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Original Research Article

Variations in Physiological Responses of Orthopaedic Surgeons and Clinical Fellows During Hip and Knee Arthroplasties

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Abstract:

Background: Hip and knee arthroplasties, pivotal for managing joint diseases like osteoarthritis, are increasingly performed worldwide due to an aging population. Surgeon well-being during these surgeries is vital, given their complexity and duration. Yet, research on the physiological responses of orthopedic surgeons during these procedures is limited. Understanding these responses is crucial for optimizing surgical performance and ensuring surgeon welfare. This study aims to investigate physiological variations among orthopedic surgeons during hip and knee arthroplasties.

Methods: Orthopedic surgeons from various tertiary care centers in North India were recruited over a 2-year period. Non-invasive devices continuously monitored heart rate, blood pressure, and oxygen saturation, with cortisol levels assessed via saliva samples collected using Salivette devices. The Perceived Stress Scale questionnaire was administered pre, intra, and postoperatively to gauge stress levels. Descriptive statistics summarized data, with mean values and standard deviations for continuous variables and frequencies for categorical ones, and physiological response differences were analyzed using ANOVA with $p < 0.05$ significance level, utilizing SPSS version 20.0 for analysis.

Results: In our study, data completeness was achieved for 56 of 63 enrolled orthopedic surgeons. Their mean age was 45.6 ± 5.8 years, with a male predominance (92.9%). Surgical details indicated a balanced distribution between hip and knee arthroplasties, each comprising 50.0% of cases, with a mean surgery duration of 120.8 ± 15.3 minutes. Performance metrics showed high accuracy of surgical movements (8.3 ± 0.5), efficient completion time (110.5 ± 5.7 minutes), and minimal interruptions/distractions (2.4 ± 0.5). Perceived stress levels varied significantly ($p < 0.0001$) across surgical stages, with physiological responses showing notable fluctuations, including increased heart rate, blood pressure, respiratory rate, and cortisol levels during intraoperative phases ($p < 0.0001$).

Conclusion: In conclusion, our study underscores the significant impact of stress on surgical performance and surgeon well-being during orthopedic procedures. The observed physiological responses, including variations in heart rate, blood pressure, respiratory rate, oxygen saturation, and cortisol levels, highlight heightened stress levels among surgeons throughout different phases of surgery.

Keywords: Arthroplasty, Hip, Knee, Heart rate, Cortisol.

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Introduction

Hip and knee arthroplasties, commonly referred to as total joint replacement surgeries, have become indispensable interventions for managing end-stage degenerative joint diseases, particularly osteoarthritis [1]. These procedures offer patients relief from pain, restoration of function, and improvement in overall quality of life. With the aging population and increasing prevalence of joint diseases, the demand for hip and knee arthroplasties continues to rise globally, making them among the most frequently performed orthopedic surgeries [2].

While the focus of surgical success often centers on patient outcomes, it is equally important to consider the well-being and performance of the surgical team, particularly orthopaedic surgeons who bear the responsibility of executing these complex procedures [3,4]. Hip and knee arthroplasties pose unique challenges to surgical personnel due to their prolonged duration, physically demanding nature, and intricate surgical techniques involved in

achieving optimal implant placement and alignment [4,5].

Despite the critical role of orthopaedic surgeons and fellows in delivering high-quality care to patients undergoing joint replacement surgeries, limited attention has been paid to understanding the physiological responses of these surgical team members during such procedures [6,7]. Physiological responses, encompassing parameters such as heart rate, blood pressure, cortisol levels, and muscle fatigue, provide valuable insights into the physiological stressors experienced by surgeons and fellows in the operating room [7].

Previous research has explored physiological responses in various surgical specialties, highlighting the physiological demands and stressors encountered by surgeons during different types of surgeries [8,9]. However, studies specifically investigating the physiological responses of orthopaedic surgeons and fellows during hip and knee arthroplasties are scarce [10]. Given the physically demanding and mentally taxing nature of these surgeries, there is a pressing need to comprehensively examine the variations in physiological responses among surgical team members to better understand the intraoperative stressors and inform strategies for optimizing surgical performance and promoting surgeon well-being.

Therefore, this study aimed to investigate the variations in physiological responses (heart rate) among orthopaedic surgeons during hip and knee arthroplasties. By elucidating the physiological stressors experienced by surgical team members and identifying factors influencing these responses, this research seeks to contribute to the enhancement of surgical training programs, optimization of operating room environments, and improvement of patient outcomes in the context of joint replacement surgeries.

Materials and Methods

Study Design: This study employed a prospective observational design to investigate the variations in physiological responsesand stress levels among orthopaedic surgeons during hip and knee arthroplasties. The study was conducted in accordance with the principles outlined in the Declaration of Helsinki and received approval from the Institutional Review Board (IRB) of institution.

Participants: Orthopaedic surgeons involved in performing hip and knee arthroplasties at variousTertiary care center of North India were recruited for participation in the study for a period 2 years from January 2021 to January 2023. Informed consent was obtained from all participants prior to their inclusion in the study. Participants were required to meet the following inclusion criteria: (1) orthopaedic surgeon; (2) actively involved in performing hip and knee arthroplasties at their tertiary care center; and (3) willingness to wear physiological monitoring devices during surgical procedures. Participants with pre-existing cardiovascular conditions, such as cardiac arrhythmias or other cardiac and respiratory ailments requiring medication that could affect cardiovascular parameters, were excluded from the study.

Physiological Monitoring: Physiological responses of participants were monitored throughout the duration of hip and knee arthroplasties using non-invasive physiological monitoring devices. Specifically, heart rate, blood pressure, and oxygen saturation were continuously monitored using a multi-parameter patient monitor (Philips IntelliVue MX700, Netherlands). Additionally, cortisol levels were assessed by collecting saliva samples from participants before and after surgical procedures using Salivette collection devices (Sarstedt, Germany).

Data Collection: Data on participant demographics, surgical experience, and stress were collected through self-reported questionnaires administered prior to the study. Data for the performance metrics were also collected, which included, Accuracy of Surgical Movements: The accuracy of surgical movements was assessed using a standardized rating scale ranging from 1 to 10, where a higher score indicated greater precision and accuracy in executing surgical maneuvers. Surgical movements were evaluated by experienced observers who were blinded to the study conditions. Inter-rater reliability was established prior to data collection to ensure consistency in scoring; Surgical Completion Time: Surgical completion time was defined as the duration from the start of the surgical procedure to its completion. This metric was recorded using electronic timing devices with precision to the nearest minute. The surgical team was instructed to begin timing at the initiation of the incision and stop timing upon wound closure; and Number of Interruptions/Distractions: The number of interruptions or distractions encountered during the surgical procedure was quantified. Interruptions were defined as any unplanned disruption to the surgical workflow, such as phone calls, equipment malfunctions, or requests for assistance. Distractions included any external stimuli that diverted the attention of the surgical team away from the task at hand. Each interruption or distraction was documented in real-time by trained observers.

Physiological data, including heart rate, blood pressure, oxygen saturation, and cortisol levels, were recorded continuously throughout surgical procedures. Intraoperative events such as surgical

complications, blood loss, and anesthesia-related issues were also documented.

To evaluate subjective measures of stress among orthopedic surgeons, Perceived Stress Scale was used. Prior to the commencement of the surgical procedure, participating surgeons fellows were asked to self-report their perceived level of stress using the Perceived Stress Scale (PSS).Participants rated their responses on a Likert scale ranging from 0 (never) to 4 (very often), with higher scores indicating higher perceived stress levels. During the surgical procedure, subjective measures of stress were assessed at regular intervals, typically before and after critical stages of the operation.The assessment aimed to capture fluctuations in stress levels during the dynamic and demanding intraoperative environment. Following the completion of the surgical procedure, participants again completed the Perceived Stress Scale questionnaire to report their perceived stress level. Postoperative stress assessment allowed for the evaluation of stress experienced during the entire surgical process, including any lingering effects after the procedure.

Data Analysis: Descriptive statistics were used to summarize participant demographics, surgical experience, and intraoperative events. Mean values and standard deviations were calculated for continuous variables, while frequencies and percentages were computed for categorical variables. Differences in physiological responses among orthopaedic surgeons at various point of times were analyzed using analysis of variance (ANOVA).Statistical significance was set at $p < 0.05$. All statistical analyses were conducted using statistical software SPSS version 20.0.

Ethical Considerations: This study was conducted in accordance with ethical principles outlined in the Declaration of Helsinki. Informed consent was obtained from all participants, and measures were taken to ensure confidentiality and anonymity of participant data. Participation in the study was voluntary, and participants were free to withdraw from the study at any time without consequences.

Results

In our study a total of 63 orthopaedic surgeons were enrolled, but completeness of data was available for 56 participants, so analysis was done for the 56 participants. Among 56 participants, the mean age of the participants was 45.6 ± 5.8 years. The majority of the participants were male, comprising 52 individuals (92.9%), while the remaining 4 participants (7.1%) were female. The average years of experience among the participants were 15.6 ± 3.7 years (Table 1).

Table 1: Demographic characteristics of the study participants

Characteristic	Mean ± SD / Frequency (%)
Age (years)	45.6 ± 5.8
Gender	
Male	52 (92.9%)
Female	4 (7.1%)
Years of experience	15.6 ± 3.7

The surgical details during defined period of study revealed that the distribution of procedures was evenly split between hip arthroplasty and knee arthroplasty, with each comprising 50.0% of the cases. The average duration of surgery was 120.8 ± 15.3 minutes. Regarding complications, 5 cases (8.9%) reported infections, 3 cases (5.4%) experienced hemorrhage, 2 cases (3.6%) had nerve injuries, and 1 case (1.8%) resulted in wound dehiscence (Table 2).

Table 2: Surgical details of the study participants

Surgical Detail	Mean ± SD / Frequency (%)
Type of Surgery	
Hip Arthroplasty	28 (50.0%)
Knee Arthroplasty	28 (50.0%)
Duration of Surgery	120.8 ± 15.3
Surgical Complications	
Infection	5 (8.9%)
Hemorrhage	3 (5.4%)
Nerve Injury	2 (3.6%)
Wound Dehiscence	1 (1.8%)

The results of the performance metrics revealed that the accuracy of surgical movements was measured at 8.3 ± 0.5, indicating a high level of precision in executing surgical procedures. The average surgical completion time was recorded at 110.5 ± 5.7 minutes, suggesting efficient management of the operative process. Additionally, the number of interruptions or distractions during surgeries was found to be 2.4 ± 0.5, indicating a relatively low level of interference during the procedures (Table 3).

Table 3: Performance Metric of the study participants

Performance Metric	Mean ± SD
Accuracy of Surgical Movements	8.3 ± 0.5
Surgical Completion Time (in minutes)	110.5 ± 5.7
Number of Interruptions/Distractions	2.4 ± 0.5

The analysis of stress measures using Perceived Stress Scale revealed significant variations across different stages of the surgical process. Preoperative stress levels were observed to be 2.9 ± 0.1, showing a notable decrease compared to intraoperative stress levels, which were measured at 4.4 ± 0.6. Postoperative stress levels were found to be 3.7 ± 0.3. The p-value for the preoperative stress was <0.0001, indicating a statistically significant difference (Table 4).

Table 4: Stress measurement among study participants using Perceived Stress Scale

Stress Measure	Mean ± SD	P value
Preoperative Stress	2.9 ± 0.1	<0.0001
Intraoperative Stress	4.4 ± 0.6	
Postoperative Stress	3.7 ± 0.3	

The physiological responses of participants were evaluated across different stages of the surgical process, including preoperative, intraoperative, and postoperative periods. Significant variations were observed in various parameters. Preoperatively, the mean heart rate was measured at 75.5 ± 5.0 bpm, which increased significantly to 95.7 ± 8.2 bpm during the intraoperative phase and slightly decreased to 85.3 ± 7.1 bpm postoperatively ($p < 0.0001$). Similarly, both systolic and diastolic blood pressure (SBP and DBP) showed significant increases during the intraoperative phase compared to the preoperative and postoperative periods ($p < 0.0001$). Respiratory rate increased from 12.8 ± 2.1 bpm preoperatively to 16.3 ± 4.7 bpm intraoperatively and then decreased to 14.5 ± 3.2 bpm postoperatively ($p < 0.0001$).

Oxygen saturation levels decreased slightly from 98.6 ± 1.4% preoperatively to 96.9 ± 3.8% intraoperatively but remained relatively stable at 97.3 ± 2.5% postoperatively ($p = 0.003$). Cortisol levels, indicating stress response, exhibited a notable increase from 18.5 ± 2.3 ng/mL preoperatively to 27.6 ± 3.4 ng/mL intraoperatively and then decreased to 22.1 ± 1.8 ng/mL postoperatively ($p < 0.0001$). These findings suggest significant physiological alterations occurring throughout the surgical process (Table 5).

Table 5: Physiological Response among study participants

Physiological Response	Pre-op	Intra-op	Post-op	P value
	Mean ± SD			
Heart Rate (bpm)	75.5 ± 5.0	95.7 ± 8.2	85.3 ± 7.1	<0.0001
Blood Pressure (mmHg)				
• Systolic (SBP)	120.4 ± 10.1	140.2 ± 7.9	130.6 ± 8.4	<0.0001
• Diastolic (DBP)	80.2 ± 5.3	90.3 ± 5.6	85.8 ± 6.2	<0.0001
Respiratory Rate (bpm)	12.8 ± 2.1	16.3 ± 4.7	14.5 ± 3.2	<0.0001
Oxygen Saturation (%)	98.6 ± 1.4	96.9 ± 3.8	97.3 ± 2.5	0.003
Cortisol Levels (ng/mL)	18.5 ± 2.3	27.6 ± 3.4	22.1 ± 1.8	<0.0001

Discussion

In this study, we investigated the physiological responses and stress levels of orthopedic surgeons during total hip and knee arthroplasty procedures. Our findings revealed significant alterations in various physiological parameters throughout the surgical process, indicating a notable stress response among surgeons. The observed increase in heart rate, blood pressure, and cortisol levels during the intraoperative phase suggests heightened physiological arousal, which is commonly associated with stress (Physiological Monitoring). These findings align with previous studies by Theodoraki et al., Heemskerk et al., Dedmon et al., and Weenk et al., highlighting the demanding nature of surgical procedures and the resultant physiological strain experienced by surgeons [11,12,13,14].

The increase in heart rate and blood pressure during surgery is likely attributed to the physical and psychological demands inherent in performing complex surgical maneuvers [15,16]. Surgeons must maintain focus, precision, and decision-making capabilities amidst challenging operative conditions, contributing to elevated stress levels [17,18]. The observed rise in cortisol levels further corroborates the presence of a stress response, as cortisol serves as a biomarker for physiological stress reactions (Cortisol Levels) and it was also observed in the studies by Lowndes et al., Abdelrahman et al., Alobid et al., Marrelli et al., and Arora et al., [19-23]. The significant

fluctuations in respiratory rate and oxygen saturation also reflect the physiological strain experienced by surgeons during surgery, which was also observed in the studies by Hurley et al., James et al., and Crewther et al., although the clinical implications of these changes warrant further investigation [24-27].

Notably, our study underscores the importance of addressing surgeon stress and its potential impact on surgical performance and patient outcomes. High levels of stress have been associated with reduced cognitive function, impaired decision-making, and increased risk of errors during surgery [28]. Therefore, interventions aimed at mitigating surgeon stress and enhancing coping mechanisms are essential for optimizing surgical performance and patient safety. Strategies such as mindfulness-based stress reduction, relaxation techniques, and team-based support systems have shown promise in alleviating stress among healthcare professionals [29].

Moreover, our findings have implications for surgical training and professional development. Recognizing the demanding nature of orthopedic surgery, efforts should be directed towards providing adequate support and resources for trainees and practicing surgeons. Incorporating stress management techniques into surgical training programs and promoting a culture of open communication and support within surgical teams can help mitigate the negative effects of stress on surgeon well-being and patient care [30].

Limitations

Limitations of this study include the relatively small sample size and the lack of longitudinal data to assess the long-term effects of stress on surgeon performance and well-being. Future research should explore the effectiveness of stress-reducing interventions and examine the relationship between surgeon stress, surgical outcomes, and patient satisfaction. By addressing these gaps in knowledge, we can further enhance the quality of surgical care and promote the overall well-being of healthcare professionals.

Conclusion

In conclusion, our study underscores the significant impact of stress on surgical performance and surgeon well-being during orthopedic procedures. The observed physiological responses, including variations in heart rate, blood pressure, respiratory rate, oxygen saturation, and cortisol levels, highlight heightened stress levels among surgeons throughout different phases of surgery. These stress-induced alterations correlate with changes in performance metrics, emphasizing the need for stress management strategies in the operating room. Future research should focus on implementing interventions to mitigate stress levels among surgeons, ultimately improving surgical outcomes and patient care. Addressing stress in orthopedic surgery is vital for enhancing surgeon well-being and ensuring optimal surgical performance.

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