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EFFECTIVENESS OF A COMPREHENSIVE MENTAL SKILLS CURRICULUM IN ENHANCING SURGICAL PERFORMANCE: RESULTS OF A RANDOMIZED CONTROLLED TRIAL

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Abstract

Introduction—We hypothesized that the implementation of a novel mental skills curriculum (MSC) during laparoscopic simulator training would improve mental skills and performance, and decrease stress.

Methods—Sixty volunteer novices were randomized into intervention and control groups. All participants received FLS training while the intervention group also participated in the MSC. Skill transfer and retention were assessed on a live porcine model after training and 2 months later, respectively. Performance was assessed using the Test of Performance Strategies-2 (TOPS-2) for mental skills, FLS metrics for laparoscopic performance, and the State Trait Anxiety Inventory (STAI-6) and heart rate (HR) for stress.

Results—Fifty-five participants (92%) completed training and the transfer test, and 46 (77%) the retention test. There were no significant differences between groups at baseline. Compared to controls the intervention group significantly improved their mental skill use, demonstrated higher laparoscopic skill improvement during retention, and reported less stress during the transfer test.

Conclusions—The MSC implemented in this study effectively enhanced participants' mental skill use, reduced cognitive stress in the operating room with a small impact on laparoscopic performance.

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Keywords

Surgery; Simulation; Skills Training; Skill retention; Mental Skills; Stress Management; Performance Enhancement

Introduction

The inherent cognitive demands of surgery, including the need to execute elaborate technical procedures flawlessly, maintain focus for extensive periods of time amidst several distractions, sustain sound clinical judgment and situational awareness, and balance attention between several intraoperative considerations (e.g., patient condition, performance of the surgical team, etc.), may exceed surgeons' stress-management abilities and lead to catastrophic errors that jeopardize patient safety.¹⁻³ It has been postulated that there is a dynamic, cascading relationship between adverse factors that contribute to surgeons' stress levels.⁴ That is, increased intraoperative workload can contribute to heightened cognitive demand, which can eventually surpass the surgeon or team's stress-coping ability, ultimately leading to excessive stress. In a recent survey of surgeons' experience managing intraoperative stressors, we found that 40% of responding surgeons had witnessed a technical complication resulting from the primary surgeon experiencing heightened stress.⁵ The vast majority of respondents (82%) indicated that stress management training would be valuable to surgeons.

Helping surgeons cope with intraoperative stress effectively may thus be critical to enhance surgical performance particularly for inexperienced surgeons. The literature suggests that surgical trainees are more vulnerable than experienced surgeons to succumb to overwhelming intraoperative stress due to their relative inexperience in the operating room, and their associated lack of developed stress management strategies.¹ In prior studies we have demonstrated that despite achieving proficiency on laparoscopic surgery simulators in a stress-free environment, surgical novices cannot fully transfer simulator-acquired surgical skill to the clinical environment in part due to overwhelming stress.⁶⁻⁸ Further, laparoscopic skills acquired on simulators may deteriorate significantly over periods of inactivity.⁶⁻¹⁰ Thus, there is a need to develop reliable methods to reduce learner stress in the operating room and maximize simulator-acquired skill transfer and retention.

Mental skills, which are psychological strategies intended to help performers reliably achieve their ideal mental state for performance,¹¹ may be able to help surgical novices reduce stress and enhance their transfer of simulator-acquired skills to the operating room. Mental skills training curricula have proved effective at enhancing the performance of several groups who have to perform under high stress conditions such as military pilots,¹² US Navy SEALs,¹³ members of police special forces,¹⁴ and elite athletes¹⁵. Compared to the more comprehensive application of mental skills in other high-stress fields though, mental imagery (i.e., synonymous with mental rehearsal and mental practice) has been the primary mental skill implemented in surgical research. A recent meta-analysis of randomized controlled trials that implemented mental imagery as a surgical training intervention found that it was effective at enhancing surgical skill acquisition.¹⁶ However,

there are several additional mental skills that may be effective at reducing surgical novices' stress and enhancing their performance.

We recently developed a novel, comprehensive, mental skills curriculum (MSC) and have examined its preliminary effectiveness when applied during simulator training of surgical novices. This curriculum consists of several performance enhancing strategies including goal setting, energy management (relaxation or increasing energy), attention and thought management, mental imagery, refocusing strategies, and pre-performance routines. In an initial prospective study novice participants that underwent mental skills training using this curriculum displayed significantly better transfer of simulator-acquired laparoscopic skill to the operating room compared with historical controls.¹⁷ Our objective in the current prospective randomized controlled study was to assess whether training using our novel mental skills curriculum would lead to application of these skills in clinical situations, reduction in participant stress under challenging conditions, and improvements in surgical skill transfer to the clinical environment and retention. We hypothesized that novices who concurrently trained in laparoscopic suturing and mental skills would demonstrate improved laparoscopic skill transfer and retention in the clinical environment compared with a control group that trained in laparoscopic suturing only.

Methods

After Institutional Review Board-approval, volunteer surgical novices (n=60, premedical students) were enrolled in this single blinded randomized controlled trial. Participants completed a questionnaire detailing demographics and prior laparoscopic and simulator experience, and had a baseline assessment on the Fundamentals of Laparoscopic Surgery (FLS) peg transfer and intracorporeal suturing,¹⁸ and mental skills use. For the latter the Test Of Performance Strategies Version 2 (TOPS-2) was used, which is a 68-item self-report instrument that measures a comprehensive range of psychological skills that have been shown to impact successful athletic performance: goal-setting, imagery, self-talk, relaxation, activation, emotional control, and automaticity.¹⁹ The instrument assesses the frequency of participants' use of these skills in practice and performance situations. Example items from the TOPS-2 include: "I set realistic but challenging goals for practice", "I rehearse my performance in my mind before practice", and "I talk positively to myself to get the most out of my performance during a procedure". Responses range from: 1-"Never" to 5-"Always". The TOPS-2 has been shown to discriminate between elite and high-level performers in non-competition performance settings, and has been shown to be reliable and valid. The non-normed fit index (NNFI) and comparative fit index (CFI) are excellent for both the competition and practice subscales, (0.97 and 0.97, and 0.96 and 0.96, respectively).¹⁹ This instrument was modified by the authors with permission for use with surgeons by replacing any reference to "competition" with "procedure" as appropriate. For example, one statement from the original instrument read "I evaluate whether I achieve my competition goals" was modified to read "I evaluate whether I achieve my procedure goals".

Participants were stratified according to FLS performance and TOPS-2 scores and randomized into intervention and control groups. The intervention group participants received FLS peg transfer and intracorporeal suturing training during nine training sessions

and mental skills training using the novel comprehensive MSC. The control group did not receive mental skills training but followed the same laparoscopic skills curriculum. Skill transfer and retention 2 months after training completion were assessed on a live porcine fundoplication model.

Training

Participants in both groups attended 9 biweekly, small group (n=2 or 3) training sessions over a period of approximately 5 months. During each session both groups received 45 minutes of FLS proficiency-based simulation training on peg transfer during the first 3 sessions followed by training in intracorporeal suturing in the remaining 6 sessions. To reach proficiency, participants had to meet previously published expert levels (i.e. 48 seconds without errors for the PEG transfer and 112 seconds with no errors of accuracy or knot security for intracorporeal suturing and knot tying)²⁰ on 2 consecutive and 10 additional repetitions. All participants were transitioned to intracorporeal suturing on session 4 or earlier once they had achieved PEG transfer proficiency.

The comprehensive MSC implemented in this study included several mental skills such as action plans (i.e., goal setting), energy management (i.e., relaxation and strategies to increase energy), attention and thought management techniques (i.e., helping participants maintain attention on target and effectively counter negative thoughts), mental imagery, refocusing techniques, and performance routines and has been described in more detail elsewhere.²¹ The MSC group participated in eight biweekly 45-minute mental skills education sessions with a mental performance coach, just before their laparoscopic training session. Each session required participants to observe video modules to educate them on specific mental skills and how they may be implemented to optimize surgical performance, complete exercises in an accompanying workbook to crystalize how learners planned to implement each mental skill during surgical simulation training and eventual surgical performance, and practice each skill during the subsequent FLS training session under the supervision and guidance of the mental performance coach to facilitate participants' development of mental skills as habits for performance. Following the 9 session training period, participants were retested according to the same protocol as the baseline assessment.

Transfer and Retention Tests

Three weeks after the conclusion of training, participants took part in a transfer test that required to put three gastrogastic sutures on a live, anesthetized porcine model to complete a fundoplication. An expert laparoscopic surgeon (DS) readied and standardized the porcine models for testing as has been described before.⁸ Participants were asked to place 3 sutures on the live pig stomach: two sutures connecting preplaced target stitches and a third one between the first two. A surgeon's knot and 2 square knots per suture were required and a 10-minute time limit was allotted for each suture. Knots were tested for accuracy and security and participants' performance was assessed using an objective score: Performance score = cutoff time (600 seconds) – task completion time (seconds) – [10 × accuracy error (mm outside black target on Penrose)] – [100 × security error (slip = 1 or knot break = 2)].⁶⁻⁸ Also, we measured participants' stress objectively (i.e., physiological stress measured with average heart rate (HR) with Polar RCX3 heart rate monitors (Polar Electro

Inc., Lake Success, NY) and subjectively (i.e., cognitive stress) with the 6-item State-Trait Anxiety Inventory (STAI-6) during the testing session. Average HR was used to measure physiological arousal, as this provided an objective indication of participants' stress during the laparoscopic tasks. We have previously found that HR is a sensitive measure of physiological stress.⁸ The STAI is a self-report instrument that uses a 4-point Likert scale to measure state anxiety, otherwise known as anxiety about an event, and trait anxiety, or anxiety as a personal characteristic.²² The shortened version of STAI, the STAI-6, consists of only six questions and focuses on state anxiety only. It has been shown to be internally consistent, reliable, and valid.²³ Two months after the transfer test, participants returned for a retention test on the same model and using the same task and assessments. The assessor was blinded to the training group of participants.

Data Analysis

Data are presented as means \pm standard deviation or medians (range) as appropriate. Objective suturing performance and heart-rate data were compared between MSC and control group participants at baseline, posttest, transfer and retention tests. TOPS scores were compared between groups and over time from baseline to posttest sessions, STAI scores were compared between groups at transfer and retention tests. A repeated measures analysis was used to analyze between group differences, differences over time, and group by time interactions. To compare the intra-group percentage of skill change between performance tests, we used the following equation: suturing score during retention test – suturing performance during transfer test / suturing score performance during transfer test. The same was used for average HR and STAI rating changes. Two-sample t-tests assuming unequal variance were used to analyze differences in mean suturing performance between groups for the transfer and retention tests, and within-group changes in suturing performance between tests. For all analyses, a p-value of $p < 0.05$ was considered significant. Following the retention test, the MSC group participants' perceived value of the mental skills curriculum was gathered anonymously with a survey (i.e., via Survey Monkey)²⁴, and responses were compiled to provide additional contextual information on their use of these skills during the retention interval. The study was designed based on pilot data to detect a 30% difference between the study groups with a power of 0.8 at an alpha of 0.05. The power analysis required a sample size of 24 students in each group; we enrolled 30 in each group anticipating a 20% attrition rate we had encountered in previous studies.

Results

There were no statistically significant differences between groups at baseline in regards to demographic data, laparoscopic performance, or mental skills use (table 1). Of the 60 originally enrolled participants 55 (92%, control group n=28; MSC group n=27) completed training and participated in the transfer test, and 46 participants (77%, control group n=22; MSC group n=24) participated in the 2-month retention test (figure 1). Four participants dropped out early after baseline testing and one participant dropped out after session 6 due to their inability to attend subsequent training sessions. Nine participants dropped out between the transfer and retention tests due to inability to participate during the retention testing session. The use of mental skills by MSC group participants improved significantly

after training compared with controls based on the modified TOPS-2 test scores (table 2). While there were no statistically significant difference in suturing performance during the posttest, transfer and retentions tests, the MSC group's suturing performance increased significantly from the transfer test to the retention test (+17.8% vs 10.1% for the control group; $p < .05$) (table 3 and figure 2). Additionally, while there were no significant differences between groups in average HR at baseline, posttest, or during the transfer test, the control group had significantly lower average HR during the retention test than the MSC group (table 4 and figure 3). On the other hand, participant STAI-6 scores indicated that the MSC group experienced less stress than the control group during both the transfer and the retention tests (table 4 and figure 4).

Regarding the MSC group's perceived value of the curriculum, 54% of participants completed the survey after the retention test. For each mental skill, at least 83% of responding participants reported that the mental skills modules were effective at enhancing their performance. Moreover, 92% of participants described instances that prompted their use of mental skills outside of the study, and 85% planned to use mental skills in future stressful situations to enhance their performance.

Discussion

In this single blinded randomized-controlled study, we assessed the effectiveness of a novel, comprehensive, surgery-specific mental skills curriculum at enhancing surgical novices' retention of simulator-acquired skills in the clinical environment. While there were no statistically significant differences between the MSC and control groups in laparoscopic suturing performance during the transfer and retention tests, the MSC group demonstrated almost double performance improvement between the transfer and retention tests compared with the control group (17.8% vs 10.1%, respectively; $p < 0.05$). We believe that this finding provides evidence about the effectiveness of our MSC at enhancing surgical skill. It is worthwhile to note that instead of observing performance deterioration after 2 months of practice abstinence as has been suggested by previous studies,⁶⁻⁸ both groups demonstrated improvements during the retention test indicative of continued learning even in the absence of practice. This suggests that mental skills training may be especially beneficial to enhance learning during longer intervals of no practice, which has been previously described also by other authors.²⁵ Indeed, the survey responses of our MSC group participants indicated that 92% had practiced the learned mental skills in everyday life situations such as exams, presentations, or other on-demand performance situations. This additional practice may have ensured that participants' use of these skills in stressful situations was more crystalized, which led to the significantly improved performance from the transfer test to the retention test compared to controls. Also, since 85% of responding participants indicated that they planned to use the mental skills taught to them in this curriculum in future stressful situations to enhance their performance, there was clearly a high-level of perceived value of mental skills training by the surgical novices that participated in this intervention. Despite the noted improvement in performance change between the transfer and retention tests in our MSC participants, there was no difference in actual laparoscopic suturing performance during the transfer test and an only 8% difference in favor of the MSC group during the retention that did not reach statistical significance. These findings are in contrast to

previously published studies that have demonstrated a clear advantage of mental imagery in surgical skill acquisition and performance.²⁶⁻²⁹ An explanation for the small effect we observed in this study could be related to differences in study designs; the majority of previous studies have focused on having novices perform surgical procedures and have not implemented proficiency-based training²⁶⁻²⁸ as was the case in this study. Also, Arora et al. (2011) trained surgical novices to proficiency on a virtual reality laparoscopic trainer, and found that mental imagery significantly enhanced participants' performance of 5 laparoscopic cholecystectomies, which was a relatively unfamiliar task for participants.²⁹ In our study, the procedural element of the transfer test remained very similar to training, only the environment and situational factors differed. The benefits of mental imagery may be maximized during the early learning phase of a new complex procedure or for rarely encountered procedures; in our study all participants developed robust laparoscopic suturing skills as a result of their proficiency-based simulator training, which may have masked any effect of imagery. Further, it is possible that some of the taught mental skills techniques may have required a longer time period for robust assimilation.

As anticipated the MSC group reported less stress during the transfer and retention stress compared to the controls, a finding that supports the effectiveness of our intervention that addressed stress management techniques. To our surprise, however, the MSC group had significantly higher average HR during the retention test than the control group. In other words, while the MSC group experienced higher physiological arousal than the control group, their cognitive stress was lower. Considering that our prior work has demonstrated that HR increases are a good indicator of stress and performance anxiety that may be responsible for the laparoscopic performance deterioration seen during transfer tests⁸ a corresponding increase in cognitive stress measures (STAI ratings) and laparoscopic performance deterioration during the test might have been anticipated. Our findings, therefore, suggest that physiological and cognitive stress may have different effects on performance, and that cognitive stress may have a bigger impact on performance than physiological given that we did not observe performance deterioration despite increased HR. Indeed, the sport psychology literature suggests that stress is actually the resulting response from an interaction of physiological responses to external events (i.e., performance demands) and one's cognitive appraisal of their ability to cope with the demands of the situation (i.e., perceived ability to perform highly and available psychological coping strategies).³⁰⁻³¹ There is no inherent emotional component of physiological arousal, but one's perception and appraisal of that arousal and ability to manage it effectively are what determine the physiological arousal's impact on performance. Thus, it is possible that due to the performance enhancing and stress management techniques taught in this curriculum, the MSC group was able to handle the performance demands of the retention test well by mitigating the negative effects of heightened physiological arousal and preventing performance deterioration. This explanation fits within Hanin's Individualized Zone of Optimal Functioning (IZOF) model, which posits that there is a dynamic interaction of emotions, thoughts, and physiological and cognitive arousal that uniquely contribute to help a performer achieve their ideal performance state for a given activity.³² For some performers, moderate physiological arousal may actually enhance their performance through activation and sharpening of focus and attention that leads them to achieve their IZOF.

However, the critical difference in how physiological arousal influences performance (i.e., positively or negatively) is determined by one's cognitive appraisal of the situation and their ability to manage the demands of the situation. It is noteworthy that the control group also performed better during the retention test compared to their post test performance despite no intervening practice. A potential explanation could be that the quality and rigor of the initial proficiency based training led to lasting learning effects; it is also possible that control group participants may have used previously learned mental skills during the retention interval but we did not assess that. Nevertheless, both groups experienced reduced cognitive stress (i.e., STAI-6 score) from transfer to retention which likely also influenced participants' performance.

Previous studies that have applied mental skills to enhance surgical novices' performance have primarily implemented single-skill interventions that focus on using mental imagery as an adjunct to physical practice.¹⁶ These mental imagery interventions have been largely successful at enhancing novices' acquisition of surgical skills. However, the curriculum implemented in our study is much more robust than those that only implemented mental imagery, as it addresses several additional important mental skills such as goal setting, energy and attention management strategies, refocusing techniques, and performance routines. Our findings in this study along with evidence from prior studies^{16, 21} provide support that mental skills training should be implemented in surgical training curricula, as a supplement to surgical simulation training.

Given the existing time constraints of surgical training the optimal implementation of mental skills training during residency may prove challenging. To address this potential challenge we are currently incorporating the components of our MSC (i.e., video modules and accompanying workbook materials) into an electronic application that allows residents to consume these materials at their convenience. Consequently, with the help of a mental performance coach, the applied portion of mental skills training can be easily implemented within residents' existing simulation training curricula, and applied to optimize the performance of each individual resident and develop these skills as routines for performance.

There were some limitations with this study. Due to logistical constraints, training frequency was limited to 9 bi-weekly sessions over approximately 5 months. While this training frequency was the same for both groups, and therefore likely had a similar impact on surgical performance, it may have been inadequate for the development of robust mental skills and may have limited our ability to detect performance differences between groups. Unfortunately, there is currently no available literature on the ideal frequency and duration of mental skills training to guide their optimal implementation and this area needs further investigation. Feedback from our MSC participants indicated that they would have liked to meet more often to practice surgical and mental skills. Nevertheless, our finding that performance improved significantly for the MSC group compared with the control group during the 2 month retention interval and the participants' self-reported use of these skills in a variety of performance situations during that period, suggest that ongoing practice of these skills helped facilitate their concrete integration in performance routines. Also, we only measured average heart rate as an objective measure of physiological arousal, and not heart rate variability (HRV). Some authors have argued that HRV is a more sensitive measure of

learners' physiological arousal compared to heart rate.³³⁻³⁴ However, our group has previously found that actual heart rate is more sensitive than HRV as a measure of learners' arousal.⁸ Also, while serum cortisol, measured through saliva, has been identified as a valid and reliable reflection of physiological stress,^{35,36} repeated measures of salivary cortisol at all testing sessions would have been fairly costly to collect given our large sample size. Given that we have previously shown that HR is a sensitive measure of physiological stress⁸ and the purchase of HR monitors is significantly less costly elected to use HR as our measurement for physiological stress.

In conclusion, this randomized controlled study indicates that our novel MSC is effective at enhancing surgical novices' laparoscopic skill retention and at decreasing cognitive stress under stressful performance conditions. Thus, surgical trainees, who may not get the opportunity to practice laparoscopy often in the clinical environment early in their careers, may retain simulator-acquired skills more effectively after mental skills training. These findings may apply to the retention of other surgical skills that are acquired in the simulation lab, but are rarely implemented in performance situations in the stressful clinical environment. Future randomized controlled studies will examine the effectiveness of this MSC by implementing it in surgical trainees' weekly surgical simulation training sessions. In future surgical skills transfer sessions, we plan to closely replicate the human operating room environment, and introduce artificial stressors to challenge surgical residents. We anticipate that these challenges, which simulate real intraoperative stressors,⁵ will increase participants' stress levels and determine if our novel MSC effectively enhances residents' performance and reduces their stress.

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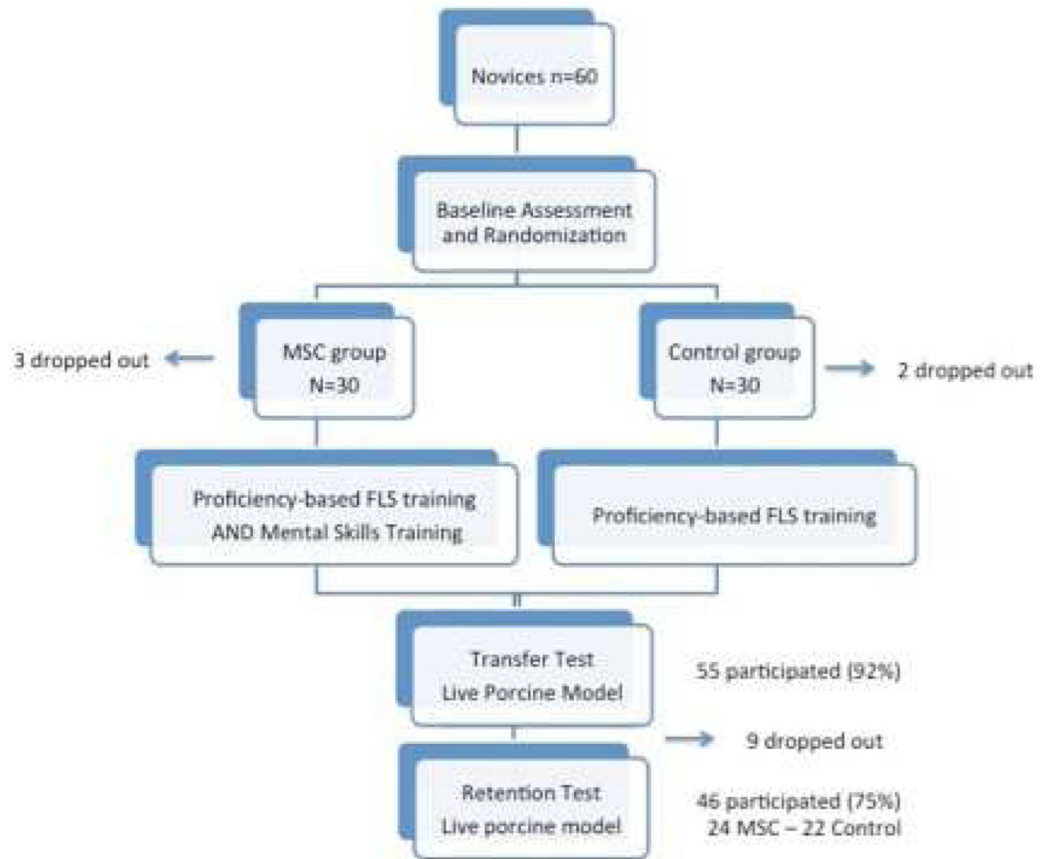


Figure 1.
Study algorithm

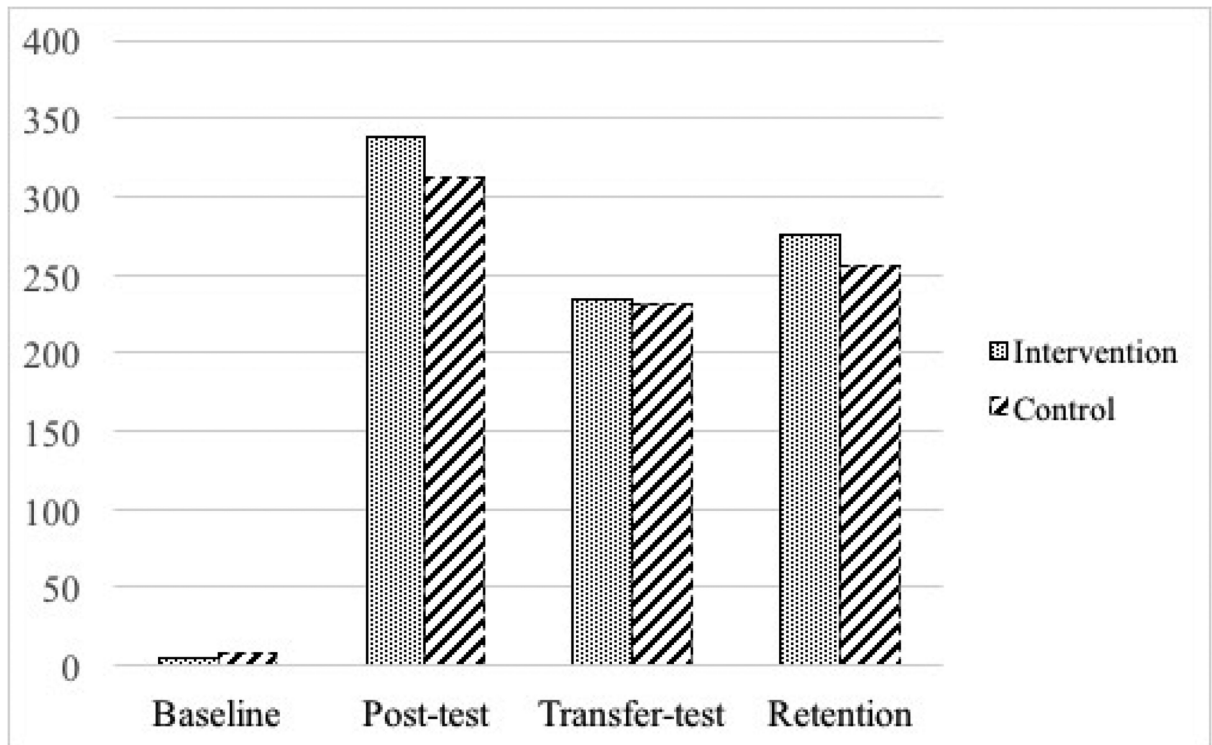


Figure 2.

Laparoscopic Suturing Performance comparison between groups

*- Y axis values represent objective suturing scores; baseline and post-test assessed on the FLS simulator while transfer and retention tests assessed on the live porcine fundoplication model

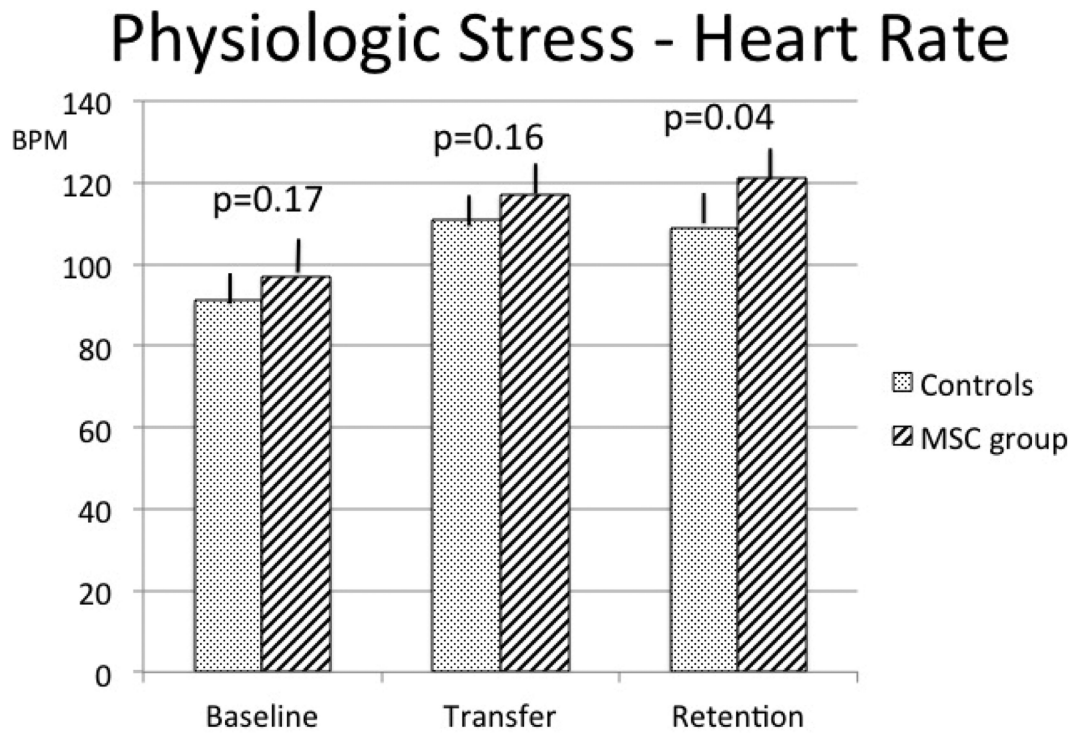


Figure 3.
Heart Rate Comparisons between groups

Cognitive Stress – STAI-6

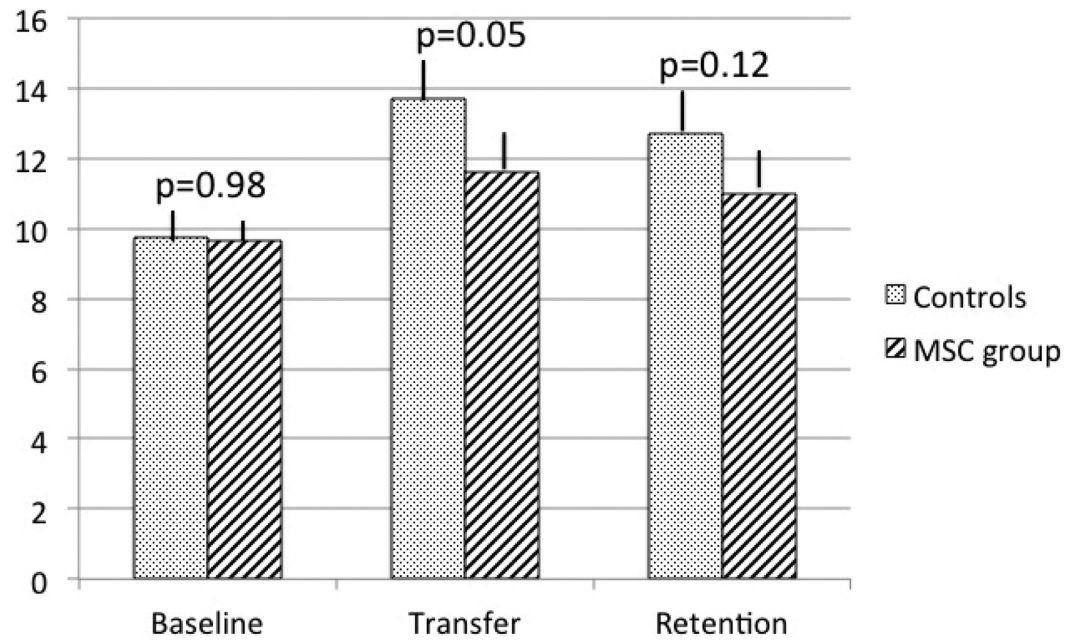


Figure 4.
State-Trait Anxiety Inventory Score comparisons between groups

Table 1

Participant characteristics at baseline

	Control Group N=28	MSC Group N=27	p-value
Age (years)	20.6±2.3	20.5±3.4	0.93
Men:Women	1:1	1.7:1	0.23
% Right handed	93%	93%	0.95
Baseline FLS Suturing Score	7±22	4±17	0.64
Baseline HR	91±37	97±25	0.17
Baseline TOPS Cumulative	249.9±26.5	243.6±23.7	0.36

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Table 2

Participant mental skills use before and after training

	Control Group N=28	MSC Group N=27	p-value
Baseline TOPS Cumulative	249.9±26.5	243.6±23.7	0.36
Posttest TOPS Cumulative	238.5±21.9	248.9±24.9	0.11
Change in Cumulative from Baseline to Posttest	-4.6%	+2.2%	0.008
Baseline TOPS Self-talk performance	3.3±0.9	3.2±0.8	0.74
Posttest TOPS Self-talk Performance	2.9±0.8	3.4±0.8	0.02
Change in Self-talk from Baseline to Posttest	-12.1%	+6.3%	0.0005
Baseline TOPS Relaxation Performance	3.2±1	3.2±0.9	0.97
Posttest TOPS Relaxation Performance	3±1	3.7±0.7	0.002
Change in Relaxation from Baseline to Posttest	-6.3%	+15.6%	0.003
Baseline TOPS Imagery Performance	3.6±0.9	3.9±0.7	0.17
Posttest TOPS Imagery Performance	3.6±0.7	4±0.6	0.03
Change in Imagery from Baseline to Posttest	0%	+2.6%	0.59

Higher TOPS-3 scores indicate greater use of mental skills.

Table 3

Laparoscopic suturing performance comparisons

	Control Group N=28	MSC Group N=27	p-value
# training repetitions	47.4±6.9	46.6±10.6	0.77
Baseline FLS Suturing Score	7.1±22.4	4.6±17.3	0.64
Posttest FLS Suturing Score	312.9±220.7	338.9±207.7	0.66
Transfer test Suturing Score	231.9±115.2	233.6±130.9	0.93
2 month Retention test Suturing Score	255.3±132.6	275.1±128.1	0.37
Performance Change from Transfer to Retention	+10.1%	+17.8%	0.04

Higher suturing scores indicate better laparoscopic performance

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Table 4

Stress Indicator comparisons

	Control Group N=28	MSC Group N=27	p-value
Baseline HR	91.4±16.7	97.1±14.6	0.17
Posttest HR	97.3±15.7	103.6±17.1	0.27
Transfer test HR	114.1±15.3	117.2±22.2	0.16
Transfer test STAI-6	13.7±3.3	11.6±3.6	0.05
Retention test HR	109.2±19.1	120.9±18.1	0.04
Retention test STAI-6	12.7±3.8	11±3.4	0.12
HR Change from Transfer to Retention	-4.3%	+3.2%	0.27
STAI-6 Change from Transfer to Retention	-7.3%	-5.2%	0.41

Higher STAI-6 scores indicate higher cognitive stress; higher heart rate (HR) indicates higher physiological arousal.