Enhancing Surgical Robotic Skills Through Performance-Guided Training: A Swimmer's Approach for Defining Key Metrics

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Objective

This study investigates the parallels between elite swimming training and robotic-assisted surgical training, focusing on skill acquisition, feedback mechanisms, and performance-guided training. By applying structured feedback techniques used in athletic training, such as video analysis and real-time adjustments, the research aims to optimize surgeon training, particularly in robotic-assisted surgery. The goal is to define key metrics that enhance surgical precision, efficiency, and adaptability.

Background

Both elite swimmers and robotic surgeons rely on precision, endurance, and continuous skill refinement to achieve optimal performance. In swimming, structured feedback and targeted training improve stroke mechanics and cardiovascular conditioning, while in surgery, performance-guided training methods use real-time feedback and digital tools to enhance technical skills. Performance-driven training models, such as cumulative sum analysis and simulation-based learning, play a crucial role in both fields. By integrating proven athletic training methodologies, this study explores how structured progression and feedback can enhance robotic surgery training, potentially improving surgeon proficiency and patient outcomes.

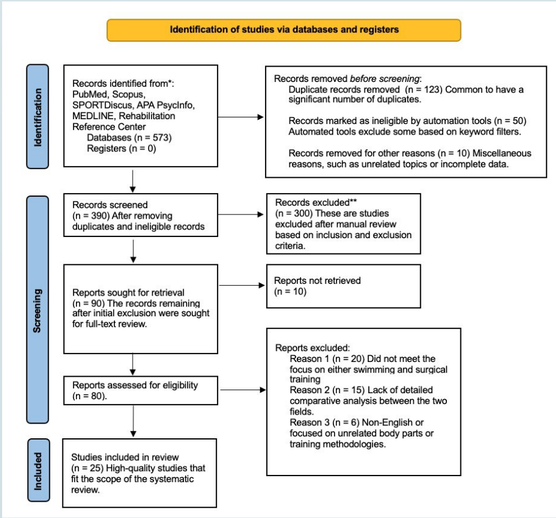


Image 1: Robotic Surgical Movement Metrics Analysis

Methodology

A systematic review was conducted following PRISMA guidelines, analyzing 573 studies on swimming and surgical training. After filtering for duplicates and ineligible sources, 25 high-quality studies were selected based on predefined inclusion criteria, including muscle memory, coordination, and crossover training potential. Research focused on skill development in both fields, examining factors such as cognitive training, real-time feedback, simulation-based training, and biomechanical analysis. Metrics like stroke efficiency in swimming and instrument coordination in surgery were compared to identify common training principles that can be applied to robotic surgery education.

Figure 1: PRISMA Flow Diagram on Study Selection Process



Results

The review identified strong similarities between swimming and surgical training, emphasizing structured, feedback-driven approaches to improving precision and skill. Video analysis in swimming and real-time digital feedback in surgery were found to be highly effective. The study also highlighted the role of cognitive training, simulation-based learning, and endurance-focused training in optimizing motor control. Key performance metrics, such as coordination, grasping efficiency, and muscle control, were identified as crucial for both swimmers and surgeons. The findings suggest that structured training programs combining real-time feedback, targeted drills, and adaptive learning can enhance surgical precision and efficiency.

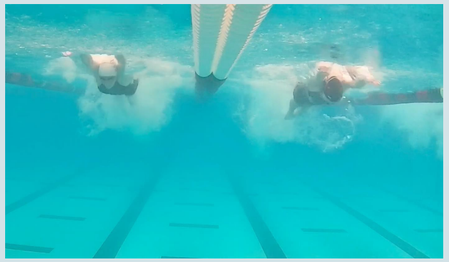


Image 2: Swimmers Movement Metrics Analysis in Competition

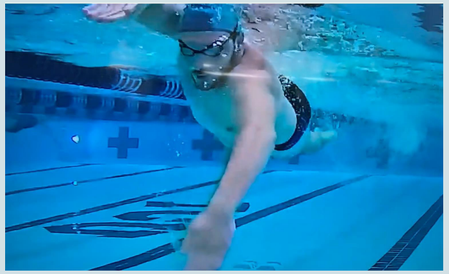


Image 3: Swimmers Movement Metrics Analysis in Practice

Conclusion

Applying performance-guided training principles from elite swimming to robotic surgery can significantly improve surgeon training. By incorporating structured feedback, precision training, and simulation-based methodologies, surgical education programs can be enhanced to develop key metrics for surgical proficiency. The study highlights the potential of integrating sports science into medical training to improve technical skill acquisition and patient outcomes. Further research is needed to validate these strategies and establish standardized training metrics in robotic-assisted surgery.

Table 1: Comparison of Swimming and Surgical Metrics

Metric Category	Swimming Metrics	Surgical Metrics	New Robotic Surgical Metrics
Coordination and Skill Acquisition	Coordinate arm and leg movements for propulsion	Monitor frequency of instrument interference	Instrument synchronization and coordination
Grasping and Catching Efficiency in Performance	Assess hand entry and pull efficiency	Track instances of missed or inaccurate grasps	Surgical grasping proficiency and error tracking
Instrument and Body Part Engagement	Evaluate core muscle engagement during strokes	Record idle or underutilized instrument time	Analysis of underutilized robotic tools or body parts
Tissue Handling and Muscle Control	Identify signs of overextension or strain	Monitor tissue damage or overhandling	Risk of injury or tool-related strain during surgery
Hand and Instrument Positioning Techniques	Analyze hand positioning and angle during stroke	Evaluate needle handling and positioning	Incorrect instrument or hand positioning in robotic surgery
Movement Efficiency in Skill Execution	Identify overreaching or inefficient movements	Assess for unnecessary or excessive movements	Detect wasted movement or energy loss during surgery
Precision of Finger and Instrument Use	Focus on finger placement and stroke shape	Measure precision and control of instrument tips	Improvement in tactile feedback and precision control
Optimal Angles and Approach Techniques	Assess arm/hand entry angle into water	Analyze instrument approach angles to tissue	Optimization of robotic tool entry angles
Task and Action Completion	Ensure full stroke pull-through	Track multiple attempts or incomplete actions	Consistency in movement completion and surgical outcomes

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