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A Discussion of the Causes and Effects of Wrong Pen Grip Posture Based on Mechanical Analysis

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Abstract. Wrong pen grip posture accounts for a very large proportion of pen grip posture in adults. In order to scientifically explore the problem of wrong pen grip posture in adults, this paper takes a certain number of college students as the research object and investigates their pen grip posture. Then, the paper points out several typical wrong pen grip postures and makes a mechanical analysis of the correct pen grip posture. In addition, considering the relatively weak finger strength of most children, the paper focuses on analysing the causes of wrong pen grip postures in adults from the root, and discusses the possible effects of wrong pen grip postures in various aspects. Finally, these analyses are used to raise awareness of the pen grip posture and help educators to change the traditional educational approach in pen grip posture.

Keywords. Mechanical analysis; Pen grip; Causes; Effects

1. Introduction

Wrong Pen Grip Posture is a common problem among adults and accounts for a significant proportion of the population. In order to explore this problem in depth, this paper selected *500* observation samples of male and female college students from all over the country, and counted their pen-holding postures when they hold pens and write. The results show that male students accounted for *42.3%* of male students' pen-holding errors, and female students accounted for *61.3%* of female students' pen-holding errors. Together, they accounted for *51.8 %* of the total number of boys and girls. The ratio of error rate between boys and girls was about *7:10*. In addition, most of the students with wrong pen grip posture tilted the paper severely during writing, accompanied by incorrect body postures such as excessive bending of the back, eyes too close to the desktop, and the body leaning close to the edge of the desktop. Therefore, the problem of pen grip posture should be paid attention to and studied.

After searching the literature, it was found that there have been studies related to the problem of pen grip posture. These studies mainly started from different stages, including the early childhood stage and the primary and secondary school stage. Gregory S B and Jiang Junli's study, addressing the early childhood stage, showed the impact of developing a correct pen grip posture on young children's writing ability and healthy

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development [1-2]. For the primary school phase, a study by Graham, S et al. analysed the current situation of pen grip posture among primary school students and proposed corresponding countermeasures [3-7]. In addition, Zhao Baojun investigated the problem of pen grip posture from the overall stage of primary and secondary school and found that the error rate of pen grip posture at this stage was as high as *73%*, and revealed the irreversible effects of poor pen grip posture on primary and secondary school students' academics and their physical and mental health [8]. However, these studies lacked convincing causal analyses, did not provide in-depth traceability of the wrong pen grip posture, and did not analyse the pen grip posture from a mechanical perspective.

Therefore, this paper will focus on two aspects, firstly to survey the pen grip posture, then to conduct a mechanical analysis, based on the results obtained to trace back and identify the causes, as well as to explore the adverse effects of wrong pen grip posture. The scientific significance of this study is to provide a better understanding of the causes of incorrect pen grip posture and to draw attention to the early stages of children's pen grip and writing, so as to effectively reduce the proportion of people with incorrect pen grip posture. At the same time, this study can also help to change the traditional educational methods and management modes of educators and parents.

2. Correct and Wrong Pen Grip Posture

2.1. Correct Basic Pen Grip Posture

Through a review and analysis of the literature [9-10], the basic correct pen grip posture was identified as shown in Figure 1.

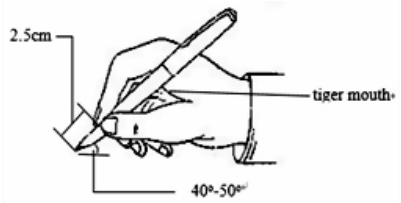

Figure 1. Correct posture of holding a pen

(1) Sitting in an upright position. First, the head should be erect and naturally relaxed forward, with the eyes about *30 cm - 40 cm* from the writing desk. Keep your shoulders flat and slightly tilted forward, with your chest about the size of your own fist from the desk, your left hand pressing the paper and your right hand holding the pen at a certain distance, and your whole body naturally relaxed.

(2) The pen is placed between the tips of the thumb, index finger, and middle finger, with the index finger positioned a little lower than the thumb and the pen tip at a distance of *2.33 cm* to *2.67 cm* from the tip of the finger. The writing paper is held at an angle of approximately *40* to *50* degrees to the barrel of the pen, with the knuckles slightly bent.

2.2. Typical Wrong Pen Grip Posture

The wrong pen grip posture can actually be broken down into *12* types, but there are four typical ones [11]. The first is the index finger over the thumb (Buried Type). As shown in Figure 2(*a*), this is one of the more typical wrong pen grip postures where the thumb

is hidden behind the index finger. The second type is the thumb button index finger (Horizontal hitch Type). The second type is thumb over forefinger (horizontal hitch type). This type of pen grip posture is mostly seen in girls, writing too hard, slow and easily fatigued, as in Figure 2(*b*). The third type is the thumb clasping both the middle finger and the index finger. This type of pen grip posture involves holding the ring finger against the barrel of the pen, with the middle finger, index finger and thumb holding the pen at the same time, as in Figure 2(*c*). The fourth type is thumb bending (Twisted Type). This type of pen grip posture involves twisting the thumb and holding the index finger against the barrel of the pen, as in Figure 2(*d*).

(*a*) (*b*) (*c*) (*d*)

Figure 2. Typical wrong pen grip posture

Typical types of errors in pen grip posture are usually shown as fisting, where the fingers are closed towards the palm of the hand to approximate the shape of a clenched fist. Three of the common errors are to carry the pen by placing the thumb directly across the index finger and pressing against it, as shown in Figures 2(*a*), (*b*), and (*c*). Another more common error is for the tip of the thumb and the tip of the index finger to be in only slight contact and for both to be at roughly the same height, as shown in Figure 2(*d*). A typical wrong pen grip posture is also characterized by an angle between the pen barrel and the paper surface greater than *45°*, and in some cases as high as *80°* or close to *90°*.

To investigate the causes of adolescents' incorrect pen grip posture, it is first necessary to analyze the mechanics of pen grip posture.

3. Mechanical Analysis of the Pen Grip Posture

Grip mainly by the thumb, middle finger, forefinger and tiger's mouth in four places of the force clamping stable pen, while relying on these places, especially the thumb, middle finger and forefinger on the pen positive pressure on the surface of the pen to produce downward push (downward pressure) friction, and the paper surface of the pen upward force N balance, such as Figure 3 and Figure 4, Figure 3 is the lateral view of the pen, Figure 4 is the longitudinal view of the pen grip.

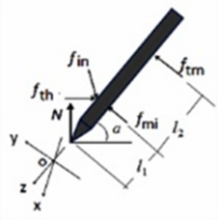

Figure 3. Lateral view of correct writing grip

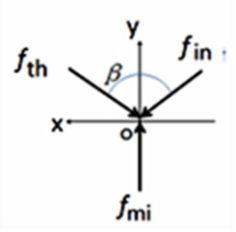

Figure 4. Longitudinal view of correct writing grip

Viewing along the longitudinal direction of the pen shaft, i.e., the z direction, according to Figure 3, the thumb and forefinger are separated by a certain angle to act on the pen shaft, so that the pen shaft is balanced in the x direction. Let f_{th} be the positive

pressure of the thumb on the pen barrel, f_{in} be the positive pressure of the index finger on the pen barrel, f_{mi} be the positive pressure of the back of the middle finger on the pen barrel, f_{tm} be the positive pressure of the palm of the hand tiger's mouth on the pen barrel, and N be the upward pressure of the paper on the pen barrel. μ be the friction coefficient of the skin of the hand and the pen barrel.

According to the diagram of forces in Figure 4, the angle between the thumb, index finger and middle finger in the direction of the force on the barrel of the pen when viewed in the direction of the barrel is roughly $\beta = 120°$. Thus, from Figures 3 and 4 and with reference to the coordinates o-xzy the following relationship is established:

x Direction:

$$(f_{th} - f_{in})\, sin(\beta/2) = 0 \tag{1}$$

y Direction:

$$f_{tm} + f_{mi} + Ncos\alpha - (f_{th} + f_{in})\, cos(\beta/2) = 0 \tag{2}$$

z Direction:

$$\mu(f_{tm} + f_{mi} + f_{th} + f_{in}) = N\, sin\alpha \tag{3}$$

Using the point of contact between the middle finger and the pen as the pivot point, derive the moment around the x-direction:

$$l_1 N cos\alpha - l_2 f_{\mathrm{tm}} = 0 \tag{4}$$

$$f_{\mathrm{th}} = f_{in} = \frac{N}{3}\left(\frac{1}{\mu}\sin\alpha + \cos\alpha\right) \tag{5}$$

$$f_{\mathrm{tm}} = \frac{l_1}{l_2} N\cos\alpha \tag{6}$$

$$f_{\mathrm{mi}} = \frac{N}{\mu}\sin\alpha - \frac{2N}{3}\left(\frac{1}{\mu}\sin\alpha + \cos\alpha\right) + \frac{l_1}{l_2} N\cos\alpha \tag{7}$$

It is worth pointing out that the size of the positive pressure of the pen on the paper is equal to the size of the paper on the pen's support force N. The method of measurement is as follows: lay a piece of paper on top of the flat electronic scale, use a sharpened pencil to write on top of the paper, and the handwriting should be obvious, and then it is clear that the display screen shows the value of the positive pressure of the paper by the pencil, as shown in Figure 5. Using this method of multiple measurements, the average positive pressure value obtained is $0.1 \pm 0.02\ Kg$, taking $N = 0.1\ Kg$.

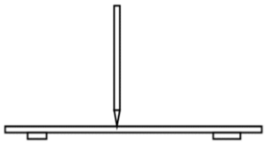

Figure 5. Writing with a pen on paper on a flat weighing surface

The coefficient of friction μ between the pen and the hand can be measured in this way: in the plane of the electronic scale on the surface of a layer of lubricating oil, and then flat put an ordinary pencil, with a finger on top of the pencil held down by the pencil rod, the end of the pencil with a spring loaded force gauge traction. At this time, slowly reduce the finger pressure on the pen until the pencil will appear to slide, record the spring force gauge readings and electronic scale readings, before and after the ratio of the two that is the coefficient of friction μ. The actual results of the measurement for the $\mu = 0.2 \pm 0.03$, take $\mu = 0.2$.

The average inclination of the pen shaft when held correctly is taken as $\alpha = 45°$. The points of force between the pen shaft and the fingers and the palm of the hand at the tiger mouth and the direction of the force are shown in Figure 4. From (1), (2) (3) and (4) and substituting the previously known data, it can be concluded respectively that

Positive pressure of the index finger on the pen: $f_{in} = 0.14$ Kg;

Positive pressure of the thumb finger on the pen: $f_{th} = 0.14$ Kg;

Positive pressure of the tiger mouth on the pen: $f_{tm} = 0.035$ Kg;

Positive pressure of the middle finger on the pen: $f_{mi} = 0.1$ Kg;

For the wrong pen grip posture, the angle between the pencil and the paper is greater than $45°$, and by setting $\alpha = 90°$, then it follows that

Positive pressure of the index finger on the pen: $f_{in} = 0.17$ Kg

Positive pressure of the thumb finger on the pen: $f_{th} = 0.17$ Kg

Positive pressure of the tiger mouth on the pen: $f_{tm} = 0$ Kg

Positive pressure of the middle finger on the pen: $f_{mi} = 0.17$ Kg

The results of the mechanical analyses regarding the pen grip posture show that the force f_{in} of the index finger acting on the pen is equal to the force f_{th} of the thumb acting on the pen and increases with the increase of the angle α between the pen and the paper; similarly, the force f_{mi} of the middle finger acting on the pen also increases with the increase of the angle α between the pen and the paper. For using the correct pen grip posture, the force points of the thumb and index finger received the greatest force and amounted to *0.14 Kg*, while the middle finger, which is used for the middle and back of the finger, received more force than the tip of the thumb and the tip of the middle finger when using the incorrect pen grip posture, amounting to *0.17 Kg*.

4. Causes and Effects of Wrong Pen Grip Posture

In order to gain a more objective understanding of the causes and effects of incorrect pen grip posture, an awareness survey of pen grip posture was conducted using a sample of college students from two universities. There are two reasons for choosing college students as the target: firstly, college students are the representatives of the cultural and intellectual groups in our country, and their pen grip posture is representative to a certain extent; secondly, pen grip posture is a habit developed from childhood, and may be difficult to be changed once it has been formed and adhered to for a long period of time, so the survey on them is equivalent to the survey on the pen grip posture of the youngest children. As education is somewhat uniform, the sample is from all over the country, which is a good representation. The survey covered the age group when they started to write, their judgement on the correctness of pen grip posture, and whether pen grip posture has any effect on their physical development. A total of 300 questionnaires were distributed to the two universities, including 150 questionnaires each for male and female students. All questionnaires were completed independently by the students and returned

on the spot. The results of the survey are shown in Tables 1-5:

Table 1. Age group of starting to write

	6-7 years	5-6 years	4-5 years	3-4 years
Percentage of male student (%)	27.33	25.33	20.00	27.33
Percentage of female students (%)	24.67	28.00	19.33	28.00

Table 2. Subjective judgment of whether one's pen grip is correct or not

	Correct pen grip	Incorrect pen grip	Don't know if the pen grip is correct
Percentage of male student (%)	52.00	14.00	34.00
Percentage of female students (%)	42.67	29.33	28.00

Table 3. Perception of the relationship between pen grip and visual acuity

	Thought to be related to myopia	Not thought to be related to myopia	Don't know if it's related to myopia
Percentage of male student (%)	36.00	48.67	15.33
Percentage of female students (%)	34.67	49.33	16.00

Table 4. Perceptions of pen grip and writing quality

	Consider that the relevant	Considered irrelevant	Don't know if it's relevant
Percentage of male student (%)	72.00	18.67	9.33
Percentage of female students (%)	74.00	18.00	8.00

Table 5. Perceptions of pen grip and physical health

	Considered not to affect t	Considered to affect	Don't know if it will affect
Percentage of male student (%)	26.33	44.67	30.00
Percentage of female students (%)	26.00	38.67	35.33

4.1. Causes of Wrong Pen Grip Posture

At present, the phenomenon of early education is common which causes a larger percentage of the number of people with wrong pen grip posture. From Table 1, it can be seen that *27.33 %* of boys and *28 %* of girls in the age group of *3-4* years have started writing, indicating that about *1/3* of the young children have already started writing at the request of their parents. Combined with the results of the previous mechanical analyses on the correct pen grip posture, it is clear that the magnitude of the force at all the force points is the largest for the thumb and index finger, which amounts to *0.14 Kg*.

However, physiologically, the muscles of the fingers of young children in this period are not yet fully developed and the strength of the front ends of the fingers is weak. For a significant number of children, it is difficult for the tips of their fingers to withstand a force of *0.14 Kg* for a long period of time. Teachers usually ask children of this age to use pencils, which require more downward pressure than water-based pens for legible writing. If teachers or parents require children to write legibly and for long periods of time, then in order to obtain sufficient positive pressure on the pen, children with low finger strength will have to adopt a fisted pen grip posture that leads the fingers into the

palm of the hand, which consists of carrying the pen with the thumb directly across the forefinger, pressing it against the forefinger, as shown in Figure 2, because only in this way will there be enough force to grip the pen. At this point, the power point has shifted from the front of the thumb and the front of the index finger to the middle or even the back of the thumb and index finger. Obviously, the middle or back of the finger is much stronger than the front of the finger. Girls are much weaker than boys when it comes to finger strength comparisons, so there will be more girls using the wrong pen grip posture.

In Table 2, *52.00 %* of the male students and *42.67 %* of the female students believed that their pen grip posture was correct, *14.00 %* of the male students and *29.33 %* of the female students believed that their pen grip posture was incorrect, and *34.00 %* of the male students and *28.00 %* of the female students did not know whether their pen grip posture was correct or not. It was also found in conjunction with the visit that the students who thought their pen grip posture was incorrect had almost all of their actual pen grip postures wrong, while most of the ones who did not know whether their pen grip posture was correct actually had the wrong grip posture as well. These two figures add up to *48.00 %* for boys and *57.33%* for girls. The data in this table confirms that more girls currently have the wrong pen grip posture.

The child is unable to write legibly and maintain a correct pen grip posture at the same time, so he or she has to adopt a wrong pen grip posture. Despite being detected by teachers and parents and their best endeavours to discourage the child from doing so, the child still insists on the wrong posture, so teachers and parents mostly choose to tolerate it in the end. Many teachers and parents have incorrect pen grip posture themselves and do not pay attention to their children's mistakes or otherwise. In addition, many parents place more emphasis on their children's academic tasks than on their pen grip posture. This incorrect pen grip posture eventually becomes habitual and difficult to correct, leading to the above observations and statistical results on the pen grip posture of college students. When these children grow up, it is very difficult to change their pen grip posture, even though many of them realise that it is incorrect and has a negative effect on their writing and posture. It is very difficult to change the pen grip posture because it has been adapted for a long time and changing it will make them feel very uncomfortable and unnatural, and they will feel that they have to exert more effort and produce worse writing. Therefore, this kind of change is almost never successful. So only those children who are strong enough to hold the pen correctly from the time they start learning to write, and who know the right and wrong pen grip posture and have been instructed in it by their teachers and parents, will have a correct pen grip posture and will keep it.

4.2. Effects of Wrong Pen Grip Posture

Writing is a thinking activity that involves the co-ordinated development of vision and movement. For children who are just beginning to learn to write, the co-ordination between vision and movement is emerging. However, for children in kindergarten and the early grades of primary schools, their bones have considerable softness and flexibility. If our writing training starts at a stage where the ossification process has not yet been completed, in the long run, this may lead to the development of a wrong pen grip posture, which in turn may lead to problems such as sloping shoulders, tilting of the head, nearsightedness, and hunchbacked Ness.

For example, if people use the wrong pen grip posture, they may not be able to see the tip of the pen when they sit upright and have to write with their head tilted. This can lead to such phenomena as sitting in a crooked position, bending over and slouching the

shoulders, having the eyes too close to the writing paper, and writing with the workbook placed diagonally, which can lead to problems such as spinal dysplasia, excessive neck fatigue, difference in the height of the left and right shoulders and arms, hunching of the back, crooked necks, myopia, and strabismus. In addition, a wrong pen grip posture where the thumb and forefinger are crossed or the thumb and forefinger do not touch may lead to a higher incidence of myopia. When writing with the thumb and index finger crossed, the eye's view is blocked by the fingers, and it is natural to write with the head lowered or tilted, shortening the distance between the book and the eyes, which increases the rate of myopia and deepens the degree of myopia in the long run [12]. In addition, cervical spine problems may occur due to excessive head-down writing. As the amount of homework increases, many students have cervical spine problems partly due to incorrect writing postures.

Also, for example, pen grip posture is not correct, long-term writing time is too long, do not get used to the rest, then the thumb, index finger and middle finger three fingers have been taut, fatigue and pain. For a long time, the middle finger will be more painful or long callus, or even joint deformation. Also, the standard posture is to be straight back, long straight back, no proper rest, it will naturally bend the spine, which for years and years the spine deformation.

In Table 3, *36.00 %* of boys and *34.67 %* of girls believe that pen grip posture is related to myopia and *48.67 %* of boys and *49.33 %* of girls believe that pen grip posture is not related to myopia. On this issue, both boys' and girls' perceptions are very close, with one-third believing that it is related and one-half believing that it is not. There are many causes of myopia and wrong pen grip posture is one of the causes. In Table 4, *44.67 %* of boys and *38.67 %*t of girls believe that pen grip posture is related to good health, *26.33 %* of boys and *26.00 %* of girls believe that pen grip posture is not related to good health, and *30.00 %* of boys and *35.33 %* of girls are not sure whether pen grip posture is related to good health. In these three categories, the difference between the percentages of boys and girls is not very great. Overall, more thought it was relevant than those who thought it was not. These data are the result of students' personal experience and better illustrate that wrong pen grip posture has an effect on physical health.

Also, requiring children to write too early can cause them to feel burdened by writing, which can lead to boredom, loss of interest in learning, and loss of patience in practising a correct pen grip. Again, children who maintain a posture for too long without proper rest will change their posture, not paying attention to their posture for a long time, not knowing that they need to pay attention to it, and after adapting to it, they gradually convert to an incorrect pen grip posture or even an incorrect sitting posture.

In addition to that, wrong pen grip posture will not be able to write a standard font, the font is too big or too small, the whole body of writing is not easy, and the font is not correct or beautiful [13]. Table 5 shows that *72.00%* of boys and *74.00%* of girls think that pen grip posture is related to the quality of writing, which is very close to each other, and most of them think it is related. At the same time, according to the above analysis of the forces on the correct pen grip posture, it can be known that the correct pen grip posture can carry the pen freely, the writing speed can be flexible, fast or slow, while the wrong pen grip posture affects the speed of carrying the pen [14].

5. Conclusion

This paper firstly reveals that wrong pen grip posture is prevalent among college students,

especially women account for a higher percentage, through a survey of college students' pen grip posture. In order to investigate the causes of this problem, a mechanical analysis of the correct pen grip posture was carried out, which showed that the index finger and thumb were subjected to the greatest pressure and that this increased as the angle between the pen and the paper increased. Combined with the tolerance of children's fingers, it is understood why many children adopt the wrong pen grip posture. In addition, this paper emphasises the adverse effects of wrong pen grip posture on health and quality of writing and it is urged to pay attention to this issue.

In future research, the problem of pen grip posture can be explored in multiple domains, including different age groups and geographic regions, to reveal its differences and associations. In addition, the issue of pen grip posture can also be incorporated into the scope of educational measurement, using specialised measurement tools to quantify the magnitude of forces at various force points when children and adults hold a pen, and to explore the optimal age at which children begin to practise writing as well as the length of time that children of different ages can continue to write with a correct pen grip posture. These findings will provide valuable references for educators and researchers, and will help to promote the further development of research related to pen grip posture.

References

[1] Gregory S B, Karl S R, Sophia L P. Task constraints on preschool children's grip configurations during drawing[J]. Developmental Psychobiology, 2007, 49(2): 216-225.

[2] Jiang Junli. Cultivation strategy of correct pen grip posture of early childhood--Taking the example of early childhood in large class[J]. Jiangsu Early Childhood Education, 2015(02): 82-84. (in Chinese)

[3] Graham, S., Harris, K. R., Mason, L., Fink-Chorizema, B., Moran, S. & Saddler, B. How do primary grade teachers teach handwriting[J]. A national survey. Reading and Writing, 2008, 21, 49-69.

[4] Koziatek, S. M. & Powell, N. J. Pencil grips, legibility, and speed of fourth-graders' writing in cursive[J]. American Journal of Occupational Therapy, 2003, 57(3), 284-288.

[5] Chwellnus, H., Carnahan, H., Kushki, A., Polatajko, H., Missiuna, C., Chau, T. Effect of pencil grasp on the speed and legibility of handwriting after a 10-minute copy task in Grade 4 children[J]. Australian Occupational Therapy Journal, 2012(59): 180-187.

[6] Huang Jinqi. Analysis and Countermeasures on the Present Situation of pen grip posture and sitting posture of primary school students[J]. Western quality education, 2017, 3(20): 227-228. (in Chinese)

[7] Tian Feng. Analysis and countermeasures on the current situation of pen grip posture and sitting posture of primary school students[J]. New Wisdom, 2020(23): 95-96. (in Chinese)

[8] Zhao Baojun. Investigation and research on pen grip posture of primary and secondary school students[J]. Modern Education Science, 2014(12): 147-148. (in Chinese)

[9] Ann-Sofie, S. Pencil Grip: A descriptive model and four empirical studies[M]. Abo Akademi University Press, 2003.

[10] Tang Shujie. Teachers should pay attention to correcting students' pen holding method and writing posture[J]. Research on Educational Practice, 2005, 06: 57-58. (in Chinese)

[11] Schneck, Henderson. Descriptive analysis of the developmental progression of grip position for pencil and crayon control on nondysfunctional children[J]. The American Journal of Occupational Therapy, 1990, 44(10): 893-900.

[12] Wu Yuxiang. A preliminary study on the association between grip strength and pen grip posture and its correlation with myopia in school children[D]. NanChang University, NanChang, 2023. (in Chinese)

[13] Graham, Struck. Dimensions of good and poor handwriting legibility in first and second graders: motor programs, visual-spatial arrangement, and letter formation parameter setting[J]. Development Neuropsychology, 2006, 29(1): 43-60.

[14] Janet, Fatima. Assessment of handwriting speed and factors influencing written output of university students in examinations[J]. Australian Occupational Therapy Journal, 2003, 50: 148-157.