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RANDOMIZED CONTROL TRIAL

Effect of Warm-up Exercises on Laparoscopic Trainer: Improvement of Operator Smoothness

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ABSTRACT

Background: Several recent studies have produced conflicting results of warming up prior to laparoscopic surgery and surgical performance. The purpose of this study was to investigate whether warming up prior to a laparoscopic task improves a subsequent task performed on a laparoscopic trainer.

Materials and methods: A prospective randomized controlled trial was conducted to compare warm-up modalities to no warm-up. The study was conducted at a single site, with 44 participants, including surgeons, medical students and surgical trainees. Randomization done within each group.

Control group was asked to do a designated task without a warm-up. Warm-up groups were asked to perform a warm-up exercise prior to the designated task. Performances were recorded and analyzed with a computerized software different performance parameters were compared.

Results: Warm-up was a significant predictor of smoothness of the operator's hand movement at the 5% significance level ($p = 0.0358$).

While there were some improvement of performances between control groups was demonstrated, they were not clinically significant.

Conclusion: This study shows that warming up prior to a task has a positive influence in the subsequent performance in smoothness of instrument movement in surgeons group. The major limitation of the study was the number of participants.

Keywords: Exercises, Laparoscopy, Simulation, Training, Warm-up.

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INTRODUCTION

Preperformance practice is standard in many nonsurgical fields. Warming up is ubiquitous among athletes, musicians, artists and military personnel. Preperformance warm-up often consists of both mental and physical exercises. Studies have demonstrated that mental practice can significantly improve performance among not only in athletes but also in surgeons as well. Conflicting results are found among studies, with some smaller studies[1] showing improvement in subsequent performance and no improvement in another study.[2] Aim of this study is to analyze surgeon's performance in performing designated tasks in laparoscopic trainers with and without warm-up exercises, using multiple metrics analysis of performance including the speed. It is expected that warming up on a similar situation not only improves the speed but also helps the brain to adopt a 2 D perception quicker.

A similar study performed to compare the effects of warming up found no effect but the warming up exercises were not similar to actual surgical procedure in this study and analysis of surgical performance was subjective of investigator bias.[2] By using a computerized performance analysis the subjective investigator bias is eliminated.

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MATERIALS AND METHODS

Surgeons, surgical trainees and medical students (total of 44) are randomized for control or post warm-up groups and tested for their speed and 3 other performance metrics.

Participants were given written explanation and written consent is obtained. An ethical approval was obtained for the study.

Control participants are tested for their speed and performance of a specific task A on a laparoscopic trainer.

Post warm-up group had warming up task B on a laparoscopic trainer for 10 minutes followed by the same specific task A.

(Task A threading through pegs)

(Task B applying paper clip chain on pegs).

The procedure was recorded and performances were analyzed with INSTRAC software program.

Outcome measures checked.

Following metrics were measured:

1. Average speed/time taken to complete the task
2. Acceleration
3. Smoothness
4. Working area.

Statistical Analysis

Performance on the laparoscopic trainer is recorded and analyzed by a software (INSTRAC) and quantitative measures are obtained.

Data were analyzed using a general linear model testing. For all statistical analyses, a p-value less than 0.05 was considered statistically significant (Flow Chart 1).

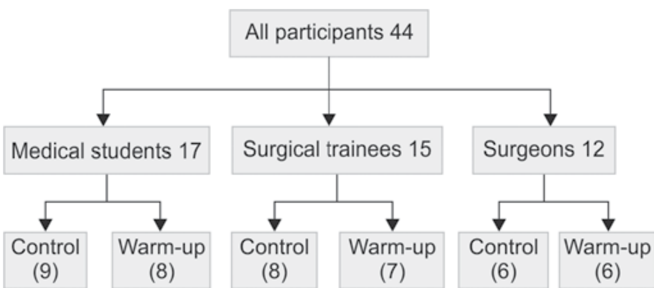
RESULTS

Descriptive statistics were produced for each of the four response variables (time, acceleration, smoothness and working areas) by surgical level (medical student, surgical trainee and surgeon) and warm-up.

A general linear model was fit to test the effect of surgical level and warm-up on each of the four response variables. The results of the 4 models are summarized below (Table 1).

Surgical level was a significant predictor of time when controlling for warm-up (p = 0.0112). But warm-up was not a significant predictor for time when controlling for surgical level (p = 0.9589). In other words, there is evidence that surgical level has an effect on time. While warm-up reduced the mean time of operation in surgeons and medical students group. But they were not to the level of clinically significant.

Flow Chart 1: Consort diagram for the study population



The interaction effect of surgical level and warm-up was not included in the model because it was not a significant predictor of time. A significant interaction effect would suggest that the effect of warming up differs between surgical levels (i.e. if warming up resulted in lower times for medical students, but did not make any difference to time for surgeons). The interaction effect was not significant in this model though, suggesting that the effect of warming up was the same for medical students, surgical trainees and surgeons.

Post hoc comparisons of the surgical level group were performed to compare mean times between the surgical levels. This showed that surgeons had significantly lower mean time than medical students (p = 0.0084) and surgical trainees (p = 0.0072). There was no significant difference between mean time for surgical trainees and medical students (p = 0.9145) (Graph 1 and Table 2).

Surgical level was a significant predictor of acceleration (p = 0.0004), While warm-up improved acceleration in all groups but warm-up was not clinically significant (p = 0.2157).

Post hoc comparisons of the surgical level group showed surgeons had significantly lower mean acceleration than medical students (p = 0.0035) and surgical trainees (p = 0.0001). There was no significant difference between mean acceleration for surgical trainees and medical students (p = 0.1677) (Graph 2).

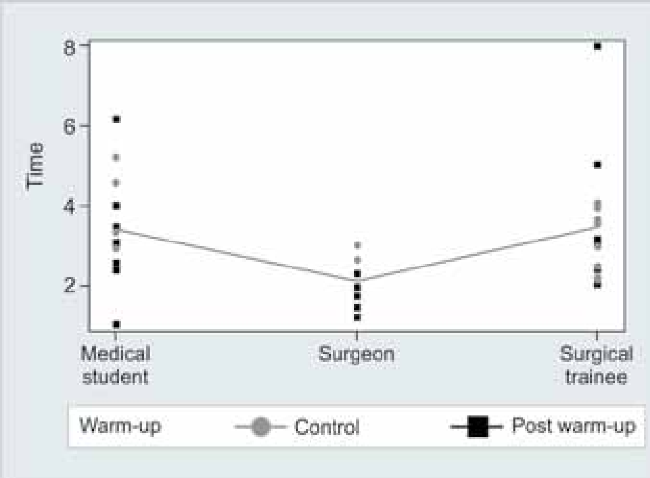
Both surgical level and warm-up were a significant predictor of smoothness at the 5% significance level (p = 0.0001 and p = 0.0358, respectively). Post hoc comparisons of the surgical level group showed surgeons had significantly higher mean smoothness than medical students ($p < 0.0001$) and surgical trainees (p = 0.0009). There was no significant difference between mean smoothness for surgical trainees and medical students (p = 0.3064).

Table 1: Analysis variable: time

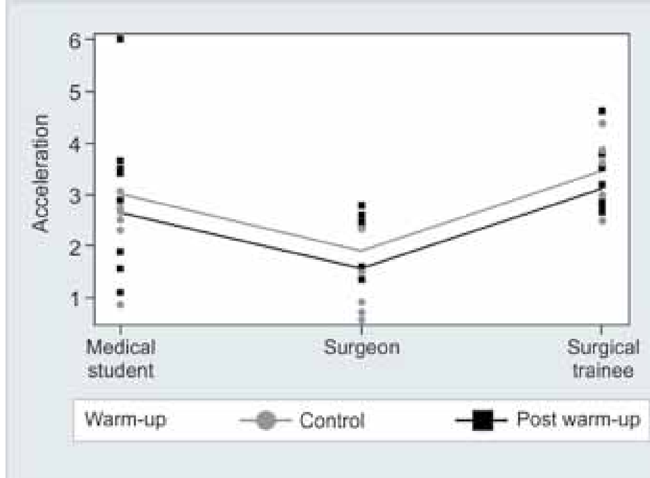
Operator	*Warm-up*	*Participants*	*Mean*	*Std dev*	*Minimum*	*Maximum*
Medical student	Control	9	3.48	0.93	2.45	5.21
	Post warm-up	8	3.35	1.50	1.04	6.16
Surgeon	Control	6	2.44	0.55	1.65	3.01
	Post warm-up	6	1.83	0.43	1.22	2.31
Surgical trainee	Control	8	3.14	0.77	2.14	4.06
	Post warm-up	7	3.83	2.06	2.03	8.00

Table 2: Analysis variable: acceleration

Operator	*Warm-up*	*Participants*	*Mean*	*Std dev*	*Minimum*	*Maximum*
Medical student	Control	9	2.64	0.80	0.87	3.65
	Post warm-up	8	3.01	1.55	1.12	6.00
Surgeon	Control	6	1.42	0.84	0.58	2.50
	Post warm-up	6	2.07	0.61	1.36	2.80
Surgical trainee	Control	8	3.22	0.66	2.49	4.38
	Post warm-up	7	3.32	0.77	2.66	4.62



Graph 1: Interaction plot for time

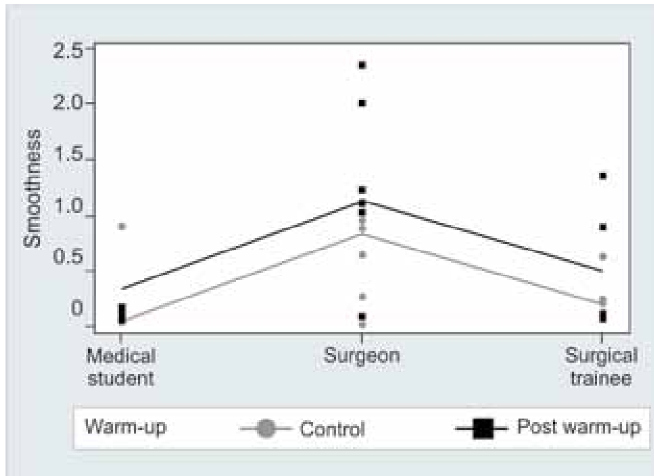


Graph 2: Interaction plot for acceleration

Post hoc comparisons of warm-up showed that those who had warmed up had significantly higher mean smoothness than those in the control group (p = 0.0358) (Graph 3 and Table 3).

Surgical level was a significant predictor of working areas (p = 0.0125). While warm warm-up reduces straying it was not significant the 5% level (p = 0.0562).

Post hoc comparisons of the surgical level group showed surgeons had significantly lower mean working areas than surgical trainees (p = 0.0039). Medical student also had significantly lower mean working areas than surgical trainees (p = 0.0470). There was no significant difference between mean working areas for surgeons and medical students (p = 0.1677) (Graph 4 and Table 4).



Graph 3: Interaction plot for smoothness

DISCUSSION

Minimally invasive surgery (MIS) has revolutionized the way surgeries are performed since its introduction and many open procedures are almost replaced by MIS because of the benefits for patients. Overall, the minimal incisions reduce postoperative pain and lead to earlier mobilization of patients and, therefore, shorter hospital stays. However, MIS is challenging for the surgeons performing the operation, because of the reduced tactile feedback and a loss of 3-dimensional (3D) vision. For trainees learning curves are longer and surgeries take longer time, triggering the need to find ways to improve speed and performance in the operating theater.[10]

This study was aimed to investigate the hypothesis that a warm-up activity prior to laparoscopic task on a simulator improves subsequent performance of specified task.

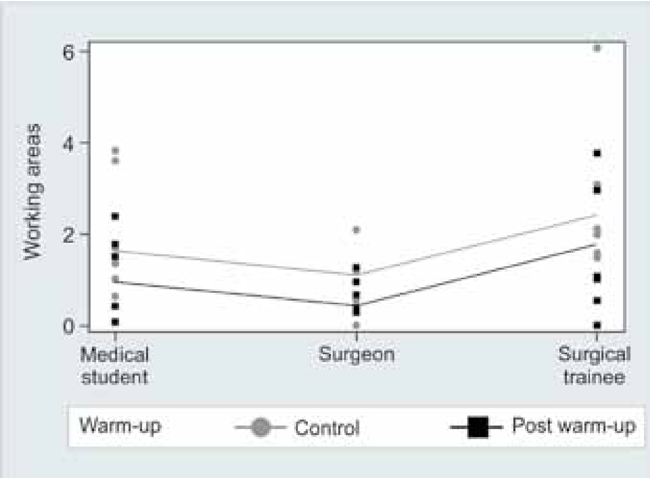
The performance was analyzed using a software named INSTRAC which analyses multiple movement metrics. A study performed by Rowland et al demonstrated the construct validity of the software.

Table 5 formulas used to calculate metrics reproduced with permission.

This study was performed with 23 controls and 21 participants. controls were recruited for each group (Surgeons, Surgical trainees, and medical students) and

Table 3: Smoothness analysis variable: smoothness

Operator	*Warm-up*	*Participants*	*Mean*	*Std dev*	*Minimum*	*Maximum*
Medical student	Control	9	0.17	0.28	0.04	0.91
	Post warm-up	8	0.21	0.29	0.06	0.92
Surgeon	Control	6	0.65	0.43	0.02	1.12
	Post warm-up	6	1.30	0.80	0.10	2.35
Surgical trainee	Control	8	0.22	0.18	0.09	0.63
	Post warm-up	7	0.50	0.53	0.07	1.36



Graph 4: Interaction plot for working areas

compared with a group who had warm-up prior to the designated task. As expected surgeons performed better in all aspects.

The post warm-up did show some improvement in time effect (speed), acceleration, and working areas but was not clinically significant. These results contrasts the outcome of a previous large randomized control study[2] which found no significant effect on warming up. Compared to the above study, in this study, the metrics are measured with a computer software, thereby observer error is avoided. Nevertheless there are some studies which show positive effect of warming up.[1,3] Due to the limited number in this study, power of the study is inadequate to prove the significance. The smaller number of surgeons participated would have widely varying laparoscopic skills and it is possible that due to sampling error, one arm could have had either very experienced or poor experienced, affecting the results.

Warming-up is routine for athletes and stage performers and there are studies in favor of warming up to improve athletic performance. A systematic review and meta-analysis of 32 studies that investigated performance after warm-up in various sports concluded that performance was improved after a warm-up 79% of the time.[4]

Apart from the main limitation of the study of small numbers, a logical question arises about the interpretation of the results to a clinical context. As the study is entirely performed in a nonclinical set up performance of the operator may be different to a situation, when performed in a clinical scenario. Nevertheless many studies[5,9] have shown the effectiveness of simulation training in improving surgeon's skill in operating room, thereby it could be logically argued that results could be generalized to a clinical context.

Van Heerzele et al (2008)[8] observed that experienced surgeons also benefit from simulator training. In their study, expert endovascular surgeons received a simulator training course, after which they showed shorter real surgery time and fewer errors, and also felt more competent to conduct the procedure. Also, group consistency was higher after the course; they all performed the task about as fast and as safe. Thus, there is evidence that skills acquired in a simulator are indeed transferable to reality and lead to reduction of errors in the operation theater[7] and an improvement in overall performance.[6]

The major difference of this study from the previous studies of similar nature is analyzing the movement and speed using computerized metric assessment tools, thereby not only avoiding the observer error but also analyzing other metrics such as acceleration, areas of tool employment. Handedness of the operator could have been analyzed using the same software but was not performed considering the small number of participants, which may not reflect accurate results.

In conclusion, this study did find a significant effect of warm-up on laparoscopic tasks in most of the

Table 4: Analysis variable: working areas

Operator	*Warm-up*	*Participants*	*Mean*	*Std dev*	*Minimum*	*Maximum*
Medical student	Control	9	1.70	1.26	0.07	3.85
	Post warm-up	8	0.90	0.88	0.07	2.40
Surgeon	Control	6	0.87	0.74	0.01	2.10
	Post warm-up	6	0.71	0.37	0.29	1.29
Surgical trainee	Control	8	2.56	1.51	1.50	6.10
	Post warm-up	7	1.65	1.36	0.01	3.79

Table 5: Formulas used to calculate metrics (Reproduced with permission from Rowland et al[9])

Metric	*Unit*	*Formula/description*
Time (t)	Seconds	
Average speed (as)	mm/second	average speed/time
Motion smoothness	mm/second^3	$\sqrt{((t^5/2) \times td^2 \times as^6)}$ td = total distance
Working area	mm	Average distance between instrument tips

performance metrics, but only clinically significant on operator smoothness. The study has major limitations due to the small number of participants.

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