Original Article

Hand Dominance Is Not of Significance in Performing Fundamental Arthroscopic Skills Simulation Training Tasks

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Purpose: To compare the performance of the dominant and nondominant hand during fundamental arthroscopic simulator training. **Methods:** Surgical trainees who participated in a 2-day simulator training course between 2021 and 2023 were classified, according to their arthroscopic experience in beginners and competents. Only right-handed individuals with complete data sets were included in the study. Ambidexterity was trained using a box trainer (Fundamentals of Arthroscopic Surgery Training, Virtamed AG, Schlieren, Switzerland).Two tasks, periscoping for learning camera guidance and triangulation for additional instrument handling, were performed 4 times with the camera in the dominant hand and then in the nondominant hand. For each task, exercise time, camera path length, and instrument path length were recorded and analyzed. **Results:** Out of 94 participants 74 right-handed individuals (22 females, 52 males) were classified to novices ($n = 43$, less than 10 independently performed arthroscopies) and competents ($n = 31$, more than 10 independently performed arthroscopies). Competents performed significantly better than novices. No significant difference was found after changing the guiding hand for the camera from the dominant to the nondominant hand regarding the camera path length and the instrument path length. Notably, tasks were performed even faster when using the camera in the nondominant hand. **Conclusions:** Our data demonstrate that the learned manual skills during basic arthroscopic training are quickly transferred to the contralateral side. In consequence, additional fundamental skills training for camera guidance and instrument handling of the nondominant hand are not necessary. **Clinical Relevance:** For skillful arthroscopy, camera guidance and instrument handing must be equally mastered with both hands. It is important to understand how hand dominance may affect learning during arthroscopic simulator training.

Introduction

Learning manual skills required for advanced arthroscopy is challenging. This is due to the altered visual perception caused by the two-dimensional representation of the three-dimensional surgical field on the monitor, the use of a 30° optic and to the altered sensorimotor perception caused by working indirectly with the camera and instruments via a pivotal point created by the portals. A skillful arthroscopic operation requires simultaneous use of both hands for camera guidance, control of viewing direction, instrument use and external movement of the leg. These different activities should be performed in an equal quality with both hands since surgery on both right and left joints must be performed. Thus, it seems reasonable to practice ambidexterity during arthroscopic training. Learning and practicing

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ambidextrous arthroscopic skills are essential for the training of young surgeons. In recent years, the use of arthroscopic simulators[1-4] and boxtrainers[5] has become more and more important. A simulator allows for equal training of the dominant and nondominant hand.

Although ambidexterity can be regarded as a fundamental skill, there are only a few studies that focus on ambidextrous training. The learning of arthroscopic skills on the simulator by using specific exercises and the monitoring of the learning progress with measurement parameters allows the scientific analysis of learning processes.[1] Using simulators, it has been shown that experts have higher levels of ambidexterity than intermediates or novices.[6-8] Hajnal et al.[9] investigated the influence of a 5-day ambidextrous training using a training box on 20 students without laparoscopic experience. Interestingly, the final performance test showed no difference between the group trained with 1 hand only and the group trained with 2 hands.

The assumption that training of handedness has a positive effect on the surgical performance and ambidextrous skills increases with experience is simple. Given the need for ambidextrous skills in arthroscopic operations, the question for future planning of training programs is how the nondominant hand can be trained most effectively.

The purpose of this study was to compare the performance of the dominant and nondominant hand during a fundamental arthroscopic simulator training. It was hypothesized that the dominant hand will perform better and, therefore, the nondominant hand requires more training to achieve the same performance.

Methods

The German Speaking Society of Arthroscopy and Joint Surgery (AGA) has made simulator training a mandatory part of arthroscopic training. The Simulator Training course for Arthroscopy (STArt) was established in 2018, and detailed description of the course and results of the training was previously published.[1] Data were collected from courses between 2021 and 2023, and all participants were asked about their handedness and the number of arthroscopic operations they had already performed. For data analysis, the trainees were divided according to their arthroscopic experience into novices with less than 10 independently performed arthroscopies and competents with more than 10 independently performed arthroscopies. Only data from right-handed individuals with complete data sets were included in the study. All attendees agreed to the anonymous evaluation of their data.

For ambidextrous training, the FAST module (Fundamentals of Arthroscopic Surgery Training, Virtamed AG, Schlieren, Switzerland) was used. Two tasks, Periscoping and Triangulation, were selected for the assessment. In "periscoping", the trainee locates an object in a virtual room, centers it in the middle of a frame, and adjusts the viewing direction by rotating the optic until the entire circular bottom of the object can be seen. If the task is performed correctly, the Virtated turns green, and the next one appears in a different position (Fig 1a,b).[1] In the task "Triangulation", the trainee locates an object, centers it in the middle of the frame, and touches the center of the Virtated with the tip of an arthroscopic hook virtually. If the task is

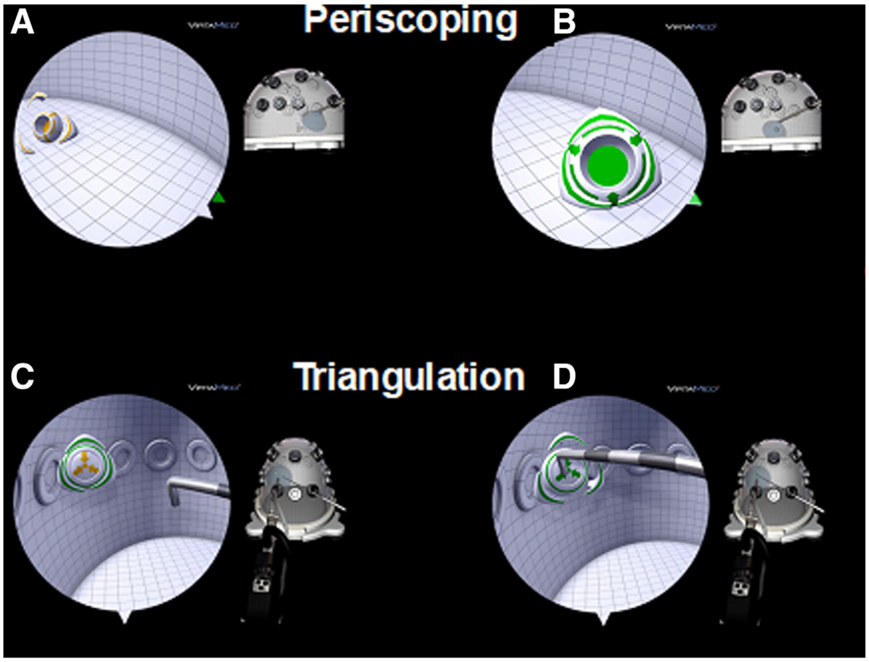

Fig. 1. Two tasks of the FAST module were selected to evaluate the performance of trainees. For periscoping (A and B), the goal is to center 10 objects successively in the virtual room and adjust the viewing direction to visualize the bottom of the object. The object turns green (B), and the next object appears. For triangulation, 10 objects must be targeted successively in the virtual room (C), centered in the middle of the frame, and the center of the object must be touched with the tip of the probe (D). If the task is performed correctly, the object turns green and the next object appears. Exercise time (in seconds), camera and probe path length (in centimeters) are recorded.

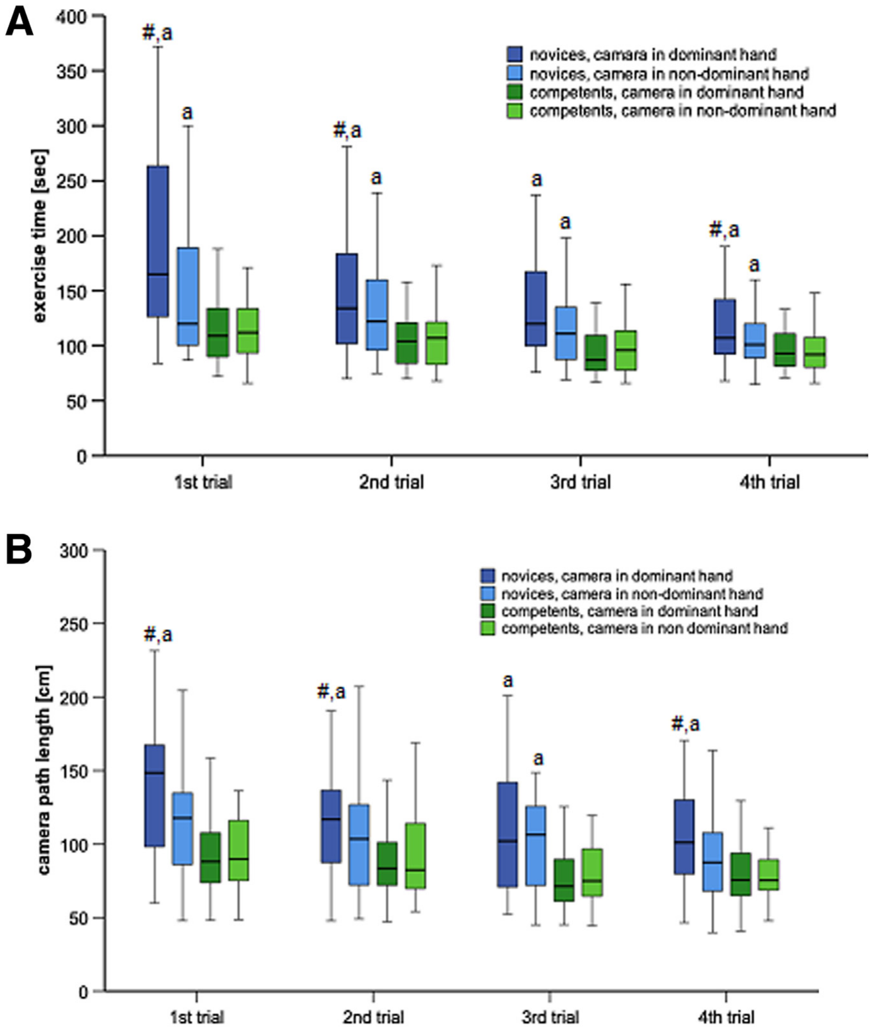

Fig. 2. Periscoping. Boxplots show performance, as determined by exercise time (A), camera path length (B), with the camera in the dominant and nondominant hand for each of 4 consecutive trials. Blue bars represent novices ($n = 43$) and green bars competents ($n = 31$). $^{\#}P < .05$, camera in dominant versus nondominant hand. $^{a}P < .05$, novices versus competents.

completed correctly, the Virtated turns green, and the next one appears in a different position (Fig. 1, C and D).

Exercises started with the camera in the dominant hand and were repeated 4 times. After a 2-hour break, each task was repeated 4 times with the camera in the nondominant hand. For performance monitoring, the measurement parameters: exercise time and camera path length were recorded for both periscoping and triangulation, and hook path length was additionally recorded for triangulation. The measurement of the camera path length and hook path length starts when entering the portal with the scope and the hook and ends when leaving the portal.

Statistical Analysis

The Kolmogorov-Smirnov test was used to check for normal distribution. Since not all data were normally distributed, nonparametric tests were used for further statistical analysis. Testing of performance between right and left hand was performed by using Wilcoxon pair difference test. Comparison of performance parameters between novices and competents was determined by means of Mann-Whitney-U-test. For all calculations, $P < .05$ was considered statistically significant. Statistical analysis was carried out using SPSS software Version 29.0 (IBM, New York, NY).

Results

Out of 94 who participated on 5 courses, 74 participants (22 females, 52 males) had complete data sets from periscoping and triangulation with 4 repetitions each and camera guidance with the dominant and nondominant hand and were classified to novices ($n = 43$) and competents ($n = 31$).

During periscoping the interquartile range, as well as the upper and lower whiskers for exercise time and camera path length, gradually decreased from repetition to repetition, indicating an increase of performance for both novices and competents. Novices performed better with the camera in the nondominant hand, with

Table 1. Periscoping

Trial		Novices (n = 43)	Competents (n = 31)	P Value Novices vs Competents
		Exercise Time (s)	Exercise Time (s)	
1st	dom	199 ± 94 (170-228)	126 ± 67 (101-150)	<.001
	non-dom	155 ± 65 (135-175)	121 ± 45 (105-138)	.029
	P value	.001	.910	
2nd	dom	160 ± 67 (139-180)	114 ± 46 (97-131)	<.001
	non-dom	140 ± 57 (122-157)	113 ± 44 (97-129)	.019
	P value	.010	.806	
3rd	dom	140 ± 52 (124-156)	101 ± 39 (87-116)	<.001
	non-dom	132 ± 57 (114-149)	100 ± 27 (90-110)	.010
	P value	.172	.984	
4th	dom	129 ± 54 (112-146)	108 ± 43 (92-123)	.018
	non-dom	114 ± 35 (103-125)	97 ± 25 (88-106)	.018
	P value	.022	.194	
		Camera Path Length (cm)	Camera Path Length (cm)	P Value Novices vs Competents
1st	dom	142 ± 61 (123-161)	102 ± 49 (84-120)	<.001
	non-dom	131 ± 91 (103-160)	102 ± 45 (85-118)	.097
	P value	.025	.860	
2nd	dom	125 ± 65 (105-145)	93 ± 34 (80-105)	.004
	non-dom	104 ± 39 (92-116)	95 ± 35 (82-108)	.281
	P value	.007	.695	
3rd	dom	107 ± 42 (94-120)	79 ± 27 (69-89)	<0.01
	non-dom	99 ± 38 (87-111)	81 ± 24 (73-90)	.046
	P value	.108	.624	
4th	dom	104 ± 55 (88-121)	84 ± 32 (72-96)	.024
	non-dom	87 ± 29 (79-96)	80 ± 22 (72-88)	.338
	P value	.007	.710	

Values are given as means ± SD (95% confidence interval).
n, number of participants; dom, camera in dominant hand; non-dom, camera in non-dominant hand.

statistically significant differences for exercise time in the first (155 ± 65 [135-175] s vs 199 ± 94 [170-228]; P = .001), second (140 ± 57 [122-157] s vs 160 ± 67 [139-180]; P = .010) and fourth trial (114 ± 35 [103-125] s vs 129 ± 54 [112-146]; P =.022) and for camera path length in the first (131 ± 91 [103-160] s vs 142 ± 61 [123-161]; P = .025) second (104 ± 39 [92-116] s vs 125 ± 65 [105-145]; P =.007) and fourth trial (87 ± 29 [79-96] s vs 104 ± 55 [88-121]; P = .007) (Fig. 2). No statistically significant difference in performance between dominant and nondominant hand was found in competents (Fig 2). Overall, competents performed better than the novices. Results of all measurements for both groups are presented in Table 1.

In the task triangulation, we observed an improvement in performance in both novices and competents. The interquartile range and the upper and lower whiskers gradually decreased for exercise time, camera path length, and hook path length after repeated practicing (Fig 3). The task was performed faster by novices with the camera in the nondominant hand and the hook in the dominant hand in the first (88 ± 28 [79-96] s vs 97 ± 23 [90-104]; P = .029), second (73 ± 18 [67-78] s vs 79 ± 19 [73-85]; P = .0049), third (67 ± 21 [61-74] s vs 72 ± 17 [67-77]; P = 0.020 and fourth (68 ± 25 [60-76] s vs 77 ± 28 [69-86]; P =.002) trial. Competents performed also significantly faster with the camera in the dominant hand in the first (75 ± 24 [66-84] s vs 82 ± 23 [74-91]; P = .044), second (63 ± 28 [56-70] s vs 67 ± 12 [63-72]; P = .0013), and fourth (56 ± 17 [50-62] s vs 64 ± 14 [59-69]; P =.002) trial (Fig 3, Table 2). When comparing camera path length and hook path length, there were only sporadic differences (camera path length: novices third trial: P =.029, competents first trial: P = .025; competents second trial: P = .048; hook path length: novices fourth trial: P = .036, competents fourth trial: P = .002), but there were no constant differences between camera guidance with the dominant and nondominant hand (Fig. 3). Competents performed significantly faster than the novices, but no statistically significant differences were found regarding camera path length and hook path. Results of all measurements for both groups are presented in Table 2.

Discussion

The most important finding of this study was that for fundamental arthroscopic training with a simulator, the

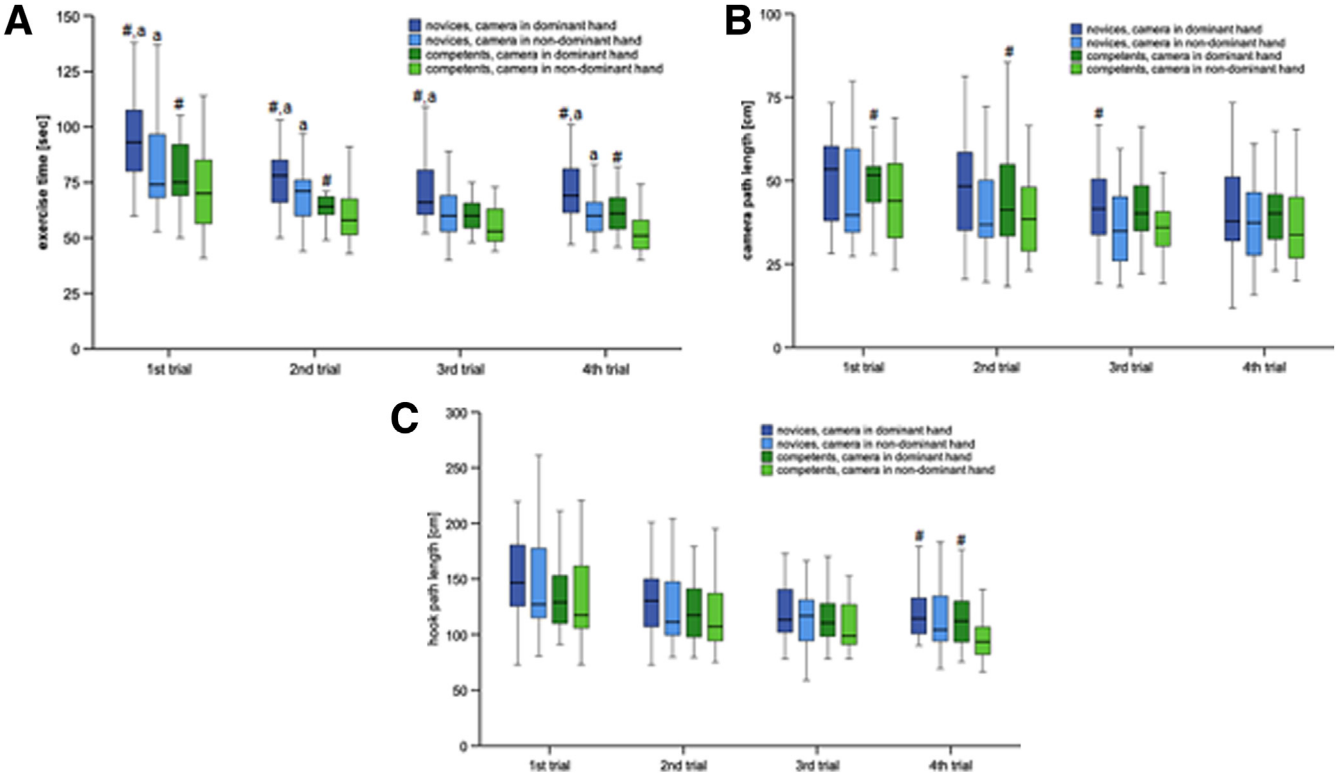

Fig. 3. Triangulation FAST-Modul. Graph showing the change in exercise time (A), camera path length (B), and hook path length (C) during subsequent training with the camera in the dominant and nondominant hand for each of 4 consecutive trials. Blue bars represent novices ($n = 43$) and green bars competents ($n = 31$). $^{\#}P < .05$, camera in dominant vs the nondominant hand. $^{a}P < .05$, novices vs competents

same amount of training is sufficient to achieve the same performance level with both the dominant and the nondominant hand. Further, the hypothesis that the dominant hand performs better than the nondominant hand must be rejected. Hence, additional exercises in basic arthroscopic training of the nondominant hand are not necessary for right-handed individuals.

The basic manual skills that are necessary for an arthroscopist can be learned and trained on a simulator. The German-speaking society for Arthroscopy and Joint-Surgery (AGA) has included simulator training in its educational curriculum.[1] The practical training starts with learning the basic arthroscopic skills on the FAST module. Motor skills, such as ambidexterity and triangulation, are practiced from the beginning and reviewed at the end of the training. An essential prerequisite for the successful implementation of a training concept is its regular evaluation, and, if necessary, adjustments of the training plan. In this context, the effect of ambidextrous training was investigated.

Although ambidexterity can be considered as an essential motor skill for arthroscopists, there are only 2 recent studies that investigated ambidexterity using simulators recently. Rose and Pedowitz[8] analyzed the impact of performance level on ambidextrous skills by means of a boxtrainer. Although not all measured performance parameters were statistically different, they concluded that experts had better ambidextrous skills than beginners. Recently Feeley et al.[7] found that experienced orthopedic surgeons have a greater degree of ambidexterity than intermediate or novice groups. However, in these studies, bilateral performance was only tested after 1 test trial and not during a sequence of exercises.

In our training schedule, participants first practice with the camera in the dominant hand. After four repetitions and a 2-hour break, the same exercises were performed with the nondominant hand. During breaks in practicing, "offline" consolidation processes take place in the brain, leading not only to storage in long-term memory but also to improved performance when the skill is tested again.[10,11] The analysis of the learning curves showed a typical pattern with a wide range of the measured values at the first attempt followed by a continuous decrease after repeated trials. A rapid improvement after the first trial is characteristic for learning a motor movement, although an adaptation to the task being performed cannot entirely be excluded. Comparison of learning curves of both tasks, periscoping and triangulation, did not show a loss of

Table 2. Triangulation

Trial		Novices (*n* = 43)	Competents (*n* = 31)	*P* value
		Exercise Time (s)	Exercise Time (s)	Novices vs Competents
1st	dom	97 ± 23 (90-104)	82 ± 23 (74-91)	.004
	non-dom	88 ± 28 (79-96)	75 ± 24 (66-84)	.044
	P value	.029	.044	
2nd	dom	79 ± 19 (73-85)	67 ± 12 (63-72)	.002
	non-dom	73 ± 18 (67-78)	63 ± 19 (56-70)	.006
	P value	.049	.013	
3rd	dom	72 ± 17 (67-77)	64 ± 13 (59-69)	.012
	non-dom	67 ± 21 (61-74)	64 ± 28 (54-74)	.066
	P value	.020	.060	
4th	dom	77 ± 28 (69-86)	64 ± 14 (59-69)	.009
	non-dom	68 ± 25 (60-76)	56 ± 17 (50-62)	.002
	P value	.002	.002	
		Camera Path Length (cm)	Camera Path Length (cm)	*P* Value Novices vs Competents
1st	dom	51± 16 (46-55)	54 ± 16 (48-59)	.657
	non-dom	47 ± 23 (40-54)	46 ± 18 (40-53)	.822
	P value	.098	.025	
2nd	dom	45 ± 16 (40-50)	46 ± 18 (40-53)	.788
	non-dom	43 ± 16 (37-48)	41 ± 18 (34-47)	.494
	P value	.144	.048	
3rd	dom	41 ± 12 (37-45)	43 ± 12 (38-47)	.565
	non-dom	38 ± 15 (33-42)	39 ± 17 (33-45)	.681
	P value	.029	.126	
4th	dom	41 ± 15 (36-46)	42 ± 12 (37-46)	.681
	non-dom	39 ± 19 (33-45)	37 ± 12 (32-41)	.961
	P value	.080	.068	
		Hook Path Length (cm)	Hook Path Length (cm)	*P* Value Novices vs Competents
1st	dom	147 ± 44 (134-161)	136 ± 38 (122-150)	.214
	non-dom	147 ± 52 (131-163)	134 ± 48 (116-152)	.222
	P value	.554	.399	
2nd	dom	131 ± 39 (119-143)	122 ± 33 (110-134)	.239
	non-dom	125 ± 38 (113-137)	115 ± 31 (103-125)	.257
	P value	.154	.183	
3rd	dom	122 ± 39 (110-134)	118 ± 27 (108-128)	.865
	non-dom	116 ± 38 (105-128)	118 ± 47 (101-136)	.747
	P value	.201	.493	
4th	dom	125 ± 43 (112-138)	118 ± 33 (106-130)	.603
	non-dom	116 ± 44 (102-130)	102 ± 43 (86-117)	.084
	P value	.036	.002	

Values are given as means ± SD (95% confidence interval).

n, number of participants; dom, camera in dominant hand; non-dom, camera in non-dominant hand.

performance after changing the guiding hand for the camera to the nondominant hand, neither in the novices nor in the competents. In contrast, comparison of the learning curves has shown that beginners and competence performed the camera and instrument movements even faster when using the nondominant hand. In consistency with other studies,[1,12-14] competents performed better than novices, which is indirectly reflected by the smaller scatter range of the measured values in the boxplots.

The observation that an untrained movement is learned more quickly by the opposite limb is known in brain research as motor transfer. Although this phenomenon has been known for a long time and supported by numerous studies,[15-19] there is little knowledge about its underlying physiological mechanism. For right-handed indivduals, it has been shown that interlimb transfer only occurs from the dominant to the nondominant arm. For left-handers, it seems to be independent of whether the dominant left or the nondominant right arm was initially trained.[19] Furthermore, it has previously been demonstrated that the direction and the extent of contralateral transfer depend on the location of processing in the brain and the complexity of the motor task.[18,20-22] With regard to the dominating spatial processing, including aspects of visuomotoric integration in the brain, the right hemisphere is probably more specialized for motor movements with a spatial component, while the left hemisphere is responsible for motor tasks connected with sensory feedback.[23-26] The processing of simple motor tasks takes place in the contralateral hemisphere. Consequently, for simple movements, e.g., writing movements and shoulder-elbow movements, it is better to start with the right hand.[15,16] In our study, we observed a rapid transfer of the learned skills to the nondominant left hand. The reason for this might be that proximal effectors controlling movement of the shoulder joint, elbow and wrist are needed for camera guidance and instrument guidance during arthroscopy. A faster transfer of proximal effectors compared to distal effectors has been found in other experiments.[15,16]

Limitations

There are some limitations in the current study. First, our results only apply to right-handed individuals, as the extent of the contralateral transfer differs between left- and right-handed individuals. Second, we did not assess the basic bimanual abilities of the trainees with standard neuropsychological tests. Therefore, it is possible that the groups differ in the average individual differences in bimanual abilities. Third, our conclusion only applies to simple tasks in a simulator trainer. Arthroscopic surgery is a complex motor task, including visual control of camera guidance on the monitor and altered sensory feedback, by working indirectly with camera and instruments via portals. Finally, the present study was limited by the small number of participants. In order to detect an effect size of Cohen's $d = 0.5$ with 80% power (alpha $= 0.05$, two-tailed) when comparing novices and competents at least 53 participants per group are required depending on the measurement parameters. For comparing measurement parameters of dominant hand and nondominant hand, 28 participants are sufficient.

Conclusions

Our data demonstrate that the learned manual skills during basic arthroscopic training are quickly transferred to the contralateral side. In consequence, additional fundamental skill training for camera guidance and instrument handling of the nondominant hand is not necessary.

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