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Hand Dexterity and Its Effect on Acquiring Basic Suturing Skills among Pre-clinical Medical Students

Pranjal Shah[1], Brinnell Caszo[1], Gnanajothy Ponnudurai[1], Mohammad Arshad Ikram[1], Siddharth Dhanaraj[2], Justin Gnanou[1*]

[1] School of Medicine, IMU University, Kuala Lumpur, 57000 Malaysia
[2] School of Dentistry, IMU University, Kuala Lumpur, 57000 Malaysia

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CORRESPONDING AUTHOR*
Justin Gnanou
justinvijay@imu.edu.my
Department of Human Biology, School of Medicine, IMU University, Kuala Lumpur 57000, Malaysia

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ABSTRACT

Introduction: Hand dexterity is essential for executing fine motor tasks, especially in surgical procedures such as suturing. Comprehending the significance of hand dexterity in suturing is essential for enhancing surgical training and expertise. Thus, this study aimed to examine hand dexterity on suturing skills among pre-clinical students.

Material and Methods: A prospective study design was used and was conducted on twenty male undergraduate medical students with no prior surgical suturing experience. The Purdue Pegboard test was used to assess hand dexterity. This was followed by assessing basic suturing skills, which involved assessment of participants' suturing skills on two types of sutures (simple interrupted and simple continuous) by independent raters using a standardized rubric and time metrics. Pearson regression analysis was used to assess the dexterity-suturing relationships.

Results: The study results indicated no association between hand dexterity and suture time for simple interrupted suture (r=0.085), while a weak negative association was observed for hand dexterity and suture time for simple continuous suture (r=0.303), suggesting individuals with a high dexterity score tool less time to complete the suture. Overall surgical assessment score showed a weak positive correlation between hand dexterity and suturing skill (r=0.308). However, no statistical significance was achieved for the correlations (p=0.05)..

Conclusion: Our study findings highlight a weak association between hand dexterity and suturing performance, which depends on the duration and complexity of the task. This finding could be used to develop structured training among undergraduate medical students in developing suturing skills.

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INTRODUCTION

Hand dexterity is a measure of hand flexibility and coordination. It is very important for fine motor skills and movements. The hand helps us to grasp, grip, and perform precise motions such as writing and sewing. Furthermore, a dexterous hand allows one to use their fingers and hands to perform daily tasks effectively. The intricate art of suturing in surgical practice demands not only technical proficiency but also a delicate interplay of hand dexterity and fine motor skills [1].

The central feature of effective functional performance of the hand relies on the synchronous interrelationship between sensory and motor components, which allows control of fingers independently regarding timing, kinetics, and force. In the medical profession, fine motor skills are essential for carrying out various activities. These include surgical procedures such as suturing, etc. As surgical procedures continue to evolve towards minimally invasive techniques and precision-driven interventions, understanding the nuanced relationship between hand

dexterity and surgical proficiency becomes paramount [2].

At the heart of surgical excellence lies the surgeon's ability to manipulate instruments with precision and finesse, a skill intimately intertwined with hand dexterity. Defined as the coordination and control of hand and finger movements to perform intricate tasks, hand dexterity serves as a cornerstone in mastering the art of suturing. Numerous studies have attempted to unravel the complex neural mechanisms underpinning hand dexterity, exploring factors such as proprioception, muscle strength, and motor control [3].

Furthermore, the evolution of suturing techniques underscores the dynamic nature of surgical practice. From traditional methods to advanced laparoscopic and robotic-assisted approaches, the landscape of suturing has undergone remarkable transformations. However, the transition towards minimally invasive techniques poses unique challenges, necessitating a reevaluation of the relationship between hand dexterity and suturing proficiency in diverse surgical settings [4]. Moreover, as the healthcare landscape continues to prioritize patient outcomes and safety, the role of surgical education and training assumes heightened significance. Effective training programs must not only cultivate technical skills but also nurture hand dexterity to foster surgical expertise [5].

To gain valuable insights into the intricate mechanisms underpinning hand dexterity, it's important to look at the various factors that affect hand dexterity. Firstly, gender emerges as a notable factor influencing hand dexterity among surgeons. Male surgeons often exhibit greater hand grip strength (HGS), while their female counterparts demonstrate superior manual dexterity. Additionally, manual dexterity appears to correlate inversely with age, with younger surgeons displaying more proficient scores. Age-related changes in brain structure and function influence motor control, affecting hand dexterity. This suggests that inherent physiological differences and age-related changes contribute to variations in hand dexterity among surgical practitioners [4].

Furthermore, prolonged hand preference induces adaptations in muscle fiber composition, significantly influencing hand dexterity [6]. These adaptations not only enhance the mechanical effectiveness of motor units but also shape motor-evoked potentials and rehabilitation strategies within the dominant muscle, thereby intricately contributing to overall hand dexterity. This dynamic interplay between neuromuscular adaptations and functional abilities underscores the nuanced mechanisms underlying hand dexterity [6]. Additionally, the intricate relationship between muscle fiber composition and motor unit firing behavior illuminates the subtle mechanisms governing hand dexterity [7].

Long-term hand preference manifests in distinct patterns of motor unit recruitment and firing behavior, characterized by lower recruitment thresholds, initial firing rates, and discharge variability in the dominant hand. Such findings suggest a higher percentage of slow-twitch fibers in preferentially used muscles, thus augmenting mechanical efficiency and providing profound insights into the neuromuscular intricacies of hand dexterity [7]. Technological advancements also play a pivotal role in shaping hand dexterity within surgical contexts. Innovations such as the da Vinci Surgical System offer enhanced manipulative capabilities to surgeons, irrespective of hand dominance. Features like wrist-like joint flexibility and motion scaling enhancement augment surgical proficiency, particularly in complex procedures such as coronary artery anastomosis. This underscores the symbiotic relationship between technological innovation and surgical skill enhancement [8].

Finally, experience emerges as a critical determinant of hand dexterity proficiency among surgeons. Experienced practitioners demonstrate greater efficiency in performing surgical tasks, as evidenced by fewer movements required for the same procedures compared to their junior counterparts. This suggests that experiential learning and skill refinement play pivotal roles in honing hand dexterity over time [9]. This brings us to two fundamental categories of hand dexterity: innate and acquired dexterity. Studies have delved into the relationship between these facets, shedding light on the complex interplay between biological predispositions and environmental influences. Research elucidates the intrinsic link between innate hand dexterity and factors like grip strength, particularly evident in young males, suggesting a foundation of physical capability influencing manual agility [10,11].

This underscores the inherent physiological predispositions that shape an individual's baseline dexterity, highlighting the role of genetics and developmental factors. Conversely, acquired hand dexterity skills manifest through a synthesis of cognitive abilities, balance, and sensory feedback. Cross-sectional studies on elderly populations reveal a correlation between cognition, balance, and hand dexterity, showcasing the dynamic nature of dexterity, which evolves over the lifespan through experiences, learning, and adaptations to age-related changes in physical and cognitive domains [12].

Furthermore, research elucidates the influence of external factors, such as surgical interventions, on acquired hand dexterity. Surgical procedures requiring precise manipulations demand a high degree of dexterity, often necessitating specialized training to optimize outcomes. Studies highlight the efficacy of simulation-based training in enhancing surgical dexterity, indicating the modifiability of acquired skills

through targeted interventions [13]. Conclusively, the contrast between intrinsic and learned hand dexterity highlights the complex characteristics of hand agility. While inherited talents based on genetics and physical predispositions establish the groundwork, learned skills arise through a complex interaction of cognitive, sensory, and contextual influences.

In this context, it is interesting to look at the relationship between hand dexterity and surgical skill performance. In a prospective cross-sectional study of medical school trainees, it was shown that students with a musical background performed better than non-musical background trainees, and they also had better hand dexterity [2]. In another study, the influence of medical students' past experiences and innate dexterity was examined using a survey. They found that innate manual dexterity skills were predictive of initial surgical suturing performance regardless of past student experiences [3]. While numerous studies have underscored the importance of hand dexterity in surgical performance, the evidence has not been universally consistent. Researchers have demonstrated a positive correlation between superior hand dexterity and improved performance in simulated surgical tasks, suggesting that individuals with enhanced manual proficiency may exhibit better surgical skill acquisition and execution, particularly in procedures requiring fine motor control and precision [14,15].

However, contrasting studies have challenged this notion, finding no significant correlation between hand dexterity and surgical outcomes in microsurgery and oral and maxillofacial surgery, respectively [4,16]. Such findings indicate that while hand dexterity may play a role in surgical skill acquisition, its direct impact on surgical outcomes may be less pronounced or influenced by other factors. Thus, in this study, we propose to elucidate the impact of hand dexterity on suturing technique among students with no prior knowledge of suturing procedures.

MATERIAL AND METHODS

Twenty healthy male participants (18-25 years) with no prior knowledge of surgical suturing were selected for this study. Individuals with any recent hand injury or surgery, any factors that can directly lead to hand deformity, including edematous, vascular, or inflammatory conditions, or with neck strain or injury, were excluded from the study. After the selection of the participants, each participant was informed about the purpose of the study, and informed consent was obtained.

The study was conducted in accordance with the Declaration of Helsinki and the guidelines of Resolution on 198/96 of the National Health Council. Ethical approval was obtained from the Joint Research and Ethics Review Committee of the university (BMS I-2023) (14).

Hand Dexterity Assessment

The Purdue Pegboard Test was chosen for assessing hand dexterity due to its ability to objectively measure fine motor skills, hand-eye coordination, and bimanual dexterity—skills essential for suturing. Its simplicity and standardized protocol make it a widely accepted tool in research and training environments.

This test is well-established and consists of four segments, each designed to assess different aspects of hand dexterity: Segments 1 and 2 involve the use of an individual's hand to insert the pins for a period of 30 seconds. Segment 1 was accomplished using the dominant hand, while Segment 2 was done using the non-dominant hand. Segment 3 involved inserting pins using both hands for a period of 30 seconds to assess bimanual synchronization. Segment 4 assessed dexterity and coordination, whereby the participant was required to assemble pins, collars, and washers using both right and left hands in 60 seconds. At the end of the test, five separate scores from the complete test procedures were calculated as follows:

1. Right Hand Score: That is the number of pins that are inserted by using the right hand in half a minute.
2. Left Hand Score: The total number of pins that are inserted with the left hand in half a minute.
3. Both Hands Score: Number of pins that can be inserted with two hands moving simultaneously in 30 seconds.
4. Assembly Score: Elapsed time required to complete five small assemblies involving little or no use of both right and left hands for an indication of speed of performance of more complex tasks.

Total dexterity was then computed by adding the actual scores from the right hand, left hand, and both hands tests (Numerical R+ Numerical L+ Numerical Both + Assembly). This combined score is the global measure of the function of the hand dexterity of the participants, which allowed for a conclusion based on a single numerical value. Each participant was given three trials, and the best trial was chosen as the final hand dexterity score.

Suturing Assessment

Pre-assessment Protocol

Prior to the suturing assessment of the participants, training and familiarisation with the equipment were carried out. This involved a 1-hour theoretical lecture on tissue treatment, knot-tying techniques, and instrument

Table 1: Rubric for Suturing Technique Assessment

Assessment Question	Grading
Grabs the needle with the instruments (and not with the fingers	Yes/No
Ties a correct squared knot	Yes/No
Holds the forceps correctly	Yes/No
Grabs the suture with the instruments in a correct fashion	Yes/No
Penetrates the foam suture pad with a 90 degrees angle	Yes/No
Manages the suture without tangling the ends in the knot	Yes/No
Damages the foam suture pad	Yes/No
Makes a parallel suture (equal length from the wound edge and equal depth on both sides	Yes/No

handling by an experienced surgeon. This was followed by a demonstration of the two types of knots to be used in our study by the surgeon. Later, a supervised practice session (90 minutes) was conducted, where the participants were allowed to practice suturing under the direct supervision of the experienced instructors.

The Task

The suturing task assigned to participants consisted of two types of surgical suturing and knots, which were assessed in a controlled and standardized manner. To ensure uniformity and fairness, all participants were provided with the same types of suturing equipment. This standardized setup ensured that all participants were assessed under identical conditions, allowing for a fair comparison of their suturing skills.

1. Simple Interrupted Suture: This involved the participants performing a basic interrupted suture on a cutaneous (skin) model. For this task, participants had to use a needle holder to drive the needle through the foam suture pad, mimicking human skin, followed by a knot to secure the suture. This task emphasized precision in needle placement, consistent suture spacing, and secure knot formation.
2. Simple Continuous Suture: This involved the participants to perform a continuous (running 5 sutures) suture on a cutaneous model, creating a longer suture line with multiple stitches. For this task, participants had to insert the needle and create the first stitch, then continue the suture in an over-and-over pattern for five stitches. This task required maintaining consistent tension throughout the suture line and ensuring even spacing between stitches.

To avoid biases and omissions in the scoring of suturing skills, each participant was videotaped during the performance of suturing tasks. These recordings were done in a room which was set aside for this purpose, and no disturbance from any outside influence was allowed. During the shooting process, the filming crew did not interfere with the tasks carried out by the participants to avoid influencing the results. The videos were then scored using the assessment tool (Table 1) as shown below by blinded independent raters.

In addition to the above assessment criteria, the time every participant took to suture was measured and was used in the formula for the final calculation to assess the suturing skill, as shown below:

Total Score = Cutoff Time (seconds) − Completion Time (seconds) − (10×Sum of Errors).

This formula is a standardized formula to assess suturing skill and is adapted from the previously published formula [17]. The formula takes into consideration the time taken to complete the suturing procedure and the count of the number of errors based on the assessment rubric. The cut-off time was calculated as the time taken by 2/3rd or 67% of the participants of the study.

Statistical Analysis

The data was expressed as means and standard deviations. To analyze the relationship between hand dexterity and suturing skills, the Pearson correlation coefficient was utilized. A p-value < 0.05 was considered statistically significant.

RESULTS

A total of 20 participants were recruited for our study. The selected participants belonged to Semester 1 of the undergraduate medical program. The participants had an average age of 20 ± 1.9 years.

Hand Dexterity Assessment

Hand dexterity assessments were conducted with each participant undergoing three trials. Based on these three trials, the best attempt for each participant was chosen. Table 2 provides the best attempt at hand dexterity values of the twenty participants.

Table 2. Hand Dexterity Scores and Suturing Technique Assessment

Assessment	Score
Hand Dexterity	
Average ± Standard deviation	55.1 ± 6.05
Minimum	42
Maximum	66
Simple Interrupted Suture Time	
Average ± Standard deviation (seconds)	130.15 ± 43.08
Minimum (seconds)	70
Maximum (seconds)	235
Simple Continuous Suture Time	
Average ± Standard deviation (seconds)	507.4 ± 158.51
Minimum (seconds)	306
Maximum (seconds)	1025
Simple Interrupted Suture	
Average ± Standard deviation	0.65 ± 1.1
Minimum	0
Maximum	5
Simple Continuous Suture	
Average ± Standard deviation	0.35 ± 0.5
Minimum	0
Maximum	2
Total Scores	
Average ± Standard deviation	21.45 ± 178.06
Minimum	-545
Maximum	293

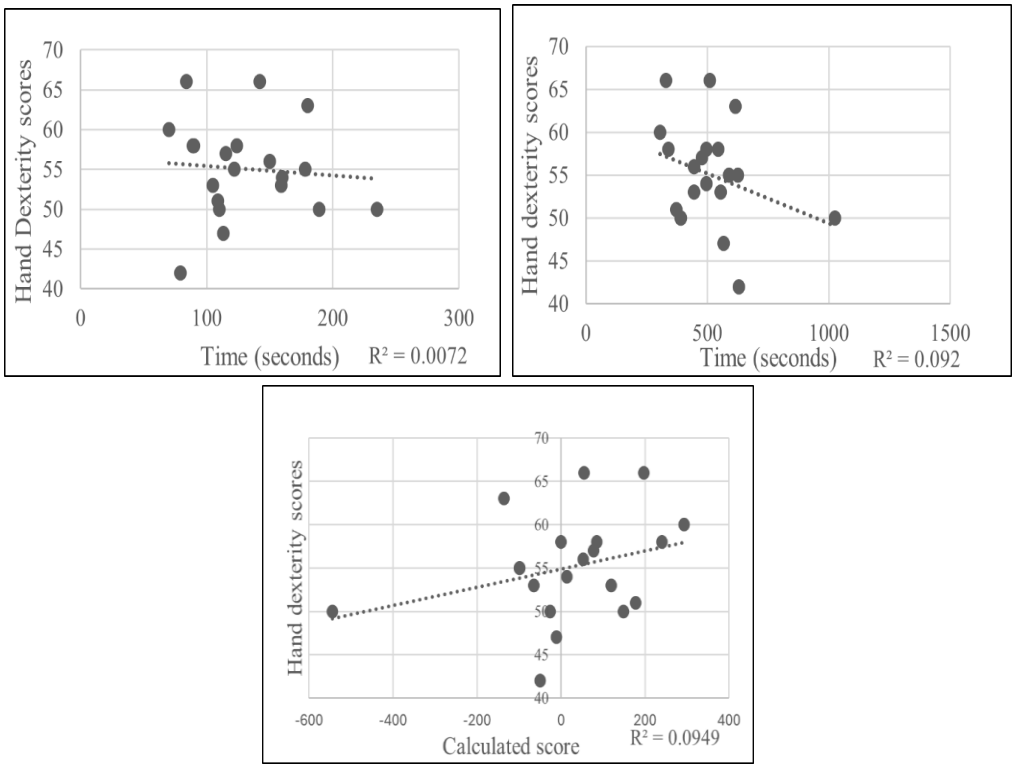


Fig. 1 A. Hand Dexterity Vs Simple Interrupted Suture Time; **B**. Hand Dexterity Vs Simple Continuous Suture Time; and **C.** Hand Dexterity Vs Total Calculated Score

While evaluating the performance of the suturing, three main aspects were looked at. Firstly, the time taken to complete the suturing procedure, secondly, the number of errors during the suturing procedure, and lastly, the overall score obtained using the selected formula. Table 2 provides the time taken by the participants for performing the simple interrupted and simple continuous sutures. As can be seen from the data, participants took a longer time performing a simple continuous suture when compared to a simple interrupted suture, as this continuous suture required five continuous sutures and a knot at the end. The participants were evaluated for the number of errors while performing the suturing procedure using the assessment tool as mentioned in the methods section. A total of eight errors were possible for each suturing procedure. The data for the average number of errors while performing simple interrupted and simple continuous sutures.

The average number of errors for the simple interrupted suture was higher when compared to the simple continuous suture. This may be due to the fact that since simple interrupted suture was of shorter duration, the participants tend to make more errors when compared to the longer duration, simple continuous suture. Interestingly, the most common type of error for both simple interrupted and simple continuous suture was managing the suture without tangling the ends in the knot. The total time taken for completing both sutures and the total errors for both sutures were used to calculate the final score based on the formula as discussed in the methods section. Table 2 provides the summary data for the total scores.

Linear Regression Analysis

A linear regression analysis was performed to study the association between suture time for both simple interrupted and simple continuous suture and hand dexterity. For the simple interrupted suture, the analysis (Fig.1A) showed no significant relationship ($r=0.085$) between suture time and hand dexterity for simple interrupted suture ($p>0.05$).

While regression analysis for the simple continuous suture (Fig.1B) and hand dexterity suggested a weak ($r=0.303$), non-significant negative relationship ($p>0.05$) between suture time and hand dexterity, indicating that the higher the dexterity scores, the shorter the time to complete the suture. Therefore, one with a lower dexterity score takes longer to complete the suture.

Lastly, regression analysis was performed to check for any association between hand dexterity and the total final score (Fig.1C). The regression model shows that there is a weak relationship between final score and hand dexterity, with r-value of 0.308, suggesting that people with higher dexterity have better suturing skills. However, the relationship was not statistically significant ($p>0.05$).

DISCUSSION

Hand dexterity, the skillful coordination of the hands and fingers, has conventionally been seen as essential for acquiring suturing abilities. Dexterity is thought to contribute to surgeons' ability to perform precise tasks, manipulate instruments, and execute complex procedures with accuracy [18]. This is one of the aspects our research delved into: whether individuals with innate dexterity may possess an advantage in mastering suturing abilities due to their enhanced adaptability to intricate motor activities [19].

Studies have examined the predictive significance of inherent dexterity in the learning of surgical skills, revealing that individuals with elevated baseline dexterity performed better in early skill evaluations. A positive association between dexterity and performance in laparoscopic operations has been identified, indicating that individuals with high dexterity completed tasks more swiftly and with greater accuracy, implying that inherent dexterity may mitigate learning curves for minimally invasive techniques [20].

Supplementary results from a simulation-based research study revealed that learners with a high initial dexterity score adapted rapidly and attained greater task accuracy [21]. Additional research introduced a neurocognitive perspective, linking hand-eye coordination to error reduction in precision tasks [22]. Moreover, further studies indicated that trainees possessing inherent manual skills achieved proficiency with fewer repetitions, underscoring the potential efficiency advantages of dexterity in surgical training [23].

Our study findings though not statistically significant, showed a weak negative correlation between hand dexterity scores and suturing time, indicating that individuals with higher hand dexterity scores took less time to complete the continuous suture and individuals with low or poor dexterity took longer time to complete the same task, thus aligning with the findings of the above studies. Nevertheless, numerous studies contest the idea that inherent dexterity is crucial, proposing that systematic training may diminish any preliminary benefit provided by dexterity. Studies have revealed no significant correlation between early dexterity and long-term surgical performance, indicating that rigorous training can mitigate initial skill deficiencies [24,25].

Another observation indicated that low-dexterity trainees attained skill levels equivalent to those of high-dexterity trainees following prolonged practice, suggesting that practice may mitigate dexterity

advantages [26,27]. Subsequent studies highlighted cognitive adaptation as more significant than physical dexterity, demonstrating that cognitive-based workouts enhanced surgical performance, even among those with initially poor dexterity [28]. Analysis of learning curves revealed that early disparities in dexterity diminished with training, resulting in both high- and low-dexterity groups attaining comparable performance at the result [29]. A meta-analysis corroborated these findings, indicating that whereas dexterity may provide a preliminary advantage, it has no impact on long-term performance outcomes [30].

Comparison of suture completion time and hand dexterity revealed that the impact of dexterity is likely to be dependent on task difficulty and duration. In the initial, abbreviated simple interrupted suture test, which is a shorter-duration task, we observed no significant correlation with dexterity, corroborating studies that challenge the importance of dexterity in uncomplicated and basic operations. Nonetheless, the extended second suture task – simple continuous suture- had a weak positive correlation, indicating that the significance of dexterity may increase in tasks necessitating prolonged accuracy and focus.

This conclusion aligns with research indicating that longer process durations might exacerbate tiredness and concentration requirements, hence affecting dexterity, particularly in complex tasks [19]. Furthermore, several studies indicate that training may mitigate baseline dexterity disparities during prolonged activities, with stamina and cognitive resilience training contributing to the normalization of performance across individuals with differing degrees of inherent dexterity [31,32].

Studies have also investigated the various other factors that can affect surgical skill performance. In one study, various factors such as age, gender, handedness, previous training or operative experience, playing an instrument, sportive activities, and computer gaming were examined as factors affecting surgical skill performance. They concluded that factors such as past training, playing an instrument, and computer gaming had a significant effect, while handedness and gender initially affected; however, with training, the effect was negated. These findings underscore the multifaceted nature of surgical skill acquisition and performance, highlighting the importance of considering a wide array of factors beyond technical proficiency alone [4].

Factors influencing surgical suturing performance encompass a broad spectrum of variables that intricately shape the proficiency and efficacy of the procedure, spanning from the surgeon's skill level to environmental and patient-related factors. A fundamental determinant lies in the surgeon's level of experience and training. Research suggests that surgeons with extensive training and practice tend to exhibit superior suturing skills, underlining the significance of honed surgical techniques and refined hand-eye coordination [33]. Conversely, novice surgeons may encounter challenges in suturing due to limited exposure and practice, highlighting the critical role of structured training programs in fostering skill acquisition and proficiency [34].

The choice of surgical instruments and suture materials represents another pivotal factor influencing suturing performance. Variables such as suture size, material composition, and needle design play integral roles in determining knot integrity, tissue handling, and overall wound closure quality, thereby profoundly affecting the success of the procedure [34,35]. Environmental considerations, including lighting conditions and ergonomic setup, significantly contribute to facilitating optimal suturing performance. Adequate lighting is imperative for ensuring clear visualization of the surgical field, enabling precise tissue manipulation and knot tying. Similarly, ergonomic factors such as the arrangement of surgical instruments and the surgeon's posture are paramount in enhancing procedural efficiency and mitigating the risk of fatigue-related errors [36,37].

Psychological elements, such as stress and distraction, exert notable impacts on suturing performance. Research has shown that music can serve as a stress-relieving mechanism, enhancing concentration and thereby improving suturing precision and efficiency [15]. Conversely, distractions within the operating room environment, such as noise or interruptions, have been shown to disrupt focus and heighten the likelihood of errors during suturing, underscoring the necessity of maintaining a conducive and focused operative atmosphere [38]. Furthermore, patient-related factors, including tissue characteristics and wound complexity, intricately influence suturing performance [38,39].

By comprehensively understanding and navigating these multifaceted factors, surgeons can optimize their suturing techniques to achieve favourable wound healing and cosmetic outcomes, ultimately enhancing patient care and satisfaction. Thus, it can be concluded that hand dexterity plays an important role in surgical skill performance. Our findings indicate that dexterity may not be essential for basic surgical operations; however, it may confer an advantage in extensive and intricate procedures. Our examination of hand dexterity in relation to suture completion time indicated that the impact of dexterity was contingent upon the duration and complexity of the procedure.

Limitations

We do acknowledge certain limitations of our study that could have affected the study outcomes. The main reason for observing a weak association is due to the

sample size, which diminished the generalisability of our findings and raised the possibility of type II errors. A larger sample could have better reflected the role of dexterity across varied skill levels and suturing procedural demands. Gender homogeneity was another limitation. In our study, we only included male participants, which limited the findings' applicability to other genders.

Incorporating a diverse sample could provide insights into possible gender-related differences in the learning of surgical skills. Our study also focused only on suturing skills to study the role of hand dexterity. This may not be relevant to other surgical skills that include distinct motor or cognitive demands, hence constraining the applicability of our findings. The choice of assessing hand dexterity could have also played a role in the outcomes of our study. We used a simplified measure of dexterity that didn't encompass vital elements such as fine motor control and hand-eye coordination, which are also crucial for surgical proficiency. Other minor variables, such as participants' stress, weariness (based on the time of the day when the experiment was conducted), may have impacted results.

CONCLUSION

The comparison of suture completion time and hand dexterity revealed that the impact of dexterity is likely to be dependent on task difficulty and duration. In a simple interrupted suture test, which is a shorter-duration task, there was no significant correlation with dexterity observed. The Simple continuous suture, which is a longer-duration task, had a weak positive correlation, indicating dexterity may increase in tasks necessitating prolonged accuracy and focus. Our findings indicate that dexterity may not be essential for basic surgical operations; however, it may confer an advantage in extended or intricate procedures. Our examination of hand dexterity to suture completion time indicated that the impact of dexterity was contingent upon the duration and complexity of the procedure.

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CONFLICT OF INTEREST

The authors declare no potential conflicts of interest concerning this study, authorship, or publication.

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