Research Square

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Posture in practice: heightened awareness of surgical resident ergonomics

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Abstract

Background

Ergonomics is an often-overlooked component of operative education. Early intervention can protect residents from physical stress and long-term musculoskeletal injury. Our aim is to evaluate residents during a simulated suturing exercise and assess the impact of self-evaluation on ergonomics.

Methods

Following informed consent, surgical residents performed a simulated complex wound closure, blinded to the study's focus. Following initial closure, residents reviewed their videos with an ergonomic self-assessment guide, repeated the exercise, and completed a post-survey. Representative video clips were analyzed to measure elbow, spine, and neck angles. Standard angles were defined as 90–110° for elbow, < 10° for spine, and < 25° for neck.

Results

Twenty residents participated across four post-graduate years (PGY): five PGY-4, four PGY-3, four PGY-2, and seven PGY-1. Across all participants, we found significant reduction in spine (12.5° vs 5.1°, $p = 0.016$) and neck (58.5° vs 46.4°, $p = 0.004$) angle during the second exercise, but no difference in elbow angle (102.7° vs 101.7°, $p = 0.744$). The post-survey revealed most residents think about their ergonomics in the operating room at least weekly (75%) and feel physical strain (95%). All residents (100%) reported improved awareness of ergonomics and perceived transferability to the clinical setting.

Discussion

Our study demonstrated a resident self-assessment of ergonomics led to significant improvement in spinal and neck angles in a simulated exercise with increased awareness of operative ergonomics and perceived transferability to the clinical setting. These findings support integration of ergonomic education early in surgical training to help reduce physical strain and promote operative longevity.

Introduction

Resident education for procedural specialties is unique in its reliance on hands-on learning for development of technical skills. Undergraduate medical education offers numerous opportunities for both low- and high-fidelity simulation experiences prior to the application of skills in the clinical setting, and those opportunities remain for trainees in graduate medical education. Barriers to simulation implementation in graduate medical education may be secondary to difficulty achieving or measuring transferability to the operating room, where increased operative caution and attending oversight

confound metrics such as operative duration [1]. Further, procedural improvement in the simulation setting has been shown to be dependent on attending involvement, indicating that attending investment in simulation curricula is critical [2]. Residents often presume they have limited control over environmental factors such as procedural table height, leading to sacrifice of proper posture or positioning in an effort to adapt to the more senior physician in the procedure.

Procedural simulation during residency allows residents to be evaluated and receive formative feedback in a low-stakes environment and provides opportunities to improve technical skills. Similar to the clinical setting, resident performance in simulation activities has been shown to correlate with training year and prior experience [3]. While transferability will never be completely optimized, exposure to procedural steps and processes remains beneficial. This also decreases reliance on patient-based learning while allowing inexperienced residents to learn in a controlled environment free of potential patient harm. While simulation activities traditionally focus on technical skills, there is opportunity for simulation focused on surgical ergonomics which may have equally important long-term implications on resident careers and the longevity of their ability to care for patients.

Ergonomics is the adaptation of the workplace environment to the worker in an effort to maximize efficiency and safety. This is directly applicable to surgical residents as operative performance is not only dependent on technical skill, but also on the procedural environment. Residents in surgical specialties report high rates of procedural-related musculoskeletal pain likely secondary to prolonged periods in suboptimal positions [4, 5]. One of the main drivers of procedural ergonomics is the height of the procedure table in relation to the provider. Therefore, addressing ergonomics early in training is critical to create a foundation of proper posture and positioning which in turn will protect residents from physical stress and long-term risk of musculoskeletal injury.

There have been promising pilot programs for ergonomics education for surgical residents, however, they are often lecture or module-based [6, 7]. Regarding simulation, repeat laparoscopic simulation after ergonomics education has led to improvement in neck and shoulder angles which demonstrates promise in the application of simulation to ergonomics training [8]. Prioritization of ergonomics early in training may promote safer procedural habits and reduce long-term musculoskeletal strain among residents. Therefore, our aim is to evaluate resident ergonomics during a standardized suturing exercise followed by a self-evaluation and repeat suturing evaluation. We hypothesized that targeted ergonomics awareness in a hands-on simulation activity will improve resident procedural positioning metrics and ergonomic awareness.

Methods

Following Institutional Review Board approval, general surgery residents attending a simulation activity voluntarily consented to study participation by completing an informed consent document. All residents in post-graduate years (PGY) 1–4 were invited to participate in this activity, and participation in the study portion was voluntary. There were no exclusion criteria. Residents were told they would be completing a

suturing exercise on pork belly, but the technical focus of the activity was not disclosed. Upon entering the simulation suite, study personnel read a standardized script acting as the “anesthesiologist” with instructions for the wound closure and a request for table height adjustment (Fig. 1). The table was set at a neutral height for an average-height resident between each participant. Residents were instructed to close pork belly in two layers in a running fashion while blinded to evaluation criteria. Following closure, residents were taken to a separate room where they reviewed a side-profile view video of their closure to complete a self-evaluation form which highlighted spine alignment, arm positioning, overall ergonomic setup, and foot support. Residents then completed the activity a second time after reviewing their self-assessment. After completing the suturing simulation twice, residents filled out a survey capturing their height, ergonomic habits, and impression of the exercise.

Both pre- and post-evaluation videos were analyzed by two independent reviewers. Inter-reviewer reliability assessed after the first five participants and showed consistent measurement among reviewers. Standard procedural angles of the neck, back, and elbow were defined according to prior literature reviewed. Proper elbow angle was set at 90–110° based on the American College of Surgeons Ergonomics Recommendations [9]. Neck angle was set at a conservative threshold of < 25° due the risk of cervical dysfunction with excessive neck flexion (< 30°), and spine angle was set at < 10° to represent nearly vertical positioning [10]. All angles were measured in Keynote (Apple, Cupertino, CA) against a standard angle within the frame (Fig. 2). Post-survey data was analyzed for baseline reported ergonomic habits, ergonomic awareness, and perceived transferability to the clinical setting. GraphPad Prism was utilized for all analysis, and t-tests, fishers exact, ANOVA, and Kruskal-Wallis tests were utilized where appropriate. Paired t-tests were used for pre- and post-intervention comparisons.

Results

All Residents

Twenty residents participated across four PGY years: seven PGY-1, four PGY-2, four PGY-3, and five PGY-4. Total class sizes for these cohorts were eight PGY-1, seven PGY-2, seven PGY-3, and seven PGY-4. Across all participants, we found significant reduction in spine angle (12.5 vs 5.1, $p = 0.016$) and neck angle (58.5 vs 46.4, $p = 0.004$) during the second exercise but no difference in elbow angle (102.7 vs 101.7, $p = 0.744$) (Fig. 3). We also observed a significant increase in the proportion of participants with proper spine angles, but no difference in proper elbow angle or neck angle (Fig. 4). These findings suggest residents may alter spine and neck angle while maintaining elbow angle during procedures. (Table 1)

Table 1

Pre vs Post Angles and Percent Correct Comparison of neck, spine, and elbow angles in the pre activity compared to the post activity. Correct angles were set at neck angle < 25°, spine angle < 10°, and elbow angle 90–110°.

Neck Angle, mean (SD)	**Pre**	**Post**	**p-value**
	N = 20	**N = 20**	
	58.5 (14.6)	**46.4 (12.6)**	**0.004**
Correct Neck Angle, n (%)	1 (5.0)	1 (5.0)	> 0.999
Spine Angle, mean (SD)	12.5 (6.5)	5.1 (3.6)	0.016
Correct Spine Angle, n (%)	8 (40.0)	19 (95.0)	< 0.001
Elbow Angle, mean (SD)	102.7 (19.2)	101.7 (13.7)	0.744
Correct Elbow Angle, n (%)	8 (40.0)	12 (60.0)	0.056

Post-Graduate Year

We then evaluated the impact of level of training by comparing post-graduate years. Across all years, we observed PGY-2s to have significantly lower initial spine angles, and PGY-3s to have significantly lower neck angles during the initial activity. We observed no difference in the post-evaluation simulation angles between years, and there were no differences in percent of residents correct across cohorts. (Table 2)

Table 2

Comparison of Post-Graduate Years Angles and percent correct comparison across PGY years for both the pre and post simulation activities. Correct angles were set at neck angle < 25°, spine angle < 10°, and elbow angle 90–110°.

Height, median cm (IQR)	**PGY1**	**PGY2**	**PGY3**	**PGY4**	**p-value**
	N = 7	**N = 4**	**N = 4**	**N = 5**	
	170.2 (22.8)	**162.6 (12.7)**	**174.0 (22.7)**	**182.9 (14.0)**	**0.167**
Neck					
Pre-Angle, mean (SD)	55.6 (18.7)	59.5 (1.9)	52.3 (6.7)	66.7 (17.7)	0.009
Post-Angle, mean (SD)	47.3 (11.2)	45.1 (12.4)	37.5 (10.3)	53.2 (15.0)	0.899
Correct Pre, n (%)	1 (14.3)	0 (0.0)	0 (0.0)	0 (0.0)	> 0.999
Correct Post, n (%)	0 (0.0)	0 (0.0)	1 (25.0)	0 (0.0)	> 0.999
Spine					
Pre-Angle, mean (SD)	24.5 (31.5)	9.4 (5.1)	15.5 (5.4)	12.2 (8.2)	0.001
Post-Angle, mean (SD)	4.4 (2.6)	5.5 (3.3)	5.8 (4.0)	5.0 (4.8)	0.937
Correct Pre, n (%)	3 (42.9)	2 (50.0)	1 (25.0)	2 (40.0)	> 0.999
Correct Post, n (%)	7 (100.0)	3 (75.0)	4 (100.0)	5 (100.0)	0.400
Elbow					
Pre-Angle, mean (SD)	104.3 (24.1)	86.8 (13.6)	98.3 (5.2)	116.7 (14.2)	0.111
Post-Angle, mean (SD)	104.1 (12.6)	89.8 (10.7)	99.0 (6.0)	110.0 (17.0)	0.150
Correct Pre, n (%)	2 (28.6)	1 (25.0)	4 (100.0)	1 (20.0)	0.054
Correct Post, n (%)	4 (57.1)	2 (50.0)	4 (100.0)	4 (80.0)	0.426

Comparison of upper-level residents (PGY 3–4) to lower-level residents (PGY 1–2) interestingly revealed no significant difference in neck, spine, or elbow angles between the two cohorts in the pre-intervention exercise (Fig. 5). We also found no difference in percent of residents within the correct range for neck, spine, or elbow angles between the two cohorts for the pre-intervention exercise.

Height Outliers

Height outliers were defined as more than 1 standard deviation above or below the mean. This cohort may have to adapt more frequently to their senior surgeon leading to worse ergonomic habits. Again, we found no difference in the initial neck, spine or elbow angles between the height cohorts (Fig. 6).

Post-Survey

The post-survey revealed most residents think about their ergonomics in the operating room at least weekly (75%), with 15% of residents reporting they never think about operative ergonomics. Additionally, 95% of residents reported feeling physical strain while operating with neck pain as the most frequently reported site (n = 12). There was no difference in ergonomic awareness between upper- and lower-level residents (67% vs 82%, p = 0.617). Residents who were height outliers had similar rates of reported daily operating table adjustments compared to average height residents (83% vs 50%, p = 0.187). All residents reported improved awareness of ergonomics and perceived transferability to the clinical setting.

Discussion

Despite increased graduate medical education emphasis on resident wellness and career longevity, ergonomics-focused curricula remain limited. We found that a resident self-assessment of surgical ergonomics led to an improvement in spine and neck angles on post-assessment with a significant increase in the proportion of residents within the proper range for spine angles. Despite improvement in mean neck angle, all residents remained outside of the appropriate range which may be secondary to trainee vision, table height, or an unrealistic standard angle. In our entire cohort, elbow angle was maintained, indicating that residents may sacrifice proper neck and spine angles in an effort to maintain optimal elbow angle while operating. This seemingly compensatory positioning may partially explain our post-survey findings of neck pain as the primary reported site of pain. Survey results also highlighted an ergonomics knowledge gap as some residents reported physical strain in the operating room while not regularly thinking about ergonomics.

We hypothesized that post-graduate year would have an impact on the initial ergonomic evaluation due to their level of experience and awareness of operating table height, however, this had less of an impact on proper ergonomics than anticipated. There was no difference in percent of residents within the correct angle range for neck, spine, or elbow angle in the pre- or post-evaluation simulation exercise across all four post-graduate year cohorts or between upper- and lower-level residents. Further analysis to delineate the impact of height outliers also demonstrated no impact of height on initial ergonomics, and these outliers did not report more frequent table adjustments in the operating room. Overall, our findings suggest that surgical ergonomics may be more reliant on individual resident awareness of their posture and operative environment rather than post-graduate training level or height. The opportunity for self-evaluation allows for learning autonomy and active engagement to prompt a habit change rather than a temporarily taught behavior. This supports the incorporation of a simulation-based ergonomics curriculum to expand on traditional didactics-based education for surgical residents.

While simulation may be an effective modality for ergonomic change, implementation requires consideration of protected educational time and faculty workload [11]. Therefore, simulation activities should be optimized to maximize educational impact while minimizing the burden on participating residents and faculty. Potential options include hybrid lecture-simulation approaches, posture coaches,

or utilizing the multi-disciplinary team, such as occupational therapy, to assist in ergonomic education [12]. Our simulation activity required one faculty member for support and medical students who volunteered their time to act as simulation proctors. Therefore, the minimal resource burden of this activity supports its feasibility of integration into pre-existing resident simulation curricula.

This study has limitations associated with all single-institution resident education studies. The primary limitation is sample size due to single-institution study design and limited number of residents available to participate. Resident participation was limited by the night float system as well as residents on off-campus clinical rotations. The sample size also limits the statistical power of our sub-analyses which should be interpreted cautiously. The Hawthorne effect as well as repeat exposure are important to address as residents were made aware that they were being observed for ergonomics followed by immediate repeat simulation. Importantly, despite increased awareness, some residents still did not improve their surgical ergonomics, suggesting awareness may not fully compensate for poor ergonomic habits. While perceived transferability was captured in our post-simulation survey, true transferability to the operative setting has not been captured and would be an opportunity for future directions in resident ergonomics curriculum development.

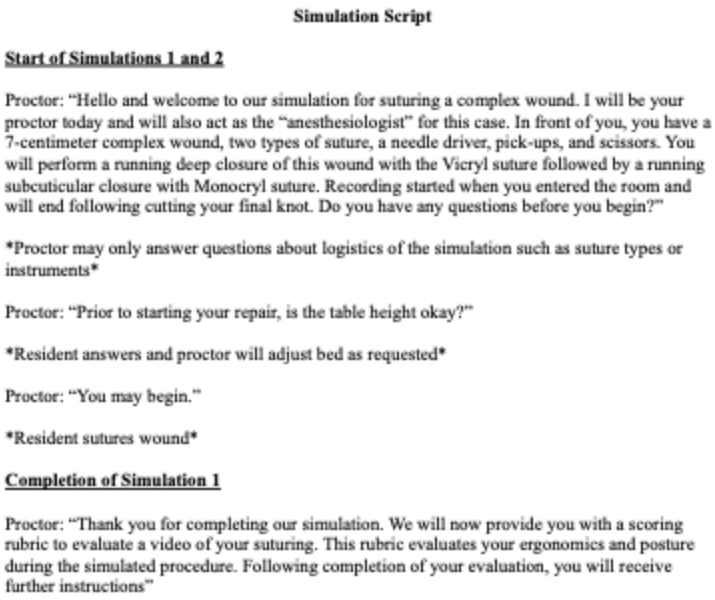
Our study demonstrated that a simulation-based ergonomic self-assessment is a feasible, low-resource addition to resident education that improves procedural posture and awareness of operative positioning. There is opportunity for further development of ergonomics curricula and self-evaluation activities for surgical residents that apply the principles of surgical simulation. Future directions should evaluate true clinical transferability and retention of simulation-based ergonomic training as well as its impact on trainee musculoskeletal strain.

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Figures



Simulation Script

Start of Simulations 1 and 2

Proctor: "Hello and welcome to our simulation for suturing a complex wound. I will be your proctor today and will also act as the "anesthesiologist" for this case. In front of you, you have a 7-centimeter complex wound, two types of suture, a needle driver, pick-ups, and scissors. You will perform a running deep closure of this wound with the Vicryl suture followed by a running subcuticular closure with Monocryl suture. Recording started when you entered the room and will end following cutting your final knot. Do you have any questions before you begin?"

Proctor may only answer questions about logistics of the simulation such as suture types or instruments

Proctor: "Prior to starting your repair, is the table height okay?"

Resident answers and proctor will adjust bed as requested

Proctor: "You may begin."

Resident sutures wound

Completion of Simulation 1

Proctor: "Thank you for completing our simulation. We will now provide you with a scoring rubric to evaluate a video of your suturing. This rubric evaluates your ergonomics and posture during the simulated procedure. Following completion of your evaluation, you will receive further instructions"

Figure 1

Simulation Script

Script utilized by simulation proctors at the start of each simulation exercise.

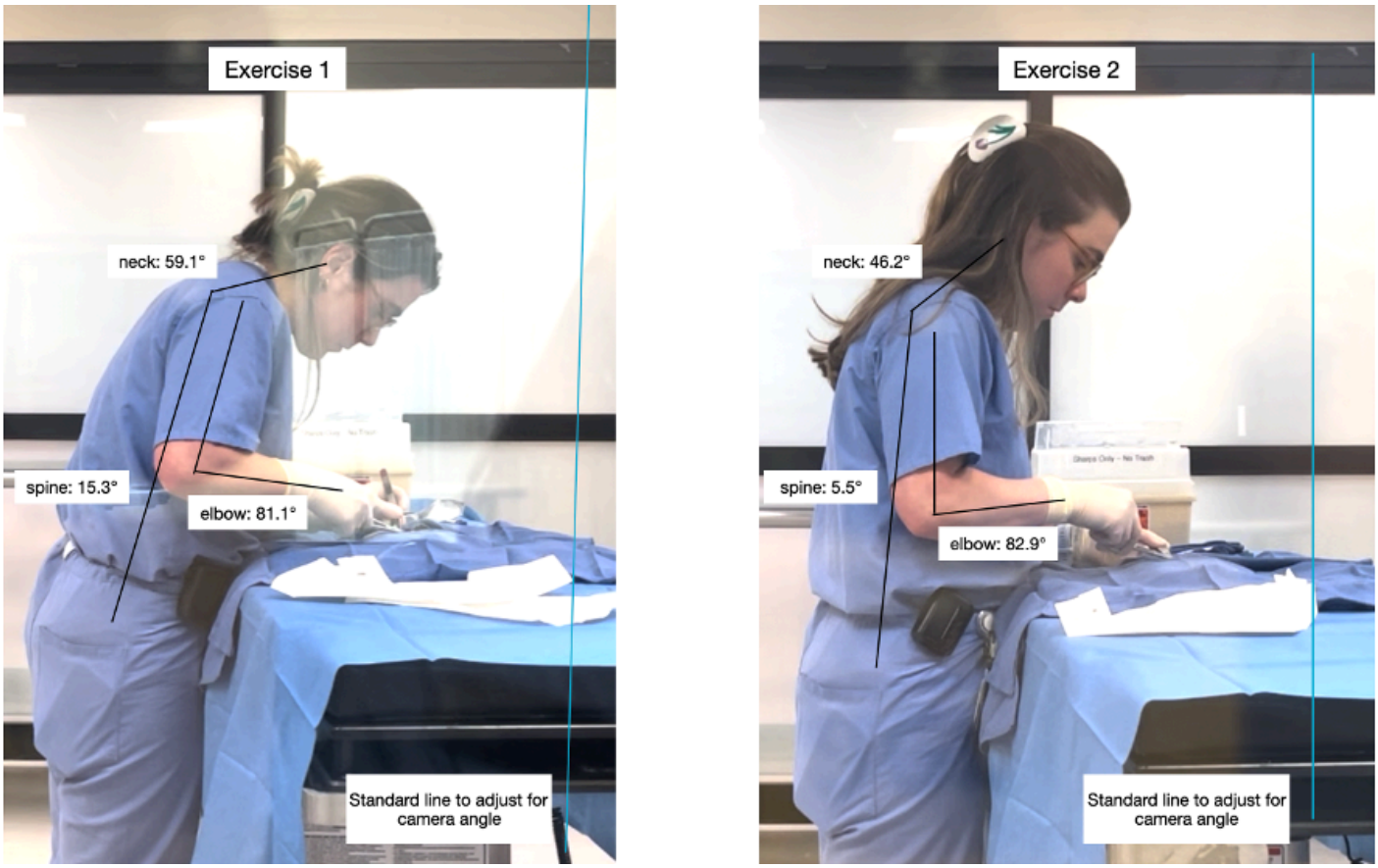


Figure 2

Example Angle Measurement

Video frame of resident performing suturing exercises 1 (A) and 2 (B) with standard line to adjust for camera angle and lines utilized to measure neck, spine, and elbow angles.

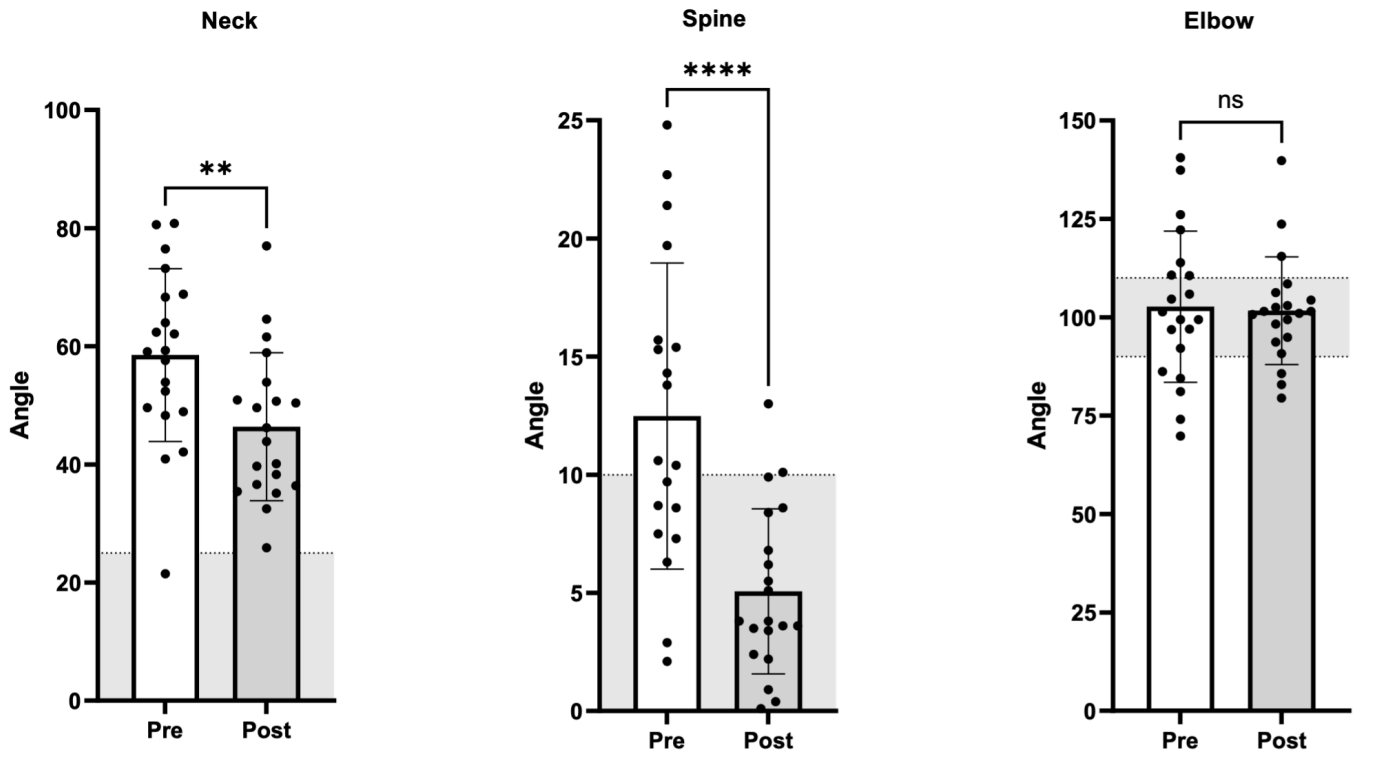


Figure 3

Pre vs Post Angles

Comparison of neck, spine, and elbow angles for all residents in the pre and post suturing simulation exercises. Shaded boxes represent the appropriate angle ranges: neck angle <25°, spine angle <10°, and elbow angle 90-110°. (**p<0.001, ****p<0.0001, ns=not significant.)

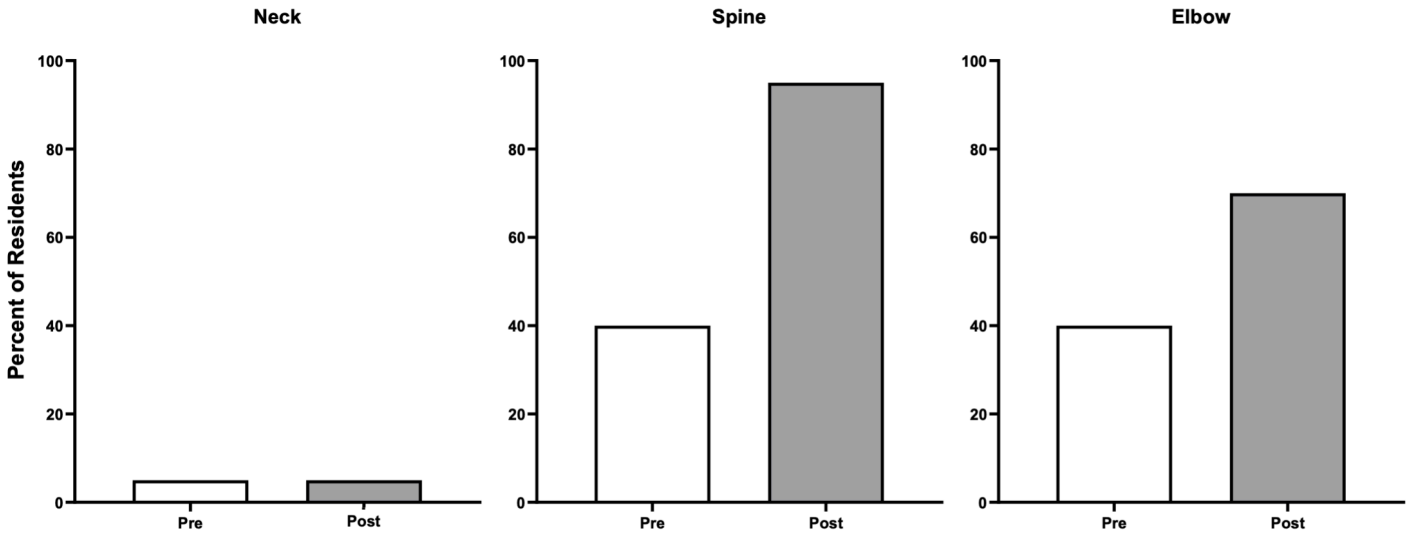


Figure 4

Pre vs Post Percent Correct

Percentage of residents across all levels with correct elbow angle in the pre and post simulation activities. Bars represent the percentage of residents who met each angle threshold which were set at: neck angle <25°, spine angle <10°, and elbow angle 90-110°.

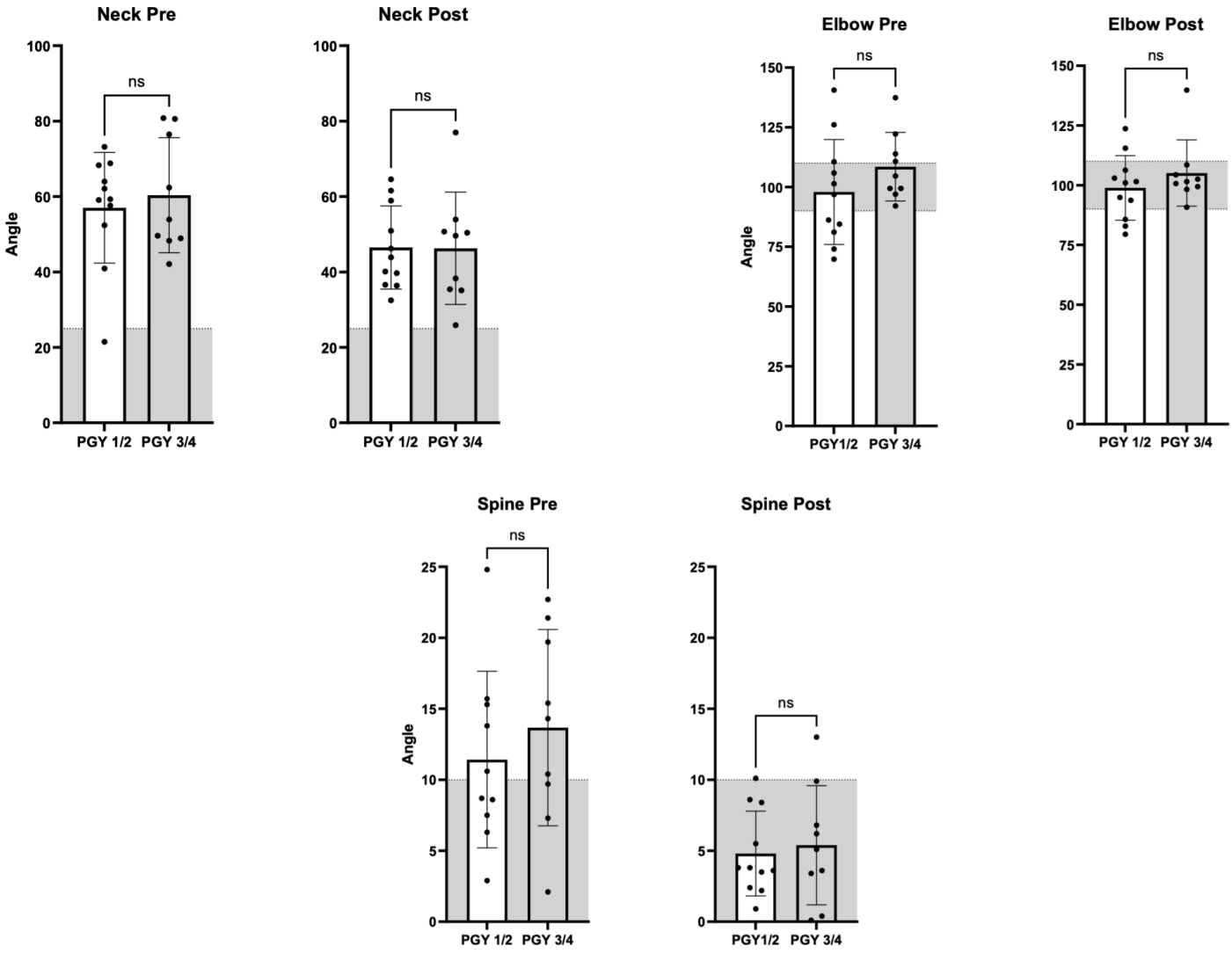


Figure 5

Lower Level vs Upper Level Residents

Comparison of lower level (PGY 1-2) to upper level (PGY 3-4) residents in each activity. Shaded boxes represent the appropriate angle ranges: neck angle <25°, spine angle <10°, and elbow angle 90-110°. (ns=not significant)

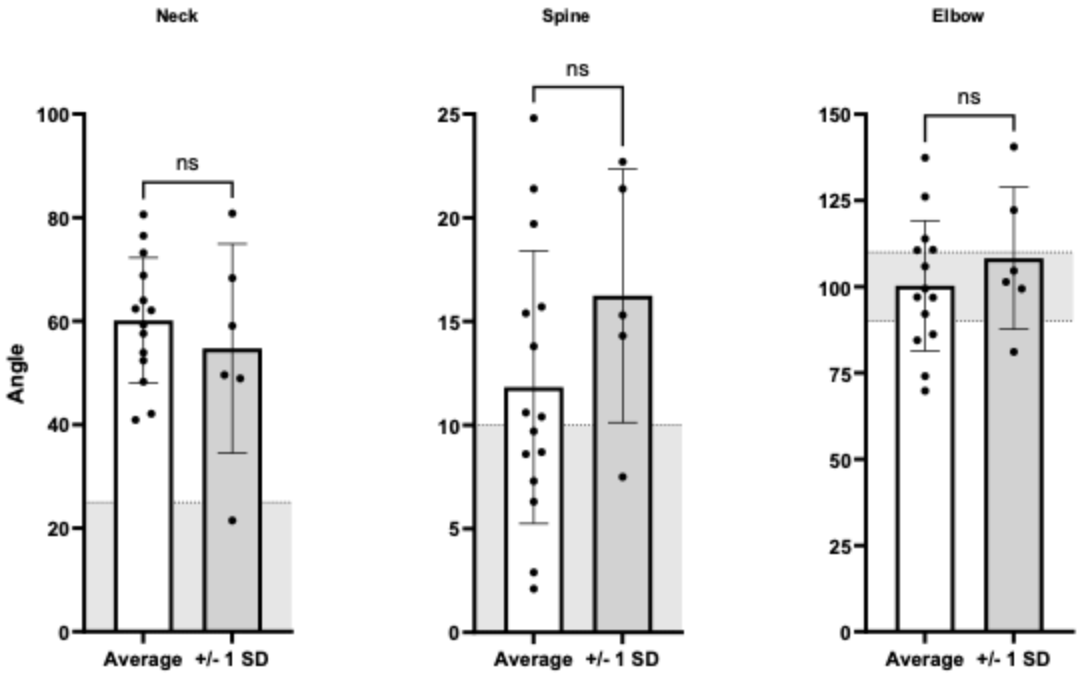


Figure 6

Height Outliers

Comparison of residents who are average height compared to those one standard deviation above or below the mean (+/- 1 SD). Shaded boxes represent the appropriate angle ranges: neck angle <25°, spine angle <10°, and elbow angle 90-110°. (ns=not significant)