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Title	Analysis of the Role of Handgrip Strength and Pinch Force on Handwriting Speed
Type	Article
URL	https://clok.uclan.ac.uk/id/eprint/56026/
DOI	https://doi.org/10.1007/s42399-025-01948-7
Date	2025
Citation	Pradeep, Gayathri, Naduvil, Sareesh, Abdulla, Gizalla, Benoj, Angela Ann and Fernandes, Vinston Scott (2025) Analysis of the Role of Handgrip Strength and Pinch Force on Handwriting Speed. SN Comprehensive Clinical Medicine, 7 (1). p. 206.
Creators	Pradeep, Gayathri, Naduvil, Sareesh, Abdulla, Gizalla, Benoj, Angela Ann and Fernandes, Vinston Scott

It is advisable to refer to the publisher's version if you intend to cite from the work.
https://doi.org/10.1007/s42399-025-01948-7

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SN Comprehensive Clinical Medicine (2025) 7:206
https://doi.org/10.1007/s42399-025-01948-7

RESEARCH

Analysis of the Role of Handgrip Strength and Pinch Force on Handwriting Speed

Gayathri Pradeep[1] · Gizalla Abdulla[1] · Angela Ann Benoj[1] · Vinston Scott Fernandes[1] · Sareesh Naduvil Narayanan[2,3]

Received: 19 February 2025 / Revised: 10 June 2025 / Accepted: 14 June 2025
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Abstract

Introduction Handwriting is a complex neuromotor skill that involves cognitive and motor processes. Reports demonstrating the relationship between handwriting speed, handgrip strength, and pinch force are scanty. Knowledge of this will help in managing illnesses that impair motor function, such as developmental or neurological disorders. This study was carried out to determine the handgrip strength, pinch force, and handwriting speed in young adults and to understand the relationship between them.

Materials and methods This cross-sectional study was conducted among 127 students (aged 18–22 years) after obtaining their informed consent. Participants' demographic data were collected using a questionnaire. Their handgrip strength and pinch force were measured using a hand dynamometer/pinch gauge (JAMAR, USA). The handwriting speed was determined by calculating the words written per minute. Student's 't' test, one-way ANOVA, and Pearson's correlation tests were performed for data analysis.

Results The mean handwriting speed of participants was significantly different in males and females. Handgrip strength and pinch force were found to be significantly higher in males compared to females. A significant negative correlation was observed between handwriting speed and handgrip strength and/or pinch force. However, these parameters were not found to be significantly different in different BMI groups.

Conclusion The current study demonstrates that handwriting speed was higher in females than in males, but both grip strength and pinch force were higher in males than in females. The grip strength and pinch force had a negative relationship with handwriting speed but BMI did not influence any of the parameters studied in young adults. These results emphasise the significance of fine motor skills over muscle strength in handwriting effectiveness, stressing the necessity for rehabilitation approaches that prioritise coordination and endurance training instead of just enhancing grip strength.

Keywords Handgrip strength · Handwriting speed · Pinch force · BMI · Young adults

Introduction

The prevalence of motor development disorders is an alarming factor as studies depict that about 6–10% of the world population suffers from or is affected by conditions like cerebral palsy, developmental coordination disorder (DCD), or autism spectrum disorder (ASD) alone [1, 2]. These conditions quite often influence the child's functional capabilities, particularly affecting their fine motor skills, which play a pivotal role in carrying out basic day-to-day tasks [3]. Handwriting is one of the most commonly affected fine motor skills in these children, which is why addressing such difficulties is essential to bring about academic success and an overall improvement in their quality of life [4].

Handgrip and pinch strength are some of the most common techniques for the assessment of both motor function

✉ Sareesh Naduvil Narayanan
sareeshnn@yahoo.co.in; snaduvil@uclan.ac.uk

1 Ras Al Khaimah College of Medical Sciences, Ras Al Khaimah Medical and Health Sciences University, Ras Al Khaimah, Al Qusaidat, Post Box 11172, UAE

2 Department of Physiology, Ras Al Khaimah College of Medical Sciences, Ras Al Khaimah Medical and Health Sciences University, Ras Al Khaimah, Al Qusaidat, Post Box 11172, UAE

3 Present Address: Department of Physiology, School of Medicine and Dentistry, AUC-UK Track, University of Central Lancashire, Preston PR1 2HE, UK

Published online: 23 July 2025

and muscle tone in the clinical and research setting [5]. Handgrip strength reflects the overall muscle capacity of the hand and forearm, while pinch force measures the strength and dexterity of the fingers [6]. In particular, these metrics are highly useful in the evaluation of fine motor skills, which can be assessed by handwriting speed. Given the physiological similarities between these factors, it is possible to establish a correlation between them and handwriting speed.

Several studies involving handwriting speed have been done in the past. Summer and Catarro's study evaluated factors influencing university students' handwriting speed during exams. They identified some influencing factors such as pencil grasp, legibility, pain during writing, and the student's academic abilities, which showed limited but noticeable associations with their handwriting performance under exam conditions [7]. Handwriting in older individuals was studied by Rosenblum and Werner, and they discovered that older persons wrote at a slower and lower pressure than younger adults [8]. However, only a few studies have been conducted correlating handgrip strength with handwriting speed. The research done by Tayyab and their colleagues on healthy young adults showed a positive correlation between the above-mentioned parameters [9]. Similarly, another study done on autistic children also showed a positive association [10]. On the contrary, a third research study done among individuals aged between 20 and 29 years stated that there was no significant relation between handwriting speed and handgrip strength, but they did establish a link between handwriting speed and visual perception [11].

Despite these studies, the association between grip strength and pinch force on handwriting speed is not very clear. A knowledge on this will help physiotherapists better understand how muscular strength affects handwriting speed, allowing them to better assist people with developmental disorders and musculoskeletal conditions. Additionally, it would help assess patients with neurological conditions within the scope of holistic rehabilitation programs. Therefore, to explore the degree to which handgrip strength, and pinch force influence handwriting speed, this research was conducted in young adults.

Materials and Methods

Study Design and Participants

This cross-sectional study was conducted at the Physiology Laboratory of Ras Al Khaimah College of Medical Sciences, Ras Al Khaimah Medical and Health Sciences University, with a sample of 127 students aged 18–22 years. The study period spanned from November 2021 to March 2022, and participants were selected using a convenience sampling method. The inclusion and exclusion criteria for the study were as follows: inclusion criteria, (1) young adults aged between 18 and 22 years, (2) participants with legible handwriting, and (3) non-native English speakers; and exclusion criteria, (1) participants diagnosed with any musculoskeletal disorder, (2) individuals with a history of pain, swelling, injury, or surgery involving one or both hands within the past six months, and (3) participants with motor neuron disease, taking medications/using drugs that affect the central nervous system (CNS). The study received approval from the Institutional Research Ethics Committee, Ras Al Khaimah Medical and Health Sciences University, Ras Al Khaimah, under letter number RAKMHSU-REC-031–2021/22-UG-M, dated 01/11/2021.

Methods

The demographic details of the participants were obtained through a questionnaire, after which they were seated in an upright position for the required measurements to be taken.

Handgrip Strength

Handgrip strength was assessed using a digital hand dynamometer (JAMAR, USA), with participants instructed to perform the test using both their dominant and non-dominant hands. The test began with the dominant hand, where participants were asked to squeeze the dynamometer with their maximum strength, and the reading was recorded, followed by performing the same procedure on the non-dominant hand as well. For each hand, three consecutive maximal recordings were obtained, with a 1-min rest interval between trials to minimize muscle fatigue. The highest recorded force from these trials was used for analysis.

Pinch Force

The pinch force was measured with a pinch gauge (JAMAR, USA), which is a dependable tool for testing hand muscle strength. Participants were instructed to complete the exam using both their dominant and non-dominant hands. They were requested to pinch the gauge between their dominant hand's thumb and index finger first, then repeat the task with their non-dominant hand. Three consecutive maximal pinch force recordings were obtained per hand. To achieve accurate measurements, each trial was followed by a 1-min rest interval. The greatest force recorded was noted for analysis.

Handwriting Speed

The subjects' handwriting speed was measured by a timed writing activity. Each subject was given a specific paragraph and was instructed to transcribe the same within 1 min. The

task was timed with the help of a stopwatch. Handwriting speed was measured by quantifying the number of words written per minute (WPM). This approach was consistent with the methodology reported earlier [7].

BMI

The BMI was computed by dividing weight in kilograms by height in meters squared, using the participant's height and weight measurements. It was classified according to the World Health Organisation (WHO) criteria, which defines four categories: (1) BMI less than 18.5 kg/m^2 as underweight, (2) BMI between 18.5 and 24.9 kg/m^2 as normal weight, (3) BMI between 25.0 and 29.9 kg/m^2 as overweight, and (4) BMI of 30 kg/m^2 or greater as obese.

Statistical Analysis

All data were represented as mean ± standard error of the mean (SEM). The Student's *t*-test was performed to determine significant differences in mean values between gender groups. Pearson's correlation coefficient was used to evaluate the relationship between grip strength, pinch force, and handwriting speed. To compare the differences among different BMI groups, a one-way analysis of variance (ANOVA) test was applied, followed by Tukey's post hoc test for pairwise comparisons. A *p*-value of ≤0.05 was considered statistically significant. Statistical analyses were conducted using GraphPad Prism software (California, USA).

Results

Demographics

A total of 127 participants were part of this study, of which 38 were males and the remaining 89 were females. The mean age of the participants was 19.14 years (±0.12), with a mean height 1.63 m (±0.01) and mean weight 58.96 kg (±0.91). The mean body mass index (BMI) was 22.10 (±0.21).

Handgrip Strength, Pinch Force, and Handwriting Speed

Significant gender differences were observed in both handgrip strength and pinch force. The mean handgrip strength was significantly higher in males (39.86 ± 1.21) compared to females (24.28 ± 0.53), with males exhibiting 64.16% greater handgrip strength than females (*$p \leq 0.05$, Fig. 1A). Similarly, the mean pinch force was markedly different between males (7.33 ± 0.34) and females (4.51 ± 0.12), with males showing 62.52% greater pinch force than females (*$p \leq 0.05$, Fig. 1B). In contrast, the handwriting speed was significantly higher in females (31.25 ± 0.45) compared to males (28.32 ± 0.69), with females writing 10.34% faster than males (*$p \leq 0.05$, Fig. 1C). These results suggest a clear gender-based variation in the relationship between strength and handwriting performance, with males showing greater grip strength and pinch force, but slower handwriting speed.

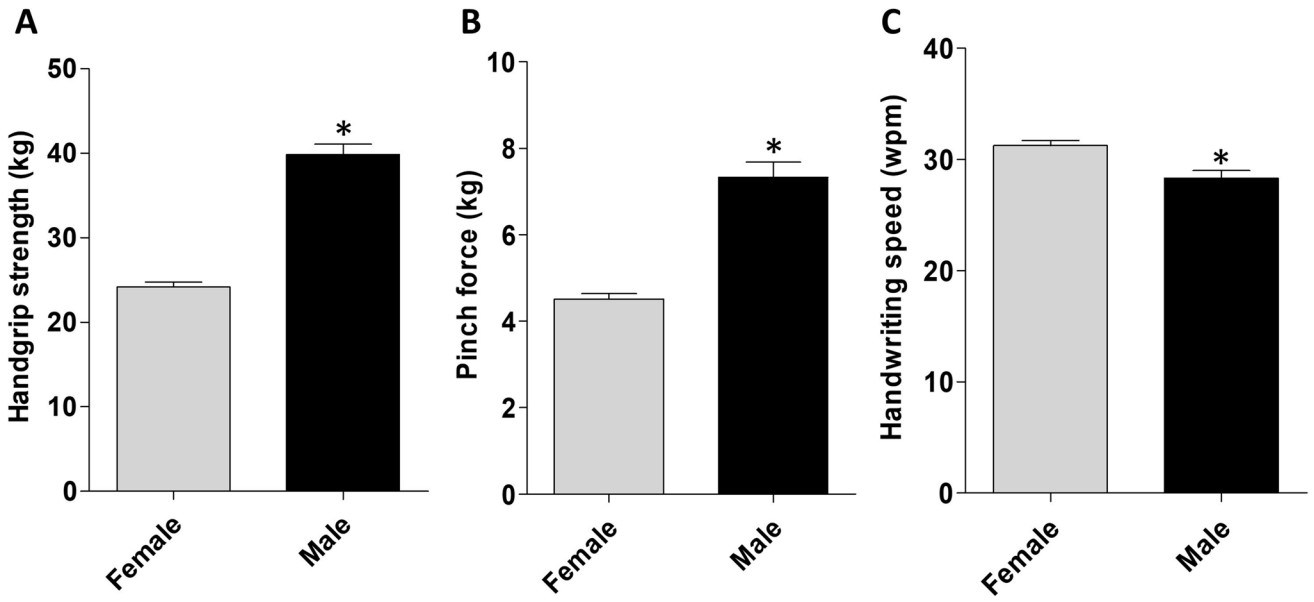

Fig. 1 Handgrip strength **A**, pinch force **B**, and handwriting speed **C** in males and females. *$p \leq 0.05$

Association of Handgrip Strength and Pinch Force on Handwriting Speed

Pearson's correlation analysis revealed a significant negative association between handgrip strength with handwriting speed ($r = -0.23$, $p = 0.006$, Fig. 2A), and pinch force with handwriting speed ($r = -0.25$, $p = 0.003$, Fig. 2B). As handgrip strength and/or pinch force increased, the handwriting speed decreased in participants.

BMI and Its Association with Handgrip Strength, Pinch Force, and Handwriting Speed

The handgrip strength and pinch force were not found to be significantly different in different BMI groups (Fig. 3A and B). Although the handwriting speed was observed to be decreased in obese individuals compared to others, this difference was not statistically significant (Fig. 3C). All the above findings highlight the role of muscle strength in fine

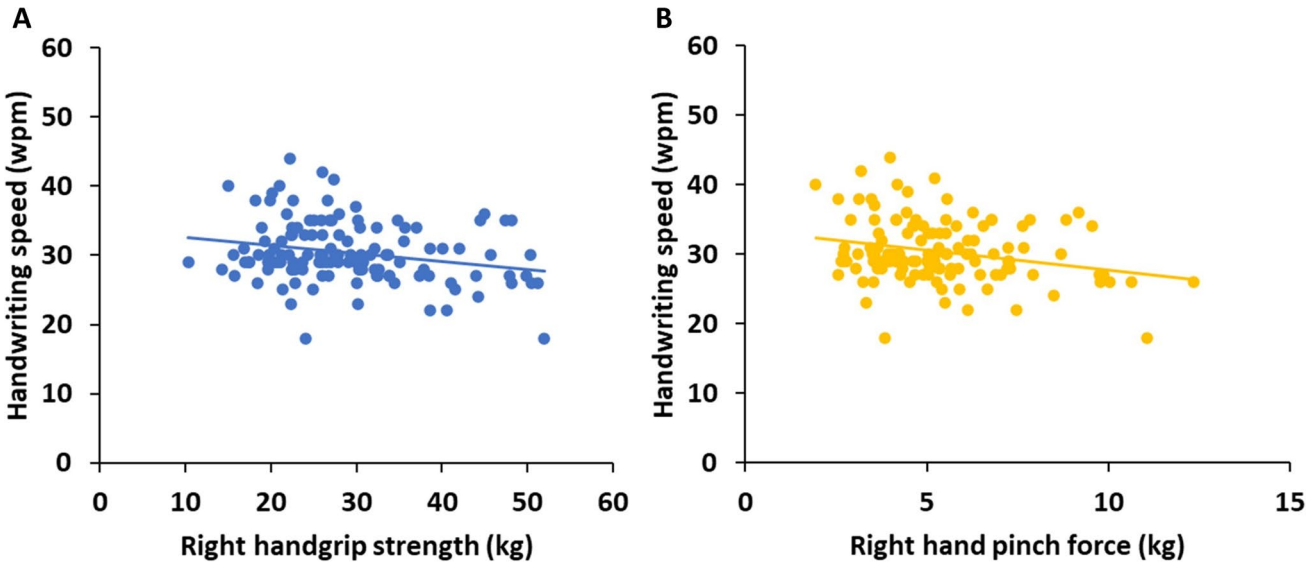

Fig. 2 Association of right-handgrip strength on handwriting speed **A**, and right-hand pinch force on handwriting speed **B**, in participants

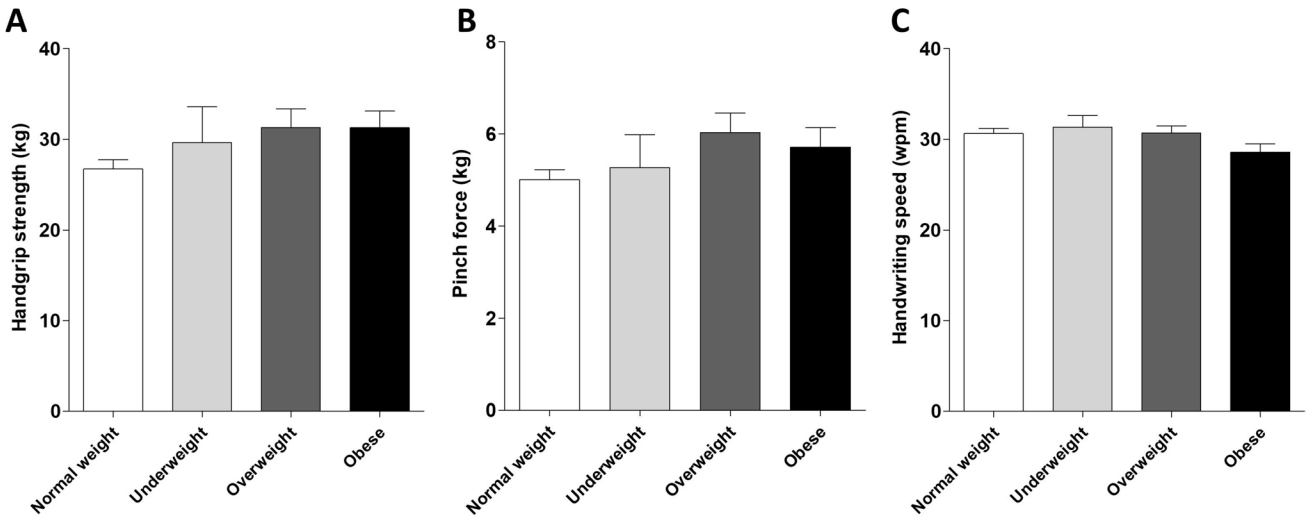

Fig. 3 Variation of handgrip strength **A**, pinch force **B**, and handwriting speed **C,** in normal-weight, underweight, overweight, and obese individuals

motor tasks like handwriting, with a clear inverse relationship between strength measures and writing efficiency.

Discussion

The findings of the present study demonstrate notable sex differences in handgrip strength, pinch force, and handwriting speed, with males demonstrating significantly greater handgrip strength and pinch force compared to females. However, despite their superior strength, males in this study exhibited slower handwriting speed compared to females, who wrote 10.34% faster on average. These outcomes align with previously conducted studies, suggesting that physiological and anatomical factors contribute to these observations [12, 13].

Various physiological factors are responsible for the higher magnitude of handgrip strength and pinch force in males. One of the prime reasons for this variation is a difference in the amount and distribution of muscle mass between males and females. Generally, males have larger muscle mass, especially in the upper body, which relates directly to an increased force production capacity [14]. The higher levels of testosterone in males further compound this by promoting muscle hypertrophy and possibly enhancing motor unit recruitment as well [15]. Testosterone affects muscle protein synthesis, leading to larger muscle fibers, especially Type II fibers, which are important for generating powerful, rapid contractions needed for tasks like handgrip and pinch force [16].

Furthermore, higher motor unit firing rates in males allow for a more effective neuromuscular activation and thus better strength results in tasks requiring force production, such as grip and pinch [17]. Anatomically, males tend to have larger hands and fingers that provide a mechanical advantage to produce stronger grip forces [18].

Despite higher grip strength and pinch force exhibited by males, females presented a higher handwriting speed. These findings are due to several physiological influences on muscle endurance and fatigue resistance, which seem to be different between the sexes. Studies suggest that women, in general, develop less fatigue for a continuous low to moderate intensity task like handwriting; this could be one reason to why they can maintain a higher speed with lower overall muscle strength [19].

One of the main determining factors for these differences is female sex hormones. Estrogen, a predominant hormone in women, promotes fat oxidation during endurance efforts, thus sparing muscle glycogen and minimising the buildup of fatigue-promoting metabolites [20, 21]. This would facilitate the continuation of energy output without the rapid development of fatigue and, therefore, would be expected to contribute to women's endurance in fine motor tasks like handwriting. In contrast, men's testosterone-driven physiology favors higher levels of muscular strength, but at the cost of more rapid glycogen depletion and higher energy expenditure that accelerates fatigue in activities extended over time [22, 23].

Gender differences in muscle perfusion may also contribute to endurance. Women tend to display greater muscle perfusion during low-intensity, sustained contractions due to stronger vasodilatory and capillary effects in the muscle tissues [24, 25]. This increased blood flow helps in clearing metabolic byproducts and improving muscle recovery which is beneficial in maintaining performance in repetitive tasks like handwriting [26]. Thus, the greater muscle perfusion observed in females could contribute to their sustained handwriting speed over time.

Another explanation for this advantage in females in handwriting speed could be the muscle fiber composition. Women have a higher proportion of type I, or slow-twitch, muscle fibers that are more resistant to fatigue and thus better suited to tasks requiring endurance [19]. These slow-twitch fibers release calcium slowly, thus promoting contractions that are sustained and allow for a longer duration of low-intensity activities with minimal fatigue. Men, however, have more type II or fast-twitch fibers that develop greater strength but fatigue rapidly, thus limiting endurance in activities such as handwriting, requiring sustained, low-force muscle activity [27, 28].

Another potential factor is the sequence of tasks in our study, which may have influenced fatigue levels and task performance. Handgrip strength and pinch force were measured before assessing handwriting speed. Given the reliance of males on fast-twitch muscle fibers and greater muscle mass, they may have fatigued more quickly during these strength assessments, which could have subsequently affected their handwriting performance. Females, who are generally more resistant to fatigue in sustained, low-intensity tasks, might have been less influenced by the earlier tasks and could, therefore, retain faster speeds of handwriting endurance [19, 29].

The study found no significant changes in handgrip strength, pinch force and handwriting speed among different BMI groups. The findings advocate for the fact that BMI, as analysed within the context of the study, is of lesser value when it comes to assessing its relevance towards either fine motor performance or muscle strength. Previous studies have revealed conflicting results regarding the impact of BMI on physical performance. Some suggest a link between greater BMI and reduced fine motor abilities, while others have found no such association [30–32].

The outcomes of this research revealed that in the tasks that demand high-intensity strength, such as handgrip and pinch force, males performed better than females because of factors such as greater muscular mass, higher levels of

testosterone, type II muscle fibers, and anatomical differences. On the other hand, females tend to excel in tasks that require endurance, such as handwriting speed. This can be attributed to various factors, including hormonal effects on metabolism, better muscle blood flow, a higher proportion of slow-twitch muscle fibers, and increased resistance to fatigue. This emphasises the relevance of muscular strength in fine motor activities such as handwriting, showing a clear inverse relationship between strength levels and writing efficiency. These differences illustrate the complex relationship among biological, hormonal, and anatomical factors that lead to sex-based differences in physical performance. Further investigation into how the sequence of tasks and other elements impact performance could yield valuable insights into these disparities.

The importance of handgrip strength, pinch force, and speed of handwriting is all very well appreciated in this study; however, these need to be read with certain limitations about generalising outcomes and depth. Data from a limited sample size (127 students) from one university alone, cannot be generalisable to a broader population. Moreover, to overcome the potential subgroup bias, university students who are accustomed to handwriting tasks were only considered as participants. This indicates a general level of task familiarity across participants. The participant group did not include individuals with varying levels of physical activity and handwriting habits, which is another limitation of this study. However, the physical activity level data collected from participants revealed that many (84.25%) were physically active, which helps to reduce the likelihood of significant confounding due to physical inactivity and supports the overall consistency of the sample.

The present cross-sectional study shows associations of handgrip strength and pinch force with handwriting speed but cannot establish causation. In addition to that, the study considers handwriting speed only, with no consideration of quality or legibility, which might also depend on grip strength. Other important factors, such as cognitive abilities, fine motor coordination, and psychological factors related to handwriting, were not included in the study. We agree that including such measures could offer a more comprehensive understanding of the factors influencing handwriting speed, and we recognize this as an important direction for future research. This indicate that more studies are needed to clear the intricacies around the very fine relationship between physical strength and handwriting performance.

Conclusions

In conclusion, the results of this study demonstrate that females displayed faster handwriting, while males exhibited stronger handgrip strength and pinch force. Interestingly, there was a negative correlation between handgrip strength and/or pinch force with handwriting speed. Body mass index (BMI), however, had no impact on any of the variables studied. Recognising the inverse relationship between strength and fine motor control can help healthcare providers to create more customised therapies, especially for people with higher muscle strength. Tailored therapies that focus on improving fine motor coordination rather than simply augmenting strength may improve functional results in activities requiring accuracy and dexterity.

Acknowledgements The authors would like to extend their gratitude and acknowledgements to all participants of this study.

Author Contribution S.N.N. conceived the presented idea, designed, directed the project, analysed and interpreted the results, and edited the manuscript. G.P., G.A., A.A.B, and V.S.F., performed various experiments and wrote the initial draft of the manuscript. All authors have contributed to the final version of the manuscript and approved it.

Funding Not applicable.

Data Availability The data that support the findings of this study are available from the corresponding author, [SNN], upon reasonable request.

Code Availability Not applicable.

Declarations

Ethics Approval The study received approval from the Institutional Research Ethics Committee, Ras Al Khaimah Medical and Health Sciences University, Ras Al Khaimah, under letter number RAKMHSU-REC-031–2021/22-UG-M, dated 01/11/2021.

Consent for Publication Not applicable as participants' details are not disclosed.

Competing interests The authors declare no competing interests.

Informed consent Not applicable.

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