Research Article https://doi.org/10.12973/ijem.10.3.517

International Journal of Educational Methodology
Volume 10, Issue 3, 517 - 530.
ISSN: 2469-9632
https://www.ijem.com/

Preparation for Writing From a Biomechanical and Ergonomic Point of View

Alenka Rot Vrhovec *
University of Ljubljana, SLOVENIA

Received: May 21, 2024 ▪ Revised: July 7, 2024 ▪ Accepted: August 15, 2024

Abstract: Writing is a complex activity. If a child's preparation for writing, which begins to develop in the preschool years, is poor, this can inhibit writing and cause problems. Because children are expected to know how to hold a pencil correctly, how to sit correctly while writing, and how to prepare and adjust the writing surface without planning, this study seeks to determine how first graders are prepared for writing in terms of selected biomechanical and ergonomic factors at the beginning of the school year. The goal was to determine whether there are any differences between students according to sex and handedness and if there is any connection between basic pre-writing skills and the ergonomic suitability of furniture (table and chair size). An empirical study was conducted involving 246 first graders from randomly selected public primary schools in Ljubljana, Slovenia, and fifteen of their female teachers. The results of the research showed that inadequate furniture size affects how students sit and that there are statistically significant differences between the positions of the writing surface for right-handers and left-handers. The research did not show a correlation between posture and pencil grip, but it is very likely that it would have been demonstrated in a larger sample. No sex differences were found between pencil grip, writing surface position, and posture; no connection between handedness, pencil grip, and posture; no connection between pencil grip, poor posture, and writing surface position; and no connection between posture and ergonomically appropriate school desks and chairs.

Keywords: *Handwriting, pencil grip, posture, pre-writing skills, writing surface position.*

To cite this article: Rot Vrhovec, A. (2024). Preparation for writing from a biomechanical and ergonomic point of view. *International Journal of Educational Methodology*, *10*(3), 517-530. https://doi.org/10.12973/ijem.10.3.517

Introduction

Motor skills include gross motor skills and fine motor skills. Educational outcomes, such as automated writing, are influenced by fine motor skills (Kavkler, 2011). In children, these skills develop in a certain order, but not all at the same time. Their development primarily depends on an individual's biological maturation, as well as the individual's circumstances, experiences, and motivation. Children can gain motor experience by chance, by imitation, and by planning: by having someone show them what to do first, then checking for appropriateness and correcting if necessary (Papalia et al., 2003). Promoting motor skills accelerates development (Marjanovič Umek & Zupančič, 2020).

The development of basic pre-writing skills is also related to motor skills. Developed graphomotor skills, which are classified as fine motor skills, are a prerequisite for learning to write. The effectiveness of graphomotor exercises is positively influenced by basic pre-writing skills, such as correct posture and pencil grip when writing and correct writing surface position. A survey was conducted among Slovenian first graders and their teachers about students' writing-related skills when they started school. The goal was to determine how well children's writing skills were developed when they started primary school and whether they were provided with sufficiently high desks and chairs at school. Of interest were the links between biomechanical factors (pencil grip and posture, sitting) and ergonomic factors (writing surface position, size of desks and chairs) and differences by sex and handedness. This study seeks to raise awareness among educators and teachers, as well as parents and school administrators, of the importance of biomechanical and ergonomic factors that affect writing efficiency, student motivation for activities on which academic success depends, and health. The goal is to encourage preschools and school curriculum planners to develop objectives or teaching recommendations to develop children's basic writing-related skills. Educators should be aware of the importance of monitoring and encouraging the development of an individual's basic writing-related skills, and of taking timely action

* **Correspondence:**
Alenka Rot-Vrhovec, University of Ljubljana Faculty of Education, Kardeljeva ploščad 16, 1000 Ljubljana, Slovenia. ✉ alenka.rotvrhovec@pef.uni-lj.si

in the event of irregularities. Educators should also make parents aware of the importance of encouraging the development of fine motor skills in children. Teachers should check the basic pre-writing skills of their students at the beginning of the school year and act accordingly, and school administrators should ensure that children have ergonomically appropriate equipment.

Literature Review

Motor Development of Children in the Preschool Years

About half of children sit without support at six months, and most at seven (Adolph & Robinson, 2015) or eight months (Marjanovič Umek & Zupančič, 2020). Grasping an object with the thumb and forefinger is mastered by half of the children at eight months, and by most at 10 months (Adolph & Robinson, 2015), at 12 months (Wart Platt, 2006), or at 14 months (Marjanovič Umek & Zupančič, 2020). They are adept at picking up small objects with a pincer grip. Later they use a similar palm position when writing (Wart Platt, 2006). By age three, a child's preferred hand use is already evident, but not always pronounced. Most children use their right hands dominantly (90%), whereas about 10% of the population is left-hand dominant, which is more common in boys than in girls (Marjanovič Umek & Zupančič, 2020; Papalia et al., 2003). The maturation of these components is important for effective motor skills, especially fine motor skills, which significantly affect the quality, accuracy, and speed of performing various tasks, including graphomotor exercises and later handwriting (Odokuma & Ojigho, 2019). The pre-literacy period, which begins in the preschool years, is when children begin to grasp various writing implements and acquire their first graphomotor experiences (Adamič, 1992; Department of Education, 2022; Odokuma & Ojigho, 2019). Preschoolers should use a variety of small tools to develop finger skills, such as scissors, and develop the pencil grip that they will use for fluent writing. Educators are expected to consider each child's individual needs, interests, and development when planning such activities, and to ensure that each child's learning and development is an enjoyable experience (Department of Education, 2022; Odokuma & Ojigho, 2019). Movement is important for health, and writing is mostly performed in a sitting position; in parallel with years of education, the time spent writing—and therefore the time spent sitting—increases. It is important to emphasize Lipičnik's (2011) assertion that even the best sitting position does not allow long-term healthy sitting because muscles become tired, also leading to poor nutrition and wear and tear on the intervertebral discs and, consequently, the vertebrae.

Pencil Grip, Posture, and Writing Surface

Writing requires the coordination of two opposing activities: simultaneously holding and moving a pencil (Marquardt, 2011a). Pencil grip is defined as the position of the fingers on a pencil (Odokuma & Ojigho, 2019), and it changes only in the early years (Yakubova, 2005). The changes are related to the developmental progression of grasping (Tuckett, 2006). Mature manners[†] of grasping emerge between three and five years of age (Odokuma & Ojigho, 2019; Tseng, 1998; Tuckett, 2006). There are four mature or effective grips: dynamic three-finger, dynamic four-finger, lateral three-finger, and lateral four-finger (Koziatek & Powell, 2003; Odokuma & Ojigho, 2019; Schwellnus, 2012). In the literature, the dynamic grip is also known as the pincer grip, in which the thumb and forefinger act as pincers, holding the pencil about 2 cm from the tip. The third finger, the middle finger, acts as a support for the index finger when writing. The fourth and fifth fingers provide stability for the palm on the writing surface. The dynamic four-finger grip is very similar to the dynamic three-finger grip, except that the pencil is held by the thumb and three other fingers. In the lateral grip, the thumb crosses the pencil and does not participate in the manipulation of the pencil. In the lateral three-finger grip, the fourth and fifth fingers support the outer part of the hand, whereas in the lateral four-finger grip the little finger rests on top of the ring finger (Odokuma & Ojigho, 2019; Shah et al., 2022).

Most research shows that the dynamic three-finger grip is the most common grip used by students (Graham et al., 2008; Koziatek & Powell, 2003; Lager Deudon, 2020; Odokuma & Ojigho, 2019; Ojigho & Odokuma, 2019; Schwellnus, 2012; Shah et al., 2022; Temur, 2011). Some believe that the criteria for an adequate grip are that it ensures writing speed and legibility of handwriting, as well as comfort that does not damage the joints over time. Despite this, only the dynamic three-finger grip is still most commonly encouraged in preschools and schools (Department for Education, 2013; Selin, 2003). This is said to allow effective distal movements of the pencil and to reduce muscle tension, which causes fatigue, through the combination of mobility and stability; it is also said to allow greater speed and legibility of writing without significant pressure (Graham et al., 2008; Odokuma & Ojigho, 2019). It is also preferred to other approaches in Slovenian literature (Gamser, 2011; Regvar, 1990; Žerdin, 2000, 2003; Zrimšek, 2003) and teaching manuals (Jamnik et al., 2009; Marquardt, 2011a; Ropič et al., 2003).

Findings on pencil grip and its influence on younger children's writing, which come from several studies, do not show consistent results. Through their research, Odokuma and Ojigho (2019) determined the dependence of pencil grip on sociodemographic factors, handedness, and writing speed. Age influenced pencil grip in children one to five years old,

[†] Pencil grips can be divided into three groups: primitive grips, characteristic of the youngest children, transitional grips, and mature grips. It is typical for mature grips that the movement of the pen is not performed by the wrist but by the fingers, whereas in immature grips the fingers are in a static position (Schwellnus, 2012; Odokuma & Ojigho, 2019).

and sex influenced pencil grip in primary school children six to ten years old. Research findings (Yakubova, 2005) show that pencil grip improves handwriting legibility, but grip correction is possible in younger children (Cigole & Merc, 2017) and first graders, whereas grip correction in second graders has been shown to be ineffective because they have already developed their pencil grip (Yakubova, 2005). Research by Feldman and Fiedler (2001) did not confirm a connection between pencil grip, handwriting legibility, and pencil grip strength of the first three fingers in first graders. The influence of pencil grip on writing speed and legibility has also been questioned in other studies, but the sample size, age of the students, and duration of the workload must be taken into account (Schwellnus, 2012; Schwellnus et al., 2013; Ziviani & Elkins, 2006). Schwellnus (2012) conducted a survey among fourth-grade students. This showed that the use of any of the four mature pencil grips did not significantly affect the writing speed or legibility of children with or without writing difficulties. A study conducted one year later showed similar results (Schwellnus et al., 2013). Again, no connection was found between mature pencil grips and handwriting speed and legibility. However, it was shown that the force of pressure on the pencil depends on the position of the thumb: it is greater when the thumb is on the index finger. The dependence between how the pencil is held and the force applied to the pencil is also confirmed by the results of Chau et al. (2006) and Temur (2011). The latter also found a sex difference in grip strength and writing speed. Boys had a stronger grip, and girls wrote faster. The results of the same study confirmed the dependence of different manners of holding a pencil on speed, but this difference was not statistically significant (Temur, 2011). Research by Sasada (2016) showed no significant difference in thumb position, either between sexes or between pencil grips.

Recent research shows that preschool children have poorer motor skills than normative data indicate (Hwang et al., 2024) and that most first graders have a static pencil grip (Sheedy et al., 2021). Children that use technological devices for more than two hours a day have poorer pencil grip strength and manual dexterity. The influence is also reflected in pencil grip. Repetitive static arm movements can reduce blood flow and prevent the delivery of nutrients to muscles, leading to muscle soreness and fatigue (Shah et al., 2022). This raises concerns about the potential impact of digital technology on changes in children's motor skills and the lack of incentives to develop these skills in the preschool years. Sufficient finger strength is required for each manner of gripping the pencil (Akselrud, 2004; Arrona et al., 2023). Research shows that fine motor skills and finger strength, and consequently the quality of handwriting, can be improved in a relatively short time with an appropriate individual approach (Akselrud, 2004; Smits-Engelsman et al., 2001).

No research was found on the connection between writing surface position and writing efficiency, but Yakubova (2005) believes that writing surface position is one of the most important ergonomic factors affecting the quality of handwriting. The writing surface (e.g., sheet, workbook, or notebook) should be placed parallel to the lower edge of the table and in front of the child in such a manner that the child does not lean to the left or right (Ropič et al., 2003), but Gamser (2011) recommends such a writing position only for beginners. Students that already know how to write should tilt the writing surface slightly toward their dominant hand while writing. For example, a left-hander should place the writing surface to the left of the body's midline and tilt it slightly to the right. The wrist must be straight (not bent), and the writing hand must be below the writing line so that the child does not smear or cover the writing with his or her hand while writing (Sattler, 2011).

Posture and sitting position are also important factors that influence writing performance (Gamser, 2011; Kavak & Bumin, 2009; Marquardt, 2011b; Sasada, 2016; Schoemaker et al., 2003). The more the hands and palms have to support the upper body, the more the hand presses on the writing surface, limiting the movement of the fingers and palms. When children write from the wrist, spasmodic strokes disrupt the basic shape of the writing, making it slower. Because it is more difficult to move the hand, children tire more quickly (Marquardt, 2011b). A relaxed and upright posture when sitting while writing is important both to improve posture and to prevent injury. The forearm and wrist should be relaxed on the desk, with the hands parallel to the floor. The non-writing hand is also on the table to hold and move the writing surface. The height of the chair that the child sits in must allow his or her legs to rest on the seat up to the bend of the knees and the feet to reach the floor so that the child can sit upright and lean against a firm backrest. If the table is at an appropriate height, the child can rest his or her forearms on the surface without having to lift the shoulders (Žerdin, 2000). In their research, Kavak and Bumin (2009) determined the effect of different ergonomic desk designs on the handwriting performance of children with physical disabilities and healthy children. The former were suited to a table with a cutout, whereas the latter achieved significantly higher results when sitting at a regular table with a twenty-degree incline. Sattler (2011) points out that special help in learning to relax the posture for writing should be given to left-handers. Long-term poor sitting posture is a major cause of spinal abnormalities, and students that sit improperly at a desk for long periods of time may experience increased kyphosis (Li et al., 2022). In a study in which 8-year-old children that participated in the Moving School project were compared with their peers that had traditional lessons, the former had less unfavorable positions of neck and trunk rotations, and almost no trunk flexions exceeding 45°‡ were observed (Lipičnik, 2011). It should be noted that the spine of taller students requires more flexion and is more prone to imbalance, and so the use of desks and chairs with appropriate height or lumbar support can be beneficial in maintaining the correct shape and posture of the spine. Posture is also an important factor in maintaining healthy vision. One study (Shi et al.,

‡ The cervical spine and neck muscles are in an unphysiological position when the neck is rotated more than 45° to the side or tilted more than 20° to the side, or when the cervical spine is bent forward or backward more than 30° (Lipičnik, 2011).

2021) showed that a distance of less than 30 cm between the eyes and the writing surface when writing increased the risk of myopia in children by about 11 times.

A skill can become a habit if it is often repeated and mechanized (Andoljšek, 1976). In any task, it is important to use energy as efficiently as possible, and this is also the case with writing. The change in energy is proportional to the intensity of the feeling of effort (Battestin, 2019). Bad habits, such as inappropriate posture among 5- and 6-year-olds, can be improved with an appropriate individual approach (Cigole & Merc, 2017).

Incorporating the Development of Basic Pre-Writing Skills into Formal Documents

In the current Slovenian Preschool Curriculum (Expert Council of the Republic of Slovenia for General Education, 1999), only one objective is prescribed in relation to the development of writing-related skills, and it refers to the development of finger dexterity or fine motor skills. For the first age period (up to three years), it is recommended that children develop writing-related skills through everyday play (e.g., folding, pushing objects, putting on clothes, picking up small objects, and assembling toys). In the second age period (from three to six years), children should develop finger and hand skills through activities such as cutting, weaving, braiding, and knitting (Expert Council of the Republic of Slovenia for General Education, 1999; Grginič, 2005).

In Slovenia, children who are or will be 6 years old in the current year enter first grade. According to the current Slovenian curriculum (Ministry of Education, Science and Sport, 2018), a continuation of the training period for prescribed skills is planned for three to four months. It is important to note that teachers are expected to monitor individual students' development and progress, and enable each student to move individually, gradually, and systematically through the phases of initial literacy defined in the curriculum. The first stage covers the development of pre-literacy skills: visual discrimination; auditory discrimination and parsing; graphomotor skills; orientation on the body, in space, and on paper; and pencil grip. Compared to a randomly selected foreign curriculum (Department for Education, 2013), the development of basic pre-writing skills is not given much attention in the Slovenian curriculum. In England, for example, in addition to holding a pencil comfortably and correctly, students should also learn how to sit correctly at a desk and develop stamina and the ability to write for long periods of time. Recommendations include that the size of the writing instrument (e.g., the pencil or pen) not be too large for the student's hand, and that any pen the student uses allow a relaxed and correct grip to avoid bad habits. The document specifically points out that left-handed children should be offered special teaching to meet their needs.

Methodology

Purpose and Objectives of the Research

Children gain experience with writing several years before they start school. This process usually begins in the child's second year of life. Although the curriculum for preschools (Expert Council of the Republic of Slovenia for General Education, 1999) only stipulates that prescribed skills must be developed, this does not guarantee that children have developed these skills before entering school. With the introduction of nine years of primary education in Slovenia (in the 2003/04 school year), there is no longer a compulsory year of school preparation. Because some children do not attend preschool, they do not participate in the preschool program. Even those children who do attend preschool receive various incentives. In Slovenia, a revision of the curriculum for preschools and the curriculum for Slovenian language instruction is underway, and so the findings of this research can serve as a starting point for planning goals that define the development of basic writing-related skills and teaching recommendations. Learning to write is based on graphomotor exercises, and, according to Zrimšek (2003), the conditions for their correct implementation are correct posture and pencil grip; Regvar (1990) points out that children must have an adapted desk and chair for this. The goal of this research was to determine how children had developed basic pre-writing skills when they entered the 1st year of primary school: how they held a pencil, how they sat during graphomotor exercises (i.e., writing), how they positioned a writing surface during this activity, and whether they had ergonomically appropriate furniture: a suitably sized chair and table. Of interest were whether students' sex and handedness (right- or left-handed) were related to pencil grip, appropriate writing surface position and posture while writing, and how basic pre-writing skills were related to each other and to ergonomic equipment. Another question was whether ergonomically correct furniture was related to students' correct sitting posture. The study also investigated which position students hold their pencils in when holding them with a dynamic tripod grip, what forms of inappropriate posture occur when writing, and how students sit when they have ergonomically inappropriate furniture.

Research Method and Research Sample

This study used a descriptive and causal non-experimental method of empirical pedagogical research. The sample was purposive and included 246 students from seven Slovenian public primary schools in Ljubljana that were in first grade in the 2023/24 school year (i.e., 15% of first graders in Ljubljana). Of these, 51.2% were boys and 48.8% were girls. Fifteen first-grade teachers also took part in the research.

Research Questions, and Processing and Displaying the Data

Based on the purpose and aims of the research, a number of research questions (RQs) were posed, grouped into four sets for clarity:

Section 1: How does students' sex relate to basic pre-writing skills (pencil grip = RQ 1, writing surface position = RQ 2, and posture while writing = RQ 3)?

Section 2: What is the connection between students' handedness and basic pre-writing skills (pencil grip = RQ 4, writing surface position = RQ 5, and posture while writing = RQ 6)?

Section 3: What is the connection between each of the basic pre-writing skills (pencil grip and writing surface position = RQ 7, pencil grip and posture = RQ 8, and posture and writing surface position = RQ 9)?

Section 4: What is the connection between posture and sitting position and the ergonomic suitability of furniture (posture and appropriate table and chair height = RQ 10 and between furniture size and sitting position = RQ 11)?

For the research, observation instructions and a teacher's spreadsheet were prepared and sent to several teachers to check their understanding and to add to them if necessary. The reliability of the observation measures used by the teachers was tested by calculating the Cronbach's alpha coefficient ($\alpha = .89$). The teachers carried out the observation three times in class and then wrote down the most common result in the spreadsheet. Under the notes, they could write down specific details of the observation that were not covered in the spreadsheet. The teachers carried out the observation without reminding the students about proper preparation for writing before or during the task. During the observation, the students performed a graphomotor exercise: they wrote patterns in a notebook with a suitably sized pencil. The teachers marked the spreadsheet, distinguishing either between sex or between pencil grips, for the students and the handedness of the students, the manner of holding the pencil while writing, the appropriateness of writing surface position while writing,[§] the appropriateness of posture,[**] the appropriateness of table and chair height, and the manner of sitting while writing (with the feet on the floor, with one or both legs under the buttocks, with the legs crossed or crossed, or sitting on the edge of a chair). In addition, the teachers observed the characteristics of the writing grip (the position of the pencil in relation to the writing surface and the height of the grip of the thumb and forefinger, the position of the palm in relation to the surface), and the characteristics of inappropriate posture and inappropriate sitting. The anonymity of schools, students, and teachers was ensured during the research.

The data obtained were statistically processed using the program SPSS. The association between different variables was calculated using the chi-squared test. The risk level was considered $\alpha = .05$. When the chi-squared test showed a statistical association, the effect size was checked using Cramér's *V*. The results of the research are presented in 11 tables below.

Findings

The results of the basic descriptive statistics showed that the majority (90.7%) of the students participating in the research wrote with their right hand, and 9.3% with their left hand. Of the first graders observed, 54.9% had a dynamic three-finger grip, 34.1% had a dynamic four-finger grip, and 11% had other grips (i.e., gripping a pen with more than three finger pads, a lateral three-finger grip, or gripping with the whole palm). Three percent of students held the pen upright, and 3% held the pen too high; the latter was only characteristic of students holding the pencil with a dynamic four-finger grip. An appropriate desk layout was shown by 68.7% of the research participants, and about a third (31.3%) did not have this. When writing, 69.5% of first graders had appropriate posture and 30.5% had inappropriate posture. Almost half of the students with inadequate posture (48%) had their eyes too close to the writing surface, 5% had their body too far from the desk, and 8% were too close to the desk. Most of the students in the study (66.3%) had an appropriately high desk and chair, and 33.7% of the students had inappropriately high furniture. When writing, 43.9% of the first graders observed sat correctly, but more (56.1%) sat incorrectly. Of those that sat incorrectly, 32% had at least one leg under their buttocks, 13% had their legs crossed, and 11% had their legs wrapped around each other or around the legs of the chair.

Students' Sex and Basic Pre-Writing Skills

The first part of the tabular presentation of the results focused on showing the connection of the students' sex with pencil grip (RQ 1), with writing surface position (RQ 2), and with posture (RQ 3). Table 1 shows that there are no significant differences between how boys and girls hold a pencil.

[§] This means that the student has the side of the workbook he or she is writing on in the middle of the body axis, that he or she is not leaning left or right, and that the workbook is an appropriate distance from the lower edge of the table (e.g., toward the upper edge of the table if the student is writing in the lower part of the workbook).

[**] This means that he or she has the right distance between his or her eyes and the workbook (so that he or she does not write "with his nose"), and that his or her body is a few centimeters from the desk.

Table 1. Comparison of Sex and Pencil Grip

Sex / Pencil Grip		Dynamic Three-Finger Grip	Dynamic Four-Finger Grip	Other Grips	Total
Boys	f	69	42	15	126
	f (%)	54.8%	33.3%	11.9%	100.0%
Girls	f	66	42	12	120
	f (%)	55.0%	35.0%	10.0%	100.0%
Total	f	135	84	27	246
	f (%)	54.9%	34.1%	11.0%	100.0%

$\chi^2 = 0.254$; $p = .881$

More than half of both use a dynamic three-finger grip to hold the pencil. The smallest proportions of boys (about 12%) and girls (10%) held the pencil with the other grips. Sex has no effect on how they hold the pencil when writing. A chi-squared test for pencil grip showed no statistically significant differences ($p > .05$) between boys and girls.

Table 2. Comparison *of Sex and Writing Surface Position*

Sex / Writing Surface Position		Proper Position	Incorrect Position	Total
Boys	f	81	45	126
	f (%)	64.3%	35.7%	100.0%
Girls	f	88	32	120
	f (%)	73.3%	26.7%	100.0%
Total	f	169	77	246
	f (%)	68.7%	31.3%	100.0%

$\chi^2 = 2.340$; $p = .126$

More than two-thirds of first graders had a correctly positioned writing surface when writing, but compared to boys about 10% more girls had a correctly positioned writing surface. The answer to the second research question is negative. The appropriateness of writing surface position does not depend on the sex of the students. Again, the chi-squared test showed that there were no statistically significant differences ($p > .05$) between boys and girls in writing surface position.

Table 3. Comparison of Sex and Posture

Sex/Posture		Correct Posture	Incorrect Posture	Total
Boys	f	82	44	126
	f (%)	65.1%	34.9%	100.0%
Girls	f	89	31	120
	f (%)	74.2%	25.8%	100.0%
Total	f	171	75	246
	f (%)	69.5%	30.5%	100.0%

$\chi^2 = 2.395$; $p = .122$

The results in Table 3 show that more than two-thirds of the first graders also had an appropriate posture when writing. As with writing surface position, an appropriate posture was observed in several girls; that is, about 9% more. The answer to the third research question shows that there is no connection between sex and writing posture. The chi-squared test also showed no statistically significant differences in posture between boys and girls ($p > .05$).

Students' Handedness and Basic Pre-Writing Skills

This section presents the answers to RQ 4–6. The connection between students' handedness with pencil grip, writing surface position, and posture is presented.

Table 4. Comparison of Handedness and Pencil Grip

Handedness / Pencil Grip		Dynamic Three-Finger Grip	Dynamic Four-Finger Grip	Other Grips	Total
Right-handed	f	122	76	25	223
	f (%)	54.7%	34.1%	11.2%	100.0%

Left-handed	f	13	8	2	23
	f (%)	56.5%	34.8%	8.7%	100.0%
Total	f	135	84	27	246
	f (%)	54.9%	34.1%	11.0%	100.0%

$\chi^2 = 0.136$; $p = .934$

Table 4 shows that most or more than half of the first graders had a dynamic three-finger pencil grip. This was the case for both right-handed and left-handed first graders. Fewer left-handers (about 9%) and right-handers (about 11%) used other grips, but 2.5% more right-handers than left-handers. The answer to the fourth research question, "Is there a connection between the right- or left-handedness of the students and pencil grip when writing?" is negative. There were no statistically significant differences ($p > .05$) between right-handed and left-handed students with regard to pencil grip; that is, there is no connection between right-handedness or left-handedness and pencil grip when writing.

Table 5. Comparison of Handedness and Writing Surface Position

Handedness / Writing Surface Position		**Proper Position**	**Incorrect Position**	**Total**
Right-handed	f	159	64	223
	f (%)	71.3%	28.7%	100.0%
Left-handed	f	10	13	23
	f (%)	43.5%	56.5 %	100.0%
Total	f	169	77	246
	f (%)	68.7%	31.3 %	100.0%

$\chi^2 = 7.505$; $p = .006$

As can be seen in Table 5, about 71% of the first graders that wrote with their right hand had a correctly positioned writing surface while writing, whereas the same could be said for less than half (44%) of those that wrote with their left hand. For the answer to the fifth research question, "Is there a connection between right- or left-handedness and writing surface position?" the chi-squared test showed statistically significant differences ($p < .05$) between writing surface position and right-handed and left-handed first graders. Cramér's coefficient showed a small effect size (.17). Most of the first graders that wrote with their right hand had correctly positioned writing surfaces, but the same cannot be said for the first graders that wrote with their left hand.

Table 6. Comparison of Handedness and Posture

Handedness/Posture		**Correct Posture**	**Incorrect Posture**	**Total**
Right-handed	f	155	68	223
	f (%)	69.5%	30.5%	100.0%
Left-handed	f	16	7	23
	f (%)	69.6%	30.4%	100.0%
Total	f	171	75	246
	f (%)	69.5%	30.5%	100.0%

$\chi^2 = 0.000$; $p = .995$

As can be seen from Table 6, almost 70% of the students, both right- and left-handed, had a correct writing posture. The answer to the sixth research question, "Is there a connection between right- or left-handedness and writing posture?" is that there are no statistically significant differences between right- or left-handedness and writing posture. The chi-squared test showed no statistically significant differences ($p > .05$) in posture between right-handed and left-handed first graders.

The Interconnectedness of Basic Pre-Writing Skills

This set of results includes the answers to three research questions. It shows the connection between pencil grip and writing surface position (RQ 7), between pencil grip and posture (RQ 8), and between posture and writing surface position (RQ 9).

Table 7. *Comparison of Pencil Grip and Writing Surface Position*

Pencil Grip / Writing Surface Position		**Proper Position**	**Incorrect Position**	**Total**
Dynamic three-finger grip	f	97	38	135
	f (%)	71.9%	28.1%	100.0%
Dynamic four-finger grip	f	55	29	84
	f (%)	65.5%	34.5%	100.0%
Other grips	f	17	10	27
	f (%)	63.0%	37.0%	100.0%
Total	f	169	77	246
	f (%)	68.7%	31.3%	100.0%

$\chi^2 = 1.443$; $p = .486$

Table 7 shows that more than 70% of the first graders that held a pencil with a dynamic three-finger grip had a correctly positioned writing surface. The same was true for two-thirds of the first graders that held the pencil with a dynamic four-finger grip and for two-thirds of those that held the pencil with other grips. The answer to the research question "Is there a connection between pencil grip when writing and writing surface position?" is no because pencil grip does not affect writing surface position. There are no statistically significant differences between the writing surface position and how the pencil is held ($p > .05$).

Table 8. Comparison of Pencil Grip and Posture

Pencil Grip / Posture		**Correct Posture**	**Incorrect Posture**	**Total**
Dynamic three-finger grip	f	102	33	135
	f (%)	75.6%	24.4%	100.0%
Dynamic four-finger grip	f	51	33	84
	f (%)	60.7%	39.3%	100.0%
Other grips	f	18	9	27
	f (%)	66.7%	33.3%	100.0%
Total	f	171	75	246
	f (%)	69.5%	30.5%	100.0%

$\chi^2 = 5.498$; $p = 0.064$

Two-thirds of the first graders that used a dynamic four-finger grip or other type of pencil grip, and 70% of those that used a dynamic three-finger grip had an appropriate posture while writing. The answer to the eighth research question, "What is the connection between pencil grip and posture when writing?" is that there is no connection between the variables, but it should be emphasized that there is a high probability that the result would have been different with a larger sample. There are no statistically significant differences between posture and grip type or pencil grip during writing ($p > .05$). However, there are tendencies in the responses; namely, that students with a dynamic three-finger grip have the most appropriate or a more appropriate posture than students with a dynamic four-finger grip and with a different pencil grip, but these differences are not statistically significant at the $\alpha = .05$ level of significance. However, it is very likely that statistically significant differences would emerge with an increase in the sample by categories of grips.

Table 9. Comparison of Posture and Writing Surface Position[††]

Posture / Writing surface position		Proper position	Incorrect position	Total
Correct posture	f	119	52	171
	f (%)	69.6%	30.4%	100.0%
Incorrect posture	f	50	25	75
	f (%)	66.7%	33.3%	100.0%
Total	f	169	77	246
	f (%)	68.7%	31.3%	100.0%

$\chi^2 = 0.207$; $p = .649$

Approximately 70% of students that have correct writing surface positions also have correct posture. About 67% of the students that have poor posture also have correct writing surface position. The answer to the ninth research question, "What is the connection between posture and writing surface position?" is that there is no connection between posture and writing surface position. The results of the chi-squared test showed that there were no statistically significant differences between writing surface position and incorrect posture ($p > .05$).

Posture and Seating in Connection to the Ergonomic Suitability of Furniture

The last set of results contains two tables. They show the connection between posture and appropriate table and chair height (RQ 10) and between furniture size and manner of sitting (RQ 11).

Table 10. Comparison of Posture and Suitability of Furniture

Posture / Furniture		Correct size	Wrong size	Total
Correct posture	f	115	56	171
	f (%)	67.3%	32.7%	100.0%
Incorrect posture	f	48	27	75
	f (%)	64.0%	36.0%	100.0%
Total	f	163	83	246
	f (%)	66.3%	33.7%	100.0%

$\chi^2 = 0.247$; $p = .620$

Table 10 shows that a third of all first graders (33.7%) were sitting in an inappropriately high chair or at an inappropriately high table. Less than a third of first graders (32.7%) that had appropriate posture did not have furniture of the appropriate size. There were about 3% more students (36%) with inadequate posture and furniture of inadequate size. It is surprising that 64% of the students who had adequate furniture had inadequate posture when writing. The answer to the tenth research question, "What is the connection between posture and appropriate table and chair height?" is that there is no connection between posture and the appropriateness of the furniture. A chi-squared test between appropriate furniture size and appropriate and inappropriate posture did not show statistically significant differences ($p > .05$).

Table 11. Comparison of Furniture Size and Suitability of Seating

Furniture / Sitting		Correct sitting	Incorrect sitting	Total
Correct size	f	93	70	163
	f (%)	57.1%	42.9%	100.0%
Wrong size	f	15	68	83
	f (%)	18.1%	81.9%	100.0%
Total	f	108	138	246
	f (%)	43.9%	56.1%	100.0%

$\chi^2 = 33.935$; $p = .000$

More than half of the first graders (about 57%) had appropriately high furniture (chair and table) and sat properly. The majority of the students (about 82%) that had inappropriately sized furniture also sat inappropriately. In answering the eleventh research question, "Is there a connection between furniture size and how people sit?" the chi-squared test

[††] Appropriate positioning refers to the appropriate distance of the surface from the bottom edge of the table and a position that does not cause the student to lean to the left or right while writing.

showed that there were statistically significant differences ($p < .05$) between adequate and inadequate furniture and sitting posture. Cramér's coefficient showed a medium or moderate effect size (.37).

Discussion

Writing is a complex process and makes an important contribution to holistic learning (Rot Vrhovec, 2020). Writing difficulties overshadow a child's abilities in other areas. Children's performance also depends on their handwriting skills, which are influenced by other skills, such as gross motor skills and fine motor control (Sheedy et al., 2021). Although we are living in a digital age and the use of computers is increasing, legibility of handwriting remains an important life skill (Feder & Meynemer, 2007). Several studies show that preschool and school-aged children have poorly developed motor skills (Hwang et al., 2024; Shah et al., 2022; Sheedy et al., 2021), which are necessary for handwriting development. Teachers are seeing increasing difficulties in children's pencil grip and problems with pain when writing for long periods of time, independent of other learning difficulties (Lager Deudon, 2020). Between 10% and 30% of school-aged children have handwriting problems (Feder & Meynemer, 2007). Handwriting skills require a physiological maturity that most children attain between ages six and seven (Rot Vrhovec, 2020). It is important that the beginner learn from the start to write sparingly and fluently with a relaxed pencil grip (Sattler, 2011). It is also important to remember that it is difficult to change an ineffective pencil grip once the child has developed one (Cigole & Merc, 2017; Yakubova, 2005). To possibly prevent or at least alleviate problems, it is worth paying attention to the development of individual handwriting skills in time; that is, already in the preschool period (Grginič, 2005). Individual needs must be taken into account (Kavak & Bumin, 2009). This assertion is also supported by the results of this research, which examined the development of first graders' basic pre-literacy skills at the beginning of the school year. It was found that 11% of children have an immature grip on the pencil when they start formal literacy learning. Among them, there are 2% more boys than girls. In contrast to a study by Odokuma and Ojigho (2019), which was conducted with children of the same age but with a smaller sample, the differences between the sexes in this study were not statistically significant. The results of this research agree with a number of studies (Graham et al., 2008; Koziatek & Powell, 2003; Lager Deudon, 2020; Odokuma & Ojigho, 2019; Ojigho & Odokuma, 2019; Schwellnus, 2012; Shah et al., 2022; Temur, 2011) that showed that the dynamic three-finger grip is the most common grip among students. The results obtained in this study confirm the claim by Adolph and Robinson (2015) that the right hand is preferred by many children (90.7%). Although no difference was found between handedness and pencil grip, it cannot be said that there is no difference between left-handers and right-handers. It has been shown that they hold pencils differently or write at a different angle, generally related to the pressure of the pencil on the surface (Miéville et al., 2024), but this was not the subject of this research.

The results of the research show that, despite having a mature pencil grip, a small percentage of children do not position the pencil correctly (3%) or do not grip it at the correct height (3%). Due to the effect of posture, the pencil is pressed too hard or too lightly on the writing surface, which affects the mobility and stability of the palm, and consequently inhibits writing, and students become tired quickly (Žerdin, 2000). The student's grip on the pencil must always be comfortable and energy efficient. However, if this is not the case and the child complains of a painful or tired hand when writing, it is reasonable to look for the causes of the problems and help the child correct his or her grip.

A focused approach can also improve control of posture (Schoemaker et al., 2003), which is necessary not only for effective writing but also for maintaining good health (Li et al., 2022). The research did not prove a statistical connection between grip and posture, but the results showed a high probability that the dynamic three-finger grip had the best effect on posture. It has been suggested that left-handed children need special attention (Department for Education 2013; Sattler, 2011). This is also confirmed by this study; namely, that left-handed children need help setting up the writing surface. The finding that 15% of first graders have an inappropriate distance between their eyes and the writing surface when writing should also be highlighted. According to a study by Shi et al. (2021), such children are 11 times more likely to be visually impaired. One-third of the students that did not have correct posture also did not have the writing surface correctly positioned. The connection between the variables was not statistically significant, but students need to be made aware that it is not enough to prepare the writing surface properly before starting to write: they also need to be taught to move and adapt the writing surface as they write. When moving toward the bottom of the sheet, it should be further from the body and closer to the top of the desk, and vice versa.

Students should be provided with conditions for healthy development and work at school. This research showed that this was not the case for almost a third (31%) of the students that took part in this study. Table and chair size affected how they sat.[##] The teachers involved in the research noticed that children with ergonomically inadequate furniture crossed their legs or wrapped them around the furniture when sitting, and some of them sat on one or both legs. The reason for this may be that the ergonomics of the chairs are not adapted to the individual. It is tiring to sit with one's feet in the air, and it is difficult to remain in such a position and even more difficult to write in a relaxed manner. If a child's legs do not reach the floor when sitting, he or she will find a position that supports the legs. There is no point in encouraging children to sit correctly if the furniture is not ergonomically correct because the students will not remain in

[##] The standard sizes according to ISO (International Organisation for Standardisation) are: for a height of 128-142 cm, the height of the table/chair is 58/34 cm, and for a height of 143-157 cm, 64/38 cm.

the correct position for long. Teachers and school management are responsible for creating appropriate conditions in preschools and schools, and parents are responsible for this at home.

The results of this research indicate that preschool children have different opportunities to develop basic pre-writing skills. One possible interpretation is that preschool children are not properly guided or incentivized to develop skills. The Slovenian preschool curriculum is one of the more open and flexible preschool curricula, which determines the basic principles and desired goals of preschool education, but it does not prescribe specific (operational) goals, methods, and content of activities in preschools (Baloh, 2018). It is not known whether educators carry out the necessary activities for developing basic skills often enough, monitor their development, and provide individual guidance, but the results show that more attention is needed. The curriculum advocates the non-directive role of educators that try to follow children's wishes and interests and offer them activities that they can choose from, but adults must take responsibility for development, even if this does not always coincide with children's wishes. It is useful to consider writing down more concrete goals or teaching recommendations to make educators and teachers aware of the importance of timely promotion and management of the development of basic pre-writing skills and an individualized approach, timely detection of potential problems, and timely appropriate responses. Parental involvement is essential in developing basic pre-writing skills.

In summary, the results of the research show that there is a need to change practice in the pre-school and first grade. Educators and teachers need to use different games and activities to ensure the development of children's fine motor skills. In kindergarten, children need to be gently and playfully encouraged to develop an effective grip on a pencil, to prepare the writing surface properly and to sit correctly. The needs of right-handed and left-handed children should be taken into account. Educators and teachers can use puppets, pictures and videos to increase motivation and effectiveness. The results are a reminder that children need to be provided with the right conditions for drawing/writing. Depending on their height, they should be provided with appropriately high chairs and tables. It is important that educators and teachers talk with children about the preparation for drawing/writing, make them aware of it, monitor the development, point out irregularities and help children to mitigate or eliminate potential problems. The main aim should be to develop the child's self-control and healthy habits. For curriculum planners, the results of the research are a warning that the development of writing preparation should be included among the goals of the curriculum, and its elements should be described in more detail in didactic recommendations (for right- and left-handed children). Since correct posture and sitting are related to an individual's health, it is important that policy makers ensure sufficient funding for appropriate equipment.

Conclusion

Handwriting is an important motor skill, and any obstacle can reduce its effectiveness. Children need to be prepared for writing in time to develop legible handwriting, fluency, and persistence, to be motivated to write, and to be able to focus on content rather than basic motor skills during early literacy. Writing is usually performed in a static sitting position, which is not good for people's health, and so particular attention should be paid to preventing health problems when developing basic pre-writing skills. The period from entering first grade to beginning literacy is about four months in the first grade of Slovenian schools, which is too short to start developing basic pre-writing skills or to change bad habits. For this reason, it is important that children already develop these skills in a planned, continuous, individualized, and relaxed environment in the preschool period. The results of this research contribute to the development of children's writing, especially in the preschool period and at the beginning of education. They may be useful to all those involved in educating young children, especially preschool and first-grade teachers, parents, and school administrators, as well as planners of teaching recommendations, preschool curricula, and primary school language curricula.

Recommendations

Based on the research results, further research could investigate the connection between pencil grip, ergonomic factors, handwriting legibility, and writing speed in first graders. This research can be extended to all of Slovenia or include more first graders or older students. The same research approach could also be applied in other countries. Results from several countries could be compared, and reasons for possible discrepancies could be identified. It is suggested that action research be carried out among 5- and 6-year-olds in preschools and in first and second grade. After an initial assessment, group and individual activities could be planned and, after a certain period of time, the effects of the activities could be checked.

Limitations

This research was carried out in 14% of the first-grade classes of public primary schools in Ljubljana. The survey could have included more first graders from Ljubljana to make the sample even more representative. Despite the precise instructions given to teachers for observing the students, it is possible that the teachers' assessment was subjective. The objectivity of the results would be further improved if the observation were carried out by the same person in all classes participating in the research. While furniture suitability was assessed, more precise measurements of desk and chair heights relative to each child's anthropometrics could provide valuable data on ergonomic fit.

Ethics Statements

The research, which included first-grade students, was reviewed and verbally approved by school administrators. Only students whose parents signed the consent form were included in the research. (At the beginning of the school year, parents review and sign several consent forms. One of these is the consent form for children to participate in research.)

Acknowledgements

The author would like to thank all the participants in the research, as well as the school management and the parents that provided their consent and made the research possible.

References

Adamič, M. (1992). Razvitost relevantnih sposobnosti učencev za začetno pisanje in branje [Developing students' relevant skills for initial reading and writing]. In A. Kozinc (Ed.), *Sodobne oblike opismenjevanja* (pp. 21–24). Zavod Republike Slovenije za Šolstvo in Šport.

Adolph, K. E., & Robinson, S. R. (2015). Motor development. In R. M. Lerner and L. Liben & U. Mueller (Eds.), *Handbook of child psychology and developmental science*, vol. 2: Cognitive processes (7th ed., pp. 114–157). Wiley.

Akselrud, R. (2004). The effect of pencil grips on handwritting and tripod grasp in children with learning disabilities (Publication No. EP14497) [Doctoral dissertation, Touro College]. Touro College ProQuest Dissertations & Theses. https://t.ly/jSzVy

Andoljšek, I. (1976). *Osnove didaktike* [Basics of didactics]. Dopisna Delavska Univerza Univerzum v Ljubljani.

Arrona, A., Vinodhkumar, R., & Manikumar, M. (2023). Correlation between hand tripod Pinch grip and handwriting quality impact on academic performance- a narrative review. *Journal of Advanced Zoology, 44*(3), 1242–1246. https://doi.org/10.17762/jaz.v44i3.1660

Baloh, B. (2018). Raba IKT pri spodbujanju sporazumevalne zmožnosti v predšolskem in zgodnjem šolskem obdobju [Use of ICT in promoting communicative capacity in preschool and early school years]. In S. Čotar Konrad & T. Štemberger (Eds.), *Strokovne podlage za didaktično uporabo informacijsko-komunikacijske tehnologije in priporočila za opremljenost šol* (pp. 77–91). Založba Univerze na Primorskem.

Battestin, J. (2019). *Osnove grafologije* [Basics of graphology]. Ara Založba.

Chau, T., Ji, J. P., Tam, C., & Schwellnus, H. (2006). A novel instrument for quantifying grip activity during handwriting. *Archives of Physical Medicine and Rehabilitation, 87*(11), 1542–1547. https://doi.org/10.1016/j.apmr.2006.08.328

Cigole, P., & Merc, K. (2017). *Vpliv načela postopnosti na razvoj grafomotorike* [The effect or the principle of gradunality on the development of graphomotorics]. Univerza v Mariboru, Pedagoška Fakulteta. https://bit.ly/3Sx87VY

Department for Education. (2013). *The national curriculum in England.* https://bit.ly/3ynQn8C

Department of Education. (2022). *Literacy teaching toolkit for early childhood. Fine motor.* Victoria State Government. https://bit.ly/3A6dl4G

Expert Council of the Republic of Slovenia for General Education. (1999). *Kurikulum za vrtce* [Preschools curriculum]. https://t.ly/Ll_hn

Feder, K. P., & Meynemer, A. (2007). Handwriting development, competency, and intervention. *Developmental Medicine & Child Neurology, 49*(4), 312–317. https://doi.org/10.1111/j.1469-8749.2007.00312.x

Feldman, A., & Fiedler, D. (2001). *The relationship between pencil grasp pattern, pinch strength, and the use of a pencil grip on handwriting legibility in first-grade children* (Publication No. EP14626) [Doctoral dissertation, Touro College]. Touro College ProQuest Dissertations & Theses.

Gamser, A. (2011). Strategije in oblike pomoči učencem z dispraksijo [Strategies and forms of support for students with dyspraxia]. In M. Košak, M. Babuder & M. Velikonja (Eds.), *Učenci z učnimi težavami – Pomoč in podpora* (pp. 8–42). Pedagoška Fakulteta Univerze v Ljubljani.

Graham, S., Harris, K. R., Mason, L., Fink-Chorzempa, B., Moran, S., & Saddler, B. (2008). How do primary grade teachers teach handwriting? A national survey. *Reading and Writing, 21*(1), 49–69. https://doi.org/10.1007/s11145-007-9064-z

Grginič, M. (2005). *Porajajoča se pismenost* [Emerging literacy]. Izolit.

Hwang, Y. S., Hsiao, Y. L., Su, P. F., Hung, J. Y., & Tsai, W. H. (2024). Kindergarten visual-perceptual and motor skills and behavioral traits predict first-grade Chinese handwriting legibility and speed. *American Journal Occupational Therapy, 78*(1), Article 7801205170. https://doi.org/10.5014/ajot.2024.050425

Jamnik, T., Ciber Gruden, J., Gombec, S., Rot Vrhovec, A., Manfreda Kolar, V., Hergan, I., & Pesek, A. (2009). *Priročnik Mladinske knjige Založbe za učitelje v 1. razredu osnovne šole* [Handbook of the Youth Book Publishing House for teachers of the 1st grade]. Mladinska Knjiga Založba.

Kavak, S. T., & Bumin, G. (2009). The effects of pencil grip posture and different desk designs on handwriting performance in children with hemiplegic cerebral palsy. *Jornal de Pediatria, 85*(4), 346–352. https://doi.org/10.2223/JPED.1914

Kavkler, M. (2011). Konceptualne osnove obravnave učencev z učnimi težavami [Conceptual bases for the treatment of students with learning difficulties]. In M. Košak, M. Babuder & M. Velikonja (Eds.), *Učenci z učnimi težavami – Pomoč in podpora* (pp. 8–42). Pedagoška Fakulteta Univerze v Ljubljani.

Koziatek, S. M., & Powell, N. J. (2003). Pencil grips, legibility, and speed of fourth-graders' writing in cursive. *American Journal Occupational Therapy, 57*(3), 284-288. https://doi.org/10.5014/ajot.57.3.284

Lager Deudon, C. (2020). What are the influences when using a tool for script writing and the position of the hand as the writing gesture? Studies on the graphic gesture are carried out at the end of the preparatory course. *Motricité Cérébrale, 41*(3–4), 82–92. https://doi.org/10.1016/j.motcer.2020.03.003

Li, C., Zhao, Y., Yu, Z., Zhenghui, Y., Xu, H., Xiang, L., & Li, W. (2022). Sagittal imbalance of the spine is associated with poor sitting posture among primary and secondary school students in China: a cross-sectional study. *BMC Musculoskeletal Disorders, 23*, Article 98. https://doi.org/10.1186/s12891-022-05021-5

Lipičnik, K. (2011). Pravilno sedenje pri pisanju [Writing in the correct position]. In C. Marquardt, J. B. Sattler, K. Lipičnik & R. Reitmeier (Eds.), *Kako se naučiti pisati! Gradivo za poučevanje pisanja, 4. poglavje* (pp. 1–8). Vesper.

Marjanovič Umek, L., & Zupančič, M. (Eds.). (2020). *Razvojna psihologija, 2. zvezek* [Developmental psychology, Volume 2]. Filozofska Fakulteta.

Marquardt, C. (2011a). Gibi pri pisanju [Gestures when writing]. In C. Marquardt, J. B. Sattler, K. Lipičnik & R. Reitmeier (Eds.), *Kako se naučiti pisati! Gradivo za poučevanje pisanja, 2. poglavje* (pp. 1–20). Vesper.

Marquardt, C. (2011b). Težave pri pisanju z vidika sodobne znanosti [Writing problems from the perspective of modern science]. In C. Marquardt, J. B. Sattler, K. Lipičnik & R. Reitmeier (Eds.), *Kako se naučiti pisati! Gradivo za poučevanje pisanja, 1. poglavje* (pp. 1–8). Vesper.

Miéville, R., Marquis, R., & Mazzella, W. (2024). Discrimination between right- and left-handed writers based on sister lines. *Journal of Forensic Sciences, 69*(3), 959–965. https://doi.org/10.1111/1556-4029.15489

Ministry of Education, Science and Sport. (2018). *Program osnovna šola. Slovenščina. Učni načrt.* [Primary school programme. Slovene. Curriculum.]. https://t.ly/7Kb0b

Odokuma, I. E., & Ojigho, E. J. (2019). Pencil grip patterns among pupils. *Sahel Medical Journal, 22*(3), 121–126. https://doi.org/10.4103/smj.smj_75_17

Ojigho, E. J., & Odokuma, I. E. (2019). Pencil grip patterns of students and skilled workers. *Journal of College of Medical Sciences-Nepal, 15*(1), 53–58. https://doi.org/10.3126/jcmsn.v15i1.19286

Papalia, E. D., Olds, S., Feldman, R., & Kruk, R. (2003). *A child's world: infancy through adolescence.* Educy.

Regvar, B. (1990). *Malček in pisava* [A toddler and a font]. Samozaložba.

Ropič, M., Urbančič Jelovšek, M., & Frančeškin, J. (2003). *Danes rišem, jutri pišem. Priročnik za učitelje in vzgojitelje v 1. razredu devetletne osnovne šole* [Today I draw, tomorrow I write. Handbook for teachers and educators in the first class of a nine-year primary school]. Rokus.

Rot Vrhovec, A. (2020). *Poučevanje učencev, katerih prvi jezik ni slovenski* [Teaching students whose first language is not Slovenian]. Pedagoška Fakulteta Univerze v Ljubljani.

Sasada, S. (2016). The characteristics of the pencil grip of 6–7-year-old children in Japan. *Asian Journal Occupational Therapy, 12*(1), 37–41. https://doi.org/10.11596/asiajot.12.37

Sattler, J. B. (2011). Levičarji [Left-handeds]. In C. Marquardt, J. B. Sattler, K. Lipičnik & R. Reitmeier (Eds.), *Kako se naučiti pisati! Gradivo za poučevanje pisanja, 3. poglavje* (pp. 1–8). Vesper.

Schoemaker, M. M., Niemeijer, A. S., Reynders, K., & Smits-Engelsman, B. C. M. (2003). Effectiveness of neuromotor task training for children with developmental coordination. *Neural Plasticity, 10*(1–2), 155–163. https://doi.org/10.1155/NP.2003.155

Schwellnus, H. D. (2012). *Pencil grip pattern: how critical is it to functional handwritting*. University of Toronto. https://bit.ly/46vBWvF

Schwellnus, H., Carnahan, H., Kushki, A., Polatajko, H., Missiuna, C., & Chau, T. (2013). Writing forces associated with four pencil grasp patterns in grade 4 children. *The American Journal of Occupational Therapy, 67*(2), 218–227. https://doi.org/10.5014/ajot.2013.005538

Selin, A. S. (2003). *Pencil grip: A descriptive model and four empirical studies.* Åbo Akademi University Press.

Shah, M., Shah, S., & Ved, V. (2022). A study to evaluate pencil grip type, hand functions - Dexterity & grip strength in children using tech for 2 or more hours a day. *International Journal of Health Sciences and Research, 12*(3), 274–284. https://doi.org/10.52403/ijhsr.20220339

Sheedy, A. J., Brent, J., Dally, K., Ray, K., & Lane, A. E. (2021). Handwriting readiness among digital native kindergarten students. *Physical & Occupational Therapy in Pediatrics, 41*(6), 655-669. https://doi.org/10.1080/01942638.2021.1912247

Shi, H., Fu, J., Liu, X., Wang, Y., Yong, X., Jiang, L., Ma, S., Yin, Z., Yao, J., Yao, X., Chen, X., & Wang, T. (2021). Influence of the interaction between parental myopia and poor eye habits when reading and writing and poor reading posture on prevalence of myopia in school students in Urumqi, China. *BMC Ophthalmology, 21*(1), Article 299. https://doi.org/10.1186/s12886-021-02058-3

Smits-Engelsman, B. C. M., Niemeijer, A. S., & van Galen, G. P. (2001). Fine motor deficiencies in children diagnosed as DCD based on poor grapho-motor ability. *Human Movement Science 20*(1–2), 161–182. https://doi.org/10.1016/S0167-9457(01)00033-1

Temur, T. (2011). Description of primary education 1st grade students' forms of holding a pencil as well as their grip and compression strengths. *Educational Sciences: Theory & Practice, 11*(4), 2199–2205.

Tseng, M. H. (1998). Development of pencil grip position in preschool children. *The Occupational Therapy Journal of Research, 18*(4), 207–224. https://doi.org/10.1177/153944929801800406

Tuckett, J. (2006). *An audit of typical pencil grasp in a nursery/reception class.* NHA and the Institute of Education University. https://bit.ly/4drWG9R

Wart Platt, M. (2006). *The wonder years: The essential guide to child development for ages 0–5*. MPH Group Pub.

Yakubova, L. (2005). *The effect of pencil grip on handwriting legibility of the first and second grade students* (Publication No. 1468458) [Doctoral dissertation, Touro College]. Touro College ProQuest Dissertations & Theses.

Žerdin, T. (2000). Grafomotorika kot sestavni del pisanja [Graphomotor skills as an integral part of writing]. In A. Kozinc (Ed.), *Slovenščina v 1. triletju devetletne osnovne šole, 1. del* (pp. 69–79). Izolit.

Žerdin, T. (2003). *Motnje v razvoju jezika, branja in pisanja: kako jih odkrivamo in odpravljamo* [Disabilities in the development of language, reading and writing: How we detect and correct them]. The Counselling Centre for Children, Adolescents and Parents Ljubljana, The Bravo Society.

Ziviani, J., & Elkins, J. (2006). Effect of pencil grip on handwriting speed and legibility. *Educational Review, 38*(3), 247–257. https://doi.org/10.1080/0013191860380305

Zrimšek, N. (2003). *Začetno opismenjevanje. Pismenost v predšolski dobi in prvem razredu devetletne osnovne šole* [Beginning literacy. Literacy in pre-primary and the first year of primary education]. Pedagoška Fakulteta Ljubljana.