

The Effect of Video Game “Warm-up” on Performance of Laparoscopic Surgery Tasks

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ABSTRACT

Background: Performing laparoscopic procedures requires special training and has been documented as a significant source of surgical errors. “Warming up” before performing a task has been shown to enhance performance. This study investigates whether surgeons benefit from “warming up” using select video games immediately before performing laparoscopic partial tasks and clinical tasks.

Methods: This study included 303 surgeons (**249 men and 54 women**). Participants were split into a control (n=180) and an experimental group (n=123). The experimental group played 3 previously validated video games for 6 minutes before task sessions. The Cobra Rope partial task and suturing exercises were performed immediately after the warm-up sessions.

Results: Surgeons who played video games prior to the Cobra Rope drill were significantly faster on their first attempt and across all 10 trials. The experimental and control groups were significantly different in their total suturing scores ($t=2.28$, $df=288$, $P<.05$). The overall Top Gun score showed that the experimental group performed marginally better overall.

Conclusion: This study demonstrates that subjects completing “warming-up” sessions with select video games prior to performing laparoscopic partial and clinical tasks (intracorporeal suturing) were faster and had fewer errors than participants not engaging in “warm-up.” More study is needed to determine whether this translates into superior procedural execution in the clinical setting.

Key Words: Laparoscopic surgical training, Video games, Warm-up, Surgical error suppression.

INTRODUCTION

In view of the 1998 Institute of Medicine’s (IOM’s) report that revealed upwards of 100,000 people die from medical errors in the United States each year, the subject of pre-procedural warm-up as a way of enhancing surgical performance is a subject worthy of investigation.¹ In spite of all efforts to date, medical errors have persisted at an unacceptable level. The report also revealed that over 57% of these errors are surgical mishaps. Recently, there has been more in-depth scrutiny of this challenge on a global scale. The World Health Organization (WHO) has stated that over 250,000 patients worldwide perish or are injured from preventable surgical miscues each year.^{2,3} The Society of Laparoscopic Surgeons (SLS) has launched a campaign in conjunction with WHO to recruit hospitals and their staff to adhere to consistent utilization of preoperative protocols, including clinical staff warm-ups, checklists, and team building techniques. This is called the OR READY program.⁴ Gallagher et al⁵ and Gallagher and Satava⁶ reported that 15 minutes to 20 minutes of warm-up with a clinical task-related simulator (bovie coagulator) suppressed errors in both the fresh and fatigued surgeons. This study used a task-specific simulator and was directed to the open arena. Clearly, warm-up protocols that are effective in enhancing laparoscopic skill performance and error suppression would be a welcomed addition to a pre-surgery routine. Video games are cost effective, motivate engagement, and are omnipresent resources. These traits would make them very attractive warm-up assets. This study will examine whether there is any laparoscopic task performance enhancement after a warm-up session with select video games.

The earliest published report dealing with warming-up and physical performance is that of Simonson and associates in 1936.⁷ These investigators showed that preliminary exercise improved running time of 100 meters for men and women. In 1952, Silver⁸ demonstrated that the conducting of practice activity (warming-up) before a des-

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ignated task resulted in better performance of that task. He also observed that excessive warm-up activity resulted in a decline in performance of said task. In 1954, Malerecki⁹ evaluated the physiological justification of “so-called warming up.” He reported that physical and mental warm-up exercises had performance benefits in the speed of running 60 meters. In 1957 Karpovich¹⁰ suggested there was a relationship between warming up and improved physical performance. He found that, in general, warming-up induces beneficial physiologic changes, such as speeding up circulation, increasing the ability to assimilate oxygen, and enabling smoother contraction of muscles. He concluded the warming-up phenomenon could be achieved actively, by exercising muscles using movements not necessarily of the same type and intensity as those used in the actual task.¹⁰

According to Shellock and Prentice, warm-up techniques can be more precisely classified into 3 major categories: (a) general (passive warm-up)—increases temperature by some external means; (b) general (active warm-up)—increases temperature by nonspecific body movements; and (c) formal (specific warm-up)—increases temperature using similar body parts that will be used in the subsequent, more strenuous or specific activity or event. Their study demonstrated that the best approach appears to be formal (specific warm-up), because this method provides a rehearsal of the activity or event.¹¹ Their investigation also revealed that the majority of the benefits of warm-up are related to temperature-dependent physiological processes.

Some of the direct physiological benefits of warm-up include release of adrenaline, which leads to increased heart rate and dilation of capillaries. This phenomenon enables oxygen in the blood to travel faster, increases production of synovial fluid located between the joints to decrease joint friction, which improves efficiency, and enhances distal blood and oxygen delivery to critical tissues, which also maximizes performance. It appears that a warm-up regimen causes an increase in the temperature of the muscles, a decrease in the viscosity of blood with an acceleration of blood flow and enhancement of the removal of lactic acid. This promotes increased enzyme activity, facilitates the release of oxygen from hemoglobin, and enhances the extensibility and elasticity of muscle fibers.¹² It has been suggested that increased muscle fiber elasticity increases the force and speed of contraction, which can also augment the efficiency of performing tasks. In addition, warming-up leads to increases in speed of nerve impulse conduction. This is an important asset for performance of any activity including laparoscopic

tasks. The increase in muscle metabolism improves the available supply of energy for performance through the breakdown of glycogen. These findings were supported by a 1994 study by Smith¹³ that concluded that physiologic warming-up (isometric preconditioning) led to increased muscle/tendon suppleness, stimulated blood flow to the periphery, increased body temperature, and enhanced free, coordinated movement.

Other investigations have studied the “warm-up” effect in areas other than physical performance. Vocal warm-up is generally accepted as vital for improved singing performance.¹⁴ In addition, vocal warming up was shown in a study by de Swart et al¹⁵ in 2007 to improve speech production in patients with adult onset myotonic dystrophy. He found that warming up can lead to an increase in speech rate and a decrease in speech variability without causing signs of fatigue or exhaustion as a result of prolonged and intensive use of the speech musculature, which translated into enhanced performance. To evaluate the effects of warming-up on physical performance, Fradkin et al¹⁶ recently performed a systematic meta-analysis to determine the evidence relating to performance improvement using a preliminary warm-up exercise. In their investigation, warm-up was shown to improve performance in 79% of the criteria examined. Their analysis suggests that performance excellence can be optimized after completion of warm-up activities, especially if they are appropriately selected. Furthermore, it was demonstrated that no evidence suggests warming-up negatively affects the performance of criterion tasks. With the abundance of credible research in this area, it can be stated that the warm-up phenomena is not a myth. Therefore, the harnessing of these effects to suppress errors and increase task efficiency in video-endoscopic surgery is a worthy investigation priority.

MATERIALS AND METHODS

This study is a quasi-experimental design based on performance of participants in the Rosser Top Gun Laparoscopic Skills and Suturing Program.¹⁷ It is a day and a half program that has been previously described and validated to develop advanced laparoscopic skills and intracorporeal suturing ability.^{18,19} Intracorporeal suturing is considered one of the most difficult clinical tasks to be performed in video-endoscopic surgery.²⁰ The data were gathered from 2001 through 2005 during the conduction of multiple courses. Groups were not randomly assigned, but were assigned by dates of the course. Participants prior to October 2004 had no video game warm-up regi-

mens and were considered the control group (n=180). Beginning October 2004, participants received the standard course with 2 video game “warm-up” periods (at the beginning of days 1 and 2 of the course) and are considered the experimental group (n=123).

This study involved 3 components. The first consisted of a questionnaire to assess multiple aspects of the trainees past experiences and included, but was not limited to, surgery experience, number of laparoscopic cases, and video game play (both past and current), as well as demographic information including age, sex, and hand dominance. The surgical experience portion of the questionnaire also included items regarding the subjects’ level of training or years in practice and subspecialty. This component was administered during the orientation of the Top Gun Training Program, before video games or surgical drills were started.

The second component was the Top Gun Laparoscopic Skill and Suturing program, which was conducted over 1 and 1/2 days (12 hours). This course consists of a highly structured training pedagogy combined with the performance of preparatory partial tasks and interrupted intracorporeal suturing exercises. The preparatory drills emphasize 2-handed choreography, nondominant hand dexterity, 2-dimensional depth perception compensation, targeting, and rehearsal of specific maneuvers used in the process of achieving an intracorporeal knot.^{17,18} The Cobra Rope task requires subjects to unwind and pass a coiled string using 2 endograspers while targeting and grasping designated colored sections of the string. Subjects are evaluated based on time. No errors are recorded. But, there is intense instructor direction and monitoring so that the task is completed under proper protocol. The second drill is the Triangle Transfer drill, requiring subjects to lift and move 5 triangular objects from one specified point to another. This drill is accomplished by inserting a needle through a metal loop atop each triangle, using the nondominant hand. A validated electronic proctor records both time and errors.²¹ The third is the Slam Dunk (Bean Drop) drill. This task requires subjects to move small pea-shaped objects from a specified area and deposit them into a 1-cm opening of a cup using the nondominant hand and a standard laparoscopic grasper. Again, time and errors are recorded. Finally, interrupted intracorporeal sutures are placed into porcine intestine. The task is performed using the Rosser standardized intracorporeal suturing algorithm, and time and errors are recorded via the electronic proctor. Subjects complete 10 trials of each task. Final calculations of time and errors (each error adds 5 seconds to score) are used to

create overall scores. The lower the score is, the better the performance.

The third component is the participants playing select video games. Surgeons in the experimental arm played 3 previously validated game titles for 6 minutes each (total time of 18 minutes) immediately before performing any partial task or suturing exercise. It should be noted that the Cobra Rope drill and intracorporeal suturing tasks were done immediately after the warm-up exercises. The games used were *Star Wars Racer*, *Silent Scope*, and *Super Monkey Ball*. The first video game was Super Monkey Ball 2 (trademark of SEGA 2001 for Nintendo Gamecube), which requires the user to pilot a spherical object around a dynamic undulating course while targeting specific items. Success was judged by total time to complete the course while collecting designated items. Each participant was given a maximum of 300 seconds to complete the course, and if the course was not completed in 300 seconds, a value of 300 seconds was assigned. The second video game, *Silent Scope* (trademark of Konami 1999 for PlayStation 2), is a simple game requiring the user to shoot various targets as they appear on the screen. Participants were instructed to “shoot” as many targets as possible in 2 minutes and 30 seconds. Scoring for this game was based on the total number of targets hit. The final video game was *Starwars Racer: Racer Revenge* (trademark of LucasArts Entertainment 2002 for PlayStation 2). This game requires the student to steer their “pod-racer” vehicle through a serpentine canyon track while competing against 5 other computer-controlled pods. Scoring of this game was judged by total time needed to complete the track. All games were viewed on either a 20-inch over-the-counter television or a 17-inch Sony Trinitron Flat Screen monitor like those used in laparoscopic surgery (Sony CPD-G220R 17-inch FD Trinitron Flat CRT Monitor, Part Number: CPD-G220R). These games require fine motor control, visual attention processing, spatial distribution, reaction time, eye-hand coordination, targeting, nondominant hand emphasis, and 2D depth perception compensation. All of them have been validated to be associated with enhanced laparoscopic task performance.¹⁷

RESULTS

This study included 303 surgeons (*249 men and 54 women*). The participants averaged 13.0 years of surgical experience (SD=10.1; range=0 to 45; median=10.3), with 3.5% reporting no surgical experience yet. The average number of laparoscopic surgeries performed by partici-

pants was 343 (SD=544; range=0 to 2500), although the median number was 114. Only 9.9% of participants had not performed any laparoscopic surgeries yet in their careers. Surgeons in the experimental and control groups were not significantly different in their years of experience ($t=0.2$, $df=282$, $P=.83$) or the number of surgeries performed ($t=-1.1$, $df=272$, $P=.24$). Perhaps more importantly, surgeons were given a pretest on suturing skill prior to any training or the video game manipulation, and there were no differences between groups in suturing skill ($t=0.5$, $df=301$, $P=.63$). In addition, there were equal percentages of men and women in both groups (82% men).

Fifty-two percent of surgeons reported playing video games at some point in the past, while 48% reported never played. Participants reported having played for an average of 8 years (SD=10.1). At the height of video game playing, participants reported averaging 7.5 hours per week (SD=12.0). Currently, participants reported averaging 1.6 hours of game play per week (SD=6.3). Although male and female surgeons were equally likely to play video games (40%), men were historically more likely to have spent more hours per week playing than women (8.3 and 4.0 hours/week, respectively; $t=2.74$, $df=98$, $P<.01$), and were still spending more time playing (1.9 and 0.5 hours/week, respectively, $t=2.21$, $df=170$, $P<.05$).

The first partial task after the warm-up session on day-1 of training was the Cobra Rope. The scores for the experimental and control groups were statistically significantly different ($t=2.28$, $df=301$, $P<.05$), with the experimental group completing 10 trials in 649 seconds (SD=178) and the control group taking 712 seconds (SD=271). As can be seen in **Figure 1**, the experimental group was faster on Trial 1 (by an average of 15 seconds, $t=2.17$, $df=296$, $P<.05$), and they stayed faster throughout the 10 trials.

Note: These figures are without controlling for sex, pre-written, experience, or cases.

The suturing drill scores both time and errors, with lower scores being an indication of higher skill. The suturing drill was the first task after the warm-up session on day 2 of training. The experimental and control groups were significantly different on their total suturing scores ($t=2.28$, $df=288$, $P<.05$). When analyzing time and errors separately, the groups were significantly different on the number of errors made (133 and 192 errors, respectively, $t=3.40$, $df=300$, $P<.001$, **Figure 2**), but not significantly different on time to complete the drill ($t=0.39$, $P=.70$), **Figure 3**).

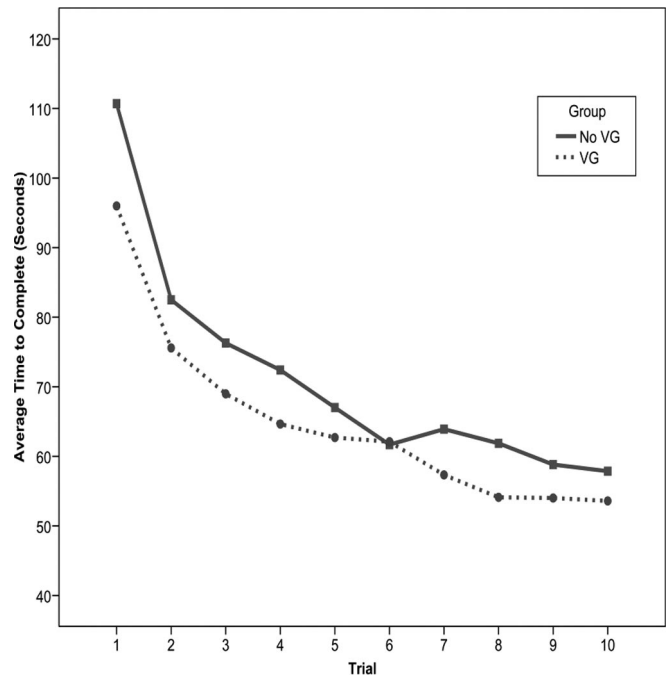


Figure 1. Time to complete Cobra rope drill by trial.

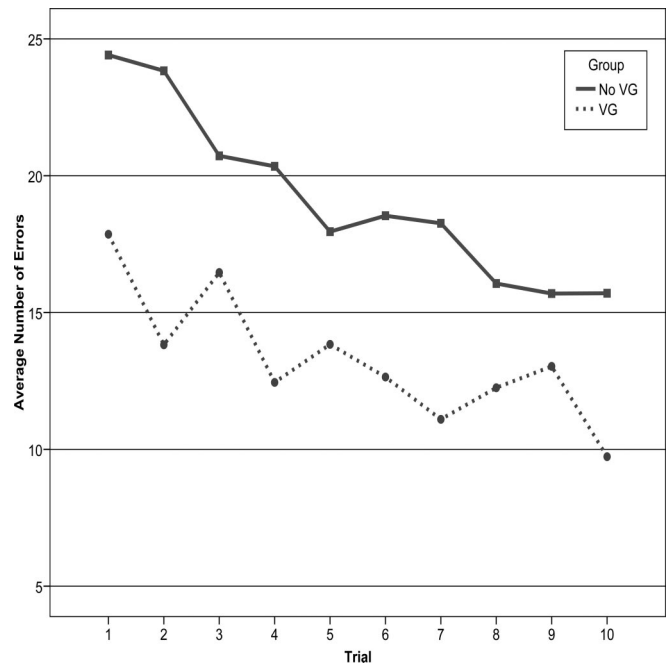


Figure 2. Average suturing errors by trial.

The Slam Dunk drill also scores both time and errors and was completed several hours after the video game warm-up. The experimental and control groups were not significantly different on their total scores ($t=1.69$, $df=295$,

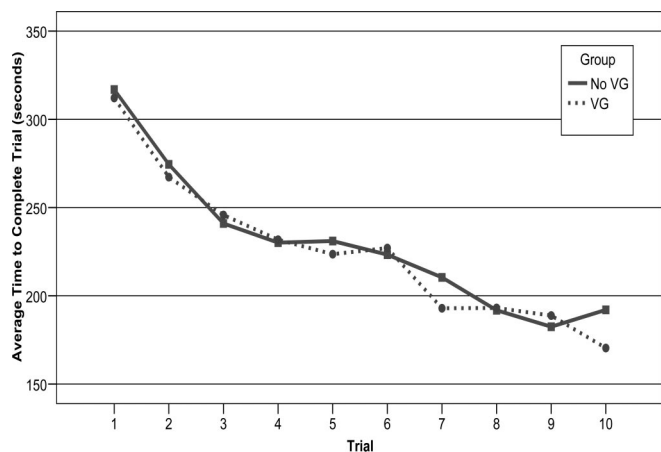


Figure 3. Time to complete suturing task by trial.

$P=.14$). When analyzing time and errors separately, the groups were not significantly different in the number of errors made ($t=0.34$, $P=.73$) or in time to complete the drill ($t=1.69$, $P=.09$).

The Terrible Triangle drill also scores both time and errors and was also completed several hours after the video game warm-up. The experimental and control groups were not significantly different in their total scores ($t=0.04$, $df=301$, $P=.97$). When analyzing time and errors separately, the groups were not significantly different in the number of errors made ($t=0.84$, $P=.40$) or in time to complete the drill ($t=-1.88$, $P=.06$).

The overall Top Gun score rolls all of the individual skill scores together to yield a composite total advanced surgical skill score. The experimental and control groups were marginally significantly different, with the experimental group performing better overall, which would be expected since 2 of the 4 drills had significant effects, $t=1.85$, $df=271$, $P=.07$.

DISCUSSION

This study assessed the use of select video games as part of a “warm-up” regimen blended into a standardized validated laparoscopic skills program. It demonstrated that the surgeons who executed the video game warm-up sessions had significantly better scores than the control group for the tasks that immediately followed their video game play. This prompts the question as to the scientific basis for this observation?

In 1985, Shellock and Prentice¹¹ demonstrated that preliminary specific warm-up activities enhanced physical performance, because this method provides a rehearsal of

the activity or event. Furthermore, the repetitive exercise appeared to warm the muscle membrane as occurs with thermal muscle warming, which improves accuracy by decreasing the propensity towards unplanned movements. The improvement in performance of physical tasks by warming and repetitive movements seems to be of the same physiological basis, and these have been referred to as the “warming-up phenomenon.”¹¹

Mano et al²² noted that warming up activities decrease the viscosity of blood within the muscle, remove lactic acid, and give the muscle fibers greater extensibility and elasticity, which increases the force and contraction of muscles, and potentially augments performance efficiency. Other mechanisms have been postulated to explain the physiological benefit of warming up.²³ In 2006, Van Beekvelt et al²⁴ hypothesized that the “warming up” phenomenon was related to the exercise-related activation of $Na^+-K^+-ATPase$. All of these effects could serve as an explanation for the observations of performance enhancement made in this study. Improvement in neuromuscular performance could directly transfer to the enhanced accuracy and error suppression with video-endoscopic tasks. The Rosser Top Gun Laparoscopic Skills and Suturing program has been validated to effectively transfer advanced laparoscopic skill in a very short period of time. Its preparatory partial drills have been proven to be rehearsal events that have significant correlation to the performance of a highly valued and difficult clinical task (intracorporeal suturing). In both studies cited, the majority of the benefits seen were related to temperature-dependent neurophysiological processes, which is consistent with the commonly held belief that warm muscles perform more efficiently than cold, stiff muscle tissue do.^{22,23} The findings in this study may be explained by the same neurophysiological warm-up enhancements.

Another interesting perspective provided by Mano et al²² is the demonstration that electrical “after discharges” of muscle are markedly reduced by repetition. After-discharges result in prolonged muscle contractions and stiffness, which interfere with efficient performance of any task. In Mano’s investigation, after 2 to 3 trials of repetitive warm-up, muscle membrane after-discharges electromyographically disappeared or became significantly suppressed. This was seen in patients with myotonia (muscle stiffness). The suppression of neuromuscular after-discharges is associated with a decrease in unwanted or uncoordinated movements.²² This phenomenon has relevance in the performance of tasks performed under video-endoscopic control where accuracy and economy of motion are an absolute necessity. One interesting observation in this

study is that 3 rounds of video games were performed during each warm-up session. This correlates with the findings by Mano.

In a study by Bartlett et al,²⁵ joint position appreciation was evaluated and found to be significantly more sensitive and improved after warm up. These findings suggest that joint position appreciation may be related through some sort of neurologic feedback mechanism to mechanoreceptors that accommodate physiological changes within the ligaments and muscles after repetitive exercise. Their study showed that an increase in the sensitivity of mechanoreceptors in response to mild exercise provided the necessary enhancement of reflex neuromuscular protective mechanisms, and knee proprioception, after a period of stretching and gentle exercise.²⁵ The surgeon uses similar muscle groups of the hands, forearms, and joints in video game play, which suggests applicability of the warm-up effect in the performance of laparoscopic tasks. In addition, it is essential when performing tasks in the video-endoscopic environment that the surgeon does not watch his or her hands to confirm their position in space. Enhanced joint positional awareness is a mechanism by which preliminary warm-up may contribute to error suppression and enhanced accuracy found in this investigation.

Another question to be considered is the question of the intensity of the warm-up sessions. In 1979, Knowlton et al¹² studied the effects of a 4-minute period of mild warming-up on oxygen uptake and lactic acid production in untrained male subjects. In the study, it was concluded that an untrained individual lacks the cardiovascular and cellular adaptations necessary to demonstrate the physiologic and metabolic benefits from a shorter period of warming-up. This suggests that well or adequately trained surgeons could benefit to a greater degree from shorter periods of warming up to achieve optimal performance, as compared to undertrained counterparts. This study did not examine this specifically, but our control and experiential group had a profound dominance of trained surgeons. This could explain why the shorter warm-up sessions had significant impact.

In 1980, DeBruyn-Prevost and Lefebvre²⁶ evaluated the effects of various warming up intensities and durations during short maximal exercise, looking at performance, heart rate, oxygen consumption, and lactic acid levels. They found that performance was improved when light warming (30% VO₂ max) was used just before the criterion exercise, while it was impaired with a more strenuous warming up intensity (70% VO₂ max). In their investiga-

tion, effective warming up was not shown to lead to an increase in lactic acid levels. A study in 1992 by Takahashi et al²⁷ 8 trained collegiate basic skiers performed a selected primary exercise for 5 minutes after varying warming up periods and conditions ranging from no warming up to working out for 30 minutes at 70% VO₂ max. It was concluded that the most effective intensity and time of warming up were 50% VO₂ max intensity and for a duration of 30 minutes, respectively (VO₂ max is commonly used in the sports community). As seen in our study, shorter, lower intensity warming-up exercise is associated with the improvement in performance. This makes the implementation of the warm-up regimen and compliance more likely. *The study also suggests that pre-task warming up results in temporary neuromuscular memory, which enhances performance and is extinguished over a resting period.*²⁸ Consequently, criterion exercise should be performed immediately after the pretask warming-up exercise. This explains the absence of the “warm-up effect” in performance of tasks removed from the immediate warm-up period in this study. The optimal warm-up duration and intensity needed to enhance a laparoscopic task will continue to be an exciting area of much needed investigation.

CONCLUSION

The use of simulators in laparoscopic surgical skills development has become a standard in the initial and continuing education landscape of surgeons. Its benefits are well documented.²⁹ Current physical and virtual simulators have inherent shortcomings including costs, realism, and participant utilization.³⁰ Therefore, the recruitment of a platform such as video games offers an engaging, ubiquitous asset that encourages a continuous “life-long learning” education posture. This study looked at the impact of a video game warm-up regimen using select video game titles prior to the performance of minimally invasive surgical tasks. Furthermore, it investigated whether this increases performance and suppresses errors. Our investigation showed that the use of a short, (6 to 18 minute) low-intensity warm-up session utilizing select video games immediately before executing video-endoscopic based partial tasks and intracorporeal suturing may be beneficial in increasing performance and suppressing technical errors. It supports previous research suggesting that properly selected over the counter video games can serve as a cost-effective resource in minimally invasive surgery training.

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