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Assessment of laparoscopic technical skills among surgery residents using a virtual simulator

Análise do ganho de habilidades técnicas em laparoscopia em residentes de cirurgia usando simulador virtual

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ABSTRACT

Introduction: The teaching of surgery has been undergoing changes and due to ethical, economic, and legal issues, the operating room is no longer the only setting for surgical education. Training with surgical simulators has emerged as an effective method, enabling skill development.

Objective: Assessment of laparoscopic technical skills among general surgery residents after training on a virtual simulator and to determine if there is a difference in this skill acquisition based on the duration of the training sessions and between residents at different levels (R1 vs. R2) who received the same training opportunities.

Method: A prospective longitudinal study was conducted with GS residents over 10 weeks using the Simbionix LapMentor® simulator. A test involving four basic laparoscopic tasks (Standard scissor cut, Grasping and clipping, Two-handed maneuver, and Electrocautery) was performed pre- and post-training on the simulator. Two training protocols were compared: Training 1 (distributed): four sessions of two hours each, with a two-week interval between them, and Training 2 (massive): two sessions of four hours, with a six-week interval between them.

Results: There was a reduction in time and number of movements in all tasks. Regarding the type of training, the distributed training was faster in Task 3 (left hand). On the other hand, the massive training group collected more balls and lost fewer balls in Task 3 but spent more time with the cautery activated without proper contact with any band. Concerning the year of residency, R1 residents showed a reduction in the distance traveled with the left-hand instrument in Task 4 after SS training, while R2 residents did not (p=0.029).

Conclusion: There was an improvement, with a reduction in both time and number of movements. Differences in training type were observed in left-hand speed, number of balls collected, number of balls lost in Task 3, and the time spent with the cautery activated without contact in Task 4. A difference in motor skills acquisition related to residency year was only observed in the distance traveled with the left-hand instrument in Task 4.

Keywords: Health Education; Simulation Training; Motor Skills.

RESUMO

Introdução: *O ensino da cirurgia vem passando por mudanças e por questões éticas, econômicas e legais, a sala de cirurgia não é mais o único ambiente para seu aprendizado. O treinamento em simuladores cirúrgicos (TSC) vem emergindo como um método eficiente, possibilitando ganho de habilidades.*

Objetivo: *Este estudo teve como objetivos avaliar o ganho de habilidades técnicas (HT) em laparoscopia por residentes de cirurgia geral (CG) após treinamento em simulador virtual e verificar se há diferença quanto a essa aquisição em relação à duração das sessões de treinamento e entre residentes de anos diferentes (R1 versus R2) submetidos às mesmas oportunidades de treinamento.*

Método: *Realizou-se um estudo longitudinal prospectivo com residentes de CG utilizando o simulador Simbionix LapMentor®. Um teste com quatro tarefas laparoscópicas básicas essenciais (1. corte-padrão de gaze; 2. preensão e clipagem; 3. manobra com duas mãos; e 4. eletrocauterização) foi realizado no pré e pós-treinamento nesse simulador. Compararam-se dois treinamentos: distribuído: quatro sessões de duas horas com intervalo de duas semanas entre elas e massivo: duas sessões de quatro horas, com intervalo de seis semanas.*

Resultado: *Para a realização das análises estatísticas, utilizaram-se os softwares SPSS 20.0 e Stata 17. Houve redução no tempo e no número de movimentos em todas as tarefas. Em relação ao tipo de treinamento, o distribuído foi mais veloz na tarefa 3 com a mão esquerda. Já o grupo massivo coletou mais bolas e perdeu menos bolas na tarefa 3; em contrapartida, ficou mais tempo com o cautério acionado sem o adequado contato com banda. Concernente ao ano de residência, R1s apresentaram uma redução da distância percorrida com o instrumento da mão esquerda na tarefa 4 após o TSC, ao passo que R2s não (p = 0,029).*

Conclusão: *Houve ganho de HT, com redução do tempo e do número de movimentos. Diferenças em relação ao tipo de treinamento foram observadas na velocidade da mão esquerda, no número de bolas coletadas e no número de bolas perdidas da tarefa 3, e no tempo acionado sem contato na tarefa 4. Houve diferença na aquisição de HT em relação ao ano de residência apenas na distância percorrida com instrumento da esquerda na tarefa 4.*

Palavras-chave: *Educação em Saúde; Treinamento por Simulação; Habilidades Motoras.*

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INTRODUCTION

The teaching of surgery has undergone several changes since the traditional model installed by Halsted in 1904, in which the resident spends a minimum period of medical residency working (and operating) real patients, under the supervision of a more experienced tutor, under the adage of "watch one, help one and operate one". In this model, the acquisition of surgical technical skills depends on the tutor's expertise and the number of interventions performed by the apprentice[1].

The learning of the surgeon in training faces several difficulties: the reduction of the hours dedicated to the operating room due to the reduction of the workload, the pressures to increase their performance, the low incidence of some diseases, in addition to the ethical debate in relation to inexperienced surgeons who operate on patients[2,3]. For ethical, economic, and legal reasons, the operating room is no longer the only environment for surgery residents to learn[1].

Traditional methods of medical education cannot compensate for the loss of this experience and the perceptual and psychomotor skills, essential for effective surgery, cannot be developed in lectures and seminars[4].

Surgical simulator training (SST) has been emerging as an efficient method of development[5], enabling surgery residents to start their training process and acquire relevant surgical skills through simulators even before entering the operating room.

The intense procedure-focused operating room environment may be good for observation and skill refinement, but it fails to deconstruct and teach specific tasks. Specialist surgeons are often unaware of the cognitive tasks they automatically invoke when performing a procedure, and often fail to transfer the skill to the resident.[6]

Recently, the general surgery (GS) residency in Brazil underwent a change in the curriculum, increasing from two to three years of training. According to Resolution N. 48, of June 28, 2018 of the National Commission for Medical Residency, the matrix of competencies in general surgery advises that residents must be able to, at the end of the third year, master the indication and operative technique of the following laparoscopic procedures: hernia repairs; anti-reflux procedures, esophagocardioplasties; splenectomies and rectosigmoidectomies.[7] However, even in traditional residences, it is difficult to believe that all GS residents will be able to perform these different procedures on real patients. Hence the indispensability of simulation.

Based on the premises of the importance of simulation, and driven by the pandemic - which was not only responsible for greatly reducing the number of elective procedures and surgeries and, therefore, the access of residents to surgical education - but also for emphasizing the obsolescence of surgical training in our institution, we first proposed to evaluate the gain of technical skills (TS) in laparoscopy with the use of a virtual simulator in GS residents and secondarily to verify whether there was a difference in the acquisition of these skills in relation to the duration of the training sessions (type of training) and in relation to residents of different years (R1 X R2) submitted to the same training opportunities.

METHODS

Ethical aspects

This study was approved by the Research Ethics Committee (REC) of the Faculty of Medical Sciences of Santa Casa de São Paulo (FCMSCSP), CAAE n. 55366221.7.0000.5479. The documentation obtained was used exclusively for the purpose of acquiring information concerning the research, and confidentiality was strictly respected.

Study design

A prospective longitudinal study was conducted with GS residents at our institution to analyze the gain in TS in laparoscopy from the training intervention in a laparoscopic virtual simulation platform. The Simbionix LapMentor® surgery simulator (Simbionix Ltd., Israel) was made available for a period of 10 weeks by the company Endocompany for the realization of this project. The educational platform Mentor Learn was used. A test consisting of four basic tasks that aimed to test essential TS in laparoscopy was performed in the simulator immediately before and after eight hours of training. Two training models with different time dispositions were compared, training 1 (distributed): four sessions of two hours of training with an interval of two weeks between each session and training 2 (massive): two training sessions of four hours each, with an interval of six weeks between them, both with a total period of six weeks.

Series

All 50 general surgery residents were invited to participate in the project, 25 R1s and 25 R2s. First-year residents were divided into groups 1 and 2 and second-year residents were divided into groups 3 and 4. Groups 1 and 3 performed distributed training and groups 2 and 4 performed massive training (Figure 1).

These four tasks were chosen because they test essential laparoscopic skills.

- Standard gauze cut: This cutting exercise requires the student to cut the perimeter of a circular gauze suspended by clips. One hand provides traction on the gauze and places it at the best possible angle to the cutting hand. It tests the use of both

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Figure 1. Organization of groups and training.

Source: Prepared by the author.

hands in a complementary way. The following variables were analyzed: exercise duration (**TIME),** number of movements (**NUM_MOVIM),** number of movements performed with the right hand instrument (**NUM_MOVIME_DIREITA),** number of movements performed with the left hand instrument (**NUM_MOVIME_ESQUERDA),** distance traveled by the right hand instrument in centimeters (cm) **(DIST_PERC_INT_D,** distance travelled by left-hand instrument in cm (**DIST_PERC_INST_E),** average speed of right-hand instrument in cm per second (s) (VELOCID_INST_D**),** average speed of left-hand instrument in cm/s (**VELOCID_INST_E**).

- Gripping and clipping: The exercise requires that leaky ducts be seized and clipped, within the specified segments, in a different color. Red segments appear in the ducts that leak at the beginning of the task and turn green only when stabilized correctly by an instrument. As soon as they turn green, they must be clipped to stop their leakage. The task must be completed before the pool overflows. This exercise aims to teach clipper manipulation, tissue handling skills, bimanual skills, laparoscopic orientation and hand-eye coordination. The variables analyzed were: exercise duration (**TIME),** number of total movements (**NUM_MOVIM),** number of movements performed with the right hand instrument (**NUM_MOVIME_DIREITA**), number of movements performed with the left hand instrument (**NUM_MOVIME_ESQUERDA),** total distance traveled **(DIST_TOTAL_PERCORRIDA)**, distance travelled by the right-hand instrument -clipper- in centimeters (cm) (**DIST_PERC_INST_D),** distance travelled by the left-handed instrument (a grasper) in cm **(DIST_PERC_INST_E),** average speed of the right-hand instrument in cm/s, (**VELOCID_MEDIA_D),** average speed of the left-hand instrument in cm/s (**VELOCID_MEDIA_E),** number of clipped ducts **(NUM_DUCTOS_CLIPADOS),** number of lost clips **(NUM_CLIPES_PERDIDOS).**
- Two-handed maneuver: Two gripping tools are used to collect balls from the inside of a jelly. The instrument of one hand stirs the gelatin to expose the balls, which, when exposed, change color, becoming green. While the gelatin is controlled by that hand, the tool in the other hand is used to grab the green ball and place it immediately above the basket. Otherwise, the balls are lost. The objective is to strengthen advanced bimanual skills, laparoscopic instrument manipulation, hand-eye coordination, and tissue handling skills. The variables analyzed were: exercise duration (**TIME),** total number of movements (**NUM_**

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MOVIM), number of movements performed with the right hand instrument (**NUM_MOVIME_DIREITA),** number of movements performed with the left hand instrument (**NUM_MOVIME_ESQUERDA),** total distance traveled **(DISTANCIA_PERCORRIDA),** distance traveled by the right hand instrument in cm (**DIST_PERC_INST_D)**, distance traveled by the left instrument in cm – one grasper **(DIST_PERC_INST_E),** average speed of the right instrument in cm/s, (**VELOC_MÉDIA_D),** average speed of the left instrument in cm/s (**VELOC_MÉDIA_E),** number of balls collected (**NUM_BOLAS_COLETADAS**) and the number of balls lost **(NUM_BOLAS_PERDIDAS).**

- Electrocautery: Hooks on both hands are used to cauterize bands that lie between two columns. Initially the bands are blue and, at each moment, a band stands out, becoming green. In this exercise, a hook should be used to expose and, with the help of the pedal, cauterize only the highlighted band. The objective of this exercise is to address the safe use of electrocautery, hand-eye coordination and manual skills with a single instrument. The variables analyzed were: exercise duration **time (TIME)** and total time to activate the cautery pedal (**TEMP_TOTAL_CAUTERIO);** Regarding the economy of parameters, the following were: the total number of movements performed (**NUM_MOVIMENTOS),** number of movements performed with the right hand instrument (**NUM_MOVIME_DIREITA),** the number of movements performed with the left hand instrument (**NUM_MOVIME_ESQUERDA,** distance traveled **(DISTA_PERCORRIDA),** distance traveled by the right hand instrument (**DIST_PERC_INST_D)**, distance traveled by the left-hand instrument **(DIST_PERC_INST_E),** average speed of the right-hand instrument in cm/s, (**VELOCID_MEDIA_D),** average speed of the left-hand instrument in cm/s (**VELOCID_MEDIA_E),** number of highlighted bands correctly cut **(NÚMERO_BANDAS_DESTACADAS_CORTADAS),** time the cautery was triggered without proper contact with bands, **(TEMPO_ACIONADO_ NO CONTACT),** cautery pedal actuation time associated with non- highlighted band (**TEMP_ACIONADO_BANDA_ERRADA)** instrument contact, and the number of erroneously cut non-highlighted bands **(NUMERO_BANDAS_NAO_DESTACADAS_CORTADAS).**

The training curriculum comprised: basic laparoscopy exercises such as 0º and 30º camera manipulation, hand-eye coordination exercises, clipping, clipping and grasping, bi-manual maneuvers, cutting and electrocautery, and other tasks of technical skills essential to laparoscopy such as object transfer, standard cutting, and ligature strap placement. In addition to these basic exercises, the training also contained three suture tasks and two complete procedure modules with the steps of a preperitoneal transabdominal inguinal hernia repair surgery and cholecystectomy. All tasks are illustrated by instructional videos watched before the exercise is performed (average of 30s).

During the training period, the volunteers were assisted by the researcher or by another surgeon or by medical school students previously trained to do so. Despite the difference in experience among the monitors, there was standardization for the help of volunteers.

There was no randomization in the division of the groups because the training was carried out during the residency routine, so it was necessary to adapt the day of training with the period that the resident was attending. Blinding was not possible because the researcher was the one who defined the schedule based on the period in which the residents were attending. Due to the nature of the intervention, they were also not blind to their group designation.

Statistical analysis

Initially, the data were analyzed descriptively. For categorical variables, absolute and relative frequencies were presented, and for numerical variables, summary measures (mean and standard deviation). The existence of associations between two categorical variables was verified using the Chi-square test or Fisher's exact test.

The comparisons of two means were performed using the Student's t-test, which presents as one of the assumptions, the normality in the distribution of the data, which was evaluated using the Kolmogorov-Smirnov test.

Mixed linear regression models (or with random effects) were used to evaluate the effect of training on the performance of each of the tasks (dependent variables). The mixed linear regression model[8] incorporates the effect of each volunteer in the form of a random effect, accommodating a possible dependence between the observations of the same volunteer. This model also assumes normality in the data. However, Gelman and Hill[9] pointed out that the escape from normality does not entail bias in the estimates. Additional tests were performed (Wald test) *ad hoc* after with Bonferroni correction under the estimated model to identify groups with different means.

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RESULTS

For all statistical tests, a significance level of 5% was adopted. Statistical analyses were performed using SPSS 20.0[10] and STATA 17[11].

Of the 50 volunteers invited to participate in the project, 36 completed the proposed training curriculum. Data from 14 participants (28%) were excluded from the analyses because they did not meet the inclusion criteria.

Overall assessment

Table 1 shows the variables that had statistical significance in tasks 1, 2, 3 and 4.

The global evaluation showed a reduction in the time to perform and in the number of movements in all tasks

In addition, statistical significance was observed in:

- Task 1, in reducing the distance traveled by the instrument of the right hand;

Table 1. Summary measures of the statistically significant performances of tasks 1, 2, 3 and 4 by training and time of evaluation, descriptive levels of global and individual effects of time and training via mixed linear models.

	Pre	Post	Multilevel model	
			Δ (Post - Pre)	Time
			Estimate (95%CI)	p
T1_TIME				
TRAINING 1	234.9 ± 72.7	160.6 ± 57.4	-78.49 (-109.87 to -47.12)	<0.001
TRAINING 2	243.1 ± 52.4	149.9 ± 52.9	-92.77 (-124.55 to -60.99)	
T1_NUM_MOVIM				
TRAINING 1	514.9 ± 180.5	401.6 ± 148.9	-117.73 (-231.71 to - 3.76)	0,018
TRAINING 2	556.3 ± 229.4	447.6 ± 158.3	-108.72 (-215.48 to -1.97)	
T1_NUM_MOVIME_ESQUERDA				
TRAINING 1	195.3 ± 81.5	121.7 ± 58.5	-74.31 (-138.30 to -10.32)	0,042
TRAINING 2	203.4 ± 91.8	169.4 ± 149.0	-33.20 (-94.14 to 27.74)	
T1_DIST_PERC_INST_D (CM)				
TRAINING 1	358.7 ± 121.5	299.7 ± 131.3	-65.29 (-163.56 to 32.98)	0,006
TRAINING 2	488.8 ± 226.4	352.2 ± 127.7	-137.46 (-228.87 to -46.05)	
T2_TIME				
TRAINING 1	146.4 ± 34.0	101.9 ± 23.5	-44.50 (-64.08 to -24.92)	<0.001
TRAINING 2	133.8 ± 49.1	102.2 ± 18.4	-31.63 (-52.51 to -10.76)	
T2_NUM_MOVIM				
TRAINING 1	187.4 ± 53.2	143.9 ± 41.9	-43.44 (-74.92 to -11.96)	0,001
TRAINING 2	188.7 ± 87.4	147.4 ± 23.1	-41.39 (-75.04 to -7.75)	
T2_NUM_MOVIME_DIREITA				
TRAINING 1	95.7 ± 31.2	71.2 ± 23.7	-24.56 (-40.81 to -8.30)	<0.001
TRAINING 2	94.1 ± 43.5	73.8 ± 17.0	-20.62 (-38.04 to -3.20)	
T2_NUM_MOVIME_ESQUERDA				
TRAINING 1	91.7 ± 25.7	72.8 ± 20.7	-18.89 (-36.31 to -1.47)	0,009
TRAINING 2	94.6 ± 46.3	73.6 ± 11.8	-20.98 (-39.52 to -2.44)	
T2_VELOC_MÉDIA_E				
TRAINING 1	3.9 ± 0.5	4.9 ± 0.6	1.06 (0.56 to 1.55)	<0.001
TRAINING 2	4.1 ± 0.7	5.0 ± 1.6	0.93 (0.40 to 1.46)	
T2_NUM_DUCTOS CLIPPEDS				
TRAINING 1	7.4 ± 3.1	9.0 ± 0.0	1.56 (0.22 to 2.90)	0,007
TRAINING 2	7.4 ± 2.9	9.0 ± 0.0	1.57 (0.14 to 3.00)	

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Table 1. Continuation.

	Pre	Post	Multilevel model Δ (Post - Pre) Estimate (95%CI)	Time p
T3_TIME				
TRAINING 1	153.6 ± 36.8	105.3 ± 19.7	-47.37 (-63.01 to -31.73)	<0.001
TRAINING 2	154.0 ± 43.5	122.6 ± 48.9	-29.39 (-45.53 to -13.25)	
T3_NUM_MOVIM				
TRAINING 1	175.3 ± 40.1	137.2 ± 34.3	-36.82 (-59.05 to -14.60)	<0.001
TRAINING 2	194.1 ± 56.8	155.4 ± 30.1	-37.56 (-59.97 to -15.15)	
T3_NUM_MOVIME_DIREITA				
TRAINING 1	95.0 ± 19.6	92.2 ± 62.9	-14.40 (-27.56 to -1.23)	0,003
TRAINING 2	108.1 ± 35.3	88.6 ± 18.7	-18.50 (-32.09 to -4.91)	
T3_NUM_MOVIME_ESQ				
TRAINING 1	80.3 ± 24.2	74.0 ± 55.9	-15.39 (-28.51 to -2.26)	<0.001
TRAINING 2	92.1 ± 27.2	66.8 ± 20.4	-23.42 (-37.40 to -9.44)	
T3_VELOC_MÉDIA_D				
TRAINING 1	3.2 ± 0.5	4.1 ± 0.6	0.84 (0.22 to 1.46)	0,027
TRAINING 2	3.8 ± 1.9	3.9 ± 0.7	0.09 (-0.55 to 0.72)	
T4_TIME				
TRAINING 1	357.0 ± 88.1	199.0 ± 74.5	-158.00 (-199.26 to -116.74)	<0.001
TRAINING 2	314.4 ± 96.1	181.7 ± 53.2	-132.71 (-173.97 to -91.44)	
T4_NUM_MOVIMENTOS				
TRAINING 1	385.2 ± 145.5	223.8 ± 102.2	-161.41 (-219.49 to -103.33)	<0.001
TRAINING 2	319.6 ± 124.9	192.8 ± 80.2	-126.76 (-184.85 to -68.68)	
T4_DISTA_PERCORRIDA				
TRAINING 1	936.1 ± 351.2	602.3 ± 301.6	-333.81 (-477.49 to -190.13)	<0.001
TRAINING 2	786.3 ± 325.8	531.5 ± 261.6	-254.83 (-398.51 to -111.15)	
T4_NUM_MOVIME_DIREITA				
TRAINING 1	228.8 ± 82.1	132.1 ± 54.3	-96.76 (-130.26 to -63.27)	<0.001
TRAINING 2	206.3 ± 62.6	120.8 ± 46.5	-84.75 (-118.93 to -50.57)	
T4_NUM_MOVIME_ESQ				
TRAINING 1	156.4 ± 70.9	91.7 ± 56.5	-64.65 (-94.47 to -34.83)	<0.001
TRAINING 2	133.3 ± 63.0	76.5 ± 42.5	-56.81 (-87.55 to -26.07)	
T4_DIST_PERC_INST_D (CM)				
TRAINING 1	566.7 ± 197.5	351.5 ± 165.1	-215.17 (-296.43 to -133.91)	<0.001
TRAINING 2	530.3 ± 180.6	321.5 ± 147.6	-205.85 (-288.97 to -122.73)	
T4_DIST_PERC_INST_E (CM)				
TRAINING 1	368.7 ± 194.9	250.8 ± 180.6	-117.82 (-201.31 to -34.34)	0,004
TRAINING 2	305.1 ± 167.6	223.1 ± 138.9	-82.04 (-168.10 to 4.01)	
T4_VELOC_MÉDIA_E				
TRAINING 1	2.4 ± 0.5	3.0 ± 0.6	0.52 (0.19 to 0.84)	<0.001
TRAINING 2	2.6 ± 0.7	3.2 ± 0.9	0.57 (0.24 to 0.91)	
T4_NÚMERO_BANDAS_DESTACADAS_CORTADAS				
TRAINING 1	20.8 ± 0.5	20.5 ± 0.8	-0.35 (-0.73 to 0.02)	0,02
TRAINING 2	20.4 ± 1.0	20.0 ± 1.4	-0.42 (-0.80 to -0.03)	

Source: Prepared by the author from the data collected in the research.

- Task 2, in increasing the average speed of the left hand and increasing the number of clipped ducts;
- Task 3, in increasing the average speed of the right hand;
- Task 4, in the decrease of the distance traveled, in the increase of the average speed of the left hand and in the decrease in the number of highlighted bands cut.

It is possible to observe in Figure 2 the pattern of decrease in time and number of movements for all tasks.

Evaluation by type of training

The impact on performance in relation to the different training models was evaluated, aiming to identify whether there was a difference in the gain of TS between them.

The training effect was found in 4 variables, as described below (Table 2):

- T3_VELOC_MÉDIA_E (p=0.019): the distributed training group showed an average increase in speed in the left hand, while the massive group showed no variation;
- T3_NUM_BOLAS_COLETADAS (p=0.012) and T4_TEMPO_ACIONADO_ NO CONTACT (p=0.007): the massive training group showed an increase in the number of balls collected and in the time to activate the electrocautery without adequate contact with bands, while the distributed group showed no variation;
- T3_NUM_BOLAS_PERDIDAS (p=0.036): the massive group showed an average reduction in the number of balls lost, while the distributed group showed no change.

Assessment by year of residency

In order to identify the impact of training on residents with different experiences, the performance of tasks in the pre-test and post-test was compared by year of residency and no longer by type of training.

In this study, tasks that did not show different average effects by type of training, but did have training effects, were considered.

An interaction effect between time and year of residency was found only for T4_DIST_PERC_INST_E (p=0.029).

Thus, as shown in Table 3, on average, the group of first-year residency students showed a reduction in the distance covered with the left-hand instrument in task 4 after the SST, while the second-year group did not show significant variation. The mean distance in group R1 was higher than that of R2 in the pre-test (p=0.008), and after training, no mean differences were observed between the groups (p=0.678).

Table 2. Summary measures of performance in tasks by training and time and estimates of mean variations via mixed linear model.

	Pre	Post	Mixed linear model		
			Δ (Post - Pre)	$\Delta_{2x4} - \Delta_{4x2}$	
			Estimate (95%CI)	Estimate (95%CI)	p
TK_6_VELOC_MÉDIA_E					
Training 1	3.1 ± 0.5	4.1 ± 0.7	0.95 (0.51 to 1.39)	-0.77 (-1.40 to -0.13)	**0,019**
Training 2	3.6 ± 1.1	3.8 ± 0.7	0.18 (-0.28 to 0.64)		
TK_6_NUM_BOLAS_COLETADAS					
Training 1	7.9 ± 1.1	8.3 ± 0.8	0.46 (-0.20 to 1.11)	1.21 (0.27 to 2.15)	**0,012**
Training 2	6.8 ± 1.3	8.5 ± 0.8	1.67 (1.00 to 2.35)		
TK_6_NUM_BOLAS_PERDIDAS					
Training 1	1.0 ± 1.0	0.6 ± 0.7	-0.44 (-1.02 to 0.13)	-0.88 (-1.71 to -0.06)	**0,036**
Training 2	1.8 ± 1.1	0.5 ± 0.8	-1.33 (-1.92 to -0.73)		
TK_8_TEMPO_ACIONADO_ NO CONTACT					
Training 1	8.1 ± 6.3	6.5 ± 3.2	-1.65 (-5.20 to 1.90)	6.88 (1.86 to 11.90)	**0,007**
Training 2	10.8 ± 7.8	16.1 ± 8.1	5.24 (1.69 to 8.78)		

Source: Prepared by the author from the data collected in the research.

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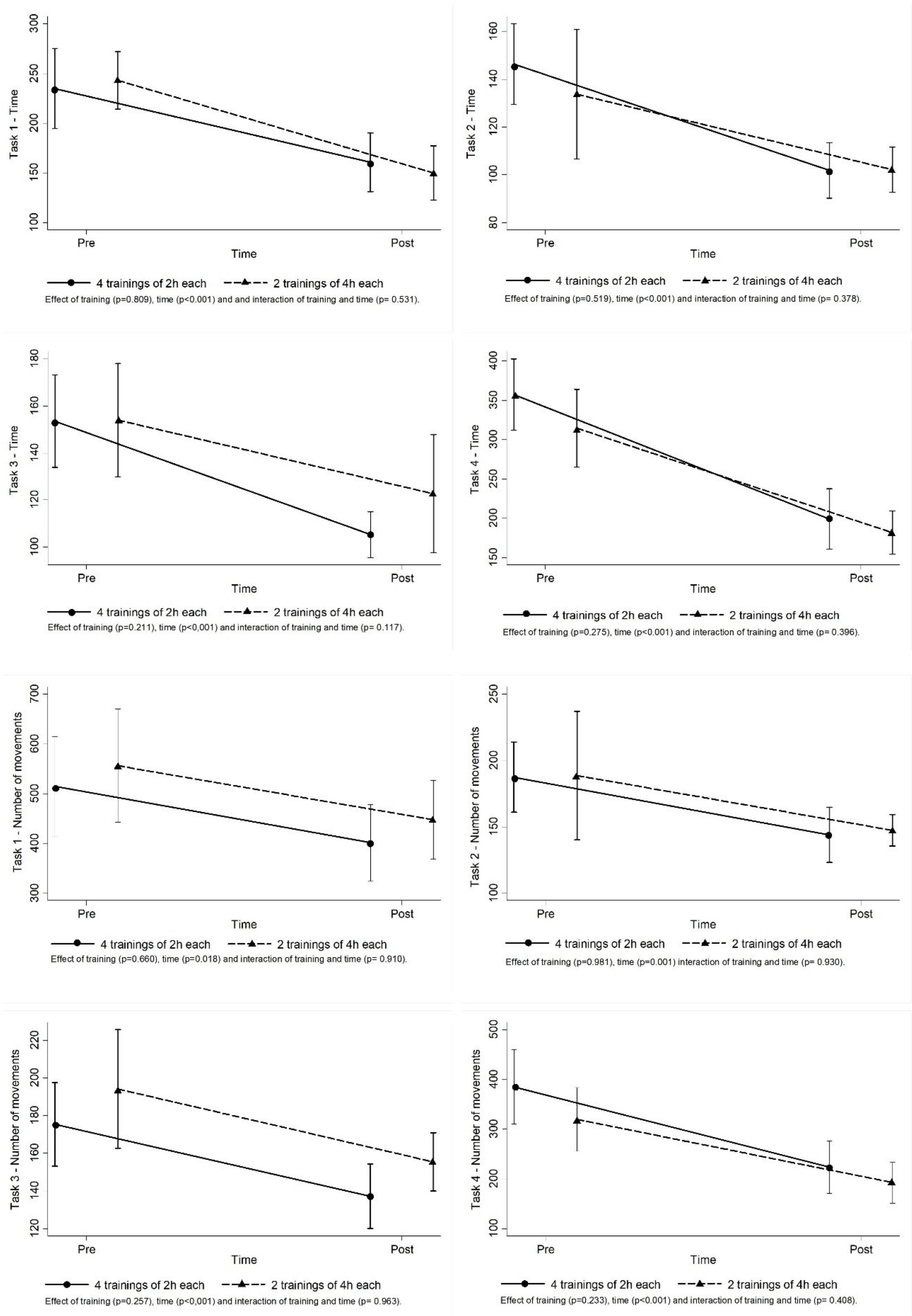
Figure 2. Graphs of averages and respective 95% confidence intervals for time and number of movements by task type.



Source: Prepared by the author from the data collected in the research.

Table 3. Summary measures of statistically significant performance in tasks by year of residence and time and estimates of mean variations via a significant linear mixed model

	Pre	Post	Multilevel model			
			Δ (Post - Pre)	Year of residency	Δ_{R2} - Δ_{R1}	
			Estimate (95%CI)	p	Estimate (95%CI)	Year of residency x Time
TK_8_DIST_PERC_INST_E (CM)						
R1	424.3 ± 229.1	250.9 ± 185.1	-173.39 (-259.85 to -86.93)	0.008¥ <0.678ʅ	126.65 (12.70 to 240.59)	**0,029**
R2	274.2 ± 105.0	227.5 ± 142.9	-46.75 (-120.97 to 27.47)			

¥ Effect of training on pre-assessment.
ʅ Effect of training on post-evaluation.
Source: Prepared by the author from the data collected in the research.

DISCUSSION

The mean age of the participants was 27.4 years, ranging from 24 to 32 years, 61.1% were male, 55.6% were in the second year of surgery residency, and all were right-handed.

It is worth mentioning that only 14% of the residents had already performed some type of simulated training in laparoscopy, but 100% had already participated as an assistant and 54.3% had already participated as a surgeon in some laparoscopic procedure, demonstrating how the teaching of laparoscopy is rooted in an outdated model, where the first contact with laparoscopy takes place directly in the operating room.

After training, a reduction in the time and number of movements in all tasks was evidenced. This result is consistent with the findings reported in previous studies, as laparoscopic surgeons with experience and qualifications are more economical in terms of time and number of movements and more accurate in terms of target/location and therefore use shorter paths[4,12].

In addition to the reduction in time and economy of movements, we had some positive result in all tasks after training with the simulator, whether the shorter distance traveled (tasks 1 and 4) or an increase in the speed of the non-dominant hand (tasks 2 and 4) or the dominant hand (task 3). We had a negative result in relation to the number of highlighted bands correctly sectioned in task 4 (after training, we had fewer bands cut correctly).

We raised the possibility of inattention and fatigue associated with this event, since this task was the last task of the test and the most meticulous, requiring greater fine motor control (it was necessary to carefully separate the highlighted band from the others and activate the electric cautery only in this band), after 2 or 4 hours of training. According to Slack, every hour after the first hour of surgery, there is a drop in the average frequency of the arm muscles, which is associated with a fatigue index.[13]

In order to evaluate the impact, performance was compared by type of training (Table 2). It is important to note that in assessing the impact that training distribution (massive *versus* distributed) would have on the acquisition of surgical skills, the delta is the most important item to be investigated. The key is to observe how much the group has evolved and not from what level it has started.

Regarding task 3, when comparing the types of training, it can be hypothesized that the massive training group did not get faster with the left-hand instrument (non-dominant) - while the distributed group had an increase in speed - because they were more tired after 4 hours of training, with a decrease in performance compared to distributed training. It may be easier to see subtle changes in the non-dominant hand. Performing the post-test immediately after the SST can be a limitation when we think about the participant's fatigue.

Regarding the number of balls collected, the massive group had a statistically significant higher average after the SST. Regarding the number of lost balls (balls that were collected from the gelatin, but were not correctly deposited in the basket), massive training was also better, losing fewer balls in the post-test. A possible explanation is that performing the post-test after 4 hours of training, despite making the resident more tired, makes the strategies used to collect the ball more refined, making it easier to remember them. In task 3, despite having no improvement in left-hand speed, training group 2 (massive) was more effective in performing the task, collecting more balls and losing fewer ones.

In task 4, the distributed group had no change in relation to the time with the cautery activated without contact with any band, while the massive group had this time increased after 8 hours of training. If we extrapolate this exercise to an *in vivo*

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surgery, the activation of the electric scalpel without contact with the structure that one intends to burn can be a serious safety failure, since it generates the risk of inadvertent injury to nearby structures.

In figures 2 and 3 it is possible to observe that the lines are almost parallel or coincidental, showing that there was no training effect.

In our study, it was not possible to demonstrate superiority of one type of training over another, since there was a statistical difference in only four variables. It is important to note, however, that the massive training apparently made the residents more efficient, but generated a higher risk by increasing the time of activation of the cautery without contact with the appropriate band. Although there was no significant difference between the trainings, the variables in which there was a difference are extremely important, because thinking about efficiency without safety does not make sense.

Based on the motor skills learning principle of mass versus distributed practice found in the domains of psychology and athletics, in the literature, there is evidence that practice interspersed with rest periods (distributed), leads to better skill acquisition and retention compared to practice performed in continuous blocks with little or no rest in between (massive). According to Moulton, surgical skill, acquired under conditions of distributed practice, is more robust and is more capable of being transferred to a realistic model than surgical skill acquired under conditions of mass practice. [14] Diesen says that repeating structured tasks over multiple sessions rather than mass training during a single session is an important aspect of motor training that is critical to achieving proficient laparoscopic skill acquisition and long-term retention.[15]

In order to determine whether there would be a better time during residency for the introduction of laparoscopy simulation, the difference in skill acquisition between residents of different years (R1 X R2) submitted to the same training opportunities was evaluated.

In this new analysis by year of residency, the type of training was not incorporated, since it was already similar in the previous analysis.

An interaction effect between time and year of residency was found only for T4_DIST_PERC_INST_E (MC) ($p=0.029$), indicating that the groups presented different mean variations, and it was not possible to evaluate the overall temporal effect.

For the distance covered with the instrument in the left in task 4, the mean in group R1 was higher (they covered a longer total distance, i.e., they were less economical) than the mean in group R2 in the pre-test ($p=0.008$), and after training, no differences in means were observed between them ($p=0.678$), demonstrating an improvement in group R1. After training, the R1 covered a shorter distance, while the R2 had no change. It is important to note in relation to the distance traveled, that R1 and R2 came out of very different positions and after training (although they evolved differently), both reached similar levels, giving the idea of homogenization of skills through simulation.

After training, the R1s covered a distance 406.84 cm shorter compared to the pre-test to perform the same tasks, while the R2 covered a distance 215.56 cm shorter after training. Although not statistically significant, it had a marginal p (0.058). Manella has previously shown that simulation improves technical skill, especially in younger residents.[12]

Regarding the comparison between first- and second-year residents, intuitively, we expected that first-year residents - because they had less experience and contact with laparoscopy - would have a lower initial performance compared to second-year residents and after training would evolve more (because they left a lower plateau). This behavior was evidenced in only one variable, demonstrating the importance of implementing the SST regardless of the time of GS residency.

CONCLUSIONS

In the situations where this study was carried out, there was a gain in technical skills, with a reduction in the time and number of movements needed to perform the activities.

Differences in skill acquisition in relation to the type of training were observed in left-hand speed and the number of balls collected, the number of balls lost from task 3, and the time triggered without contact in task 4.

A difference in the acquisition of skills in relation to the year of residency was observed only in the distance covered with an instrument in the left hand in task 4.

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AUTHORS' CONTRIBUTIONS

Caroline Petersen da Costa Ferreira was responsible for conceptualization, Methodology, Investigation, Data Collection, Formal Analysis, Writing, Review and Editing. Luiz Arnaldo Szutan contributed to: Review. Maurício Alves Ribeiro contributed to: Data collection.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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DATA AVAILABILITY STATEMENT

Research data is available in the body of the document

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