (2003), a functional tripod grasp avoids physical problems which may affect the hand and the wrist (Brown, 2003). (Figure 2.1) In a study in 2003, Koziatek and Powell found that the lateral quadropod and four finger pencil grasps are equally as functional in writing tasks as the dynamic tripod and dynamic quadropod pencil grasps in terms of writing speed (Koziatek & Powell, 2003). Schneck and Henderson (1990), on the other hand found that older

children tend to use two-pencil grasps – a tripod and lateral tripod grasps (Schneck &. Henderson, 1990).

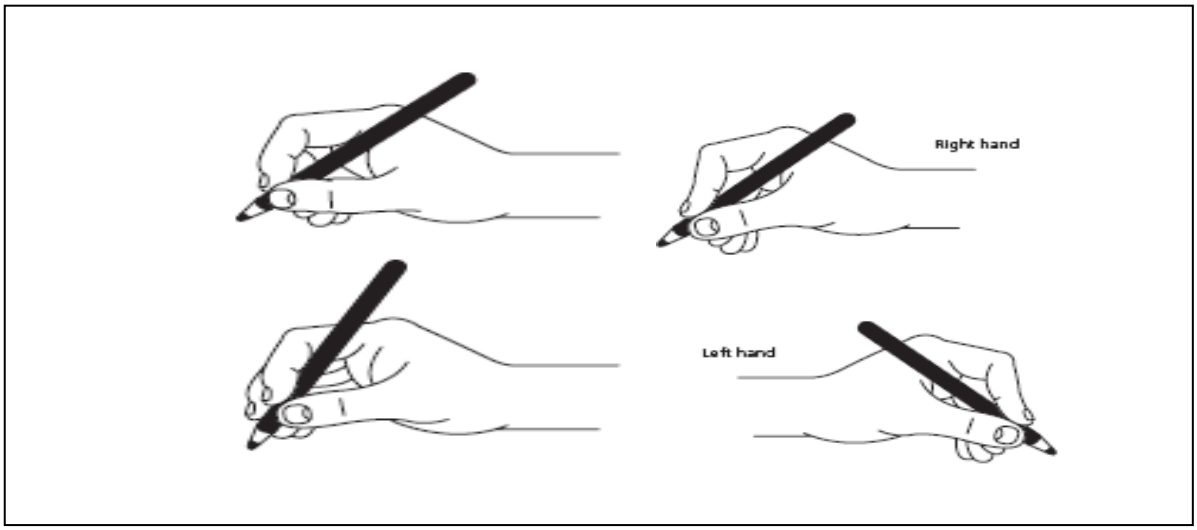


Figure 2.1 Appropriate tripod pencil grips for a left and right handed child –Adapted from (Royal Children's Hospital in Melbourne , 2005)

The tripod pencil grasp, is when the pencil is positioned so that there is equal pressure between the thumb, the side of the middle finger and the tip of the index finger. The index and middle fingers must be slightly flexed and all three joints in each finger. Ferriell, Fogo, McDaniel, Schillig, Shehorn Stringfellow and Varney (1999) noted that the degree of index-finger flexion and the degree of forearm pronation/supination play a big role with the refinement of the dynamic tripod grasp (Ferriell et al., 1999). Thus it is important to position the fingers in the correct manner on the pencil shaft to allow in hand manipulation of the pencil, with the wrist in extension and the thumb being the digit nearest to the tip of the pencil. There should be no pressure on the meta-carpal joint or the fingertip of the index finger (Brown, 2003).The joints of the thumb should also be positioned in slight flexion (Summers, 2001)

According to the South Australian Curriculum on Handwriting, (2010), in the tripod pencil grasp the thumb should be placed 15 mm away from the tip of the pencil if the child is right handed and 30 mm if they are left handed.

2.4.2.2 Inefficient pencil grasp

Poor or inefficient pencil grasp habits are developed during early experimentation when learning to write. The grasp can become a claw-like, tight grasp, which can lead to underdevelopment of the groups of muscles that are required for writing and thus inhibit fluent movements required for fast and legible writing (Feder & Majnemer, 2007).

Thus results in an inefficient pencil grasp that can lead to slow writing and a pencil grasp with a closed web space can make the writing process more of a gross motor action with the whole arm and hand instead of finger and wrist movements being used. This results in insufficient letter formation, poor pencil control and fatigue. Continual clenching of the hand to hold a pencil can cause inflammation of the ligaments of the hand leading to carpal tunnel syndrome (Brown, 2003).

Although Schneck, (1991), suggested that inefficient pencil grasps do not always have handwriting difficulties (Schneck, 1991) it has been found that children with poor handwriting have a higher tendency to have decreased proprioceptive-kinesthetic finger awareness leading to inefficient tight pencil grasps with hyperextension of the distal joint of the index finger and more than 90 degrees of flexion at the interphalangeal joint of the thumb (Summers, 2001).

Pencil grasp difficulties can also be identified if the middle finger is on top of the pencil; the thumb is over or under the index finger, the pencil low in the web space, the thumb is held in an extended position or if the thumb and index finger are held parallel.

Watt, Payne, Barton and North (2009) felt children who have difficulties in handwriting, and drawing and may be observed by teachers as having dysfunctional pencil grasps. However, they state an occupational therapist will need to distinguish whether other problems related to the sensory and motor development of the hand and postural system are present (Watt et al., 2009).

2.5 Assessment of handwriting

It was concluded that problems in the development of handwriting could be divided into three categories:

- lack of maturation of motor ability,
- a deterioration of the script initially learned,
- the development and constraint of a personal writing style (Ziviani, 1996).

It is important that handwriting performance be evaluated using a valid, reliable, standardised tool combined with informal classroom observation and teacher consultation. The quality of handwriting is evaluated with standardised tests at the Grade 2 level for example using the Minnesota Test of Handwriting (Reisman, 1999). Handwriting will be evaluated in terms of handwriting speed averages and quality of handwriting. The hand producing the handwriting will be evaluated in terms of pencil grasp and tripod grasp strength.

Another handwriting assessment that was considered was the Test of Handwriting skills, revised. This assessment is an untimed test which test manuscript and cursive writing. This test could be used from the age of 6 to 18 years. It takes 10 minutes to administer and 15 minutes for marking. This assessment's purpose is to assess neurosensory integration ability, it is designed to identify handwriting problems (Milone, 2007). This test was not used in the research study as it is designed to evaluate individually and not optimal in group evaluation.

2.5.1 Handwriting speed

Handwriting speed is relative to the individual's age and grade, and it is measured in letters per minute. These measurements need to be considered with care as Graham, (2006) indicated that handwriting speed and legibility did not follow the same pattern of development in each child (Graham, 2006). Case-Smith, (2005) however compared writing speeds between different studies and found that there is a strong relationship between the speed of writing and age and school grade (Case-Smith, 2005).

A study by Phelps and Stempel, in 1987 found the average writing speed for Grade 2 is 35 letters per minute (Phelps & Stempel, 1987) but Larsen and Hammil, in their 1989 study found the average to be 20-25 letters per minute (Larsen & Hammill, 1989). This average was later used in studies by Hamstr-Beltz and Blote in 1993 (Hamstra-Bletz & Blote, 1993). In 2005, Case-Smith reviewed the available literature on the speed of writing in conjunction with legibility as a basis of functional writing, but was not able to draw any conclusions as the methodology of these studies was very different (Case-Smith, 2005). Presently it is widely agreed that the Grade 2 average is 20-25 letters per minute (Tseng & Cermak, 1993)

2.5.2 Quality of handwriting

Poor quality of handwriting has been found to be strongly influenced by increased writing speed, rushing to complete assignments. There is a balance between quality of handwriting in children and the speed at which they are expected to write (American Occupational Therapy Association, 2002). It is indicated by Peterson and Nelson's research in 2003 stated that legibility of handwriting should precede writing speed (Peterson & Nelson, 2003).

Writing quality can also influence the outcomes of assignments and projects in the classroom.

2.5.2.1 Legibility

Dennis and Swinth (2001) indicated that there is no significant difference between tripod grasps and inefficient grasps in terms of legibility when writing (Dennis & Swinth, 2001). Wood, Webster, Gullickson and Walker (1987) felt handwriting legibility is influenced by teaching styles indicated by the child's teacher and school (Wood et al., 1987). Legibility of handwriting is very strongly influenced by the learning and rules of letter formation (Meulenbroek & Van Galen, 1990). It is a skill that is essential for integration of spelling and other academic concepts in the classroom situation.

Writing legibility is evaluated in terms of letter formation, alignment, spacing, size and the slant of the letters. Poor legibility is therefore related to poor letter formation and disproportionate sizing of the letters (Case-Smith, 2001). Berminger; Vaughan, Abbott, Abbott, Rogan, Brooks, Reed and Graham in 1997 indicated that 20% of primary school children have been identified as being at risk for developing handwriting problems based on their legibility (Berninger et al., 1997). The development of legibility in handwriting is facilitated first by teaching letter formation followed by letter alignment, size and spacing. Once these foundations are consolidated and practised, legibility improves. Weintraub, Drory-Asayag, Dekel, Jakobovits and Parush 2007 found that girls tend to have better legibility than boys (Weintraub et al., 2007).

Assessment of legibility is usually done on a Likerdt scale. The Likerdt scale is an ordered, one dimensional scale. It is a well known psychometric questionnaire. It typically has a format consisting of answer options (Likert, 1932)

2.5.3 Descriptors of factors affecting Handwriting

Lyytinen-Lund, 1998 developed a comprehensive assessment checklist based on the researched descriptors of pencil grip and associated features for efficient handwriting in children (Lyytinen-Lund, 1998).

The reliability of the descriptors in the checklist was tested for validity and interrater reliability. It was found that the check list was valid and reliable.The checklist was used, to assess the presence of these descriptors by observation. It was finalized and used by Selin in her research in 2003. Children were assessed using observation and photographs and the checklist was then completed (Selin, 2003).

The descriptors used were based on studies by Sassoon, Nimmo-Smith and Wing as well as Ziviani and Elkins in 1986 and Lyytinen-Lund in 1998 (Lyytinen-Lund, 1998); (Sassoon et al., 1986); (Ziviani & Elkins, 1986). These were scaled to include the ideal positions of the body upper limb and digits associated with good

handwriting to positions associated with poor handwriting. An example of the scale on the checklist for the distance of the fingers from the tip of the pencil is

The fingers are

- 01 at a functional distance from the tip of the pencil
- 02 too close to the paper
- 03 spread over the shaft

Descriptors used in the checklist covered aspects of pencil grasp like:

- proximity of the fingers to the pencil tip
- digit closet to the tip of the pencil
- angle of distal joint of index finger
- angle of distal joint of thumb
- fingers used
- number of digits touching the shaft of the pencil
- hand used to write and
- which body part the writing movements were conducted with

Postural descriptions as described by Sassoon et al., (1986); included the child's working posture when writing, the position of the supportive non dominant hand, position of the writing hand and arm on the table, wrist position of the writing hand and other aspects like the position of the paper on the table were also considered.

2.6 Remediation of handwriting

For intervention of handwriting one can use a remedial or a compensatory intervention. Compensatory strategies improve a student's participation in school accommodations, adaptations, and modifications of certain tasks, routines and settings, whereas remedial strategies are used to improve the child's functional skills in a specific area such as the pencil grasp (Case-Smith, 2005).

Analysis of standard and non-standard grasps suggests that more remediation attention should be focused upon correcting the factors underlying poor handwriting performance (Ziviani & Elkins, 1986).

2.6.1 Correction of pencil grasps:

Intervention of the pencil grasp is indicated in the case of grasps that limit visual input of the tip of the pencil, fisted grasps, biomechanical stress to a joint, grasps that fatigue the hand, hyperextension or excessive flexion of the thumb's interphalangeal joint and severe hyperextension of the index finger distal interphalangeal joint.

While Schneck and Henderson, (1990), suggested that the pencil grasp does affect handwriting and other research indicates that the pencil grasp does not necessarily affect the legibility of handwriting there is a suggestion that it does have an effect on the biomechanical stress to the joint (Schneck &. Henderson, 1990). According to Naidu, (2008), a good pencil grasp allows the child to write quickly and smoothly and it is therefore essential to establish and correct the inefficient pencil grasp as early as possible after the child starts to use a pencil (Naidu, 2008). The pencil grasp builds on the child's fine motor skills and develops engrams of motor learning in terms of letter formation and fluency of writing. Writing is a taught skill and children need to practice writing in the correct way so that the correct motor engrams are laid down (Cusumano, 2008).

Without intervention, the child's grasp that he/she starts in preschool with, is likely to be remain a lifelong grasp. Amundunson, (2005), states in his research that even by Grade 2, changing the pencil grasp is stressful (Amundson, 2005). Changing to a tripod grasp from another incorrect grasp can feel awkward to many children, especially if it requires a change in established habits/engrams (Naidu, 2008).

One of the suggested strategies to improving pencil grasp is provide the child with a moulded pencil grip that will allow the fingers to form a tripod pinch on the grip placed on their pencil. Koziatek and Powell (2003) also suggested that when children write slowly, the use of a commercial pencil grip on the pencil facilitates their writing speed (Koziatek & Powell, 2003).

2.6.1.1 Pencil Grips

The pencil grip is designed to reduce the pencil grasp pressure and it promotes better thumb positions for the thumb. It also improves the involvement of the index finger without pinching and distension of the distal joint (Peterson Directed Handwriting, 2008).

Receiving a pencil grip e.g. the Stetro pencil grip may feel strange initially but it open the process for participation by different muscle groups. The subject may resist using the pencil grasp because of the change in the hand pencil grasp (Peterson Directed Handwriting, 2008).

There are various aspects to consider when applying an assistive device such as a pencil grip as suggested by Kedlaya and Kuang (2008) (Kedlaya & Kuang, 2008). One need to consider the effectiveness of the pencil grip, whether it will improve the child's functional capability in the classroom, affordability of the grip, availability in shops, pricing of the pencil grips as well as the maintenance of it within a classroom situation. One also needs to consider the operability, whether it is easy to place correctly by the child or the teacher. Lastly the dependability to which the device operates with repeatable and predictable levels of accuracy requires consideration.

Pear-shaped pencil grips, which position the fingers in a dynamic tripod grasp, have been found to recruit more motor units than a normal pencil or a triangular pencil grip. Ferriel et al (1999) therefore recommended that these pear shaped grips may be more effective in facilitating an efficient tripod grasp (Ferriell et al., 1999).

A number of pear shaped pencil grips are commercially available.

- "The Jumbo Grip: is available for children who need support up to the proximal interphalangeal joint on the index finger. The Jumbo Grip is also used by adults needing ergonomic support and cushioning for arthritic or fatigued hands." (Nelson, 2009).
- The Stetro pencil grip: the soft plastic shape supports the distal interphalangeal joint of the index finger and it promotes a good thumb

position (Nelson, 2009). The Stetro pencil grip is a gumball shape with dents for the fingers to form an appropriate pencil grip. It promotes a thumb forwards position in left handed writers.

- The Solo Grip: for a right handed child, it promotes a much improved thumb position (Nelson, 2009).
- The Crossover Grip: This grip is the same as the Stetro pencil grip, with an additional shield over the thumb and index finger. It is especially designed for pencil grasps, where the thump overlaps the index finger or pencil (Nelson, 2009).

The Stetro pencil grip was selected for this study as it causes minimal obstruction to the hand, thus avoiding dependence on the pencil grip once the tripod grasp had been established. It is ergonomically designed and allows the child to focus on the class work instead of the writing position of their fingers. It allows the fingers to be place in the tripod grasp, which facilitates the natural physiological action for writing, thus reducing pain and fatigue (Stitzer, 2006). This single pencil grip can be used by left or right handed children and used on all standard pencils providing comfort and encouraging the correct pencil grasp.



Figure 2.2: The Stetro Pencil Grip (Learning Gear, 2009)

2.7 Summary

Handwriting problems may stem from various causes. Occupational therapists have an important role to distinguish between causes in order to manage handwriting difficulties appropriately (Pollock et al., 2009). It is indicated by research, as discussed, that the underlining foundations of pencil grasps are essential to handwriting.

Feder, Racine and Majnemer (2008) described the failure to attain handwriting competency during the school-age years as influencing a child's academic success and self-esteem (Feder et al., 2008) Handwriting is a complex occupational task that has many underlying component skills that may interfere with writing performance. Hand skills are vital to the child's interaction with the environment especially in the class with writing performance (Case-Smith, 2005).

Occupational therapists look at internal factors which are all important for hand writing, but especially at the pencil grasp as it influence writing speed and legibility. A good pencil grasp is one of the first steps in developing good handwriting skills. Intervention of the pencil grasp is indicated by dysfunctional grasps that limit visual input of the tip of the pencil, fisted grasps, and biomechanical stress to a joint, grasps that fatigue the hand, hyperextension of the thumb's interphalangeal joint and severe hyperextension of the index finger distal interphalangeal joint (Pollock et al., 2009).

One of the suggested strategies to improving pencil grasps is to provide the child with a moulded pencil grip that will allow the fingers to form a tripod pinch on the grip placed on their pencil. Koziatek and Powell (2003) also suggested that when children write slowly, the use of a commercial pencil grip on the pencil facilitates their writing speed (Koziatek & Powell, 2003). The pencil grip is designed to reduce the pencil grasp pressure and it promotes better thumb positions for the thumb. It also improves the involvement from the index finger without pinching and distension of the distal joint (Peterson Directed Handwriting, 2008).

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Research Design:

This study was conducted using a quasi experimental quantitative research design with a conveniently selected experimental and control group in different classes at the school where the research took place. (Kielhofner, 2006)

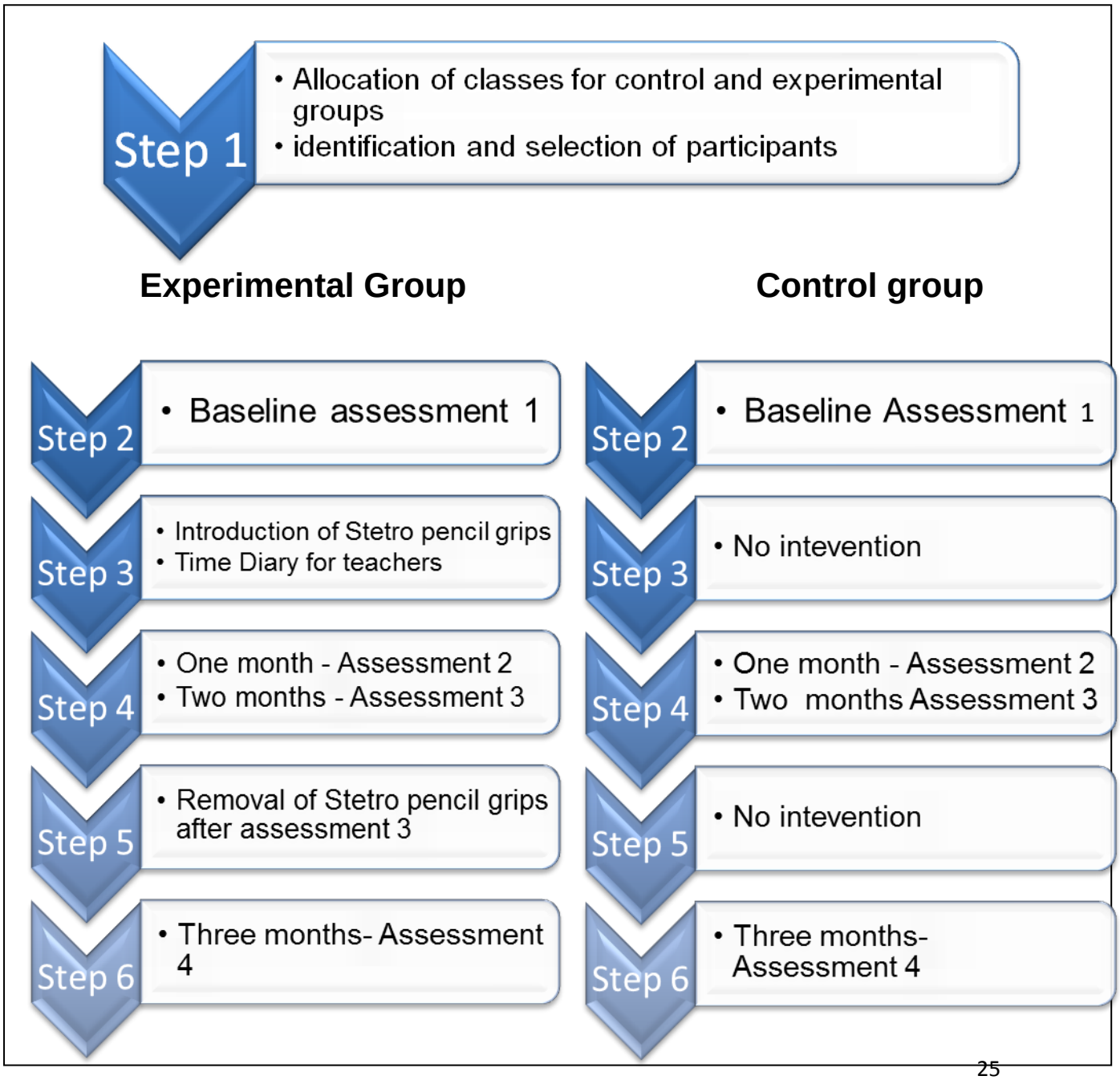


Figure 3.1 Outline of research design

The selected research design, allowed for the investigation of the effectiveness of a commercially available assistive device, the Stetro pencil grip used with children with handwriting problems. The independent variable was the use of a Stetro pencil grip. It facilitates the experimental group's pencil grasp into a tripod pencil grasp. The dependant variables were the participant's pencil grasp, handwriting speed and quality and their tripod pinch strength. The dependant variable determined the effectiveness of the pencil grip and is measured at the beginning, during and the end of the study.

A longitudinal, repeated measure, test-retest, study method with evaluations of handwriting once a month for three months was carried out (Kielhofner, 2006). Each participant underwent pre-testing to obtain baseline scores in terms of handwriting ability for comparison to later evaluations. Within this selected research design, the internal validity was controlled for by selecting the experimental and control groups from different classes to prevent contamination of the intervention between children in the same class.

The use of a control group allowed the researcher to consider natural maturation and development of the participants in the experimental group (Kielhofner, 2006). Both groups experienced similar class programs and followed similar activities within the class environment and they received the same academic and developmental activities within the school environment. To deal with maturation over the period of the research the participants in the experimental and control groups were from the same school with similar environments in each class, thus minimising other variables.

External validity was considered by using a standardised test to measure the handwriting quality, with standardised scoring (Kielhofner, 2006).

3.2 Study population:

The study population were Grade 2 learners at St. Peter's Preparatory school for girls and boys, with inefficient pencil grasps.

3.3 Sampling method:

Learners with handwriting problems in the Grade 2 classes at St Peter's School were conveniently divided into a control and experimental group selected from different Grade 2 classes to prevent contamination of the intervention. Both groups are situated in the same school system allowing for similar socioeconomic status and same educational inputs, but boys and girls participants were on different campuses. All participants were in the same grade allowing for same age testing,

Participants were identified in the specific classes by evaluating their pencil grasps with assistance of the Grade 2 teachers and were included if they had a problem with their pencil grasp and their parents/legal guardians gave permission for them to take part in the study and they agreed to participate.

3.3.1 Inclusion Criteria

Learners:-

- who had poor handwriting and/or an inefficient pencil grasp as indicated in Figure 3.2.

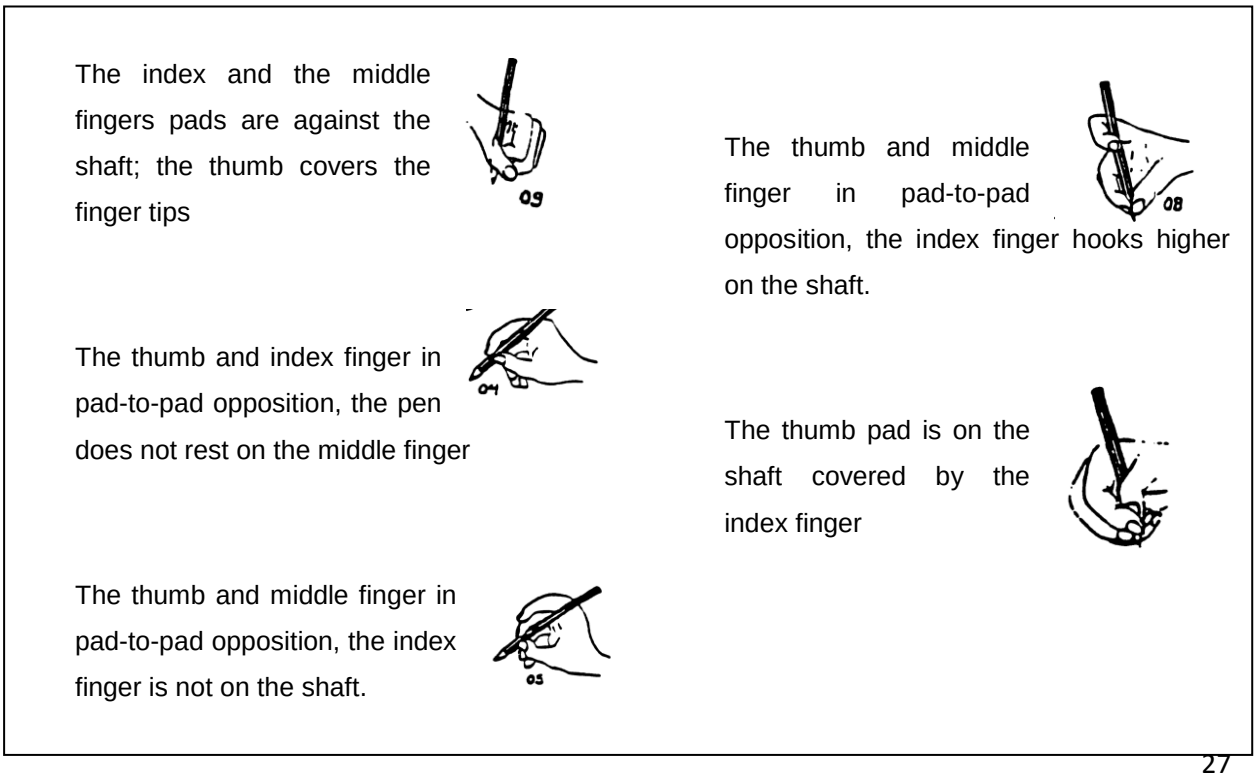


Figure 3.2 Inefficient pencil grasps taken from Lyytinen-Lund (1998) observation schedule

- who were in Grade 2 and within the age group 7-8 years old.
- whose parents/legal guardians gave signed informed consent and who had given verbal and written assent.

3.3.2 Exclusion Criteria

- Learners who had received any type of intervention for fine motor skills or handwriting.
- who parents/legal guardians had not consented or if consent were withdrawn.
- who had a functional pencil grasp.

3.3.3 Sample size:

The sample size consisted of 45 participants, with 23 participants in the experimental group and 22 participants in the control group. A sample of at least 18 participants per group was indicated initially to allow 90% power to detect a change in score for the intervention group which is four units greater than the control group when testing at the 0.05 level of significance. The sample size was larger than initially suggested to allow for loss of participants.

The assumed standard deviation of 3.54 follows from the fact that the suspected range of change for a non intervention child is 10 units (-5 to 5), which constitutes four standard deviation and the standard deviation is inflated by a factor $\sqrt{2}$ since the differences were based on observation.

The loss of participants from the sample was to be accounted for by not using the data of the participants leaving the study for analysis. No participants withdrew from the study and all data was used for analysis.

3.4 Ethical considerations

All participants' caregivers received an information sheet (Appendix A) and were asked to sign the informed consent forms (Appendix B). Parents/legal guardians were also asked to sign consent for photographs to be taken of the participants. (Appendix C)

The participants were asked for verbal assent to participate in the study and signed an assent form. (Appendix D)

Letters requesting permission to carry out the study at the boys and girls sections of St Peters school were written to the headmasters. (Appendix E) Permission was obtained from the schools – St Peters (Appendix F) and the Gauteng Education Department (Appendix G) for the study to take place at the school.

Ethical clearance was obtained from the Human Research Ethics Committee at the University of the Witwatersrand (Certificate no M 090444) (Appendix H)

Information sheets were also provided for the teachers who will monitor the children in class (Appendix I) and they signed informed consent to take part in study. (Appendix J)

Participants and their parents/legal guardians had the opportunity to withdraw from the study at any given time without any consequences.

The participants' identities were kept confidential. All information containing names and contact details were kept separate by the researcher in a locked cupboard. All data sheets were coded.

Feedback will be given to all parents/legal guardians of participants' after the study has been concluded on request.

3.5 Measurement Techniques

3.5.1 Pencil Grasp

Descriptors of dysfunctional pencil grasps and associated factors were identified from photographs by using an observation schedule adapted from Lyytinen-Lund (1998) (Appendix K). The format was edited. The photographs were taken at each writing

assessment, by assistant researcher. The photographs were taken of the participant's hand, writing posture, position of non-writing hand as well as the pencil grasp.

To assess the descriptors of the actual pencil grasp the following aspects were reviewed by using the Lyytinen-Lund (1998) observation schedule

The descriptors of pencil grasp in the hand observed were

- hand used to write,
- the fingers closest to the tip of the pencil,
- the angle of the distal joint (DIP) of the index finger position,
- whether the writing movements occurred in the hand or fingers
- the finger position on the pencil
- the angle of the interphalangeal joint (IP) of the thumb and lastly
- . position of the wrist of the writing arm,

The following descriptors of factors associated with position of the upper limbs and posture while writing were recorded:-

- position of the non writing hand,
- posture while writing,
- position of the writing arm

The actual pencil grasp and its functionality was identified from the schedule according to the following criteria.

Efficient grasps

- The thumb and the index finger in pad-to-pad position, pencil rests on the middle finger,- tripod or lateral grasp
- The thumb, index and middle fingers in pad-to-pad opposition, pencil does not rest on the middle finger, - quadropod or four finger grasp

Inefficient grasps

- The index and the middle fingers pads are against the shaft; the thumb covers the finger tips or thumb wrap grasp
- The thumb and index finger in pad-to-pad opposition, the pen does not rest on the middle finger
- The thumb and middle finger in pad-to-pad opposition, the index finger is not on the shaft.
- The thumb and middle finger in pad-to-pad opposition, the index finger hooks the shaft higher.
- The thumb pad is on the shaft covered by the index finger or thumb tuck grasp.

During the administration of this test the pencil grasp of the participants were observed and photographed. The photographs were scored at a later stage, with the Lyytinen-Lund observation schedule (1998).

3.5.2 Photographs

The progression of the change in pencil grasp was monitored by the photographs which were taken at each evaluation. The photos were analysed per test by the categories mentioned above. The photographs were also used to compare the initial dysfunctional pencil grasp to the final testing photographs, in order to determine the lasting effects of the Stetro pencil grip.

It allowed assessing the gradual change of the position of the fingers on the pencil, as well as monitoring the participant's non-writing hand, posture and the functionality of the pencil grasps.

3.5.3 Minnesota Handwriting Assessment:

The test that was used to assess changes in the handwriting speed and quality was the Minnesota Handwriting Assessment (Reisman, 1999). (Appendix M)

This test was selected because the execution time is short and limits the learning component of the task. It is short enough to prevent the participants to become bored of the tasks. This test eliminated memory component as it is meaningless sentence. This test was easily administered and within a group situation. This test was chosen as it only took up to 10 minutes to administer. The evaluation was used within a group of 12.

Its scoring criteria were specific on the quality of the handwriting and included the rate of the writing, legibility, sizing, spacing, form, and alignment. It gave a clear indication of the participants' handwriting and where there were difficulties. The handwriting assessment contained appropriate words for a Grade 2 learner.

Purpose of the test was to evaluate copying of words in a sentence that contains every letter of the alphabet. To ensure standardisation standard error of measurement was used with the standard error of difference. The test was both reliable and valid in terms of content validity, construct or criterion-related validity, concurrent validity (Reisman, 1999) (Appendix M).

The test determined if there was a positive change in the participants' writing speed and quality. The rate of the writing was determined by the number of letters that was written in 180 seconds.

- Legibility was scored if a letter was present and whether it was recognisable separate from the word.
- Form was scored whether the letter was written in the correct form and not confused with another letter.
- Alignment was scored if the letter was written on the baseline.
- Size was evaluated by whether the letter touched the appropriate lines.
- Spacing was scored by the distance between letters.

This test was developed from over 2000 participants and the participants were assessed in first grade and second grade at different stages of the year. The sample included urban and rural school districts. The test included right and left handed writers during development. The test also took gender, age and handedness into consideration in the scoring.

The test made use of interrater (r = 0.99 with experienced raters and r = 0.98 with inexperienced raters) and intrarater reliability over 7 days (r=0.98 with experienced raters, r=0.96 with inexperienced raters) which both indicated good reliability and test retest stability was achieved. This test's test-retest reliability is moderate (r = 0.72) (Reisman, 1993).

3.5.4 Tripod Pinch strength

The strength of the tripod pinch was used as a quantitative measurement of developing hand function and recorded at all evaluation periods. (Mitchell, 1976).

The instrument used to assess the pinch strength was a JAMAR pinch meter. The JAMAR pinch meter allows for a true pinch pattern, as the therapist supported the weight of the gauge. The norms for pinch grasp strength published by Newman, Barnes, Young, Kehoe and Newman are specific per child's age group, and the gauge accuracy 0, 5 N (Newman et al., 1984)

The strength of all participants' tripod pinch was tested focussing on the thumb, index and middle finger in order to determine and record strength difference after the use of a pencil grasp and compared to norms by Mathiowetz, Wiemer and Federman for 6-9 years old children (Mathiowetz et al., 1986). The pinch strength of 7 year olds is 1.4-5.0 kg and the peak for 8 year olds is 1.8- 7.7 kg.

3.5.5 Time Diary for wearing of Stetro Pencil Grip

The Time Diary was designed to verify the validity of the study to tract the participants and whether and how long they used the assistive device. It was designed to be easy to complete to assist teacher participation. (Appendix L)

The time sheets were used to validate that the participants did indeed use the pencil grasp in class for the writing activities in the class. The data was not actively used within the study.

The participating teachers in the experimental classes received a daily roster, in a form of diary, from where they noted the time the Stetro pencil grip was used for writing and whether the experimental group participants were using it correctly.

The diary contained the following headings: Date, child present, grip used, and the length of the writing task on that day.

The diary also had a small section where the teacher could write observations and complaints of the pencil grips. The participating teachers completed the diaries everyday for the duration of the research. The diary form allowed them to tick the columns if the child was present as well as the column for wearing the grip. They had to fill out the columns date and time period written each day. The diary was kept simple and easy to use to encourage compliancy of the daily monitoring

3.6 Research Procedure

Permission was gained initially from the Gauteng DoE (Appendix G), headmasters of the boy and girl schools (Appendix F). Once permission had been obtained from the school and the Gauteng DoE the researcher approached the Grade 2 teachers and invited them to take part in the study. The researcher informed the participating teachers of their role in the study and they were provided with an information sheet (Appendix I) and asked to sign informed consent (Appendix J). An information meeting was held where the length of the study, the expectations of the study on the participants, the testing on a monthly basis, as well as the obligations expected from the teachers was explained.

It was emphasized that their participation was essential for this study and if their class was part of the experimental group they would be required to monitor the use of the pencil grip and the time using the grip each day.

3.6.1 Training of Teachers

All the Grade 2 teachers were also introduced to the identification criteria. There were three teachers, from St Peter's boys' school and two teachers from St Peter's girls' school. Altogether five Grade 2 classes were used for the study. They were asked to

identify possible learners with poor handwriting for inclusion in the study using the inclusion criteria (Figure 3.2) to identify those with inefficient pencil grasps.

The placement of the pencil grip on a pencil was demonstrated to all teachers with all the landmarks to indicate correct placement being explained. The pencil grip was to be placed on the HB pencils just behind the sharpened section. An arrow pointing down towards the tip of the pencil on the pencil grip ensured the correct alignment for right handed children. For left handed children the arrow pointing up. The pencil grip had one indentation with a star marking indicating where the thumb was to be positioned. The index and ring fingers were positioned in the other indentations.

All the teachers were trained by the researcher in the use of a time diary they were required to keep on a daily basis. The diary was explained to the teachers and they were shown how to use the pencil grips and time diaries a week before initial evaluation of the participants took place. The training was done within a group sessions at school and during the teacher's weekly preparation meeting. The researcher was at hand to answer any other questions or enquiries as they arose during the research.

Although all the teachers were trained only the teachers in the experimental group classes would be keeping a time diary to record absences, time that the pencil grip was worn in class and the length of the writing tasks during the day. The teachers were asked to do this so the participants' compliance with the assistive device programme could be established.

3.6.2 Recruitment of participants

After teachers had indentified learners with handwriting problems the classes at the boys school and the classes at the girls school were separated and randomly selected into experimental and control groups. This was done by another occupational therapist to blind the researcher as to which participants were in which group.

Three classes were then allocated as experimental and two as control group classrooms Each experimental and control group remained within a class to limit contamination of the intervention.

Information sheets and informed consent forms were sent to the learners' parents/legal guardians (Appendix A-B). When the learners' parents/legal guardians gave informed consent and the learners themselves gave informed assent, they were included in the study.

There were 13 female participants and 12 male participants in the experimental group 9 female participants and 13 male participants in the control group in the participating classes.

3.6.3 Assessments

The baseline values of the participants' pencil grasps, grasp strength and handwriting quality were established on the initial assessment.

The pencil grasp were evaluated by using the Lyytinen-Lund, (1998) observation schedule, with altered lay-out, with aid of photographs taken of the preferred writing hand, the supporting hands and writing posture.

The tripod pinch strength was measured with a pinch meter.

The handwriting quality was evaluated with the Minnesota Handwriting Assessment, to ascertain the writing difficulties the participants had. This test considered the rate of writing, the alignment, spacing, form, legibility, and sizing.

The researcher assessed the handwriting of all the participants participating in the study with the help of a research assistant who was another occupational therapist.

They executed the evaluations using the Minnesota Handwriting Assessment and the pinch meter. While both took the photographs in situ, all the pen grasp evaluations from the photographs were done by the researcher only. Teachers concerns and observations about the participants were also noted by the researcher.

The evaluations were done within each class just before break time during early school hours to eliminate the effects of fatigue. The participants used their own personal desks and chairs that they use each day. The tables and chairs were all standard and could not be adjusted for individual needs. All participants' feet could rest on the floor. During

the evaluation the participants, the researcher, the researcher assistant and the teacher were present. All five classes were evaluated within a week of each other between Mondays-Fridays. Each evaluation was done at the same time of day in each class.

After one month the handwriting evaluation and grasp strength test, was repeated with both groups in the study. The evaluations were repeated at the end of the second and third month as well. These continuous testing allowed the researcher to monitor the progress in handwriting in both the experimental and control groups.

3.6.4 Intervention

The study was carried out in the final term of a private school from September to November. It is believed that the second half of Grade 2 is the proper time to assess the quality of learner's handwriting as they should have mastered the skill at this stage (Overvelde & Hulstijn, 2011). The experimental group received a pencil grip on their standardised HB pencils to be used in all handwriting tasks during school writing activities. The control group did not receive any intervention strategies and continued to write with a standard HB pencil. The South Australian Curriculum, 2010, stated that the functional distance of a right-handed participant is 15 mm from the tip of the pencil and 30 mm for a left-handed participant. Left-handed learners need more distance around the writing point to provide a visual field around their obscuring hand. The Stetro pencil grip was adjusted according to the correct distance from the tip of the pencil for all participants.

The participants in the experimental classes received the Stetro pencil grip to be used for all written work within the classroom for two months. This specific pencil grip was selected for this study as it is a cost effective, available pencil grip that is widely used in school environments. It correctly placed the participants' fingers in an appropriate manner without being intrusive in the hand.

The teachers whose classes formed the experimental group were given extra pencil grips to replace those that were broken or lost to ensure continuity of the intervention.

Pencil grips were removed from the experimental groups' pencils after two months, and a final evaluation was done one month after the removal of the assistive device to evaluate the sustainable change of the pencil grasp of the participants.

Compliance with the use of the pencil grip in the experimental group was monitored by the teachers. They noted in a diary, the days on which the pencil grip was used and the duration of use of the pencil grips in class.

3.7 Reliability

3.7.1 Measurement techniques

Reliability of the study was considered in terms of:

3.7.1.1. Participants

Participants fatigue was considered by using evaluation tools that did not take a long time to administer to allow for optimal performance in the evaluation.

The test environment was kept constant and familiar. The execution of evaluation was done within the participants' own classroom at school and performed before break time, to limit fatigue of the participants.

3.7.1.2 Evaluation

The Minnesota Handwriting Assessment and the pinch meter both had good inter rater reliability so these could be used by both the researcher and the research assistant to obtain reliable results as both are experienced assessors. Both the researcher and research assistant tested non-participants to practice the execution of the measurement tools.

The month between each assessment reduced any learning effect of the evaluation measure.

3.7.1.3 Intervention

The effect of the intervention was controlled by a control group that was included in the study and who received the same input in the classroom over the duration of the study as the experimental group, without receiving the Stetro pencil grip. The experimental and control groups had participants of similar age, gender and all participants were in Grade 2.

3.8 Data Analysis

The data were analysed with the assistance of a statistician, to determine the significance and clinical importance of the study. The demographic data was analysed using descriptive statistics using percentages.

The percentage of participants in the experimental and control group using each of the descriptors related to pencil grasp, were compared at baseline to ensure there was no significant difference between the groups initially and that they were comparable.

The data for all three assessments were compared at each evaluation between the experimental and the control group. The data at each evaluation was also compared to the data from the baseline evaluation.

The tripod pinch strength scores within and between the two groups were compared and made use of the non parametric statistics using the Mann Whitney U test because of the small sample size to determine the p value with significance set at 0.05.

The analysis of the pencil grasp observation schedule (Lyytinen-Lund, 1998) and Minnesota Handwriting Assessment was done by using Fisher's exact test and non parametric statistics using the Mann Whitney U test with significance set at 0.05 to determine the differences within and between the two groups.

The difference between assessments two, three and four on the scores of the Minnesota Handwriting Assessment were compared using Fisher's exact test and non parametric statistics using the Mann Whitney in order to establish if changes achieved by using the Stetro pencil grip had been maintained.

CHAPTER 4

RESULTS

Forty five participants in either the boys or the girls' school at St. Peter's Preparatory school in were included in the study. The participants were divided into experimental and control groups with 23 participants in the experimental and 22 in the control group. No participants dropped out of the study over the three month period when assessments were completed. All the teachers of the control group completed the diaries in the classroom as requested.

4.1 Demographics

4.1.1 Gender

There was no difference in the gender distribution within the control and experimental groups. A similar number of participants were recruited from the Grade 2 classes for boys and girls who presented with handwriting problems. (Table 4.1)

Table 4. 1: Demographic characteristics of all participants in study (n=45)

Characteristics	Experimental Group (n = 23)	Control Group (n =22)	Total (n =45)	p value
Boys	47.82% (11)	52.18%(12)	23	0.86
Girls	54.54%(12)	45.45%(10)	22	

*Significance set at 0.05

4.2 Baseline Assessments

4.2.1 Descriptors associated with Pencil Grasp (from the observation schedule, by Lyytinen-Lund 1988)

The baseline assessments for the descriptors of factors associated with pencil grasp the experimental and control groups were compared using Fisher's exact test.

Table 4.2. Comparison of descriptors associated with pencil grasp at baseline for the two groups (n=45)

Descriptor	Experimental Group (n = 23)	Control Group (n =22)	P
Hand used to write			
Right	74%	86%	0.78
Left	26%	14%	
Finger closest to the tip of the pencil			
Thumb	31%	18%	0.80
Index finger	48%	50%	
Middle finger	17%	27%	
Ring finger	4%	5%	
Angle of the distal joint (DIP) of the index finger position,			
Flexed	26%	23%	0.80
Extended	22%	32%	
Hyper extended	52%	45%	
Writing movements occurred in			
Fingers	65%	50%	0.23
Hand	35%	50%	
Arm	0%	0%	
The finger position on the pencil			
Functional distance from the tip of the pencil	30%	27%	1.00
Too close to the paper	70%	73%	
Spread over the shaft	0%	0%	
Angle of the interphalangeal joint (IP) of the thumb.			
Flexed	87%	77%	0.50
Extended	13%	14%	
Hyper extended	0%	9%	
Position of the wrist of the writing arm			
Extended/turned back	70%	73%	0.89
Flexed	30%	27%	

*Significance set at 0.05

Comparisons of the baseline assessments indicated the experimental and control groups were comparable at baseline for descriptors of factors associated with pen grasp with no statistically significant difference between them.(Table 4.2) The majority of the participants in the study were right handed. The right and left handed participants were distributed among the experimental and control groups.

The writing movements used during baseline evaluation showed no significant difference between the groups ($p \leq 0.23$). The majority of the participants in the experimental group wrote with movement in the fingers, while in the control group half the participants wrote with finger movement and the other half used hand movement.

The distal joint of the index fingers were mostly hyper-extended in both the experimental and control group and both groups. The fingers position of the fingers in both groups was mostly too close to the paper. The position of the distal joint of the thumb was in both groups flexed.

The position of the writing arm was majority on experimental and control group resting on the paper and the wrist was extended.

4.2.2 Descriptors of Position and Posture associated with Writing (from the observation schedule, by Lyytinen-Lund 1988)

The baseline assessments for the descriptors of position and posture associated with writing in the experimental and control groups were compared using Fisher's exact test. (Table 4.3)

There were no significant differences between the experimental and control group during initial evaluation for descriptors of posture associated with writing.

Position of the supportive, non-dominant hand showed insignificant difference between the two groups for this aspect ($p \leq 0.22$). Associated movements were only seen in participants in the control group.

Table 4.3. Comparison of descriptors of position and posture associated with writing at baseline for the two groups (n=45)

Descriptor	Experimental Group (n = 23)	Control Group (n =22)	P
The position of the supportive non dominant hand			
Non-writing hand rest on paper	83%	64%	0.22
Non-writing hand rest on lap	17%	27%	
Non-writing hand makes associative movements	0%	9%	
Posture while writing			
Normal, good	35%	23%	0.96
Leaning over	39%	50%	
Slanting to the side	26%	27%	
Other	0%	0%	
Position of the writing arm			
Rests on the table	87%	91%	0.82
Does not rest on the table	13%	9%	

*Significance set at 0.05

4.2.3 Type of pencil grasp (from the observation schedule, by Lyytinen-Lund 1988)

All participants had a dysfunctional pencil grasp at their initial baseline assessment as it was an inclusion criteria for the study. Only 14% of all participants had a tripod grasp, and only 9%, quadropod grasp. These two grasps were appropriate grasps, but were accompanied by increased pressure when holding the pencil or hyper extended finger joints. The majority of the pencil grasps seen were a thumb wrap grasp with the thumb over the index and middle fingers. (Figure 4.1)

The other grasps that presented, were the thumb and middle finger in a pad-to-pad opposition either with the index finger on the pencil shaft or hooked higher around the shaft of the pencil and a grasp where the thumb was covered by the index finger. All three of these grasps present with limitation to movement in the finger joints.

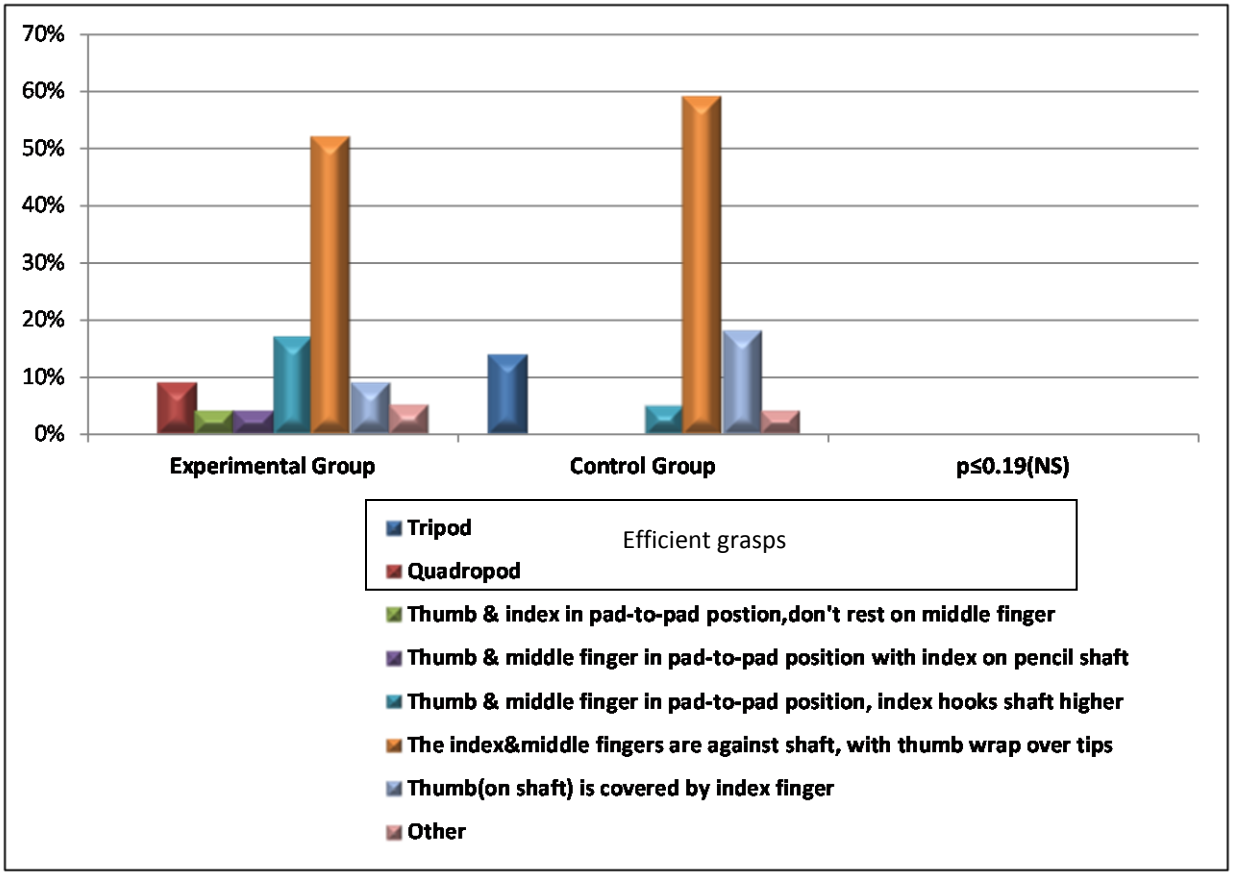


Figure 4.1. Type of pencil grasp at baseline for the two groups (n=45)

The difference between the experimental and control groups for pencil grasp was statistically insignificant at baseline evaluations.

4.2.4 The quality and speed of Handwriting as measured by Minnesota Handwriting Assessment

No significant difference was indicated between the experimental and control group for any aspects of handwriting measured on the Minnesota Handwriting Assessment on baseline assessments except speed. The experimental group wrote significantly faster than the control group on the initial assessment (p≤ 0.05) The other differences were

minimal indicating that the two groups were at a similar level handwriting and comparative at the start of the research. (Table 4.4)

Table 4.4. Comparison of handwriting scores at baseline for the two groups (n=45)

Subscale	Baseline scores Control Group Mean (SD)	Baseline Scores Experimental Group Mean (SD)	p value
QUALITY			
Legibility	32.52 (1.37)	32.5 (1.82)	0.92
Form	31.13 (1.83)	31.08 (2.01)	0.86
Alignment	31.00 (2.18)	29.75 (3.39)	0.11
Size	29.65 (5.03)	28.3 (5.95)	0.45
Space	31.56 (2.15)	30.92 (2.67)	0.41
SPEED	23.13 (8.63)	27.67(8.10)	0.05*

*Significance set at 0.05

4.2.5 Tripod pinch strength

No significant difference was found between the experimental and control group for tripod pinch strength measured in kilograms on baseline assessments. The experimental and control groups were similar indicating insignificance difference which allows the data collected to be compared. (Table 4.5)

Table 4.5. Comparison of pinch strength scores at baseline for the two groups (n=45)

Tripod pinch strength in Control Group Kgs Mean (SD)	Tripod pinch strength in Experimental Group Kgs Mean (SD)	p value
2.95 (0.71)	3.25 (0.94)	0.11

*Significance set at 0.05

4.3 Descriptors associated with Pencil Grasp (from the observation schedule, by Lyytinen-Lund 1988)

The four assessments for the descriptors associated with pencil grasp of the experimental and control groups were compared using two sample t-tests with equal variances.

The changes are compared between initial assessments and final assessments to mark the long term affects of the pencil grip. Differences between other monthly assessments did not reveal any significance or clinical difference.

Differences within each group was also considered to determine what changes in the descriptors occurred in the participants over a three month period.

4.3.1. Hand used to write

No participants changed the hand with which they wrote during the duration of the study.

4.3.2 Finger closest to the tip of the pencil

Ideally in a dynamic tripod pinch the thumb should be nearest the tip of the pencil with the index finger slightly behind or in line with the thumb.

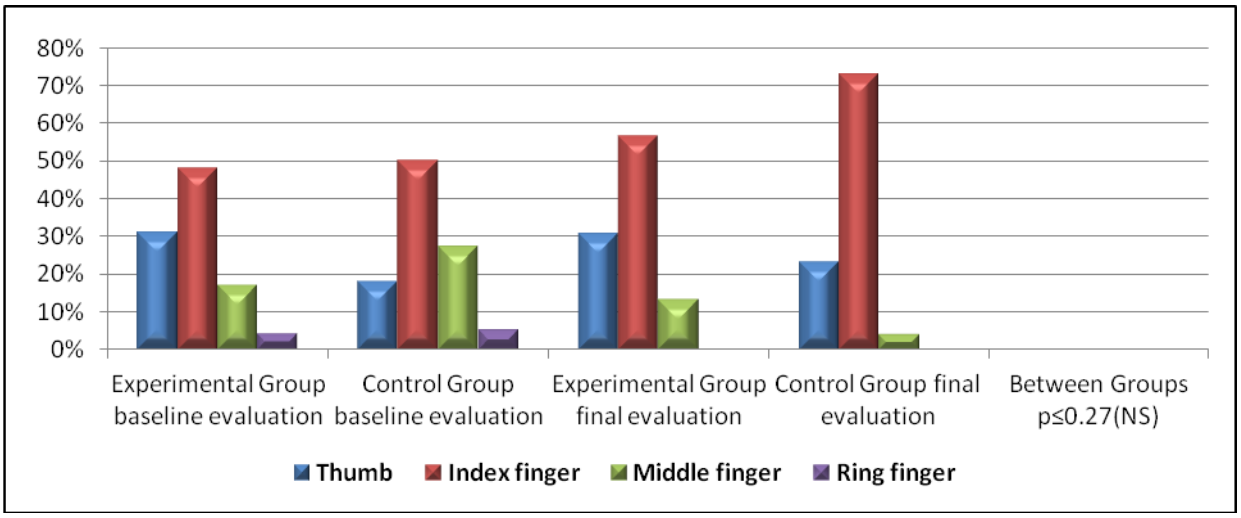


Figure 4.2: The fingers closest to the tip of the pencil at baseline and final assessments (n=45)

Although there was no significant difference between the groups at the final evaluation, the experimental group maintained the position of their thumbs in relation to the tip of the pencil. There were no significant changes within the experimental or control groups however for this aspect. There was a 4% improvement in the experimental group (p≤0.96) and 23% improvement in the control group (p≤0.12) in having the index rather than the middle finger nearest to the tip of the pencil more in line with a tripod pinch. There were no significant changes within the experimental or control groups however for this aspect. (Figure 4.2)

4.3.3 Angle of the distal joint (DIP) of the index finger position

The DIP joint of the index finger should be slightly flexed when writing. When comparing the initial and final assessments for both groups 53% percent of all participants' index finger DIP position changed. There was no significant difference for this variable when the groups were compared on the final evaluation (p≤0.53).

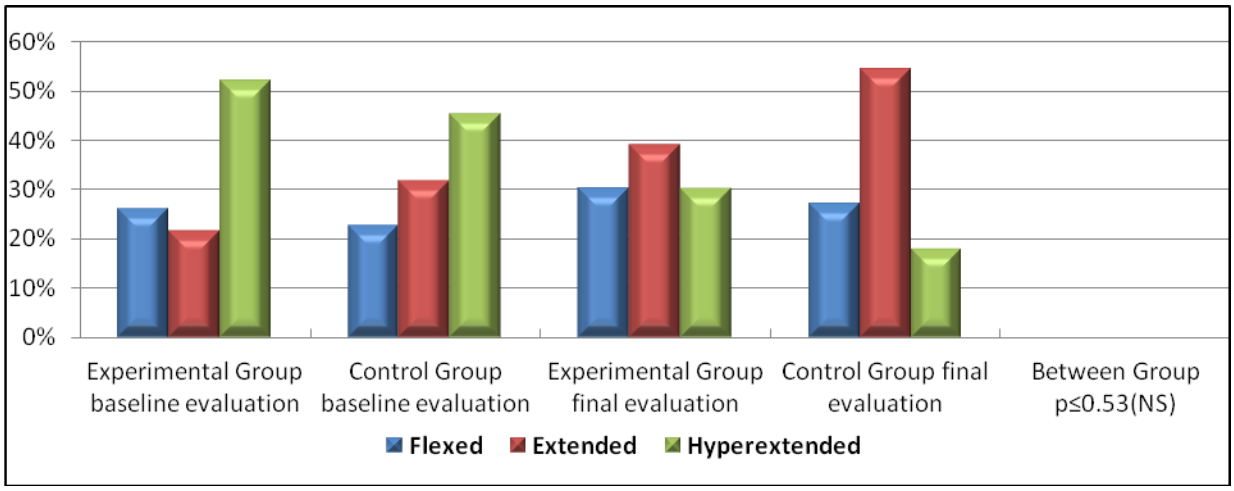


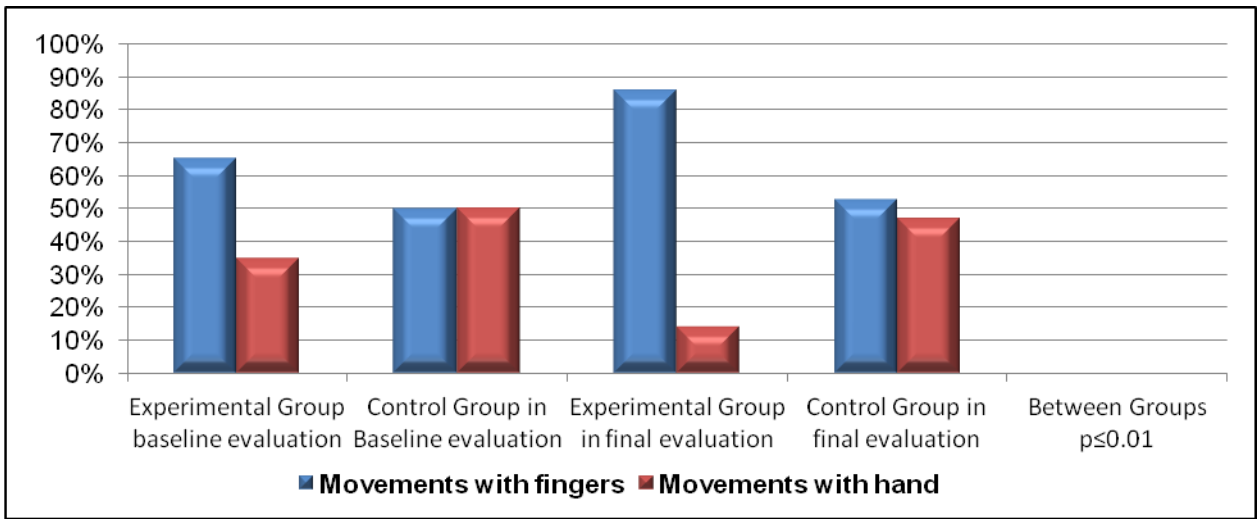
Figure 4.3 The distal joint of the index finger position at baseline and final assessments (n=45)

Only 30% of the experimental group still used a hyper-extended index finger DIP joint position on the final assessment with a significant change to a more mature grasp with the index finger DIP joint in a flexed position or an extended position at this joint (p≤ 0.01) over three months. (Figure 4.3)

Although change was seen within the control group this was not significant (p≤0.08) with the percentage using the slightly less desirable position of extension at the at the index finger DIP joint at the end of the study still over 50%. There was a natural maturation in the control group from hyperextension of the index finger to a more appropriate extension.

4.3.4 Writing movements

There was a significant change in the participants' use of fingers rather than the hand to produce writing movements when the control and experimental group were compared (p≤0.01). The experimental group showed greater change to the use of finger movements when writing which is desirable.

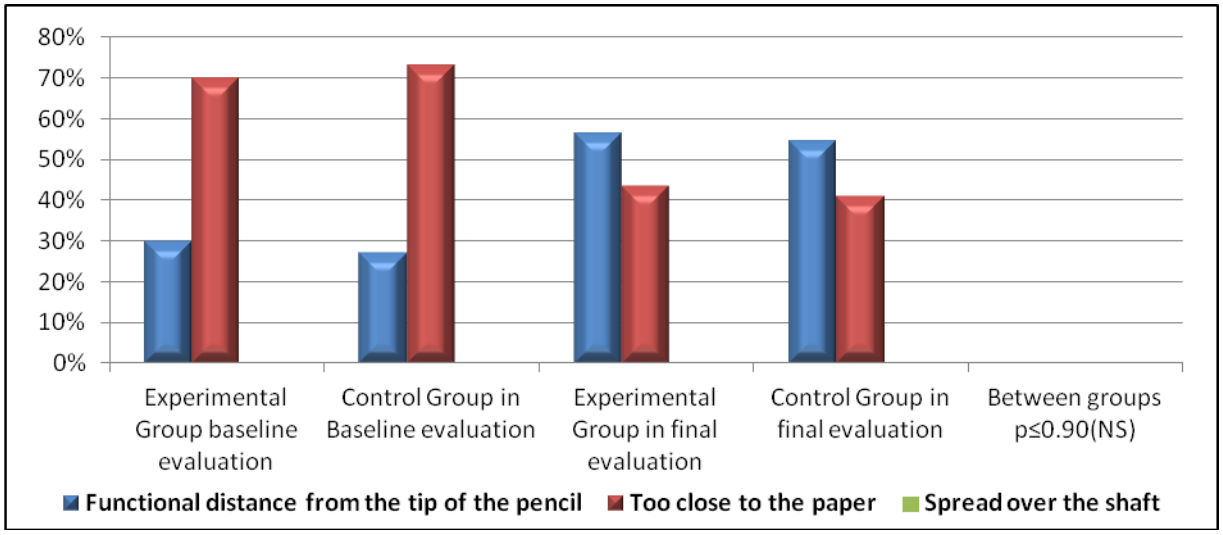


The change to the use of finger movements to write with the fingers instead of hand movement was not significant within either the experimental group (p ≤ 0.10) or the control group (p ≤ 0.71).

4.3.5 Finger position on the pencil

Both groups matured in finger position on the pencil from holding the pencil too close to the paper to holding it a functional distance from the paper. (Figure 4.5) The differences did between the groups did not show significance (p≤0.9) after the three month study.

Both groups matured in this aspect of pencil grasp and more than 50% now place their fingers in the correct distance from the tip of the pencil but there was no significant difference within the groups for either the experimental (p≤0.10) or the control group (p≤0.09).



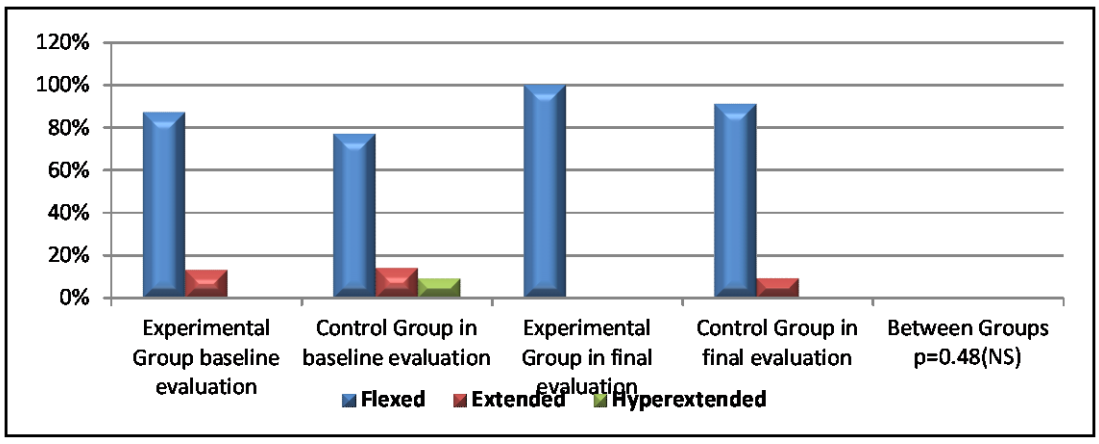
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Figure 4.5: Finger position on the pencil grasp (n=45)

4.3.6 Distal joint position of the thumb

The IP joint of the thumb should remain flexed when writing but should not be flexed more than 90 degrees.

Figure 4.6: Distal joint position of the thumb at baseline and final assessments (n=45)



Both groups matured in the thumb position from a hyper extended thumb towards a flexed thumb position. The differences between the two groups are not significant (p≤0.48).

Although 100% of the experimental group developed the flexed thumb joint position, which is of clinical importance as this is associated with a mature tripod or lateral pencil grasp, the within groups changes were not significant for the experimental (p≤0.08) and control group (p≤0.08).

4.3.7 Wrist position of the writing hand

The wrist position of the writing hand did not show any significant difference between initial baseline and final evaluation between the groups (p≤0.10). here was a small improvement of the wrist into a extended position which is optimal for handwriting in both groups. (Figure 4.6)

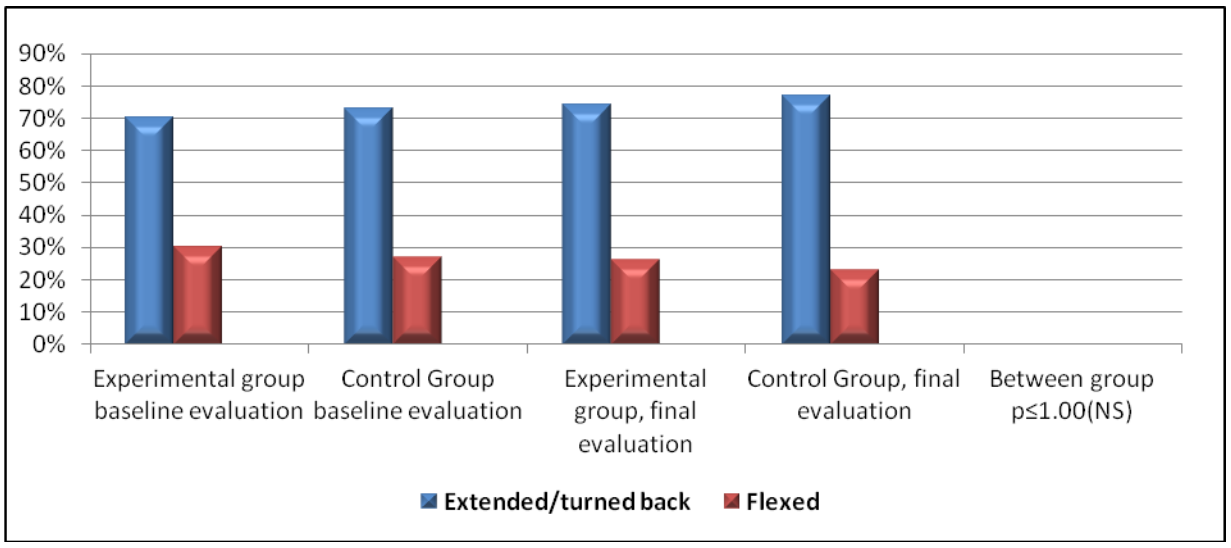


Figure 4.7 : Wrist position of the writing hand at baseline and final assessments (n=45)

There was a 9% increase in control group participants' wrist position from a flexed position to an extended position which develops with maturity which was not a significant within group change (p≤0.71). The experimental group showed similar improvement which was also not a significant within group change (p≤0.45).

4.4 Descriptors of Position and Posture associated with Writing (from the observation schedule, by Lyytinen-Lund 1988)

4.4.1 The position of the supportive non dominant hand

The position of the non-writing supporting hand did show a slight increase in the number of participants stabilizing the paper but did not show any significant difference between baseline and final evaluation between the groups. (p≤0.83)

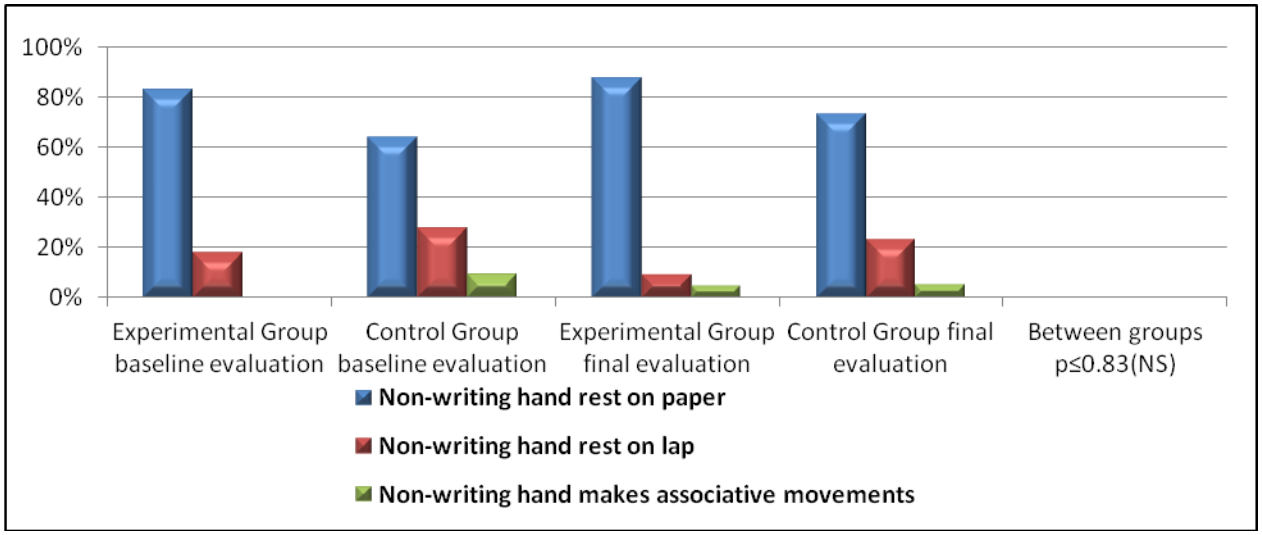


Figure 4.8 The position of the supportive non dominant hand at baseline and final assessments (n=45)

There were no significant within group changes seen in the experimental (p≤0.10) or control group (p≤0.54). Although one participant in the experimental group showed associative movements in the final assessment that were not seen initially and this aspect had decreased in the control group.

4.4.2 Posture while writing

Posture while writing should be with the trunk upright and the head flexed forward. This position was evaluated as normal good. Other positions like leaning over forward and slanting the trunk to the left or right affect the ability to write (Figure 4.9). There was no significant difference between the experimental and control group on the final evaluation (p=0.96).

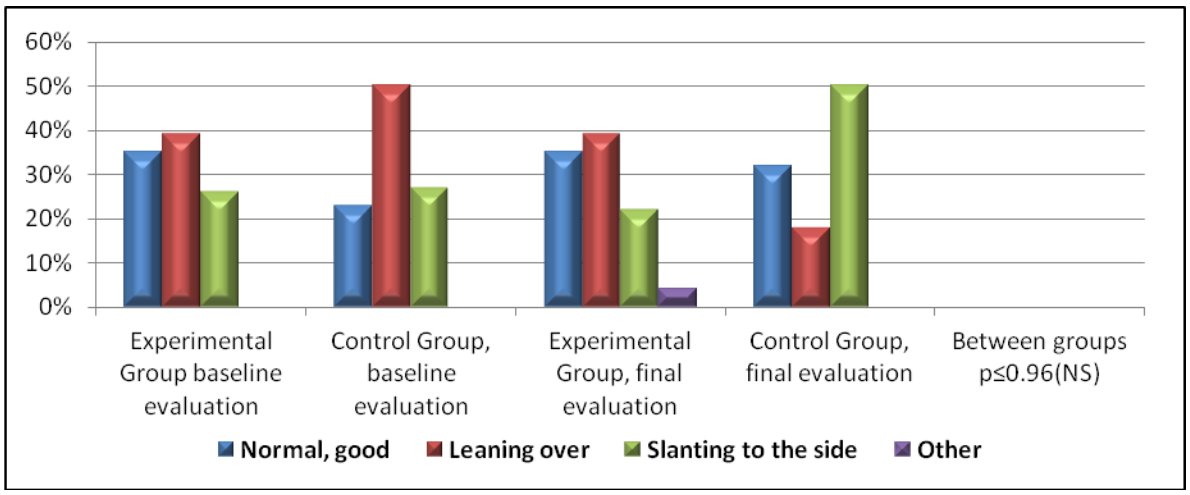


Figure 4.9: Participants' writing posture at baseline and final assessments (n=45)

The experimental group's writing postures remained relatively similar between the initial and final evaluation at the end of testing and there was no significant difference within this group (p≤0.10). There was a similar finding for the in terms of significance for the control group (p≤0.42), however their posture changed from flexed or leaning over to lateral flexion or slanting to the side.

4.4.3 Position of the writing hand

The majority of participants rested their writing hand on the table when writing and there was no significant difference between the groups at the final assessment (p≤0.10). (Figure 4.10)

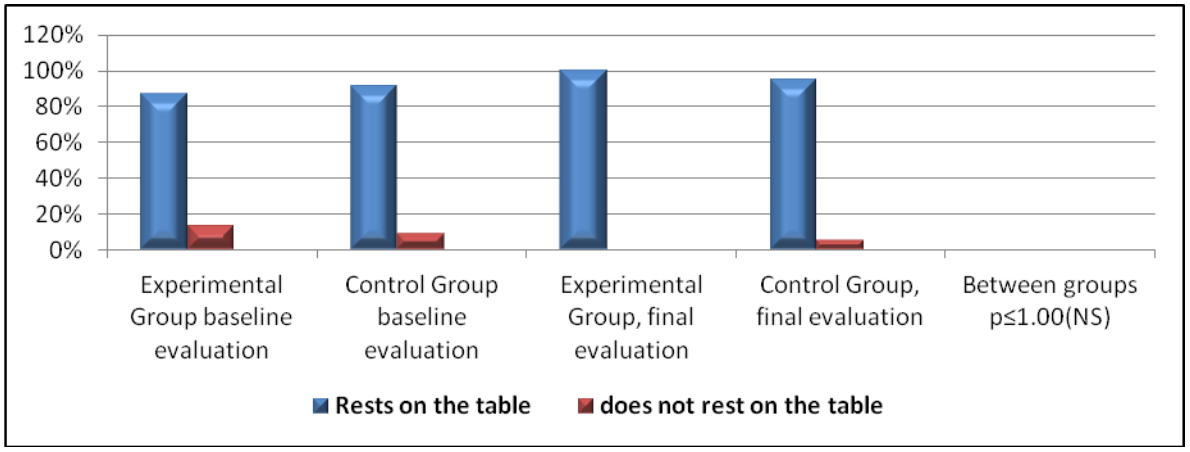


Figure 4.10 Participants' arm position of the writing hand at baseline and final assessments (n=45)

Participants in the experimental group, the percentage shifted for resting their arm on the table was 87% to 100 % which was not a significant improvement (p≤0.10) but the fact that 100% of this group were resting their hand on the table in the final assessment is of clinical importance as they were stabilising their arm in the performance in handwriting tasks. The change within the control group was also not significant (p≤0.50) and only one participant in the control group did not rest their writing hand on the table in the final assessment

4.5 Type of pencil grasp (from the observation schedule, by Lyytinen-Lund 1988)

While 39% of the participants' pencil grasps remained unchanged, the pencil grasps in the experimental group had significantly improved to more efficient grasps when compared to the control group on the final assessment (p≤0.01).

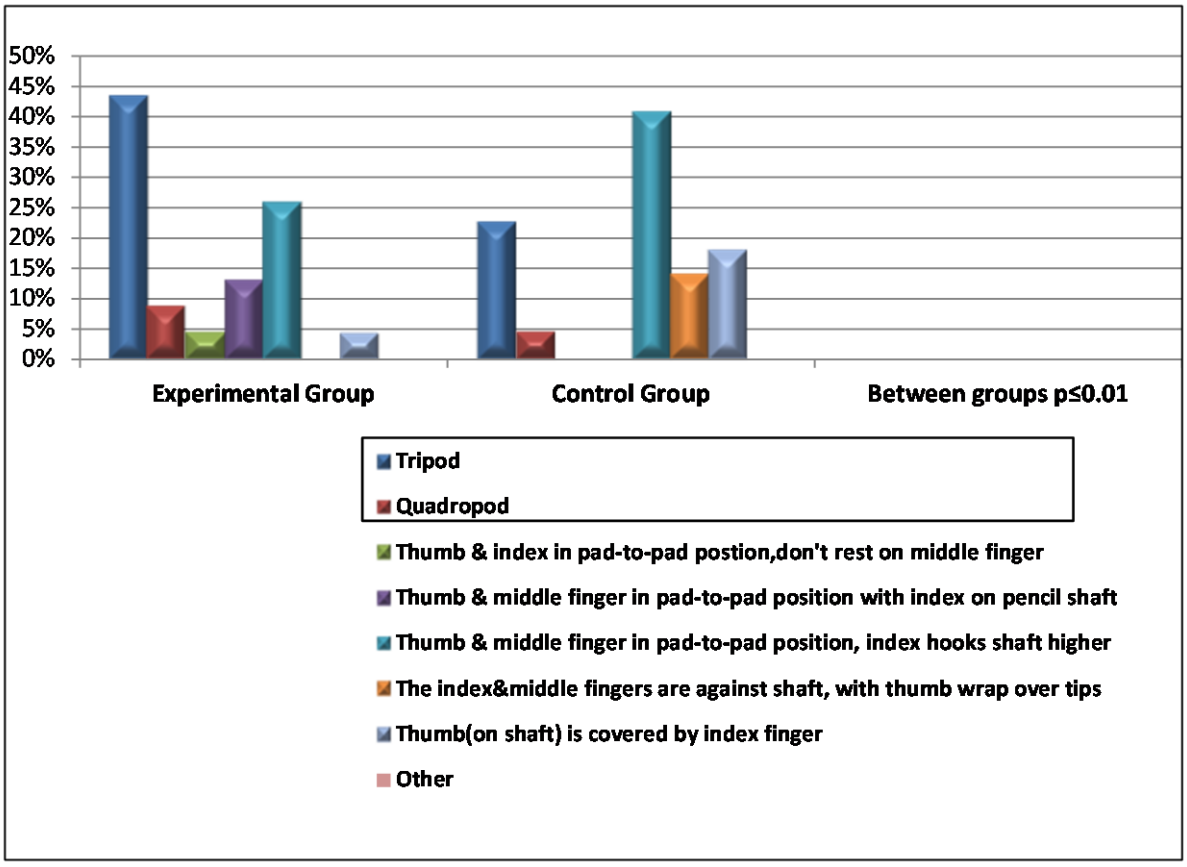


Figure 4.11 Pencil grasp at final evaluation (n=45)

Twenty six percent of the experimental group developed the functional pencil grasp over the intervention period and showed a within group significant improvement (p≤0.02) Although there was some improvement to more efficient pencil grasps in the control group there was no statistically significant improvement in their grasps (p≤0.62). (Figure 4.11)

The experimental group showed a significant shift compared to the control group in achieving efficient pencil grasps (p≤0.01). Seventy percent of this group's pencil grasps became efficient while 68 % of the control group participants' pencil grasps remained inefficient.

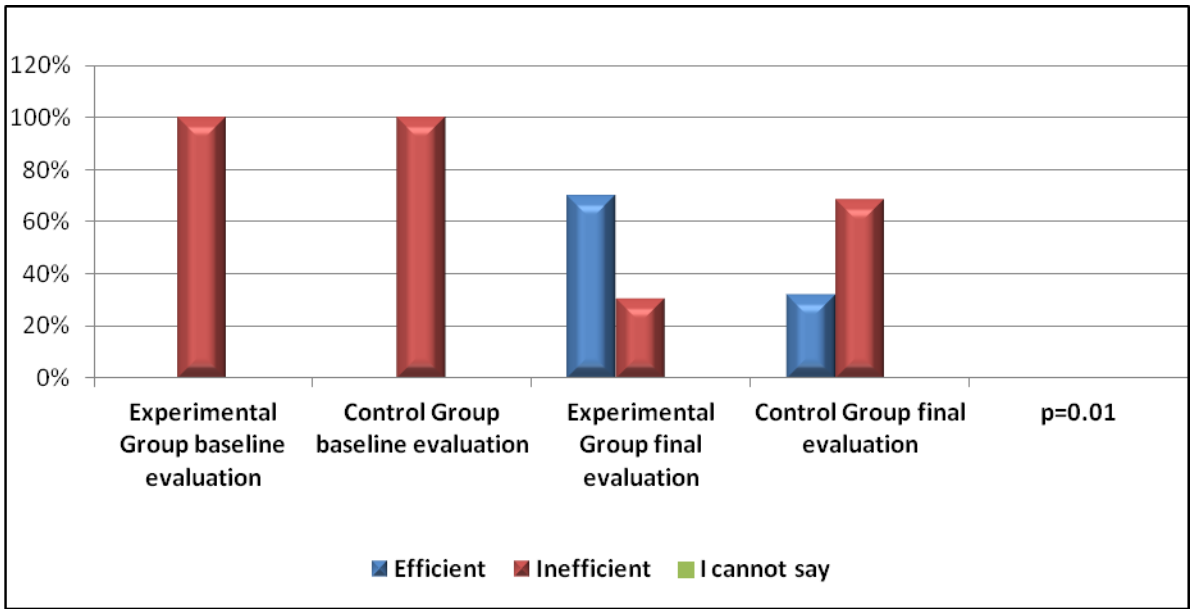


Figure 4.12: Change in efficient pencil grasps between initial and final evaluation (n=45)

4.6 The Quality and Speed of Handwriting as measured by the Minnesota Handwriting Assessment

Differences between baseline evaluation and final evaluation in the control and experimental groups on the Minnesota Handwriting Assessment did not indicate statistically significant differences at the final assessment. The control group showed greater positive change in the writing legibility, form, size and speed than the

experimental group. The experimental group's alignment of letters and space improved more in comparison to the control group. (Table 4.6)

Table 4. 6. Comparison of final scores for the Minnesota Handwriting Assessment between the experimental and control group after three months (n=45)

Subscale	**Final Scores Control Group Mean (SD)**	**Final Scores Experimental Group Mean (SD)**	***p* value**	***Confidence Intervals***
QUALITY				
Legibility	33.41 (0.85)	33.09 (1.28)	0.26	-0.13 - 0.77
Form	33.13 (1.04)	31.95 (2.08)	0.65	0.18 - 2.18*
Alignment	33.00 (1.27)	32.04 (2.20)	0.08	-0.57 – 1.61
Size	32.45 (1.34)	31.61 (3.33)	0.27	0.10 – 3.18*
Space	33.04 (1.05)	32.61 (1.44)	0.61	-0.34 – 1.18
SPEED	33.40 (1.92)	33.04 (3.30)	0.30	-0.90 – 2.36

*Significance set at 0.05

* confidence intervals do not cross 0- both figures positive

Although two confidence intervals for form and size showed clinical significance, as both values were positive and did not cross zero, the control group had consistently higher scores than the experimental group. The differences between the groups were very small and showed both groups had improved in terms of the handwriting scores.

When considering the within group changes over the duration of the study most aspects in the Minnesota Handwriting Assessment showed significant improvement for both groups. The control groups writing improved significantly for all aspects and only legibility and form did not improve significantly in the experimental group (Table 4.7 and 4.8).

Neither group showed any significant changes in the first month on Test 2 in their handwriting except for speed which increased significantly in the control group. The control group showed significant improvement in form, alignment and space in the writing by Test 3 at the end of the third month.

Table 4.7 Scores and differences within control group after three months using the Minnesota Handwriting Assessment (n=23)

Control Group	Subscale	Baseline Scores Mean (SD)	Test 2 Scores Mean (SD)	p value Baseline to Test 2 scores	Test 3 Scores Mean (SD)	p value Test 2 to Test 3 scores	Final Scores Mean (SD)	p value Test 3 to final scores	Difference Baseline to Final Scores	p value Baseline to final scores	Effect size overall
	QUALITY										
	Legibility	32.52 (1.37)	32.55 (1.41)	0.80	33.09 (0.81)	0.12	33.41 (0.85)	0.12	0.89	0.006*	1.11
	Form	31.13 (1.83)	31.73 (1.55)	0.18	32.73 (0.98)	0.01*	33.13 (1.04)	0.14	2.00	0.001*	1.92
	Alignment	31.00 (2.18)	30.68 (2.78)	0.48	32.47 (1.42)	0.007*	33.00 (1.27)	0.01*	2.00	0.001*	1.50
	Size	29.65 (5.03)	29.95 (4.11)	0.69	31.50 (1.54)	0.10	32.45 (1.34)	0.02*	2.80	0.01*	2.17
	Space	31.56 (2.15)	31.68 (1.78)	0.69	31.91 (0.92)	0.004*	33.04 (1.05)	0.61	1.48	0.003*	1.47
	SPEED	23.13 (8.63)	30.27 (6.83)	0.001*	31,36 (5.21)	0.31	33.40 (1.92)	0.08	10.27	0.000*	1.24

* significance set at 0.05

Table 4.8 Scores and differences within experimental group after three months using the Minnesota Handwriting Assessment (n=22)

Experimental group	Subscale	Baseline Scores Mean (SD)	Test 2 Scores Mean (SD)	p value Baseline to Test 2 scores	Test 3 Scores Mean (SD)	p value Test 2 to Test 3 scores	Final Scores Mean (SD)	p value Test 3 to final scores	Difference Baseline to Final Scores	p value Baseline to final scores	Effect size overall
		Using Stetro pencil grip					Stetro pencil grip removed				
	QUALITY										
	Legibility	32.5 (1.82)	32.05 (3.14)	0.65	33.33 (0.97)	0.13	33.09 (1.28)	0.23	0.59	0.10	0.45
	Form	31.08 (2.01)	31.52 (2.16)	0.37	32.48 (1.17)	0.13	31.95 (2.08)	0.14	0.87	0.17	0.44
	Alignment	29.75 (3.39)	30.05 (2.58)	0.55	32.48 (1.36)	0.05*	32.04 (2.20)	0.26	2.29	0.01*	1.04
	Size	28.30 (5.95)	28.24 (8.22)	0.84	30.81 (4.76)	0.03*	31.61 (3.33)	0.65	2.50	0.001*	0.98
	Space	30.92 (2.67)	31.43 (2.36)	0.64	32.62 (1.32)	0.03*	32.01 (1.44)	0.60	1.69	0.006*	1.17
	SPEED	27.67 (8.10)	30.14 (7.14)	0.09	32.67 (3.86)	0.16	33.04 (3.30)	0.24	5.37	0.004*	0.66

* significance set at 0.05

The experimental group still writing with the Stetro pencil grip at this stage had significant improvement in alignment, size and space in their handwriting

In the final assessment the control group showed further significant improvement in alignment and size while the experimental group all scored slightly less in some aspects of handwriting on their final assessment, a month after the removal of the Stetro pencil grip. The greatest deterioration was seen for legibility in five participants (23.8%) and space in four participants (19.05%). All other lower scores after the removal of the Stetro pencil grip were for one participant only.

Effect size of the improvement was calculated and all aspects of writing assessed on the Minnesota Handwriting assessment showed a large (more than 1 SD) change.

Speed, legibility and form in the experimental group only showed a moderate effect size with the size of writing achieving just under 1 in terms of effect size or change. Thus the intervention was not as effective in terms of change in the experimental group.

4.6.1 Longitudinal change in writing speed

The number of participants in the control group who showed a significant difference in writing speed between the initial assessment and Test 2 at one month was greater than for the experimental group.

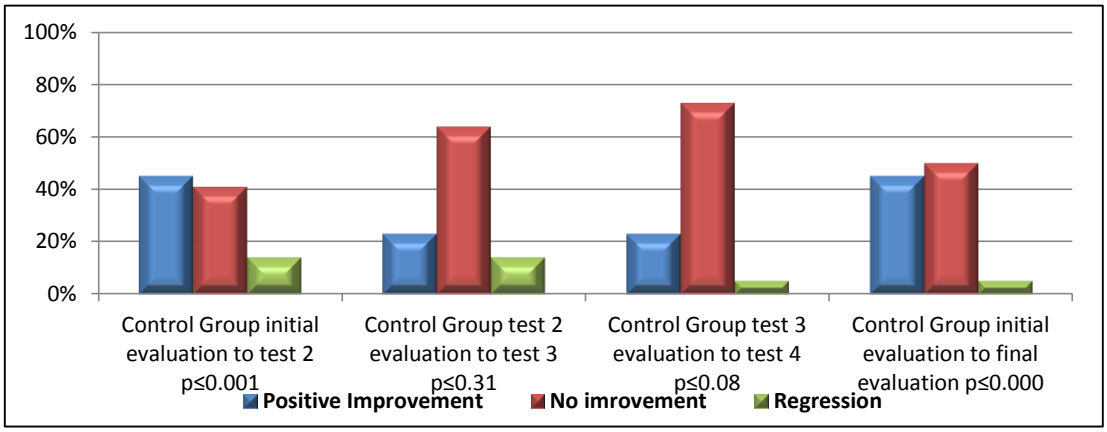


Figure 4.13 Comparison between each evaluation in the control group in the category of writing speed (n=22).

As for the experimental group there was no significant improvement for Test 3 and Test 4 with 4% and 1% of the participants regressing respectively and becoming slower. The greatest number of participants improved their speed of writing when the baseline and the final assessment were compared with a significant increase in writing speed of $p \leq 0.00$.

There was not a significant difference for the experimental group in writing speed between the baseline initial assessment and Test 2 at one month. ($p \leq 0.09$) for the experimental group..The writing speed still did not improve significantly for Test 3 where a 16% regression in speed was seen while they were still using the Stetro pencil grips.

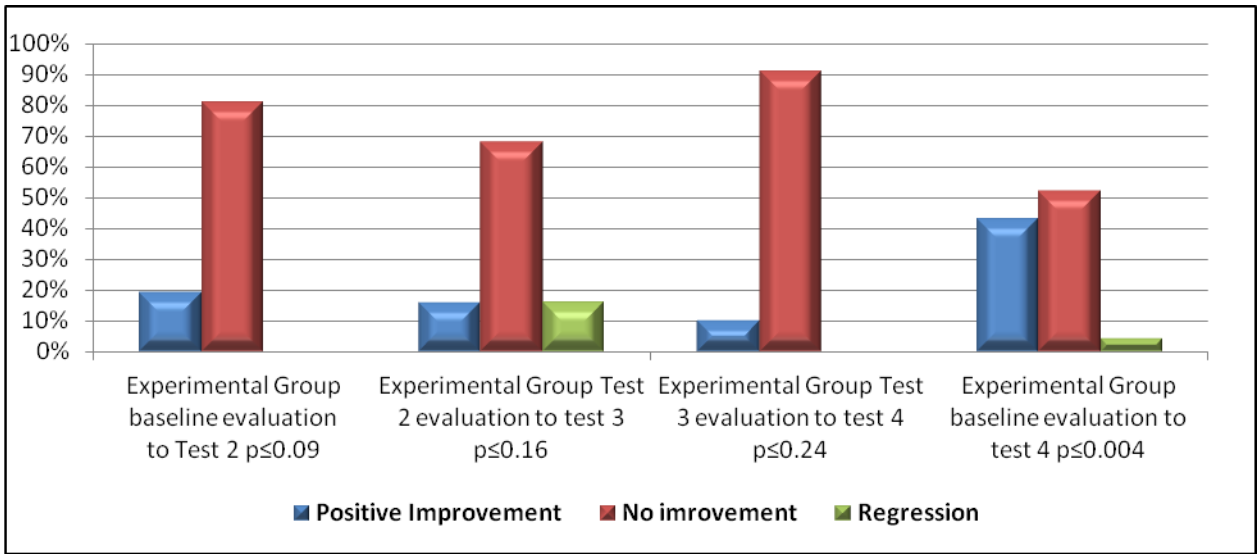


Figure 4.14: Comparison of improvement between individual testing in the experimental group in the category, writing speed (n=23)

There was no significant improvement in speed between Test 3 and Test 4 a month after the removal of the Stetro pencil grips either but no regression was seen.. Writing speed did increase significantly from baseline to the final assessment with ($p \leq 0.004$) and regression occurred in 2% of the sample at this stage. (Figure 4.14)

4.6.2 Tripod Pinch Strength

The difference between the initial and final evaluation of the experimental group indicate a bigger change in strength in pinch grip after using the Stetro pencil grips, but there

was no significant difference between the groups on the final evaluation (p= 0.35).(Table 4.9).

Table 4. 9: Comparison of pinch strength final scores between the experimental and control group after three months (n=45)

	Tripod pinch strength in Control Group Kgs Mean (SD)	Tripod pinch strength in Experimental Group Kgs Mean (SD)	p value	Confidence intervals
Baseline score	2.95 (0.71)	3.25 (0.94)	0.35	-0.79 to 0.43
Final Score	3.89 (1.02)	4.07 (1.02)		

Significance set at 0.05

There was a significant increase in both groups for pinch strength over the three month period of the study. (Table 4.10) The pinch strength increased on each assessment for the control group. There was an initial decrease in the experimental group for pinch grip at month 2 and then the strength increased.

Table 4.10 : Comparison of Pinch strength scores within experimental and control group over three months (n=45)

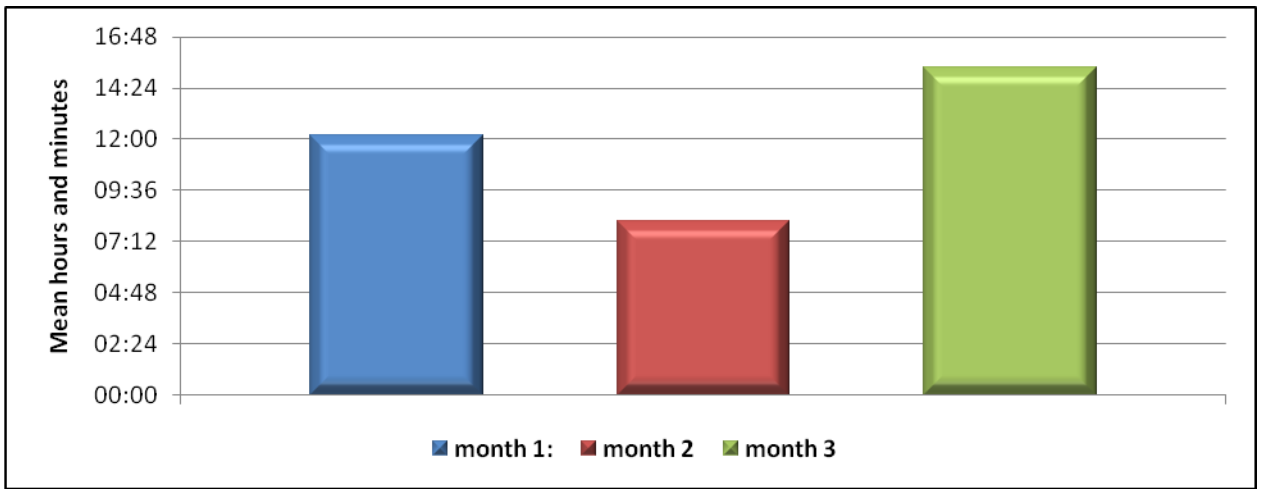
	Baseline Scores Mean (SD) (Kg)	2mnth Scores Mean (SD)	3mnths Scores Mean (SD)	Final Scores Mean (SD)	Difference Baseline to Final Scores	p value Baseline to final scores
Control Group Pinch - Kg	2.95 (0.71)	2.97 (0.80)	3.35 (0.64)	3.89 (1.02)	0.94	0.003*
	Using Stetro pencil grip			Stetro pencil grip removed		
Experimental Group Pinch - Kg	3.25 (0.94)	3.10 (1.38)	3.32 (1.32)	4.07 (1.02)	0.82	0.001*

* significance set at 0.05

4.7 Adherence to the programme

The time spent writing using the Stetro pencil grip varied between 30 to 60 minutes a day in class for each participant. The teachers' diaries indicate that the participants used the pencil grip everyday they were in class except for when they were absent. The absenteeism in the classes ranged from two to six participants a month over the three month period.

Figure 4.15: Mean hours and minutes per week the Stetro pencil grip was used in class when writing (n=23)



The mean hours a week that the Stetro pencil grips were used when writing varied with less time being spent in the second month and more in the third month when the grip was removed.

4.8 Summary

Review the two groups initially indicated that they were comparable for all variable except for handwriting speed, which was faster in the experimental group.

When the groups were compared at the end of the study there was no significant difference in the descriptors associated with pencil grasp and the descriptors of position and posture associated with writing between the groups except for writing movement with the fingers which was better in the experimental group. There was a significant

difference between the groups in terms of pencil grasp in which the experimental group had significantly more efficient pencil grasps.

The null hypothesis that there will be no difference in the descriptors associated with pencil grasp and the descriptors of position and posture associated with writing as well as the pencil grasp of Grade 2 learners with handwriting difficulties, who do and do not use a Stetro pencil grip in a classroom programme is therefore accepted with the exception of writing movement with the fingers and pencil grasp.

There was no significant difference in the quality and speed of handwriting as measured by the items on the Minnesota Assessment of Handwriting and for pinch strength between the groups at the end of the study. The control group had improved their speed at this stage and the initial difference seen between the two at baseline no longer existed. The null hypothesis is therefore accepted as the intervention of using a Stetro pencil grip to writing in a classroom programme has no effect on the speed and quality of handwriting or pinch strength of Grade 2 learners with handwriting difficulties.

When the within group changes were analysed the participants in the control group improved significantly in terms of all quality of handwriting and speed of handwriting on the items on the Minnesota Handwriting Assessment. The participants in the experimental group did not show significant improvement in legibility and form with the effect size indicating that improvement for both speed and quality in the control group was greater. A similar result was found for improvement in pinch strength which was significant in both groups.

Therefore the null hypothesis that there will be no change in the speed and quality of handwriting and pinch strength of Grade 2 learners with handwriting difficulties who do not use a Stetro pencil grip in a classroom programme, over a three month period was rejected. This null hypothesis could not be completed rejected for the learners using the Stetro pencil grip as there was no significant change in their legibility and form in writing.

When considering descriptors of handwriting and pencil grasp both groups showed improvement in most of these. The lateral posture when writing of the participants in the control group deteriorated but the change that occurred in the other descriptors indicates

participants were developing more mature pencil grasps and positioning for writing. Only the experimental group showed significant improvement in any descriptors associated with handwriting - the angle of the distal joint (DIP) of the index finger position. This group also had a significant improvement in pencil grasp.

The null hypothesis that there will be no change in the descriptors associated with pencil grasp and handwriting of the same learners was however accepted except for DIP position and pencil grasp in those learners who did use a Stetro pencil grip.

The analysis of the participants' writing quality and speed over a three month period showed that significant change in both groups did not occur until the second month. The control group continued to improve in the third month while the scores for some of the quality in the experimental group decreased slightly after the removal of the Stetro pencil grip. None of these changes were significant. Their speed of writing and pinch strength was not affected by this removal.

The null hypothesis which states that improvement in the speed and quality of handwriting and pinch strength of Grade 2 learners with handwriting difficulties, who use a Stetro pencil grip in a classroom programme for two months, will not be retained on removal of the Stetro pencil grip in the following month is therefore rejected.

The adherence to the intervention was considered good with the hours that the Stetro pencil grip was used in class aligning with the writing as requested by the teachers. The grip was used by all the participants when they were in class during their writing period for at least 30 minutes every day.

CHAPTER 5

DISCUSSION

This chapter will consider the results found in relation to the effectiveness of the Stetro pencil grip in Grade 2 learners identified with handwriting difficulties. The effects of the Stetro pencil grip were evaluated in terms of the observations of pencil grasp; handwriting qualities as well as the tripod grasp strength. The observation of the pencil grasp included descriptors like writing movements, wrist position of the writing hand, finger position in relation to the pencil, distal joint position of the index finger, distance from tip of pencil to the fingers, distal joint of the thumb, pencil grasp and whether the pencil grasp was functional. Descriptors of writing position and posture like writing posture and arm position of the writing hand were also considered. The handwriting quality was assessed in terms of legibility, form, alignment, size, space and speed of writing. The tripod grasp strength was measured and compared between the experimental and control groups.

5.1 Participants

The participants all attended the same school and were recruited from five Grade 2 classrooms and were divided by class into an experimental and control group. There was an even distribution of boys and girls in the groups. There were no drop outs in the study as even though learners were absent on some days all the participants were assessed on each of the four assessment times.

The learners between 7-8 years were identified by the teachers as having handwriting problems and assessment of their pencil grasps, descriptors of their posture and their handwriting confirmed this. The majority of the participants in the study had developed dominance and used a preferred right hand and continued to used the same hand throughout the study even though the norms in the McCarthy Scales which indicate that only 85% of children have established clear dominance by the age of 8 years and 6 months (Kaufman et al., 1978).There were a high percentage of participants in both

groups who used their left hand to write compared to the 10% average for left hand dominance reported in the literature (Hardyck & Petrinovich, 1977).

Writing is still essential for children to be able to communicate effectively and also necessary in the academic schooling system. Pencil grasp is only a small element of the handwriting, but a correct pencil grasp along with the position while writing form a very important component in the for early stages of writing development (Selin, 2003).

5.2 Handwriting dysfunction at Baseline Assessment

In order to meet the first objective and determine the participants dysfunction related to handwriting observation of descriptors in both the experimental and control group, participants were identified to have dysfunctional pen grasps on the baseline assessment. There were no significant differences between the groups and the groups were therefore comparable for these aspects.

The majority of the participants in both groups showed positions of the fingers that were described by Summers (2001) and Selin (2003) as incorrect when grasping a pencil to write (Summers, 2001) (Selin, 2003). These included the index finger or other fingers rather than the thumb closest to the tip of the pencil, the DIP joint of the index finger in hyperextension and the finger proximity to the tip of the pencil were considered in the functionality of the pencil grasp (Table 4.2). The position of hyperextension at the index DIP joint has been shown by Summers (2001) to be associated with joint laxity and to have an effect on the pencil grasp. She reports that this deviation from the standard tripod grasp has been seen to get less with age and a decrease in laxity (Summers, 2001).

In terms of near tip pencil grasp Thomas found that in 1997 up to 82% of 7-9 years olds used this method to write. The mean of 71% found for the participants of this study, although slightly less still indicate a problem with this aspect (Thomas, 1997). For other descriptors the majority of participants did use the correct movements and they did write with their fingers rather than their hands, with the IP joint of the thumb in flexion and their wrists' extended (Table 4.3).

In terms of the participants' posture and the position of their writing hand, only their posture was of concern with flexion forward or to the side being observed in most. The correct use of the non-dominant hand to support the paper and resting the writing arm on the table was not of concern as this was done by the majority of the participants.

Only 23 % of the participants, 8% in the experimental group and 14% in the control group had pencil grasps that could be considered efficient (Figure 4.1). The results of the Minnesota Handwriting Assessment indicated that the speed and quality of the handwriting was similar for both groups although at this stage the experimental group wrote significantly faster.

The strength of the tripod pinch in both groups was also comparable and fell within the norms given by Mathiowetz (1986) for 7 year olds at 1.4-5.0 kg and 8 year olds at 1.8-7.7 kg (Mathiowetz et al., 1986) although the values for the participants were in the lower range.

5.3 Effectiveness of Stetro pencils grips on handwriting and pencil grasp dysfunction

5.3.1 Changes between Groups

The second objective of this study was to establish if the Stetro pencil grip had any effect on the pencil grasp dysfunction and the speed and quality of handwriting as well as the tripod pinch strength of the Grade 2 participants. The results for the experimental and control group were compared for the final assessment after the experimental group had used the Stetro pencil grip for two months and had written for the following month without it.

For the descriptors associated with pencil grasp finger closest to the tip of the pencil, the angle of the DIP joint, the position of the fingers on the pencil and the position of the wrist were considered in the functionality of the pencil grasp there was no significant difference between the groups in the final assessment. The same results were found for the descriptors related to the slight changes in the position of the participants' writing

and non-writing arms and their posture. There was no significant difference for these aspects between the groups.

There was a significant increase the number of the participants in the experimental group who had started to write with their fingers rather than their hand however when compared to the control group. The use of these fingers movements indicate the use of intrinsic movements which also make the pencil grasp dynamic instead of static (Schneck &. Henderson, 1990). Thus it appears that the Stetro pencil grip is effective in the participants' natural development of the finger mobility in a stable hand. It assists with the development and maturation of the balance of the stability and mobility of the hand. This balance is essential as the mobility aspect of the hand which is required to use the index and middle fingers to write needs to be facilitated by the stabilisation of the longitudinal arch of the hand (Stitzer, 2006). The ring and small fingers then remain flexed, to provide the stable base for the hand (Naidu, 2008).

A significantly positive change in the type of pencil grasp used was also found in the experimental group. Thus for this aspect the effectiveness of the pencil grip was indicated in the difference between the initial and final evaluation even after the pencil grip devices had been removed for one month. Over half of the participants in the experimental group now used efficient tripod and quadropod pencil grasps, indicated by Ferrandino in 2007 as the most appropriate pencil grasps, compared to a quarter of the control group (Figure 4.11) (Ferrandino, 2007). Thus the Stetro pencil grip was important in changing the pencil grasp for the participants in this study, Grade 2 learners with handwriting difficulties. The results for the control group indicate that their pencil grasps were not automatically and naturally corrected and that a habitual inefficient grasp has been retained by the majority of the group. These results are supported by the research and literature which indicates that habitual inefficient pencil grasps do not autocorrect and require intervention of some kind to alter the grasp (Cusumano, 2008). These findings also support those for writing with finger movements as both these grasps allow the fingers to move to perform small, precise movements to guide handwriting movements.

The effectiveness of the Stetro pencil grasp in facilitating efficient pencil grasps at this stage in the participants skill development was emphasised by Cusumano, in 2008. She stated that an efficient pencil grasp should be facilitated as early as possible if the pencil grasps is to build appropriate fine motor skills and develops the correct engrams for motor learning (Cusumano, 2008). The inefficient pencil grasps still found in the control group included an index finger hooked higher on the shaft of the pencil as well as the grasp with a thumb wrap over the index finger. Selin (2003) indicates that the thumb wrap grasp occurs when there is a lack of stability in the metacarpophalangeal joint of the thumb with a resultant closure of the web space when writing.

In both these grasps the movement of the fingers is sill limited especially when the index finger is hooked higher on the pencil shaft than the thumb and middle finger. The index finger is prevented from guiding the movement and the middle finger becomes the guiding force of the pencil. In the thumb wrap grasp free, easy movement of the index finger is prevented by over stabilisation of the thumb (Amundson, 2005). These grasps negatively impact precision and stability of the pencil and the endurance in the hand muscles which influences the control of the pencil and the neatness quality of writing. According to Brown, (2003), one need to strive for a functional tripod grasp as it avoids physical problems which may affect the hand and the wrist (Brown, 2003).

However, the significant change in pencil grasp for the experimental group did not affect their handwriting legibility or quality and had no significant effect on the tripod pinch strength when compared to the control group. The use of the Stetro pencil grip therefore was not effective in changing any of these aspects related to handwriting in this study. The clinically significant differences found using confidence intervals, for the quality of handwriting in form and size both improved more in the control group indicating that not using a Stetro pencil grip may allow for more improvement in the quality of handwriting (Table 4.6). The reasons for this result are discussed in detail under the changes within the groups.

What was found however was a significant change within both groups, for these aspects indicating that the handwriting and pinch strength of the Grade 2 participants did improve over the three-month period of the study.

5.3.2 Changes within the Groups

The within group changes were assessed to fulfil the third objective of the study, on all the aspects measured in this study for both the experimental and control group. The changes seen in the descriptors associated with open grasp and of the positioning and posture were consistent with the changes in pencil grasp described above but when they were analysed for both groups there was no significant change in these aspects except for DIP index finger position in the experimental group.

The significant decrease in the use of hyperextension of the index finger DIP joint, in the experimental group, was an important finding. A greater number of participants were using DIP flexion when writing at the end of the study, the position of which indicates they are using less pressure to hold the pencil and pressing on the paper (Ziviani, 1983). Research by Ferriell et al (1999) and Brown (2003) indicate the position of the fingers and the joints is highly important for the pencil grasp for manipulation of pencil and finger movement in the handwriting process. The distal joint of the index finger should be flexed appropriately to avoid stress on the joint (Ferriell et al., 1999) (Brown, 2003).

Although a change was seen in DIP flexion in the control group this was not significant and the majority of participants still using extension rather than flexion at this joint indicating there may still be stress at this joint in this group. The change in the position of this joint is supported by research that shows an age-related decrease in the occurrence of hyperextension in the index finger DIP joint which suggests a refinement of pencil grasp from 7-8 years upwards (Ziviani, 1983) (Summers, 2001). In this group the change in position of the index finger DIP can be assumed to be related to natural maturation of the pencil grasp.

The results for the experimental group appear to be related to more than natural maturation and this is supported by Peterson's statement in 2008 indicating that the Stetro pencil grip would improve the involvement of the index finger, decreasing the pinching and hyperextension of the distal joint (Peterson Directed Handwriting, 2008). The pencil grip appears to have assisted 22% of the participants to assume the more

appropriate position in the DIP of the index finger with 30% now using DIP flexion, which decreases the chances of fatigue and cramps in handwriting.

This change in DIP joint position indicates a positive change which is supported by Brown (2003) who showed that the pencil during handwriting should be positioned so that there is equal pressure between the thumb, the side of the middle finger and the tip of the index finger so that all finger joints flex slightly. She indicated this allows better manipulation of the small movements of the hand in guiding the pencil (Brown, 2003).

It was therefore also important to look for change in the distal joint position the distal IP joint of the thumb. The flexed distal thumb joint allows for more appropriate pressure holding the pencil and allows for improved stabilisation of the pencil in the pencil grasp. Although there was not a significant change in this descriptor, 100% of participants in the experimental group wrote with flexion at the IP joint of the thumb at the end of the study and only one participant in the control group still wrote with their thumb extended. Peterson (2008) indicated that the Stetro pencil grip decrease the pressure output of the thumb on the pencil and facilitates a flexed, appropriate position of the thumb. The Stetro pencil grip also specifically promotes the thumb in a more forward position in left-handed participants (Peterson Directed Handwriting, 2008). The differences in left and right handed participants were not analysed as this was outside the scope of this study.

It was found that the change in other descriptors had occurred also indicated some maturing of the pencil grasp in the participants. Fewer participants in both groups were writing with their middle and ring fingers closest to the tip of the pencil. Over 70% of the control group and now positioned their index finger nearest to the tip of the pencil at the end of the study. While this showed a developmental maturing of their pencil grasp the greater percentage of the experimental group participants wrote with their thumb nearest to the tip of the pencil indicated more of them are achieving the desired position for a mature tripod pencil grasp (Selin, 2003) .

It is not only the finger placement on the pencil that is considered but also the distance of the fingers to the tip of the pencil. Gripping the pencil near the tip is related to gaining better control. Although the Stetro pencil grips were placed at the correct distance from

the tip of the pencil and in the final assessment for both groups some improvement in positioning the fingers a functional distance from the tip of the pencil was seen, approximately 40% of participants in both groups did not achieve this (Figure 4.5).

There was little change in the position of the wrist when writing and the writing and non-writing arms with a few more participants in the experimental group now holding the paper they were writing on with their non-writing hand. It was noted that although only slightly more participants wrote with an extended rather than a flexed wrist at the end of the study the amount of extension used by participants in the experimental group was more functional. They no longer extended their wrists as much and mostly used a better position of the wrist for handwriting which should be 10^0 of extension, as it allows full range of motion in the fingers (Pendleton & Schiltz-Krohn, 2006).

The participants' writing postures of the experimental group, did not indicate significant changes in the duration of the study while in the control group a change in opposition from a flexed to laterally flexion in their writing posture was seen by the end of the study. This reason for this change was not clear but needs to be monitored and further investigated.

In order to write with precision, one requires proximal stability; this includes the shoulder, elbow and wrist to stabilise the hand, thus resting the writing arm on the table for support (Ferrandino, 2007). The placement of an arm resting on the table surface provides stability to encourage precision movements of the fingers (Case-Smith, 2005) The results of the arm position on the table improved slightly for the control group with the experimental group having all the participants resting their arms on the table at the end of the study. According to Naidu, (2008), this position is essential for the development of fine motor skills as it provides proximal stability which leads to the development of a relaxed mature pencil grasp. In the age range of the participants it allows them to guide the writing movement with their fingers and hands instead of the shoulder and upper limb (Naidu, 2008). Guiding the movement with the hand is not desirable as discussed above but there was no significant change within the groups as far as this aspect was concerned with some improvement being seen within both groups.

The changes seen in the descriptors except for sitting posture when writing in the control group were all positive and showed a maturing of aspects related to pen grasp and factors associated with handwriting.

It was also important to establish what differences occurred in the participants' actual handwriting as well as their pencil grasp and the descriptors investigated in this study over a three-month period. When the results of the Minnesota Handwriting Assessment were analysed the change in handwriting legibility and quality was significant for all aspects in the control group and for all aspects expect legibility and form in the experimental group.

No significant improvement was seen in either group at the first reassessment after one month for any aspect of handwriting except speed in the control group who were significantly slower at baseline assessment.(Table 4.7 and 4.8) The introduction of Stetro pencil grip seemed to have little effect on the handwriting of the experimental group and by the second reassessment at 2 months they showed a similar increase to participants in the control group for speed and legibility which were not significant.

Graham et al, (2005), stated that the introduction of a pencil grip might affect the grapho-motor skill and ability to use muscles in the fingers and hands to form and align letters that has already been learnt while maintaining a functional pencil grasp. This is found true in the study as it was evident that the control group fared better initially. No evidence of these problems were found a month after the introduction of the Stetro pencil grip in the experimental group when they were reassessed. There was a very small decrease in legibility and even though the pencil grip may have placed the participants' fingers in a corrected grasp position that they were not accustomed to, they only used they pencil grip for between 30 to 60 minutes in the classroom so it appears not to have had any detrimental effect on the handwriting. They also had a month to get used to the pencil grips before they were reassessed.

There were significant improvements for alignment and space in the quality of writing for both groups on the second reassessment at 2 months. Alignment in handwriting is the ability to write each individual letter in the correct orientation and slanting and along with

spacing is one of the first steps to develop good handwriting quality, as this is consolidated and practised (Reisman, 1999). It was encouraging to see these two aspects were being consolidated in these participants.

Other items like form and size varied in the significance of their improvement and it must be considered with the small sample size that either a Type II error may have occurred in analysing the scores on each item of the test. Overall it is clear that the participants' handwriting showed a significant improvement with large effect sizes for the control group and moderate to large effect sizes for the experimental group.

Overall these findings reflect those of Overvelde and Hulstijn (2011) who demonstrated considerable improvements in handwriting throughout Grade 2. This study also showed that learner identified with handwriting problems in Grade 2 decreased as they were found to have significant positive change in their writing by the end of Grade 2 and into Grade 3 (Overvelde & Hulstijn, 2011). The changes in the two groups in this study therefore confirm that development of handwriting legibility skills continues within the classroom. Practising handwriting is a daily part of the participants' schoolwork (Miller et al., 2001) and the participants continued with their normal, daily activities in the classroom throughout the study, resulting in progression and development of fine motor skills, awareness of expectations on a fine motor level resulting in a the improvement of their handwriting quality.

There was a progressive change in the speed of writing in both groups throughout the three months of the study which was significant between baseline and final assessments for both groups. In this study the results supported a relatively constant improvement of writing speed over three months even though unlike other aspects related to quality of writing changes between assessments were not significant. This finding is supported in Graham's study in 2006, where he found that handwriting speed does not necessarily follow the same pattern of development as other handwriting skills (Graham, 2006). The effect size of the experimental group for writing speed was not as great as that of the control group but they were writing significantly faster as the baseline assessment so it appears the introduction of the Stetro pencil grip did not affect the speed of their handwriting unduly and they continue to develop this aspect irrespective. The

participants writing speeds fell within the age-appropriate levels of 20-25 letters per minute as suggested by Hamstra-Beltz and Blote, in 1993 (Hamstra-Bletz & Blote, 1993)

The findings of other studies by Koziatek and Powell (2003) and the American Occupational Therapy Association that suggest a commercial pencil grip can increase writing and that the development of an efficient the pencil grasp also has an impact on the writing speed were not supported by this study (Koziatek & Powell, 2003) (American Occupational Therapy Association, 2002). It is clear since the changes within the groups for speed and quality of handwriting are similar in both the experimental and control groups that the significantly improved pencil grasps seen in the experimental group did not appear to play a role in the improvement of the participants' handwriting and probably only have a positive effect on the biomechanical stress to their joints (Ziviani & Elkins, 1986) (Schneck and Henderson, 1990).

The change that was noted after the introduction of the Stetro pencil grip was a slight decrease in tripod pinch strength within the experimental group which was not found for the control group. This may have been due to the activation of appropriate muscle groups' in the fingers designed for fine motor tasks such as handwriting and the opening of the web space which results when a pencil grip is used (Peterson Directed Handwriting, 2008).

The other results for tripod strength measured throughout following months indicated a statistically significant increase in tripod pinch strength between the baseline and final assessment within both the experimental and control groups. The change in the experimental and control groups were similar and probably due to maturation and development of the hand and fine motor skills (Table 4.10). The Improvement in the tripod pinch strength while it may be associated with the improvement in handwriting cannot be related in any way to the change in pencil grasp found in this study. This finding did not support Peterson (2008) who, indicated that dysfunctional pencil grasps can lead to underdeveloped groups of muscles in the hand and strengthening muscles used in a tripod pinch will result in an improved pencil grasp (Peterson Directed Handwriting, 2008).

The last objective of the study was to establish if improvement seen in handwriting was retained when the Stetro pencil grip was removed after 2 months. Very small average regression was seen in the experimental group for some items on the Minnesota Handwriting Assessment one month after the Stetro pencil grip was removed with 10 % of the group showed improvement and the rest maintaining their handwriting at the same level (Table 4.14) .

During the same time the control group showed greater improvement in the handwriting with 22% of participants continuing to improve (Figure 4.13). Although this was not significantly greater than the experimental group overall these changes indicate that the experimental group may have been a little disadvantaged by the removal of the Stetro pencil grip and it may have slowed their progress slightly. Only one participant regressed when the Stetro pencil grip was removed and 10% continued to improve during this time. (Figure 4.14)

It was clear at the end of the study that the main effectiveness of the Stetro pencil grips was on pencil grasp and that 70% of the experimental group had improved efficient pencil grasps. The application of the pencil grips had little effect on the legibility and quality of the participants' handwriting and they continued to improve their handwriting skills at the same pace and to the same level as the control group who did not wear the Stetro pencil grips. The study resulted in showing the clinical importance of the Stetro pencil grasp in terms of its effect on altering the pencil grasp in a short term classroom programme with an effect on descriptors like writing with the fingers instead of the hand and improving the position of the, distal joint of the index finger on the pencil.

In the final assessment 68% of the participants in the control group still displayed inefficient pencil grasps, which may need class intervention or further occupational therapy intervention. Although these inefficient pencil grasps have not affected the pace and quality of their handwriting in Grade 2 they may have an effect in the future. Schneck and Henderson, 1990, indicate that inefficient pencil grasps, if not corrected, will affect handwriting speed and quality when demands increase in every grade and throughout the years work (Schneck &. Henderson, 1990).

For the 30% of the participants in the experimental group it is clear that their inefficient pen grasps cannot be addressed in a classroom programme and further investigation into the factors underlying their continue problems is needed. Their inefficient pencil grasps might be linked to other difficulties. Marr, Cermack, Cohn and Henderson, (2003) suggested that both internal and external factors influencing handwriting and pencil grasps need to be considered and the assessment of other internal factors like fine motor co-ordination, motor planning, in-hand manipulation and kinaesthetic awareness must be considered (Marr et al., 2003).

The study indicates that the problems with inefficient pencils grasps can be addressed in a short term classroom programme in Grade 2. This will allow the majority of the learners to develop the required efficient pencil grasps they need without disrupting the teachers programme or compromising them in terms of the speed and quality of their handwriting. This allows the occupational therapists to deal with the smaller number of learners for whom this programme is not effective and deal with their problems on an individual level.

Limitations of the Study

The sample size was a limitation of the study even though a power calculation had been performed. The changes seen over the three months were smaller than expected and since the descriptors were assessed on small scales of 1-3 or 1-4. This limited the statistical procedures that could be used to analyse the statistics as data for the sample was not normally distributed.

The use of the Stetro pencil grips in class, although consistent because they were part of the classroom routine organised by the teacher was only for a short period every day being mostly 30 minutes. This may have not been enough time for the pencil grips to have been effective in resulting in a change in handwriting or pinch strength that literature indicated might be expected. Although pencil grips are used as temporary strategies to improve a child's pencil grasp it is dependant on the child, classroom and home environment on how long a pencil grip must be used. Change of pencil grasp can take anytime between a month and 6 months (Ferriel et al, 1999)

CHAPTER 6

CONCLUSION

The study considered the effectiveness of the Stetro pencil grip in terms of descriptors associated with handwriting including position of finger thumb and wrist joints when writing, the position of the pencil in the hand, hand dominance, and movement when writing. Descriptors of arm position, posture pencil grasp and the speed and quality of handwriting as well as, tripod pinch strength were also considered. The study focussed on the therapeutic effects of the Stetro pencil grip in classroom settings with Grade 2 learners identified as having handwriting difficulties.

The study showed that the Stetro pencil grip made a significant difference in the efficiency and functionality of the pencil grasp when the experimental and control groups were compared. The participants in the experimental group showed a significant improvement in writing with their fingers rather than their hands. Within the experimental group there was also a significant change in the position of the distal joint of the index finger from hyperextension to flexion or extension when holding the pencil.

Using the Stetro pencil grip had no effect on the speed or quality of the participants' handwriting and except for a small decreases initially no effect on their tripod pinch strength either. Both groups showed continued improvement on all aspects of handwriting though the final three months of Grade 2. The Stetro pencil grip was effective in facilitating an efficient pencil grip in the experimental group resulting in a decreased need for therapy in this group. The intervention improved the underlining foundations of the pencil grasp. This indicates the Stetro pencil grip had therapeutic value in the classroom setting by affecting the pencil grasp positively which is important to future demands of handwriting in later grades if fatigue is to be avoided and the required speed maintained.

Although 30% of the experimental group did not benefit from this intervention and will need further investigation to establish the cause of their handwriting difficulties the study shows that some handwriting difficulties like pencil grasp can be addressed in a

classroom programme. The improvements in handwriting and strength which occurred while the Stetro pencil grip was being used were retained once it was removed after two months. Although these improvements cannot be related to the use of the Stertro pencil grip, wearing it to improve pencil grasp was not detrimental to the participants' handwriting development in any way.

6.1 Recommendations:

The use of the Stetro pencil grasp can be used in a short two month classroom programme to resolve the majority of inefficient pencil grasps problems found which may result in fewer referrals to occupational therapy.

The development of poor pencil grasps is already established and has to be remediated in Grade 2 so perhaps the use of pencil grips needs to be considered earlier. A number of authors feel the inefficient pencil grasps seen are because learners cannot achieve the efficient mature grasps due to instability and possibly lax ligaments in their hands. (Selin, 2003) (Summers, 2001) The Stetro pencil grips and training should therefore be made available to teachers in the foundation phase of primary schools. Difficulties in handwriting can prevented if it is caused by dysfunctional pencil grasps.

A longer use of Stetro pencil grips needs to be researched with continued used into Grade 3 to establish if they have any effect on the speed and quality of handwriting.

Learners who have used the Stetro pencil grips in Grade 2 also need to be followed up in Grade 3 to see if there is an effect on the speed and quality of handwriting in relation to their use of efficient pencil grasps and to see if these grasps are retained long term.

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Appendices:

A. Information sheet to parents
B. Informed consent to parents
C. Informed consent for photographs
D. Informed assent to children
E. Permission letter to headmaster
F. Permission letter from the schools
G. Permission form for Gauteng Education Department
H. Ethical Clearance Certificate
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K. Observation Schedule for describing pencil grasp
L. Minnesota handwriting Assessment
M. Daily diary rosters for teachers

APPENDIX A. Information sheet to parents:

Dear Parent,

I am Ms. Esmie Smit, an occupational therapist working for Ingrid G. Bench Occupational Therapists. Currently I am doing my M Sc. Occupational Therapy specializing in paediatrics at the University of the Witwatersrand. My research is focused on the investigation of the functionality of a Stetro pencil grip and whether it has lasting effects on a child's handwriting speed and quality. I would be most grateful if you and your child would consider participating in this study.

This study is being done to be able to determine if intervention can be given to a child within a classroom situation to improve handwriting, minimising expensive therapies and assessments. I would like to determine if a child's web-space can be corrected with only the use of a pencil grip.

The expectations from the participants in this study:

I anticipate that the handwriting speed and quality may improve after using the pencil grip for the term and it will have lasting effects on the child's web-space. I would like to compare the use of a pencil grip to the other children in grade 2. The participants will be divided into 2 groups. One group will receive pencil grips for the term while the other group would continue with normal class work activities. Both groups will write a short writing test before the study will commence. They will write the test twice more during the term. The last test will be written after the 3 months without any writing aids to determine the lasting effects of the pencil grips. Photographs will be taken of the child's hand holding the pencil only.

All information will be kept confidential. Records will be kept of whether the child has used the Stetro pencil grip in the classroom as prescribed but no names will appear on

the records as codes will be used. Confidentiality will be maintained by the use of a code instead of names on all results. Only one researcher will have a list of names and codes to enable the code to be linked to a particular child. This list will be kept locked in an office.

At any given time you feel you want to withdraw your child from the study, you may certainly do so without having to give a reason. This study is completely voluntary and not taking part in it, or withdrawing from it, carries no penalty of any sort – schooling will not be influenced.

Feedback on the study will be provided on request.

If you have any enquiries, more information may be obtained from Ms Esmie Smit at the cell phone number 083 455 0798 or the secretary of the Wits Ethics Committee on human subjects, Anisa Keshav on 011 717 1234

If you are happy to allow your child to take part in the study, please read and sign the attached consent form.

Thank you.

Kind regards,

Esmie Smit

APPENDIX B . Informed consent form

Consent form

I agree to allow my child to participate in the study outlined in the information sheet.

Parent:

Name:

_____

Signature:

_____

Date:

_____

Appendix C Informed consent for Photographs

Consent form

I agree to allow my child's hand to be photographed for the study as outlined in the information sheet.

Parent:

Name:

_____

Signature:

_____

Date:

_____

APPENDIX D Verbal assent form for the children:

Hi,

I am Esmie and I would like to see how well you can write. Will you agree to do some writing tests for me this term?

The teacher may ask you to use this grip on your pencil to help you hold your pencil more easily when you are writing in class. Will you do that?

The teacher will check to see if you use the grip for your writing work in class.

Child:

Name:_____

Witness _____

APPENDIX E Permission Letter to St Peter's Preparatory School for boys and for girls:

Dear Headmaster,

I am Ms. Esmie Smit, an occupational therapist working for Ingrid G. Bench Occupational Therapists. Currently I am doing my M Sc. Occupational Therapy specializing in paediatrics at the University of the Witwatersrand. My research is focused on the investigation of the functionality of a Stetro pencil grip and whether it has lasting effects on a child's handwriting speed and quality. I would be most grateful if your school would consider participating in this study.

This study is being done to be able to determine if intervention can be given to a child within a classroom situation to improve handwriting. It avoids expensive therapies and assessments. I would like to determine if a child's web-space can be corrected with only the use of a pencil grip.

The expectations from the participants in this study:

I think the handwriting speed and quality will improve after using the pencil grip for the term and it will have lasting effects on the child's web-space. I would like to compare the use of a pencil grip to the other children in grade 2. The participants will be divided into 2 groups. One group will receive pencil grips for the term while the other group would continue with normal class work activities. Both groups will write a short writing test before the study will commence. They will write the test twice more during the term. The last test will be written after the 3 months without any writing aids to determine the

lasting effects of the pencil grips. Photographs will be taken of the child's hand holding the pencil only.

All information will be kept confidential. Records will be kept of whether the child has used the Stetro pencil grip in the classroom as prescribed but no names will appear on the records as codes will be used. . Confidentiality will be maintained by the use of a code instead of names on all results. Only one researcher will have a list of names and codes to enable the code to be linked to a particular child. This list will be kept locked in an office.

Benefits to the participants: Yes, if it is proven that the pencil grip has positive lasting effects of the child's handwriting, your school will be informed of the findings. For the other group that did not receive the pencil grips during the study will be given on pencil grip or referred to the appropriate facilities.

If you have any enquiries, more information may be obtained from Ms Esmie Smit at the cell phone number 083 455 0798.

If you are happy to allow your school to take part in the study, please read and sign the attached consent form.

Thank you.

Kind regards, Esmie Smit

Appendix F Permission Form from headmasters:

I agree to allow my school's grade 2 learners to participate in the study outlined in the information sheet.

Headmaster:

Name:

_____

Signature:

_____

Date:

_____

Appendix G Permission Form for Gauteng Education Department

UMnyango WezeMfundo
Department of Education

Lefapha la Thuto
Departement van Onderwys

Enquiries : Shadrack Phele [MIRMSA]
Tel. no. : +27 11 355 0285

Tuesday, June 30, 2009

Ms Smit Esmie
18 Kolmans
Sovereign Street
Wilgeheuwel
2040

Dear Ms Smit Esmie

PERMISSION TO CONDUCT RESEARCH: PROJECT

The Gauteng Department of Education hereby grants permission to conduct research in its institutions as per application.

Topic of research	: "An investigation into the effect of a Stetro pencil grip on the writing and pencil grasp at Grade 2 children with handwriting difficulties."
Nature of research	: MSc. [Occupational Therapy]
Name of institution	: University of the Witwatersrand
Supervisor/Promoter	: Denise Franzen

Upon completion of the research project the researcher is obliged to furnish the Department with copy of the research report (electronic or hard copy).

The Department wishes you success in your academic pursuit.

Yours in Tirisano,

p.p. Shadrack Phele [MIRMSA]

Ms Mmapula Kekana
Chief Director: Information Systems and Knowledge Management
Gauteng Department of Education

OFFICE OF THE CHIEF DIRECTOR
INFORMATION & KNOWLEDGE MANAGEMENT
Room 1501, 111 Commissioner Street, Johannesburg, 2001 P.O.Box 7710, Johannesburg, 2000
Tel: (011) 3550809 Fax: (011) 0248 E-mail: mmapulak@gpg.gov.za or elridar@gpg.gov.za

Appendix H Ethical Clearance Certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Ms Esme Smit

CLEARANCE CERTIFICATE	**M090444**
PROJECT	An Investigation into the Effect of a Stetro Pencil Grip in the Writing and Pencil Grasp of Grade 2 Children
INVESTIGATORS	Ms Esme Smit.
DEPARTMENT	Occupational Therapy Department
DATE CONSIDERED	09.04.29
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 09.04.29 **CHAIRPERSON** .....
(Professor P E Cleaton Jones)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : D Franzsen

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...

Appendix I Information sheet to teachers

Dear Teacher,

I am Ms. Esmie Smit, an occupational therapist working for Ingrid G. Bench Occupational Therapists. Currently I am doing my M Sc. Occupational Therapy specializing in paediatrics at the University of the Witwatersrand. My research is focused on the investigation of the functionality of a Stetro pencil grip and whether it has lasting effects on a child's handwriting speed and quality. I would be most grateful if you and your class would consider participate in this study.

This study is being done to be able to determine if intervention can be given to a child within a classroom situation to improve handwriting. It avoids expensive therapies and assessments. I would like to determine if a child's web-space can be corrected with only the use of a pencil grip.

The expectations from the participants in this study:

I think the handwriting speed and quality will improve after using the pencil grip for the term and it will have lasting effects on the child's web-space. I would like to compare the use of a pencil grip to the other children in grade 2. The participants will be divided into 2 groups. One group will receive pencil grips for the term while the other group would continue with normal class work activities. Both groups will write a short writing test before the study will commence. They will write the test twice more during the term. The last test will be written after the 3 months without any writing aids to determine the lasting effects of the pencil grips. Photographs will be taken of the child's hand holding the pencil only.

All information will be kept confidential. Records will be kept of whether the child has used the Stetro pencil grip in the classroom as prescribed but no names will appear on the records as codes will be used. . Confidentiality will be maintained by the use of a code instead of names on all results. Only one researcher will have a list of names and

codes to enable the code to be linked to a particular child. This list will be kept locked in an office.

Benefits to the participants: Yes, if it is proven that the pencil grip has positive lasting effects of the child's handwriting, you and the child in your class will be informed of the findings. For the other group that did not receive the pencil grips during the study will be given on pencil grip or referred to the appropriate facilities.

At any given time if you feel you want to withdraw your class from the study, you may certainly do so without having to give a reason. This study is completely voluntary and not taking part in it, or withdrawing from it, carries no penalty of any sort – schooling will not be influenced.

Feedback on the study will be provided on request.

If you have any enquiries, more information may be obtained from Ms Esmie Smit at the cell phone number 083 455 0798 or the secretary of the Wits Ethics Committee, Anisa Keshav on 011 717 1234

If you are happy to allow you and your class to take part in the study, please read and sign the attached consent form.

Thank you.

Kind regards,

Esmie Smit

Appendix J Informed consent form -Teachers

Consent form

I agree to allow the research to be done in my classroom and that I will participate in the study outlined in the information sheet.

Teacher:

Name:

_____

Signature:

_____

Date:

_____

Appendix K Observation Schedule for describing pencil grasp.

Adapted from Lyytinen-Lund 1998

Student's name:_____

Photo of pencil grip: ____Photo after _____minutes

Observation by:_____

School:_____

Class:_____ Teacher:_____

The students working posture and movements:

M	The student is writing with	01 the right hand 02 the left hand 03 alternatively both hands
V	The non-writing hand	01 rests on the paper 02 rests on the lap 03 makes associative movements
T, U	The writing movements are conducted with	01 the fingers 02 the hand 03 the arm
X	The subject's writing posture is	01 normal, good 02 leaning over 03 slanting to the side 04 other, describe

O	The arm of the writing hand	01 rests on the table 02 does not rest on the table
N	The wrist of the writing hand is	01 extended or turned back 02 flexed

PENCIL GRIP

Y	The finger or the fingers closest to the tip of the pencil	01 thumb 02 index finger 03 Middle finger 04 Ring finger
Q	The distal joint(DIP) of the index finger is	01 Flexed 02 Extended 03 in hyperextension
R	The pencil grip is: The fingers are:	01 at a functional distance from the tip of the pencil 02 too close to the paper 03 spread over the shaft
QT	The distal joint (DIP) of the thumb is	01 flexed 02 extended 03 in hyperextension

P Which of the following pencil grips bears the greatest resemblance to the grip of the subject:

01	The thumb and the index finger in pad-to-pad position, pencil rests on the middle finger.
02	The thumb, index and middle fingers in pad-to-pad opposition, pencil does not rest on the middle finger.
04	The thumb and the index finger in pad-to-pad position, pencil does not rests on the middle finger
05	The thumb and middle finger in pad-to-pad opposition, the index finger is on the shaft.
08	The thumb and middle finger in pad-to-pad opposition, the index finger hooks the shaft higher.
09	The index and the middle fingers are pad against the shaft; the thumb covers the finger tips.
11	The thumb is pad against the shaft covered by the index finger
12	Other, describe

Z Do you consider the students pencil grip:

01	Functional
02	Dysfunctional
03	I cannot say

Appendix L- Daily Roster and Diary Page for the teacher:

Code	Date	Attendance (Y/N)	Pencil grip (Y/N)	Time writing

Appendix M- Minnesota Hand Writing Assessment

the brown jumped lazy

fox quick dogs over

Name

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5 6 7 8 9 10 11 12 A B C D E

Printed in the U.S.A.

Minnesota Handwriting Assessment Record Form

Name _____ Date _____

School _____

Teacher _____ Examiner _____

Grade *Circle the marking period that most closely matches the assessment date.*

1st Grade January | 1st Grade April | 2nd Grade October | 2nd Grade January | 2nd Grade April

1st Grade	Rate Score		Legibility Score	Form Score	Alignment Score		Size Score	Spacing Score
	January	April	January–April	January–April	January	April	January–April	January–April
Performing Like Peers	18–34 ○	22–34 ○	33–34 ○	30–34 ○	29–34 ○	29–34 ○	27–34 ○	30–34 ○
Performing Somewhat Below Peers	11–17 ○	13–21 ○	32 ○	25–29 ○	20–28 ○	22–28 ○	15–26 ○	26–29 ○
Performing Well Below Peers	10 or fewer ○	12 or fewer ○	31 or fewer ○	24 or fewer ○	19 or fewer ○	21 or fewer ○	14 or fewer ○	25 or fewer ○

2nd Grade	Rate Score			Legibility Score	Form Score	Alignment Score	Size Score	Spacing Score
	October	January	April	October–April	October–April	October–April	October–April	October–April
Performing Like Peers	26–34 ○	29–34 ○	33–34 ○	34 ○	31–34 ○	31–34 ○	27–34 ○	32–34 ○
Performing Somewhat Below Peers	15–25 ○	17–28 ○	20–32 ○	32–33 ○	28–30 ○	26–30 ○	19–26 ○	29–31 ○
Performing Well Below Peers	14 or fewer ○	16 or fewer ○	19 or fewer ○	31 or fewer ○	27 or fewer ○	25 or fewer ○	18 or fewer ○	28 or fewer ○

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