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Does mental practice supplemented by mirror therapy promote flexion ability after total knee endoprosthesis?

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Abstract

Background and objectives: Many research groups recommend mental practice as an (cost-) effective additional means in orthopaedic and neurological rehabilitation. Mental practice is supposed to stimulate neurological representations of movements (understood as the theory of functional equivalence of motor imagery and motor execution) and thus support rehabilitation. Accordingly, a mental training program supplemented by mirror visual feedback (action observation in a sagittal positioned mirror) added to the traditional rehabilitation program of the clinic was developed for patients with implanted total knee endoprosthesis. The effectiveness of this program was investigated within a randomized-controlled intervention study. The primary aim was to improve the range of motion in the patients' knee flexion.

Methods: The therapeutic process of 40 patients (M = 62.54 years, SD = 9.64) was monitored over half a year. After the surgery, the experimental group (EG) conducted physiotherapeutic exercises mentally and with the mirror. The control group (CG) completed the same exercises physically. In the investigation, which was carried out with a five-fold repetition of measuring, the criteria surveyed were, among others, flexion, gait parameters, physical function/symptoms, and the degree of coping with the disease.

Results: With regard to the main criterion of flexion, the EG attained values that were significantly higher than those of the CG. All secondary outcomes did not differ significantly between the groups.

Conclusion: The study supports the hypothesis that patients who exercise mentally and with the mirror perform better with regard to the criterion of flexion. Mental training supplemented by mirror therapy can be regarded as a promising therapy component in orthopaedic rehabilitation.

Introduction

Issues relating to demographic change, with an ever-growing share of elderly people in the total population, are gravitating nearer and nearer to the center of today's sociopolitical debate. Enabling elderly people to maintain their autonomy and avoid care dependency is thus of increasing importance. At the same time, there is a continuing increase in endoprosthetic surgeries in the field of joint surgery. In Germany, around 149,000 knee endoprostheses were implanted in 2014 [1]. In contrast, in 1994 there were only 14,000 procedures [2]. In the United States, the demand for primary total knee arthroplasties is projected to increase by 673% to 3,480,000 million procedures between 2005 and 2030 [3].

The last twenty years have brought about major improvements concerning the quality of prostheses and surgical techniques, yet treatment outcomes after an implantation remain unsatisfactory [4,5]. After rehabilitation, residual symptoms and movement limitations often remain despite sufficient bone healing. Over the course of holistic medical examination and efficient medicine, there has been a change in the views of rehabilitation after the implantation of a knee endoprosthesis; both process-based and structural schedules in rehabilitation were to be optimized [6,7]. As a result, there is now a consensus concerning the fact that postoperative immobilization is contraindicated and that, by contrast, early mobilization of the knee joint is important [8]. Regaining mobility and the development of muscle tissue to stabilize the new joint are both seen as immediate goals of the rehabilitation. Following an often long-lasting arthrosis, patients suffer misloads, gait disorders and muscular atrophy [9], which rehabilitation thus has to undo. In light of this complex problem, a search for innovative approaches is well underway in order to support the conventional approaches of physiotherapy and physical therapy in regaining flexibility and thus mobility.

Accordingly, based on the positive effects of mental practice in young adults [10], numerous research groups have suggested the repeated and conscious imagination of motion sequences without their execution [11] as a new and low-cost tool for orthopaedic and neurological rehabilitation [12-20]. In particular, motor imagery is described as an active process during which the representation of a specific motor action is internally reproduced within the patient's working memory without any overt motor outcome [19]. The imagery focuses on visual or kinesthetic information rather than on the other senses. Visual imagery means the ability to see an object or scene in

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your mind (in a usually static way and from a third-person perspective). For example, visual imagery is performed when you imagine your bended knee on a step. Kinesthetic imagery, in contrast, requires the ability to evoque the somato-sensory feelings related to the movement, i.e. to perceive muscles contractions mentally (in a usually dynamic way and from a first-person perspective) [21]. Motor imagery often refers to the singular internal reproduction of a motor act. If this is repeated extensively, consciously, systematically and with the intention of improving performance, it is termed mental practice [12].

Neuronal simulation theory [22], understood as a theory of the effects of mental practice, proposes functional similarities and a partially overlap of neural substrates between physically executed and kinesthetically imagined movements specifically in the motor and sensory regions. However, the neural activation for the imagined movements seems to be less intense and less localized than it is when actually performing the task. Weak or immobilized patients, who cannot perform active motor training (e.g. after the immobilization of a fracture by a cast or through paralyses after a stroke), should benefit from this cognitive training procedure in their movement execution [23,24].

Thus far, intervention studies in orthopaedic rehabilitation have successfully demonstrated the therapeutic use of mental practice for back pain [25], ruptures of the cruciate ligament [26,27], meniscal lesion [28], ankle sprain [29] and amputations [6,30]. Yue's & Cole's [31] results, which showed an increase in muscle strength through mental practice in healthy controls, led to a rise in interest by physicians and physiotherapists to integrate mental practice into their therapy programs. Initial studies on mental training for immobilized healthy persons showed a reduced loss of strength [32], greater flexibility of the joint, and less muscular atrophy [18,19]. In the context of early rehabilitation after a hip endoprosthetic surgery, mental training was shown to positively influence gait [33].

Imagination ability correspondingly refers to the influence of the effects of mental practice, but it is exactly this ability which decreases strongly at a higher age [34]. Since the mean age of patients in orthopedic rehabilitation is > 60 years, mental practice programs have to be edited for patients to build up a more adequate imagination of the movement in question. One possibility to facilitate the generation of a vivid movement imagination is the mirror technique [35]. For a systematic review of effects of mirror-based inductions see [36]. Initially developed for patients with phantom pain after amputations [37,38], mirror therapy has thus far been used in neuro-rehabilitation after stroke [39-41], but also in one study after orthopaedic injuries [42]. In mirror therapy, self-initiated movements are combined with specific visual stimulation, which leads to an activation of the affected hemisphere [43,44]. For this purpose, a mirror is placed in the patient's midsagittal plane, such that the patient can see the movement of the unaffected extremity while the amputated or paralyzed extremity is behind the mirror [45]. The patient has the impression of moving the affected part, which leads to an activation of the contralateral hemisphere, as well as the avoidance of the learned non-use of the affected extremity [46]. Importantly, the use of mirror therapy in immobilized patients could be an important supplement to mental practice. While competitive athletes, for whom the mental practice was initially developed, often have a clear concept of their appropriate motion sequences, patients usually have a poor imagination ability of the movements relevant to their rehabilitation. Thus, observing mirrored movements of the knee joint could provide perceptual stimulation to this specific target group, which should support controlled imagination of the movement.

The present study aims to provide a clinically and economically highly relevant transfer of basic scientific findings to a rehabilitative therapeutic approach for mental practice and mirror therapy. With this ultimate goal in mind, a training program for patients after knee endoprosthesis surgery was developed and evaluated in an orthopedic rehabilitation.

The aim of this randomized-controlled intervention study is to determine whether an additional mental training program, supplemented by mirror therapy, leads to better results than the traditional physiotherapy concept in early postsurgical rehabilitation of knee endoprosthesis. The goal of the study's hypotheses was the following: Those patients who have been treated with mental training, supplemented by mirror therapy, should show greater, more extensive and longer-lasting successes when compared to patients of the control group who only received the traditional therapy program. Expectations in the single variables of the four evaluation dimensions were: the primary outcome: a) *range of motion in the knee joint*: larger flexion; secondary outcomes (b-d): b) *gait parameters*: a higher gait speed, combined with a reduction of the portion of stand phases and an increase in gait symmetry; c) *physical functional and symptoms*: smaller limitations in physical functioning, less pain and less stiffness; and d) *the degree of coping with the disease*: a smaller depressive processing tendency and less active problem-oriented coping.

Methods

Participants

In this intervention study, the participants consisted of 40 patients with knee endoprosthesis surgery who were aged from 41 to 86 (M = 62.54, SD = 9.64; 17 female/23 male). In addition, *profession, professional state, unemployment/inability to work, level of education, sport practices (in adolescence/adult age/last year before the operation), previous conditions, first- or follow-up surgery* as well as possible *previous experiences in relaxation techniques or mental training* were assessed. The following medical and psychological inclusion and exclusion criteria were defined beforehand.

Inclusion criteria: Initial implantation of a sliding prosthesis or total endoprosthesis, extential medical examination of the patient's general health condition and recording of previous conditions in the area of the lower extremities, start of the stationary stay: one day prior to the surgery and execution of the surgery by a determined surgeon (name blinded).

Exclusion criteria: proceeded chronical-degenerative prior conditions on the operated knee, strong arthrosis at the contralateral leg (ICRS-value ≥ 2), overweight (BMI ≥ 30), multimorbid conditions (inter alia back pain, diabetes, coronal diseases or cancer), alcohol-use disorder, depression, intake of psychotropic drugs, non-ability to speak German, inability to hear.

Deniers: Participants who met the inclusion criteria but did not want to participate in the investigation were documented with regard to their medical and sociodemographic characteristics to control for possible biases of the sample. Reasons for objecting to participation were concerns about the course of the surgery (4 patients), lack of interest in participating in the study/the study's content (2 patients), and explicit reservations against mental training (1 patient).

Dropouts: Only one of the 40 patients who was part of the EG, had to leave the investigation after the second measurement point because of health problems (strong pain in combination with impaired medication). This patient was excluded from the statistical analyses.

Participants took part voluntarily and did not receive compensation for their participation. The first contact with the patients was held by telephone, three days prior to their hospital stay.

After being informed about the content of the investigation, they were asked if they wanted to take part in the study, and a meeting at the day of their arrival in the hospital was arranged. At this first intervention session, participants gave their written informed consent. The procedures were approved by the local Medical Ethics Commission.

Investigation design and intervention schedule

The following section is intended to explain the complex procedure. It is divided in five parts: investigation design, general procedure of the interventions, order of the interventions and training contents, type of intervention in the EG, and type of intervention in the CG.

Investigation design: The design was randomized and followed the format of a two-factor two-group design, one of which was conducted with repeated measurements. The therapeutic process of the knee endoprosthesis patients was documented at five measurement points over half a year. The hospital stay at the ATOS clinic in Heidelberg, Germany lasted on average for two weeks. Following this, patients received stationary subsequent cure at an institution of their choice, which was in most cases near to the participants' home. Six weeks after the surgery, most participants reported for aftercare check-up. The dates of the measurement points were one day prior to the surgical intervention (t_1), two days after surgery (t_2), at the end of the hospital stay (t_3), six weeks after surgery (t_4) and six months after surgery (t_5). The data of the last measurement point were gathered by post. Data at the third measurement (t_3) point reflect short-term, at the fourth measurement (t_4) point mid-term, and at the last measurement point (t_5) long-term, changes respectively.

Allocation of the participants to the EG and CG, was determined by a principle of chance, using random selection without replacement. The study was single blinded, as participants did not have any information about the group and investigation plan or about the training methods of the group that they were not part of.

Trainings for both EG and CG consisted of the same contents, which were performed additionally to the traditional rehabilitation program of the clinic. The groups only differed in the nature of their intervention. Whereas the EG practiced the training program mentally and with a mirror, the CG executed the same exercises with the same duration and intensity, but without a mirror and only in a physical way.

General procedure of the intervention sessions: During the first intervention session, rehabilitation goals were defined in form of a "therapy order" [47]. Furthermore, patients could ask questions about the composition and function of the knee joint as well as about the target gait, and the actions taken to optimize the gait. In the EG the instructors introduced the mental training technique with a three-minute video. This video demonstrated the technique with two cases – one of an athlete and the other of a hip endoprosthesis patient. The roles of relaxation and effect mechanism of the mirror technique were explained. Participants received all information orally as well as in written form in the training manual.

In each intervention session, participants learned and practiced the contents. One day prior to, and two and twelve days after, surgery the intervention session and measurement point were held at the same time. In this case the instructor first measured flexibility of the knee joint with a goniometer, an action which was followed by the intervention, and finally by the data collection by questionnaire and video camera for the analysis of the gait at the end of the session. Oral instructions about the single exercises, as written in the instructor manual, were standardized. The table in the instructor manual contains explanations about the detailed procedure during the intervention sessions by describing the execution of the task and their order. Possible difficulties during the exercises were anticipated and instructions for optimization were proposed.

Order of the intervention session and the training contents: The intervention consisted of five supervised intervention sessions of 45-60 minutes each and was passed by both EG and CG. Sessions took part across 12 days, while patients received hospital treatment. The first session took place one day prior to the endoprosthetic surgery. Further sessions were held on two, five and eight days after surgery. The last session was held twelve days after surgery, which was one day prior to discharge from the hospital.

The intervention sessions, as well as the data collection, were carried out by the author herself and by three employees. Experimental conditions and the behavior of the investigator were standardized by recording instructions and procedure as explained in an investigator manual to limit restrictions of the study's internal validity to a minimum. Patients were encouraged to train the learned movements individually on a daily basis throughout the four-week-time period until the aftercare check-up (15 minutes per day). Furthermore, they led a training diary, in which they noted the date and duration of training to control their amount of training.

Contents of the intervention sessions were functional movements of the musculoskeletal part "lower leg/knee joint/upper leg". Therefore, six groups of exercises were created (Table 1) after consultation of the operating physician and the physiotherapist of the hospital. All exercises were also part of the regular clinic-internal rehabilitation program.

The training program was constructed progressively and contained three basic movements (Table 1, Exercise 1-3), all of which were intended to improve extension and flexion, tasks on gait (Exercise 4), stair climbing (Exercise 5) and one individually chosen "everyday movement" (Exercise 6). The time for partial and full load on the operated leg was chosen according to the medical indication.

Nature of the intervention sessions in the EG: Systematic mental training was the principal focus of the training program. At the beginning of every session and every autonomous training routine, respectively, patients underwent a 5-10-minute-long guided relaxation period. This consisted of breath relaxation in combination with progressive muscle relaxation in the manner of Jacobson [48,49]. The autonomous training was performed with an audio recording. Alternatively, patients could read about the principles of relaxation in the training manual for patients. This "patient fibula" contained a detailed description and justification of the concept, as well as pictures of the different exercises. The three-part guided training program consisted of contralateral motor training, motor mirror training and mental training. The importance of physical experience, in this case contralateral training, in order to achieve an overlap between imagery and execution has been highlighted in several papers [18,50].

The basic exercises (i.e. the first three exercises) were compiled after this pattern. In a first exercise sequence, the respective movement was tested two to three times motorically using the non-operated extremity and with eyes open [51]. Afterwards, the movement was carried out

Table 1. Contents of the intervention sessions in the experimental and the control group

Movements to be learned	Time of the intervention sessions
1. Basic movement • *Flexion-extension in the lying position*	Int_2 day 2 postoperative
2. Basic movement • *Flexion-extension in the standing position with partial weight-bearing*	Int_2 day 2 postoperative / Int_3 day 5 postoperative
3. Basic movement • *Loads on leg: "heel-toe"*	Int_3 day 5 postoperative / Int_4 day 8 postoperative
4. Tasks on gait *a. 3-point-gait with crutches,* *b. 2-point-gait with crutches,* c. *Without crutches*	Int_4 day 8 postoperative / Int_5 day 12 postoperative
5. Stair climbing *a. Small staircase,* *b. Stairs*	Int_4 day 8 postoperative / Int_5 day 12 postoperative
6. Individually chosen "everyday movement" • *Putting on taking off socks, pressing down the clutch...*	Int_5: day 12 postoperative

with eyes closed twice to sensitize on its kinaesthetic aspects. During the second phase, the participant performed all the respective exercises with the mirror technique [52]. Thus, the relevant preconditions for mental training were set up. In the last step, the patient performed the movement mentally with the operated extremity two to three times. Table 2 shows the basics of the procedure. All three basic exercises were conducted following this procedure. An exemplary description of the first basic movement can be found in the supplement.

Content of the intervention session in the CG: The CG received the same therapy program as the EG for five sessions, with the only difference that all exercises were executed only motorically. The CG performed the same standardized physiotherapy exercises on the functional movements of the musculoskeletal part "lower leg/knee joint/upper leg" (Table 1), and also kept a diary on their training.

Evaluation criteria and measurements

The effects of the mental training program were measured by several dependent variables. Evaluation criteria were of an objective, subjective and moderating nature. Objective measure were measures of *flexibility of the knee joint*, as well as features of the *gait*. Subjective measure were *symptoms and physical function limitations as well as disease management*. Control variables were *imagination abilities, general expectations for self-efficacy, sport habits, previous experiences in relaxation techniques or mental training* as well as the *daily time spent on physiotherapeutic exercises.* Only well-established instruments with satisfactory statistical quality were chosen for therapeutic evaluation.

Range of motion in the knee joint: The flexibility of the knee joint (flexion) was measured with a goniometer according to the neutral-zero method. According to this method, the bigger the flexion-value, the better the performance in this criterion. This parameter of interest was the maximum possible flexibility post-surgery [53-55]. After also consulting physicians, physiotherapists and psychologists of the hospital, the flexion variable was defined as the main criterion.

Ability to walk: The patient's gait was measured three times by video, directly prior to the surgery, before leaving the hospital 12 days after surgery as well as 6 weeks later. Basic characteristics of the objective gait (*gait speed, stand phase percentage, and gait symmetry*) were calculated.

Symptoms and physical function limitations: Symptoms and function limitations in the knee joint were measured by the arthrosis-specific patient questionnaire Western-Ontario-and-McMaster-Universities-Athrosis-Index (WOMAC), adapted for the German language [56]. The three subscales of the WOMAC function, pain and stiffness contain 12 items, which are rated on a 11-point scale (*0 = no* to *10 = extreme function/pain/stiffness*). The term function describes the functionality of the knee joint when performing certain everyday-life tasks, such as putting on socks or getting up from the bed. The value in this variable reflects difficulties in performing these tasks. Cronbach's α, taken as a measure for internal consistency, was between .80 and .96, while test-retest reliability was between .55 and .74. Concerning the validity, Stucki, *et al.* [56] reported significant relations between the extent of radiologically determined arthrosis and knee flexibility.

Disease management: The subscales *depressive processing* and *active problem-oriented coping* of the Freiburger Fragebogen zur Krankheitsverarbeitung (FKV-LIS; [57]) were chosen to measure subjective disease management. The subscales consist of five items each, which are to be rated on a five-point scale (from *1 = not at all* to *5 = very strong*). For example, one item of the scale *depressive processing* captures the tendency to *react impatiently* and *feel irritated towards others* (item 4). An item-example of the *active problem-oriented coping* scale is the tendency to *take active efforts to solve the problems* (item 2). Cronbach's α, as a measure of reliability, was at .77 for *depressive processing* and .73 for the coping-scale.

Control variables: Imaginative ability, understood as the ability to generate inner pictures in lively but controlled way, is seen as a basic condition for mental practice. *Imaginative ability* was measured by an adapted form of the Movement-Imagery-Questionnaire-Revised, Hall, et al. (MIQ-R; [58]). The MIQ-R consists of eight items. Four items measure *visual imaginative ability* and the other four of which measure *kinaesthetic imaginative ability*. Patients had the instructions to first perform the given movement and then to recall either the image or the accompanying feeling. Then they had to rate how difficult the act of imagination was on a seven-point scale (*1 = very easy* to *7 = very hard*). Retest-reliability values for the MIQ-R after one week are .83. Cronbach's α is .87 for the visual component and .91 for the kinaesthetic component.

Table 2. Contents of the intervention sessions in the experimental group

Movements to be learned	Modality
1. Basic movement • *Flexion-extension in the lying position*	2-3 times with eyes open* 2 times with eyes closed 2-3 times looking in the mirror** 2-3 times MENTALLY***, motion instructions spoken out loud
2. Basic movement • *Flexion-extension in the standing position*	analogous to 1. Basic movement
3. Basic movement • *Loads on leg: "heel-toe"*	analogous to 1. Basic movement
4. Tasks on gait *a. 3-point-gait with crutches,* *b. 2-point-gait with crutches,* c. *Without crutches*	active – MENTALLY in alternation
5. Stair climbing *a. Small staircase,* *b. Stairs*	active – MENTALLY in alternation
6. Individually chosen "everyday movement"	active – MENTALLY
Aim: Each movement is mentally practiced 5 times.	

*Notes:**"Contralateral" motor training, non-operated knee, ** Motor training of the non-operated knee in front of the mirror, trains operated knee, *** Mental training, operated knee

Statistical analyses

Differences in baseline assessment were tested by unifactorial variance analyses (EG vs. CG) and numerically enlarged α level (10%). Since it can be expected that the level before the surgery affects the recovery process after the surgery, the values collected at the first measurement point (t_1) are included in the calculation as covariates in the case of significant group differences.

In order to test the effectiveness of the intervention, multivariate analyses using discriminant analyses and univariate, two-factor variance analyses with repeated measurements were used as the main inferential statistical analyses. In a first analytic step, discriminant analyses were carried out in order to test the discernibility of the experimental condition as opposed to the control condition with regard to its central tendency for singular and combined dependent variables. The discriminant analyses also functioned as a filter that allows the selection of variables according to statistical criteria. The dependent variables that clearly separate the groups are selected. This method of variable restructuring thus counteracts the mismatch between the total sample size of 40 subjects and the high number of dependent variables. The composition of the first pool of variables (*AV-Pool*$_1$) is based on the results of the descriptive analyses. It was not possible to select the variables according to theoretical content, since there are no findings on mental training in orthopaedic rehabilitation after knee endoprosthetics to which a reference would be necessary. The discriminant analyses then lead to a second pool of variables, *AV-Pool*$_2$. Backhaus [59] suggests a sample size at least twice as large as the number of variables included in the model (*AV-Pool*$_1$). On the basis of this, between three and five variables were selected in which the groups differ most in their statistical characteristics. The decision to use a multivariate method in a first step brings three advantages [60]: first, an α error accumulation is avoided [61]; second, the combination of individual indicators can lead to a clearer and more interpretable differentiation of the groups; and third, the consideration of multicollinearity enables a more precise interpretation.

In a second analytic step, the univariate, two-factor variance analyses with measurement repetition were performed with the individual variables of the new pool of dependent variables (*AV-Pool*$_2$). The EG as opposed to the CG is calculated as a comparison.

Due to the lack of prior research studies, an a *priori* power analysis was not conducted. Furthermore, some variables are also analyzed with individual case contrasts. These results are additionally compared with those of single factor variance analysis follow-up tests. Conventional limits ($p \leq .05$: *, $p \leq .01$: **, $p \leq .001$: ***; two-sided test) were used for the main statistical tests and SPSS 20 was used for all statistical analyses.

Results

Baseline assessment

The results of the calculations at the first measurement point (t_1) one day before the surgery can be interpreted as the baseline values, since groups are not expected to significantly differ before the intervention. Accordingly, the single variate variance analyses showed no significant differences between the baseline values, with the exception of one variable. Only the baseline values of the dependent variable portion of stand phases differed between the EG and the CG, despite being randomized (F (1, 35) = 4,36; p = .04; η^2 = .11). Therefore, this variable will be integrated as a covariate in further analyses.

AV-pools of the discriminant analyses

From the 10 possible variables of the *AV-Pool*$_1$, the variable *flexion*, defined as the main target criterion, was selected as an objective measure from the *range of mobility in the knee joint* and the *gait symmetry* out of the variables for the *gait pattern*. The subjective measures, which were considered particularly significant, were *symptoms and physical functional limitations* as well as *disease management*. In the first area, both the total WOMAC value and the WOMAC *subscales function*, *pain* and *stiffness* were examined in greater detail. Concerning the *subjective disease management*, both subscales *depressive processing* and *active problem oriented coping* were included. For each of the five measurement points, gradual combinations of two to five variables were included in the discriminant functions until the discriminant function had the greatest separating force between the groups. The results of the discriminant analyses for the measurement points are presented separately below. It should always be note that the discriminant analytical results refer to the optimum level of separability between the groups involved (minimum-maximum principle of the variance-covariance matrices included).

Primary outcome

Range of motion of the knee joint: Importantly, concerning the course of development of the two groups regarding their *range of movement of the knee joint* (hypothesis a), there was a short-term trend of superiority for the mentally trained EG at the *flexion* variable. This can be seen in the descriptive data (Table 4) and was confirmed by the inferential statistical data (Table 5). Discriminant analyses were used to separate the two groups in a first step via the four variables *flexion – gait symmetry – active coping - pain*. They revealed a significant discriminant function for t_3, the measurement point at the end of the hospital stay [$X^2(_{4;n\,=\,32})$ = 11.16; p = .03], with *flexion* [F (1, 30) = 6.63; p = .02] being the significant factor. The single variable, two factor analysis of variance with four measurement points only showed extremely significant results for the factor *time* [*time* F (3, 69) = 80.28; p = .00; *time*group* F (3, 69) = 1.07; p = .37]. *Flexion* was significant at the third measurement point in another single factor analysis of variance [F (1, 37) = 6.78; p = .01].

Secondary outcome

Ability to walk: As for the development of the ability to walk in the two groups (hypothesis b), there were only small differences between the performances of the two groups in the variables *speed of walking and portion of stand phases* (Table 4). For the variable *gait symmetry*, descriptive analyses could show a better improvement of the EG, as compared to the CG at two measurement points (t_3 and t_4). The following inferential statistical analyses were thus only computed with this variable. The multivariate discriminant analyses yielded significant values for t_3 [$X^2(_{4;n\,=\,32})$ = 11.16; p = .03]. As there were no significant results of the sole variable gait symmetry at this measurement point, no further analyses of the variable were computed.

Physical functions and symptoms: With regard to the development of *physical functions and symptoms* (hypothesis c), the parameters of the groups were quite similar in two of three variables (*physical functionality and stiffness*) in the short- and middle-term period (Table 4). Therefore, inferential statistical analyses were not computed. However, the descriptive statistical analyses revealed differences between the third variable (*pain*) at t_3 and t_4 in favor of the CG, and at t_5 in favor of the EG (Table 4). Accordingly, the discriminant analyses revealed significant values for the discriminant function of the four

Table 3. Baseline Assessment

Variable at t_1	EG (n = 19)		CG (n = 20)		F	*P-value**
	M	SD	M	SD		
Flexion	113	12.27	116	11.00	1.39	.25
Gait speed	1.03	0.22	0.95	0.17	.02	.88
Stand phase percentage	66.90	3.15	65.09	1.89	.89	.35
Gait symmetry	2.18	1.86	3.26	2.35	.00	.95
WOMAC Function	4.17	2.45	4.28	1.77	.14	.71
WOMAC Pain	4.11	2.33	4.37	2.30	1.33	.26
WOMAC Stiffness	5.50	2.79	4.88	2.64	5.49	.02
Depressive processing	2.0	0.82	1.8	0.63	.04	.84
Coping	3.5	0.80	3.6	0.56	0.26	.60

*Significance level set to $\alpha = .10$

Table 4. Means and standard deviations of the experimental and the control group regarding primary and secondary outcome during the experiment.

		t1			*t2*			*t3*			*t4*			*t5*		
		n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
*Flexion**	EG	19	113	12.27	19	15	16.51	18	87	18.59	12	99	16.45	-	-	-
	CG	20	116	11.00	20	50	18.23	20	72	16.64	18	102	22.81	-	-	-
Gait speed	EG	18	1.03	0.22	-	-	-	17	0.65	0.15	11	0.94	0.17	-	-	-
	CG	18	0.95	0.17	-	-	-	16	0.62	0.14	9	0.87	0.21	-	-	-
*Stand phase percentage***	EG	18	66.90	3.15	-	-	-	17	67.01	2.99	11	65.77	4.04	-	-	-
	CG	18	65.09	1.89	-	-	-	16	67.27	4.61	9	66.98	2.69	-	-	-
*Gait symmetry****	EG	18	2.18	1.86	-	-	-	17	3.49	3.16	11	4.83	4.98	-	-	-
	CG	18	3.26	2.35	-	-	-	16	4.74	3.30	9	2.19	1.91	-	-	-
WOMAC Total score	EG	19	4.60	2.24	19	6.02	2.03	18	4.19	1.87	15	2.88	1.64	11	1.63	0.98
	CG	20	4.51	1.75	20	5.27	1.87	20	4.06	1.64	18	2.19	1.87	11	2.13	1.72
WOMAC Function	EG	19	4.17	2.45	19	6.85	2.69	18	4.08	2.46	15	2.88	1.64	11	1.63	0.98
	CG	20	4.28	1.77	20	6.24	2.40	20	4.15	1.66	18	2.91	1.87	11	2.13	1.72
WOMAC Pain	EG	19	4.11	2.33	19	5.20	2.36	18	4.06	1.87	15	2.88	1.64	11	1.29	1.24
	CG	20	4.37	2.30	20	3.82	2.41	20	3.16	2.01	18	2.64	1.95	11	2.38	2.41
WOMAC Stiffness	EG	19	5.50	2.79	19	5.97	2.50	18	4.44	2.33	15	3.67	1.96	11	2.50	1.36
	CG	20	4.88	2.64	20	5.78	2.66	20	4.88	2.36	18	4.11	1.97	11	4.14	3.01
Depressive processing	EG	19	2.0	0.82	19	1.8	0.80	18	1.6	0.64	15	1.6	0.61	11	1.7	0.72
	CG	20	1.8	0.63	20	1.8	0.49	20	1.7	0.44	18	1.5	0.46	11	1.3	0.24
Coping	EG	19	3.5	0.80	19	3.6	0.91	18	3.4	0.85	15	3.3	0.92	11	2.3	1.09
	CG	20	3.6	0.56	20	3.7	0.77	20	3.7	0.69	18	3.3	0.99	11	3.1	1.08

Notes. *Values of healthy controls range from 120°-150° of flexion, ** Reference value of healthy controls is 60%, ***Reference value of healthy controls is 0%.

variables mentioned above at t_3 ($X^2(_{4;n=32}) = 11.16$; $p = .03$]. Still, there were no significant results for the single variable pain. The decision was thus taken to refrain from further variance analytical analyses of the variable.

Degree of coping with the disease: Concerning the development of the two groups' *disease management* (hypothesis d), the mentally trained EG had better short- as well as long-term outcomes in the *active coping variable* (Table 4). Multivariate discriminant analyses showed significant values for the discriminant function at t_3 ($X^2(_{4;n=32}) = 11.16$; $p = .03$), but not for the single variable active coping. Neither an univariate two factor variance analysis with repeated measures, nor an univariate single factor variance analyses, could confirm a significant improvement (Table 5).

Control variables: All variance analytical tests with repeated measures were computed again, including the control variables age, sex, sport habits and previous experiences in relaxation techniques or mental training, as well as the mean expectations of self-efficacy. The results were not changed by including the covariates.

Discussion

The present research investigates the effects of a mental training program supplemented by mirror visual feedback in orthopedic rehabilitation. The aim of the randomized-controlled intervention study with total knee endoprosthesis surgery patients was to determine whether the cognitive/visual training program leads to better results than the traditional therapy concept in early postsurgical rehabilitation of knee endoprosthesis. The present evaluation study for patients with total endoprosthesis provides important new findings to improve mobility through mental training in the lower extremity, more precisely in the knee joint. The main finding of the present study was that in the primary outcome (1), the range of motion of the knee joint, patients in the mental practice/mirror training EG showed a significant treatment effect in the variable flexion at short-term-duration (t_3 : 2 weeks post-surgery). Importantly, the present research was able to confirm the safety and feasibility of the intervention, and, furthermore, reported adherence was good. Therefore, the intervention could be considered for a safety and feasibility trial for mental practice for other groups of endoprosthetic patients, such as persons with unicondylar sled knee-prosthesis or with hip prosthesis. However, the intervention did not reach all its anticipated goals. We were not able to demonstrate a significant difference in the secondary outcomes (2), probably due to the small effect sizes.

In the primary outcome (1), the effects of mental practice on range of motion have been shown for the upper extremity with healthy

Table 5. Summary of the inferential statistical results.

1) Discriminant analysis				
	Measurement points			
	t2	*t3*	*t4*	*t5*
Discriminant function	n.sign.	sign.	n.sign.	n.sign.
*AV-Pool*1	-	*Flexion gait symmetry- active Coping-pain*	-	-
Significant single Variables (*AVPool*2)	-	*Flexion:* sign. *Coping:* marg. sign.	-	-

2) Analyses of variance with repeated measurements*					
Variable		Group:	Time: *t2* *t3* *t4* *t5*		
Flexion		EG CG	time extremely sign./interaction n.sign.		
Coping			time sign./interaction n.sign.		
Contrasting effects: Variable		Comparison of the levels			
		1 vs. 2	1 vs. 3	1 vs. 4	1 vs. 5
Flexion	*Time*	extremely sign.	extremely sign.	extremely sign.	**
	Interaction	n.sign.	sign.	n.sign.	**
Coping	*Time*	n.sign.	n.sign.	n.sign.	marg. sign.
	Interaction	n.sign.	n.sign.	n.sign.	n.sign.

3) Follow-up measurements with univariate, single factor variance analyses				
	t2	*t3*	*t4*	*t5*
Flexion	n.sign.	sign.	n.sign.	**
Coping	n.sign.	n.sign.	n.sign.	n.sign.

Notes.
Conventional limits were used ($p \leq .10$ = marginally significant; $p \leq .05$ = significant; $p \leq .01$ highly significant; $p \leq .001$ = extremely significant). * A 2 x 4 analysis of variance was performed on the variable flexion, and a 2 x 5 analysis of variance on coping. ** Flexion was not measured at this measurement point.

participants as well as with patients. Therefore, our findings on the enhanced range of motion fit the existing literature. A study into distal radius fracture on patients with three weeks of immobilized wrist was able to demonstrate significantly less limitation of movement in the variables dorsal extension and ulnar abduction through mental training [18]. Furthermore, another more recent study investigated the effects of mental practice and mirror training in comparison to a CG that received a relaxation intervention on wrist function after distal radius fracture [19]. Importantly, these results showed that the EG outperformed the CG in all outcome measures, whereas the mental practice group performed best and showed the greatest improvement in grip strength. However, in another randomized-controlled trial with patients who were immobilized after flexor tendon repair [62], a 6-week mental practice program was unable to show significant influence on the active motion of the fingers. This might have been due to differences in the assessment procedure and the content of the intervention that focused on the flexion of the fingers and the wrist.

The effects of mental practice on range of motion of the lower extremity have been reported in only a few studies. The use of the mental practice of stretching by competitive athletes (synchronized swimmers) has been shown to enhance ankle, hamstrings and adductor flexibility [63]. In another study with healthy adults, mental practice coupled with proprioceptive neuromuscular facilitation resulted in a better range of motion of the hip joint than that which was achieved by physical training alone [64]. Thus, our findings can expand this literature by generalizing the effects of mental practice on the range of motion of lower extremities to a clinical sample.

In the present study, patients in the CG experienced smaller increases in their flexion ability directly after hospital treatment compared to the EG. At mid-term (t_3: 12 days after surgery) no differences were found. However, the long-term effects (t_5: 6 months post-surgery) could not be assessed for the variable flexion, because of postal data collection.

An important detail for the interpretation of this finding is that the guided intervention sessions only took place in the first 2 weeks after the surgery, during which the patients were hospitalized in the clinic for acute care. It should also be noted that total endoprosthesis is used in cases of severe destruction of the knee joint when compared to the unicondylar sled prothesis [65], and that the implantation of this prosthesis represents a much more extensive surgical procedure. It is thus gratifying that total endoprosthesis patients were also able to benefit from the mental practice program in the short term. One possible explanation for this is that patients after total endoprosthesis surgery require guided instructions according to the mental training concept for more than 2 weeks, in order to be able to show continually better flexion values, when compared to conventionally treated patients during the 6 weeks of follow-up after the procedure.

In the secondary outcomes (2), a significant difference could not be demonstrated in the present study. We could only detect differences on the level of descriptive statistics. The positive effects of the flexion variable were only partially reflected in the variables of walking ability. For example, there were no differences in walking speed between the EG and CG. It should be noted that the evaluated intervention was aimed at improving mobility in the knee joint and not focused on the ability to walk. The patients "walked", with two forearm crutches in 3-point gait, for the first time in the fourth of the five intervention sessions. The fact that the results concerning walking ability were not significant can be attributed to the physical limitations of the newly operated patient and the arrangement of the measurement points. Only 6-7 weeks after the artificial joint replacement should the patient be able to put full weight on the operated leg without pain. Walking without crutches usually takes 10-12 weeks [65]. Therefore, it is not surprising that the differences between the groups were not significant in the gait measurements, which are only taken 2 and 6 weeks after the surgery.

The *symptoms and physical functional limitations* of the variables *pain* and *stiffness* did not differ significantly between the groups during any of the measurement times. The different characteristics between the groups in the variable *pain* could not be confirmed by inferential statistics. An explanation for this would be purely speculative, as many factors can be considered in addition to chance. Consequently, no interpretation is given at this point.

In terms of the variable *physical functioning*, the mental training group achieved a significantly better performance in the mid-term period. At the same time, significantly better flexion values were found for the EG when compared to the CG. These results allow some interpretation with regard to the fourth measurement point. The items of the scale cover difficulties in certain everyday tasks, such as bending down to the floor or putting on and taking off socks. All these tasks involve a flexion movement in the knee joint. The mental training program was aimed at the functionalization of the mental movement representation, more precisely the optimization of the internal mapping of the flexion movements. The imagination of bending the operated leg was worked out and practiced by the patients of the EG through the basic exercises one to three (Table 2). Since the mental training patients clearly and significantly improved mobility in terms of *flexion*, it can be concluded that this difference can indeed be attributed to the more functionalized mental movement representation. In addition, six months later, the EG also showed a clearly better performance in the follow-up postal survey with regard to *physical functionality* than they did at the time of baseline measurement before the operation.

Furthermore, significantly positive effects on the dimension of active coping could be demonstrated in an evaluation study with CG design on mental training after hip endoprosthetics [33]. In the present evaluation study, there were indications at a descriptive statistical level that patients who were mentally trained developed better disease processing in the short- and long-term in relation to *active coping*. However, the different development characteristics between the groups could not be confirmed by inferential statistics. One explanation could be that the 2-week mental training program with 5x60-minute interventions was too short and not intensive enough to achieve significant effects on the subjective processing of the disease, when compared to the mental walking training in the study with hip endoprosthesis patients [33], in which 9x30 minute sessions were used within 3 weeks.

Taken together, our data indicate that flexion of the knee joint can be positively influenced by mental practice. This result is compatible with the Simulation Theory of Mental Imagery [22]. The optimization of the primary endpoint in the EG may be ascribed to the regular use of the neuronal structures, in the strict sense of the internal representation of the leg movement sequence. The effects in the CG could be explained, on a neuronal level, by the loss of movement representations, which may have led to temporary loss of memory of the leg function [66] and inefficient central control of movement. In contrast, in the EG, differentiation and stabilization of the internal representation of the movement took place. This may have inhibited the usual process of loss of mobility through immobilization after surgery. Hence, continuous input from a limb in the form of repeated mental performance of a movement appears to be a central requirement for preventing the impairment of central reorganization and central control.

Strengths and Limitations of the Study, and Recommendations for Future Work

This study, in our opinion, has several strengths. In the last few years the maintenance of autonomy of elderly people is highly discussed, and there has been an increase in the number of endoprosthetic surgeries. However, despite improvements in the quality of prostheses and surgical techniques, there remains a lack of feasible, cost-effective post-surgery treatments to improve the outcomes of implantations. Studies have previously shown that mental practice might be a relevant technique, but its potential for the treatment of endoprosthetic patients is still a poorly characterized phenomenon. Our study is, to our knowledge, the first experiment examining possible effects of a mental practice training program for 40 patients after an endprosthetic surgery of the knee joint across a six month period. It is also the first study that showed an effect on the range of motion of the knee joint. Concerning the variable flexion, patients that received a mental practice training program showed a significant treatment effect in the short-term period.

The standardized procedure of the mental training program can be considered a safe and feasible trial to improve the outcome of a knee endoprosthesis surgery. Given that an appropriate facility is available, it is relatively easy to conduct, and to do so in a cost-effective way. Furthermore, the mental training program used in this study might have the potential to contribute to the treatment of elderly people who run a higher risk of suffering from osteoporotic fractures not only of the wrist, but also of the humerus, spine, or hip [67,68], and will thus become immobilized and probably lose their autonomy. Einsiedel, *et al.* [68] demonstrated that the risk of losing autonomy after a wrist fracture is almost as high as the risk of doing so after a hip fracture. This is partly related to upper extremity dysfunctions with activities of daily living, such as dressing, washing and eating. Post-endoprosthetic surgery strategies tackling the problems mentioned above might reduce negative outcomes and considerably improve quality of life. So far, no proactive strategies have been published that counteract the problems of immobilization. Because of the expected clinical benefits of preventing the loss of motor function that occurs during immobilization, and because of the low cost and simple application of the intervention, further research on the effects of mental practice in orthopedic rehabilitation is fully deserved.

Nevertheless, this experiment has several limitations that must be considered. The small sample size of this study implies the risk of detecting inflated effects and could affect the robustness of the findings. The observations reported above make it impossible to draw the firm conclusion that mental practice reduces the resulting loss of range of motion of the knee joint after knee surgery. Another decisive source of interference that can be noted is the influence of follow-up treatment. Most patients were treated in a special rehabilitation clinic of their choice between the second and sixth postoperative week. The implementation of combined physiotherapeutic, physical, balneological and training therapy strategies is standard. In order to control this source of interference, specific aspects of the therapy process during the follow up treatment were recorded and evaluated retrospectively. However, the evaluation at an individual level has shown that the constellation, duration and intensity of the treatments differ greatly. Despite the limitations of the present study, we consider the use of mental practice to optimize the range of motion after surgery to be a purposeful one.

In addition to its strengths and limitations, the present study allows several recommendations to improve the methodological features and raises several issues that require future research. Regarding the findings on flexion (in which significant differences were found between the groups only with regard to the short-term, but not mid-term, effects), it seems desirable to extend the supervised training to the period of follow-up treatment, i.e. from the third to the sixth postoperative week, in future studies. However, this will only be possible in a clinic in which acute care and follow-up treatment are combined. The comparison of the results of a two-week treatment with a six-week treatment with mental training would make it possible to formulate more precise recommendations regarding the amount of training that should be assigned to knee endoprosthesis patients. From the results of the examination of walking ability, it can be concluded that a mental training program specially designed for the training of walking ability, understood in the sense of the mental walking training according to Mayer, *et al.* [6], would be necessary in the second phase of rehabilitation in the course of the follow up treatment in order to achieve measurable changes in gait criteria. Mobility measurement and gait analysis at the last time of measurement, i.e. half a year postoperatively, would in this case also be informative.

Conclusions about the efficacy and the effectiveness of mental practice after endoprosthesis should be drawn to integrate three different levels of measures [19]. First, one should focus on the motor performance. The assessment of leg function should include functional measures and kinematic analysis of movements. The imaging and quantification of leg muscles will allow a better understanding of the association of muscle atrophy and leg function. Secondly, it will be interesting to focus on psychological variables, such as age-adjusted imagery ability, capacity of working memory, and the individual representation of movements. Finally, future work should assess central processes by using functional and structural neuroimaging. Indicators of central control processes, such as preparation time of movements, might be useful in interpreting the findings.

Given the incidence of arthrosis and the demographic megatrends, it is important to determine whether mental practice is effective in improving outcomes in older persons. This aspect should be studied in controlled, follow-up designed trials with adequate power and with subgroups for mental practice versus mirror therapy.

Conclusion

The present work has shown that movement improvement in knee endoprosthesis patients can be achieved by a combination of mental training with mirror training that supplements conventional therapy. The integration of mental training and mirror therapy in proven movement therapy procedures promises, without significant personnel, material and financial expenditure, a further development of existing treatment options, in order both to shorten the rehabilitation time after implantation of a knee endoprosthesis and to facilitate the resumption of everyday life. This additional measure can ensure the success of knee surgery and prevent future diseases, which also comes with long-term cost savings for social insurance carriers. A regained mobility of knee endoprosthesis patients can help to avoid the need for future care.

The present study thus provides a clinically and economically highly relevant transfer of basic scientific findings to a rehabilitative therapeutic approach for mental practice and mirror therapy.

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