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ORIGINAL ARTICLE

## A randomized trial of training the non-dominant upper extremity to enhance laparoscopic performance

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### Abstract

**Introduction:** In laparoscopy, the surgeon's dominant arm will execute difficult tasks with less effort compared to the non-dominant arm. This leads to a relative overuse of muscles on this side. We hypothesized that training the non-dominant arm would improve laparoscopic skills. **Material and methods:** At baseline, all participants performed three validated tasks on a virtual reality simulator. After randomization, subjects in the intervention group were assigned training tasks. All these tasks had to be performed with the non-dominant hand. Within a week after a three-week study period, participants performed the same three tasks as before. **Results:** Twenty-six participants were included, 13 in each group. At baseline, there were no differences between groups on all tested parameters. Compliance to training tasks was good. At the end of three weeks, subjects in both groups showed similar improvement of skills on the non-dominant side. On the dominant side, however, subjects in the training group showed significant better improvement of skills on four out of eight parameters. **Conclusion:** Specific training of the non-dominant upper extremity appears to lead to improvement of skills on the dominant side, a phenomenon known in literature as intermanual transfer of skill learning. To improve laparoscopic skills, bimanual training is recommended.

**Key words:** *Laparoscopy, training, upper extremity, intermanual transfer*

### Introduction

Handedness, also known as lateralization or hand dominance, is one of the most frequently occurring functional asymmetries present in approximately 96% of the human population (1–3). This asymmetry could well have consequences for surgical skills, when these are predominantly performed by the dominant hand. Obviously, complex tasks are executed with less effort by the dominant side. As a consequence, a relative overuse of the dominant upper extremity is expected. Especially laparoscopic surgeons will be prone to this overuse, as laparoscopy often involves more complex tasks than open surgery.

Gupta et al. (4) reported in their study that physical fatigue and lack of synchronized movements of the non-dominant hand were the most noted deficiencies in residents compared to experienced laparoscopic urologists.

Training in box trainers and virtual reality (VR) simulators has been shown to enhance laparoscopic skills (5–7). A study by Larsen et al. (8) furthermore underscored that VR simulator training resulted in better technical performance and less operation time in laparoscopic salpingectomy. However, some trainees may never reach proficient psychomotor skills relevant for laparoscopy (9). The possible limitations of VR training are the availability of trainers and the

troublesome implementation of VR training in a busy residency program (10,11). Our previous study among residents and clinical consultants performing laparoscopic surgery showed a significantly larger proportion of physical complaints in the dominant upper extremity compared to the non-dominant side (12). This may be due to the fact that surgeons are inclined to perform complex tasks with their dominant arm. Enhancement of skills of the non-dominant upper extremity may result in a more equal distribution of tasks and, as a consequence, decrease work load and subsequent physical complaints of the dominant extremity. In this study, the effect of training the non-dominant upper extremity in everyday activities on virtual reality trainer performance is described. We hypothesized that specific training of the non-dominant hand and arm would result in improved skills on this side and, consequently, equip one better for laparoscopy.

## Material and methods

### Subjects

The study was conducted in the Radboud University Nijmegen Medical Center, which is a tertiary medical center. Residents and clinical consultants from surgical departments in our centre were recruited by mass e-mailing. True ambidexter persons were excluded. Subjects were told they had to be prepared to spend approximately 15 minutes a day on training the non-dominant upper extremity in everyday activities for three weeks. Right-handedness was assessed using the (translated) ten item Edinburgh Handedness Inventory (Oldfield 1971). Experienced in laparoscopy was defined as having performed (i.e. being the primary surgeon) more than 50 laparoscopic procedures. Subjects were randomized between a three-week training schedule or no training.

### Training

We specifically choose training tasks that could be performed in private time at any location. For the purpose of this study, a diary was developed in which subjects in the training group had to record or perform the tasks (hand writing, drawing lines in labyrinths, cutting specific forms of paper and painting of drawn pictures). For an example of completed tasks (drawing line in labyrinth and handwriting) see Figures 1 and 2. Also, subjects in the training group were asked to brush teeth at least once a day for two minutes with the non-dominant hand. Cutlery had to be changed from left to right and vice versa with every dinner. Subjects in the intervention group were provided with

all the required material (diary, glue, scissors, pencils and manual tooth brush). To measure the compliance of participants in the training group, all tasks were assigned a specific score and with all tasks being performed, a total of 100 points could be collected. The effect of training was compared to subjects in a control group without specific training of the non-dominant hand and arm. All participants were asked not to train on box trainers or virtual reality trainers for the period of three weeks. Furthermore, subjects in the control group were asked not to perform any of the tasks mentioned above with their non-dominant hand. Testing at baseline and after three weeks was performed on a non-surgical day for participants.

### Virtual reality simulator

For objective assessment of the effect of training the non-dominant hand, evaluation on a virtual reality simulator was performed. In this way, skill acquisition and individual hand performance were assessed objectively (13,14). At baseline and after three weeks, all subjects performed three tasks on a laparoscopic virtual reality (VR) simulator for laparoscopy (Lap-Sim Virtual Reality Trainer, Skills Meducation, Hilversum, the Netherlands). Subjects were able to adjust the position of the simulator to their own optimal height. The three validated basic skill tasks were *navigation*, *grasping* and *lifting & grasping*, which provide specific parameters per hand (15). The parameters used were time in seconds, path length in meters (total distance covered with trocar) and angular path in degrees (measure for internal rotation of trocar). These variables signify efficiency and economy of movement. All three tasks generate these parameters separately for each hand, except "time" in the *lifting & grasping* task. For both groups, the percentage change was calculated and compared between the two groups; a negative value implies improvement whereas a positive value implies deterioration. This calculation was performed for the dominant and non-dominant upper extremity separately.

### Power analysis and randomization

No previous studies reported on the expected difference after specific training the non-dominant hand in everyday activities. Hence, no sample size calculations could be performed. We aimed at a minimum of ten subjects in each group. After completion of the three tasks at baseline, randomization was performed using sealed opaque envelopes. These sealed envelopes contained papers with "intervention" or "control", were shuffled and an envelope was drawn by each participant. All participants knew the goals of the

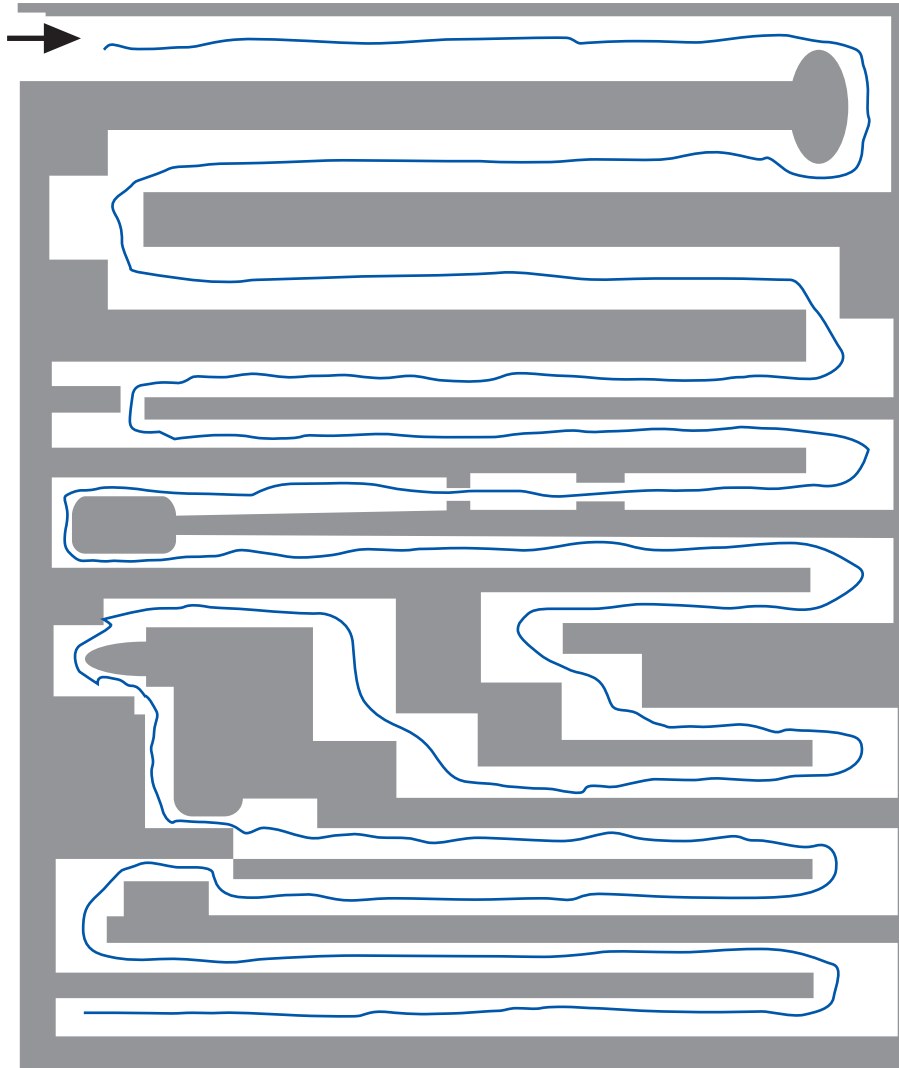


Figure 1. Example of a completed labyrinth (labyrinth from diary for subjects in the intervention group).

study. Blinding was not performed. It was intended to analyze only cases that were available after the study period.

#### Statistics

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 16.0 (Chicago, Illinois, USA). For normally distributed data, student t-test was performed. For non-parametric testing, Mann Whitney *U* was performed. In all analysis,  $p < 0.05$  was considered statistically significant.

#### Results

Twenty-six subjects were included and performed the tasks at baseline. One person in the control group was

excluded from analysis because measurements after the three-week study period were not possible. Thus, a total of 13 subjects in the training group and 12 in the control group could be analyzed.

Out of 25 participants, 24 reported to be right-handed. This was analogous to the results from the Edinburgh Handedness Inventory, where median score for right handedness was 9 (range 8–10; 10 is the score for strict right-handedness). There were no differences in baseline characteristics for age, gender and experience in laparoscopy. None of the variables of baseline VR tasks showed a significant difference between groups (data not shown).

The diaries showed that there had been a good “compliance” in the intervention group (mean 88 points; range 69 to 100). During or after the performance of tasks, six out of 13 (46%) subjects in the intervention group experienced physical

ik doe mee aan een ergonomisch onderzoek en dit is mijn niet-dominante hand  
 ik doe mee aan een ergonomisch onderzoek en dit is mijn niet-dominante hand  
 ik doe mee aan een ergonomisch onderzoek en dit is mijn niet-dominante hand  
 ik doe mee aan een ergonomisch onderzoek en dit is mijn niet-dominante hand  
 ik doe mee aan een ergonomisch onderzoek en dit is mijn niet-dominante hand

Figure 2. Example of hand writing task (translation of text: I am participating in ergonomic research and this is my non-dominant hand).

complaints in their non-dominant hand or arm, mainly after hand writing and brushing teeth.

Performance of the non-dominant hand after three weeks revealed no significant change compared to the controls (Table I). On four parameters, however, the dominant hand showed significant improvement of skills in the intervention group, whereas there was less improvement or even deterioration in controls (Table II).

## Discussion

To our knowledge, this is the first study in which specific training of the non-dominant upper extremity was examined in a randomized controlled trial. We hypothesized that training of the non-dominant upper extremity would result in improvement of skills on

Table I. Change in task variables after three weeks of the non-dominant hand.

	Intervention group (n = 13)	Control group (n = 12)	P-value
Navigation: time	-8	-5	0.594
Navigation: path length	0	0	0.635
Navigation: angular path	-13	-8	0.307
Grasping: time	-21	-23	0.583
Grasping: path length	-25	-22	0.421
Grasping: angular path	-29	-38	0.516
Lifting & grasping: path length	-18	-16	0.241
Lifting & grasping: angular path	-17	-17	0.689

Data reported as median percentage of change between baseline and three weeks. A negative value denotes an improvement, whereas a positive value implies deterioration.

Table II. Change in task variables after three weeks of the dominant hand.

	Intervention group (n = 13)	Control group (n = 12)	P-value
Navigation: time	-3	+8	0.273
Navigation: path length	0	+10	0.080
Navigation: angular path	-12	+6	0.025
Grasping: time	-14	+7	0.038
Grasping: path length	-10	+10	0.038
Grasping: angular path	-22	+9	0.016
Lifting & grasping: path length	-13	-14	0.375
Lifting & grasping: angular path	-13	-11	0.238

Data reported as median percentage of change between baseline and three weeks. A negative value denotes an improvement, whereas a positive value implies deterioration.

that side. However, our study could not show a significant improvement of skills on the trained non-dominant side compared to controls. Instead, we observed a significant improvement of the contra-lateral dominant extremity after training the non-dominant side.

It has been shown that practice of some novel tasks with one arm can improve performance of the other arm doing the same task. In the literature, this phenomenon is known as “intermanual transfer of motor skills” (16–20). In studies examining this phenomenon, subjects are trained unilaterally in specific tasks. Subsequently, the same series of tasks have to be performed using the opposite hand and/or arm (unexposed side) and the time to accomplish task and accuracy were then compared. With different tasks, intermanual transfer can occur from the dominant to the non-dominant side and vice versa. Regarding the neural correlates associated with intermanual transfer, several studies have been published (21–24). Functional magnetic resonance imaging and positron emission tomography (PET)-computed tomography scanning showed that the cerebellum, prefrontal cortex and supplementary motor area may play a role in intermanual transfer of acquired skills. Furthermore, an intact posterior part of the corpus callosum is required for this transfer (20,25–27).

Previously, a rather stringent distinction was made between dominant and non-dominant hand function. Recent studies, however, provide evidence for various degrees of handedness with both sides having specific advantages in movement tasks (1,28–30). In these experimental studies, the dominant limb system shows specialization for controlling limb trajectory

(movements from one fixed point to different targets), whereas the non-dominant system appears more specialized for controlling limb position (movements from different points to one fixed target). In everyday activities, this is e.g. observed in cutting bread and hitting a nail with a hammer. In interlimb transfer of motor learning it was, furthermore, concluded that different features of movement transferred in different directions. It has been shown that opposite arm training improves only the initial direction of dominant arm movements, whereas it improves only the final position of non-dominant arm movements (1). In our study, all parameters that improved on the dominant side after training the opposite side are considered to be parameters for trajectory control. These findings are analogous with the aforementioned studies.

Some authors have reported on the relationship between the degree of handedness and its effect on intermanual transfer of skill learning (31,32). For example, less strongly right-handed individuals exhibited better intermanual transfer of sequence learning. To correct for this possible confounder, we compared the self-reported handedness with the results from the Edinburgh Handedness Inventory and found that these were consistent in 24 out of 25 cases. Only one subject in the training group scored six items on right-handedness and four items on ambidexterity. Therefore, no corrections for true ambidextrous subjects were necessary. Exclusion of the one left-handed subject did not alter the results.

Interestingly, we found that subjects in both intervention and control group showed improvement of skills with their non-dominant hand on all parameters. This may be due to the fact that at baseline, non-dominant hand performance was less compared to the dominant side. Consequently, a better score after three weeks is more easily accomplished. Regarding the dominant side, we observed that on all but two parameters, all subjects in the control group decreased their skills compared to their initial measurement. We were not able to find a satisfactory explanation for this finding. Hypothetically, this may be due to the possibility that they were more tense/competitive compared to subjects in the intervention group and, consequently, showed less skill. It is known that stress impairs the performance of laparoscopic tasks (33). Furthermore, this may be an unexpected side effect of not having performed blinding.

Our study has possible limitations for the extrapolation of the results. Firstly, although the groups showed no differences in baseline characteristics, a variety of medical doctors with different experience in surgery and laparoscopy were included. We therefore have to be cautious to extrapolate these findings to the group of residents in which training studies are mostly

performed. Another matter is the small sample size of our study. For reliable sub group analysis to be performed, more participants are required. One participant was lost to follow-up. Since this was only one person on a total sample size of 26 and all but one parameters showed the same direction of effect, no effect on the final results is expected. Furthermore, as skills were tested on a VR trainer, it has to be seen what the actual effect on surgical skills will be. Finally, at baseline, we did not correct for previous experience in video gaming. Video game skills have been shown to correlate with laparoscopic skills (34,35). However, as the setting of the current study was a randomized controlled trial, we do not think this may have altered our results.

In conclusion, our study demonstrates that training of the non-dominant upper extremity in everyday activities seems to improve laparoscopic skills on the dominant side. Larger studies are needed to confirm these findings. In view of the intermanual transfer of motor skills, we recommend bimanual training for improving bimanual skills and ambidexterity.

**Declaration of interest:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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