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Research Article

# Computer-Aided Multimedia Training in Orthopedic Rehabilitation

## ABSTRACT

Eisermann U, Haase I, Kladny B: Computer-aided multimedia training in orthopedic rehabilitation. *Am J Phys Med Rehabil* 2004;83:670–680.

**Objective:** To compare a computer-aided training program with a conventional training program in orthopedic rehabilitation.

**Design:** The study was a randomized, nonblinded, controlled trial in which follow-up data were obtained at 6 mos. In an inpatient rehabilitation center, a consecutive sample was taken of patients with first total hip replacements or first total knee replacements 23–42 days after surgery. Indication groups were examined separately. The study population included 189 women and 85 men. Mean age was 69 yrs (38–86 yrs). Patients received either computer-aided training (case group) or conventional training (control group) within the framework of their inpatient rehabilitation program. The main outcome measures were levels of acceptance and effectiveness (Harris Hip Score, Hospital for Special Surgery Score, FIM™ instrument, and Hanover Functional Ability Questionnaire).

**Results:** Both forms of training showed significant improvements until discharge in scores and items used for the result evaluation independent of patient sex, age, and educational level. The 6-mo follow-up showed that between the groups, there was no statistically significant difference in the level of improvement concerning functional capacity. Furthermore, patients displayed their acceptance of the system by rating it with average values between "good" and "very good."

**Conclusions:** For patients with total hip replacements or total knee replacements, computer-aided training can be regarded as the equivalent to conventional training in relationship to the results of the rehabilitation program. The system is a new tool in orthopedic rehabilitation. To identify the relative importance of the system, further research is needed.

**Key Words:** Rehabilitation, Total Hip Replacement, Total Knee Replacement, Tele-rehabilitation, Computer-Aided Training

Orthopedic knee and hip impairments can lead to permanent disabilities because of lack of training during and after inpatient rehabilitation. A new concept developed in Germany supplements this training with remote monitoring and periodic reassessment. This concept, called Universal Training Assistant, is a telerehabilitation system consisting of hardware and software components with training and training analysis and with information and communication functions. It enables a patient at all stages of orthopedic rehabilitation to benefit from remote medical or therapeutic treatment.

Tele-rehabilitation in general is the remote delivery of rehabilitative services such as monitoring and training of persons with disabilities using telecommunication technology.[1] Reported findings from early exploratory trials are encouraging.[2–4] However, there have been no randomized, controlled trials demonstrating clinical effectiveness in rehabilitation so far.

The Universal Training Assistant was tested in a German rehabilitation clinic with respect to effectiveness using this new type of training method. The basic idea was to compare this computer-aided training using the Training Assistant with training provided in a conventional manner. The intention was to raise the levels of acceptance (measured in terms of declaration of consent) and effectiveness (effects on functional status, activities of daily living, pain, etc.).

Conceptually, the idea was to develop comprehensive, closed-loop tele-medical treatment and care for patients undergoing orthopedic rehabilitation. In this context, the word "comprehensive" not only stands for defining ideal individual training programs for the patient by the therapist, but also for analyzing the patient's current training performance and course of therapy, keeping the patient informed and involved and communicating and interacting with him or her. The closed loop is defined by qualitative and quantitative variables entered manually by the patient or automatically calculated for training and course of therapy, which are transferred on completion of training to the therapist, such as details of intensity and frequency of training. Based on these results and the information originating from the interaction with the patient, the therapist specifies further individual optimized training programs. The system also allows incorporation of new exercises into the patient's training schedule to keep the treatment up to date in accordance with current guidelines and the patient's training progress.

## METHODS

Patients received either computer-aided training (case group) or conventional self-training (control group) within the framework of their 3- or 4-wk inpatient rehabilitation program. To perform the computer-aided training, the patient was instructed for half an hour by a physiotherapist, who explained the system and selected and modified the exercises for the patient on the Training Assistant. In accordance with their individual capacities, the patients used the system 3–5 times a week for 30 mins without supervision. The conventional self-training was performed in a group of 8–10 patients under supervision of a physiotherapist. The patients received an exercise program that was either performed without or with simple tools like balls or rubber bands. This training was performed 3–5 times a week for 30 mins. The subjects were assessed during a 4-mo interval between December 2000 and March 2001. A comprehensive program of inpatient rehabilitation was provided to each patient, tailored to meet each patient's skills and abilities. The following services were provided as part of the rehabilitation program to both groups: medical services, nursing, physical therapy, and occupational therapy.

### Description of the Intervention

*Computer-Aided System.* The Universal Training Assistant is used to perform a selection of computer-aided, multimedia, real-time training exercises relevant to rehabilitation of motor abilities and skills (basic training and special training). The system features two different versions especially designed for the needs of the user groups, patients, and therapists. In the therapist's version, the specialist creates the ideal training program for the individual performance capacity of the patient by defining suitable exercises (Fig. 1).

The exercises are grouped into "pools" for specific indications and correspond exactly with those used in conventional rehabilitative training. In addition, the therapist can set analysis variables for each exercise to obtain feedback on training performance. Depending on the specifications, devices for describing or recording movement, such as accelerometers, Web cams, chest sensors, and wristbands, are activated automatically. By implementing these devices into the training schedule, the visualization and interpretation of the training and the assessment of the patient's compliance is feasible. Furthermore, the therapist can specify questions the patient has to answer at the end of a training unit (e.g., about the course of training and acceptance, perceived pain, and "strenuousness;" these factors are important for planning the course of further training). Finally, the therapist can receive a record of the training unit (date and time, duration, type and execution of the training, answers, and patient's remarks) and also refer back to the patient record and send news to the patient.

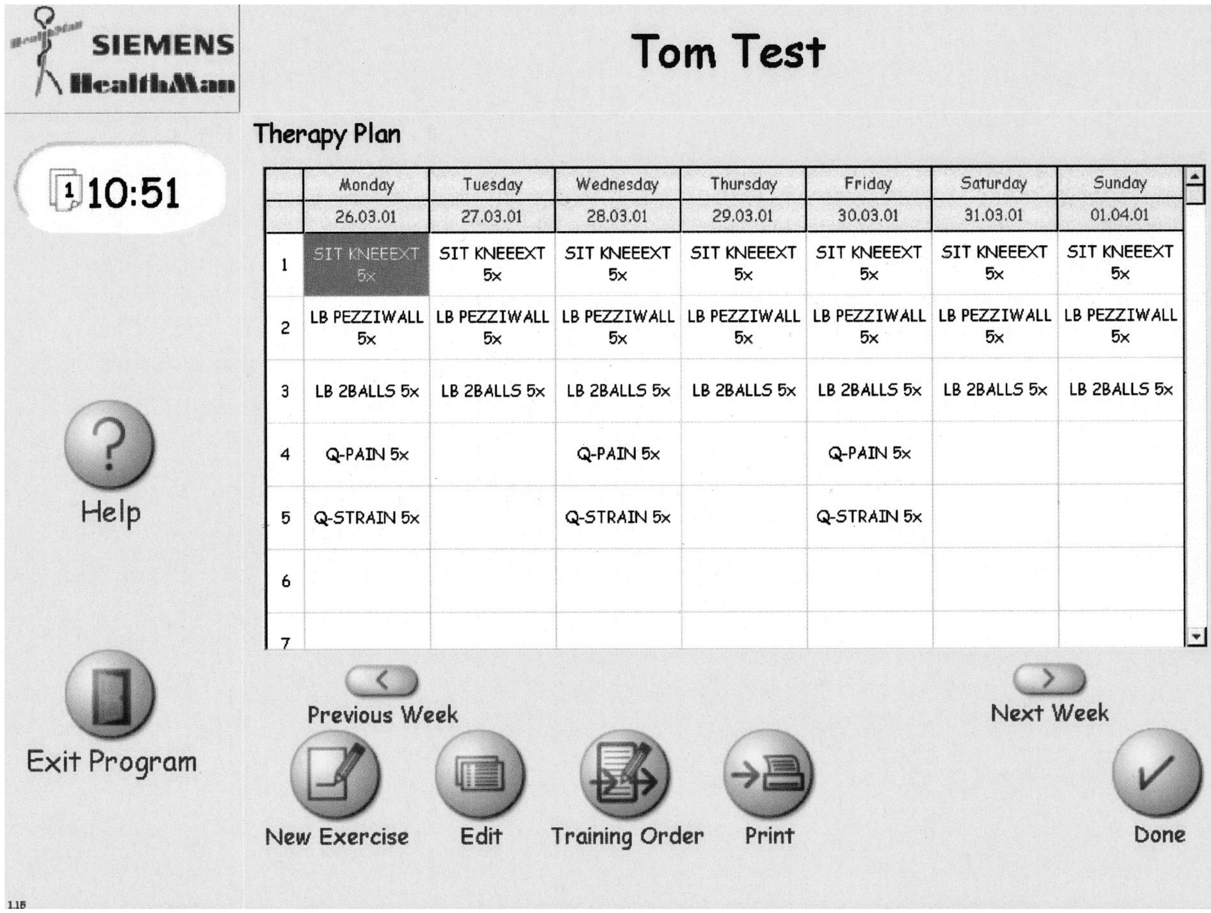


**Figure 1:** Example of patients' time schedule.

The patient's version offers the training programs created by the therapist (i.e., the Training Assistant conducts the patient through the program). Assistance is available for each exercise, and each set comprises movement description, training load, and multimedia assists (video animations and audio sequences). To enhance communication, the patient has the opportunity to send a message to the therapist. With the aim to offer quick and reliable program operation, especially for computer-illiterate users, a simple, clear, and visually attractive interface has been designed that features large buttons and lettering and virtually excludes the possibility of input errors (Fig. 2).

*Structure.* All data generated by the patient using the patient station are transferred to a server of the service supplier or provider. The therapist can review the data using his or her therapist station, evaluate it, and if appropriate, select a new training program adapted to the altered abilities and skills of the patient. This program will then again be transferred to the server and will appear during the next training session. The basis for this system structure (Fig. 3) is a client-server communication infrastructure consisting of a central server and dedicated clients (patient and therapist workstations). This infrastructure makes possible tele-training, tele-monitoring, and tele-coaching, and it fulfills all security-relevant criteria (e.g., data security, authentication).

## Subjects

Selection criteria for the sample included all persons referred to a rehabilitation clinic within 5 mos with total hip replacement or total knee replacement. Other prerequisites were that patients had to be able to train and to fill in a questionnaire. Patients who fulfilled these inclusion criteria were randomized to receive either computer-aided training with the Training Assistant (case group) or conventional training (control group) within the frame of their inpatient rehabilitation program.

Patients with hip arthroplasty and patients with knee arthroplasty were examined separately. The target per study was at least $2 \times 60$ patients (cases and controls). This database is large enough to be able to draw conclusions concerning statistically significant average values for both dependent and independent samples with an error probability of $\alpha = 0.05$ and $1 - \beta = 0.80$.[5]

Figures 4 and 5 outline the progress of subjects through the various phases of the randomized, controlled trial. There were no statistically significant differences between

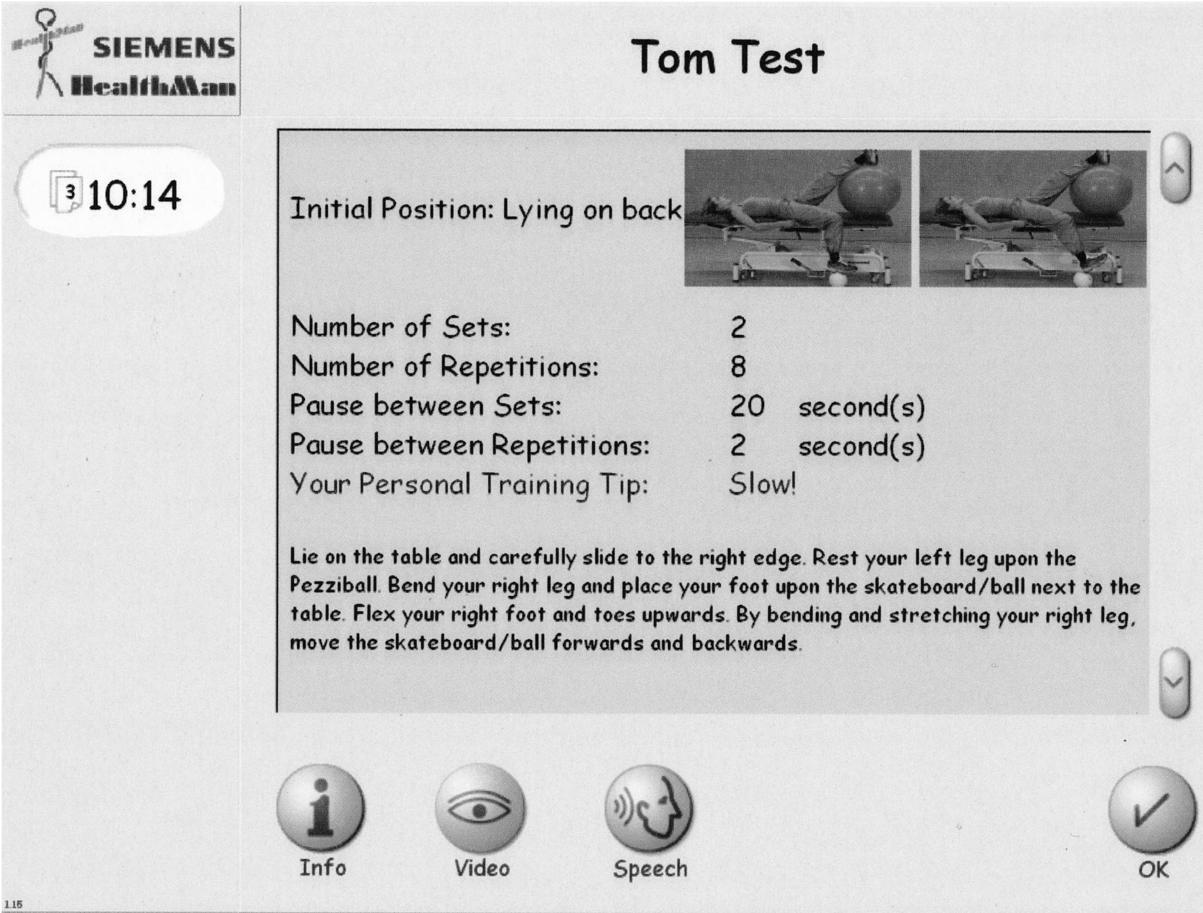


**Figure 2:** To offer quick and reliable program operation, especially for computer-illiterate users, a simple, clear, and visually attractive interface has been designed that features large buttons and lettering and virtually excludes the possibility of input errors.

the groups for the baseline demographics of patients.

## Instruments

For ascertaining aspects of functional status, activities of daily living, pain, and range of motion, established assessment instruments were used: Staffelstein-Score for total hip and total knee replacements,[6] Harris Hip Score,[7] Hospital for Special Surgery Score,[8] and the FIM™ instrument.[9–11] The data were collected by a number of rehabilitation physicians who had been introduced to the instruments and scores beforehand. Staffelstein-Score is similar to Harris Hip Score and Hospital for Special Surgery Score. The Hanover Functional Ability Questionnaire (FFbH)[12,13] was filled in by patients. The FFbH for patients with osteoarthritis is part of a series of short, self-administered questionnaires for the assessment of functional limitations in activities of daily living among patients with musculoskeletal disorders. The resulting FFbH scores can range between 0 (minimal functional capacity) and 100 (maximal functional capacity). A score of >70 points has to be viewed as normal functional capacity and an improvement of ≥12% as clinically meaningful.

## Procedure

Data were collected during the clinical inpatient period at two reference points: the time of admission and the time of discharge. A 6-mo follow-up was done to assess the long-term benefit of the treatment on patients using a questionnaire, which included the FFbH.

Descriptive statistics were computed for all relevant variables. Nonparametric tests were performed to examine differences regarding scores of outcome measures. Change from pretreatment to posttreatment was analyzed using the Wilcoxon's test. Group averages were compared using the Kolmogorov-Smirnov test. Data were analyzed with the SPSS 10 package (SPSS, Chicago, IL).

In addition, computer-aided surveys were done. These surveys were used to establish the level of acceptance. They were carried out in the following way: after a specified number of training units with the computer, the patients of the case groups were given a questionnaire by the computer (i.e., they were questioned on-line regarding the criteria managing the system, arrangement of the training, training times, effectiveness

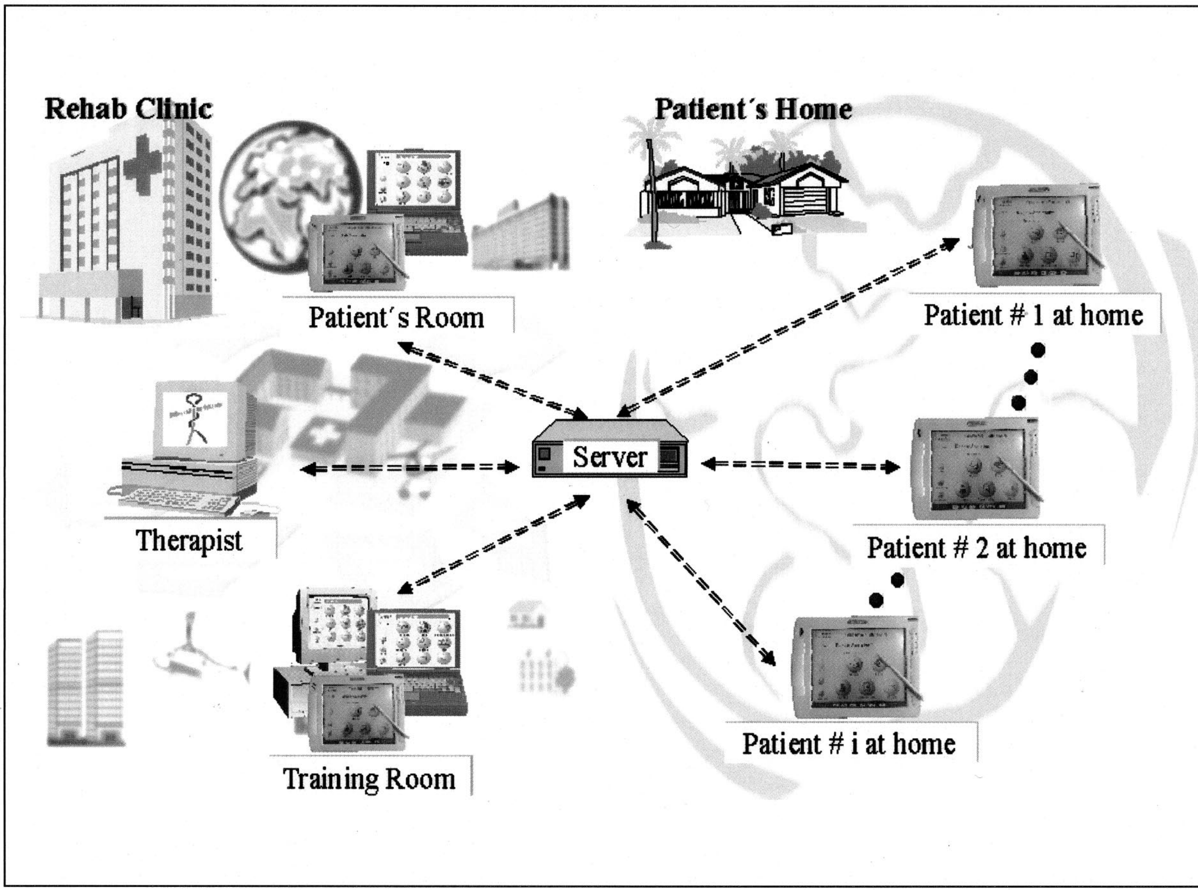


**Figure 3:** Client-server communication infrastructure consisting of a central server and dedicated clients (patient and therapist workstations). This infrastructure makes possible tele-training, tele-monitoring, and tele-coaching, and it fulfills all security-relevant criteria (e.g., data security, authentication).

of the training, recommendations for training, and enthusiasm for the training). The patients assessed most of the criteria on the basis of 5-point scales ranging from +2 to −2. For managing the system in general and multimedia arrangement of the computer-aided training there were mean values ranging between "good" and "very good."

Supplementing the acceptance aspect, physician and therapist focus group discussions[14] were held. Specific kinds of data, surveyed using qualitative methods, are only comparable with a limited extent, but they offer a much better picture of how the subject actually thinks and feels. The results obtained from qualitative procedures were combined with the results obtained from quantitative procedures and interpreted collectively.

## RESULTS

### Acceptance and Practicability

*Dropouts.* In total, 77 of 373 patients (21%) meeting the inclusion criteria declined to take part in the study. The main reason for this was that these patients (68 of 77, 88%) rejected computer-aided training; apparently, these patients had been put off by warnings related to certain health problems they had. For example, patients with poor eyesight were informed that overexertion might affect their vision. Three patients dropped out of the study early because they did not feel comfortable operating the computer (Figs. 4 and 5).

*Acceptance of Computer-Aided Training from the Patients' Viewpoint (Case Groups).* To establish the level of acceptance, all 142 patients of the case groups were questioned online (see above). Duration (of an individual training unit) and frequency (i.e., number of training units per week) were predominantly considered to be "reasonable." Effectiveness of the training, on average, was rated 1.4 (SD = 0.6) regarding physical fitness and 1.3 (SD = 0.8) regarding general strain, in each case on a 5-point scale ranging from +2 (very helpful) to −2 (useless). A total of 131 of 142 cases (92.3%) would recommend this training to other patients with similar complaints, and only one patient (0.7%) would not be able to recommend it to others. Assessment of enthusiasm for training was similarly positive.

*Acceptance of Computer-Aided Training from the Viewpoint of the*

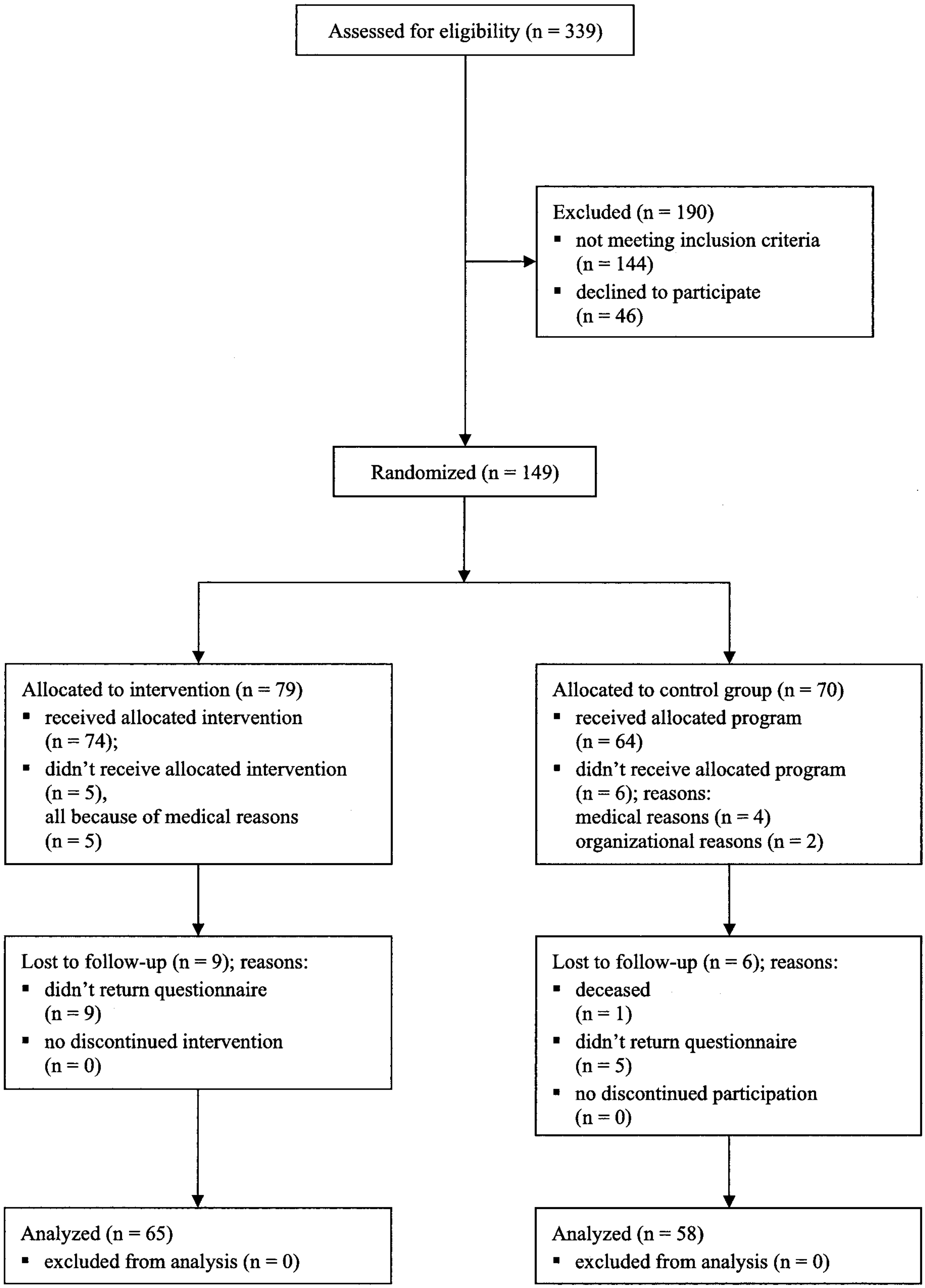


**Figure 4:** Recruitment of patients with total hip replacements.

*Physicians and Therapists.* To establish the level of acceptance, the physicians and therapists were invited to give their assessments in a focus group discussion on the criteria: course of training, arrangement of training, its effectiveness, supervision, and enthusiasm for training. They were asked to observe the criteria from their own viewpoint and to describe the patients in this light (acceptance of the training by the pa-

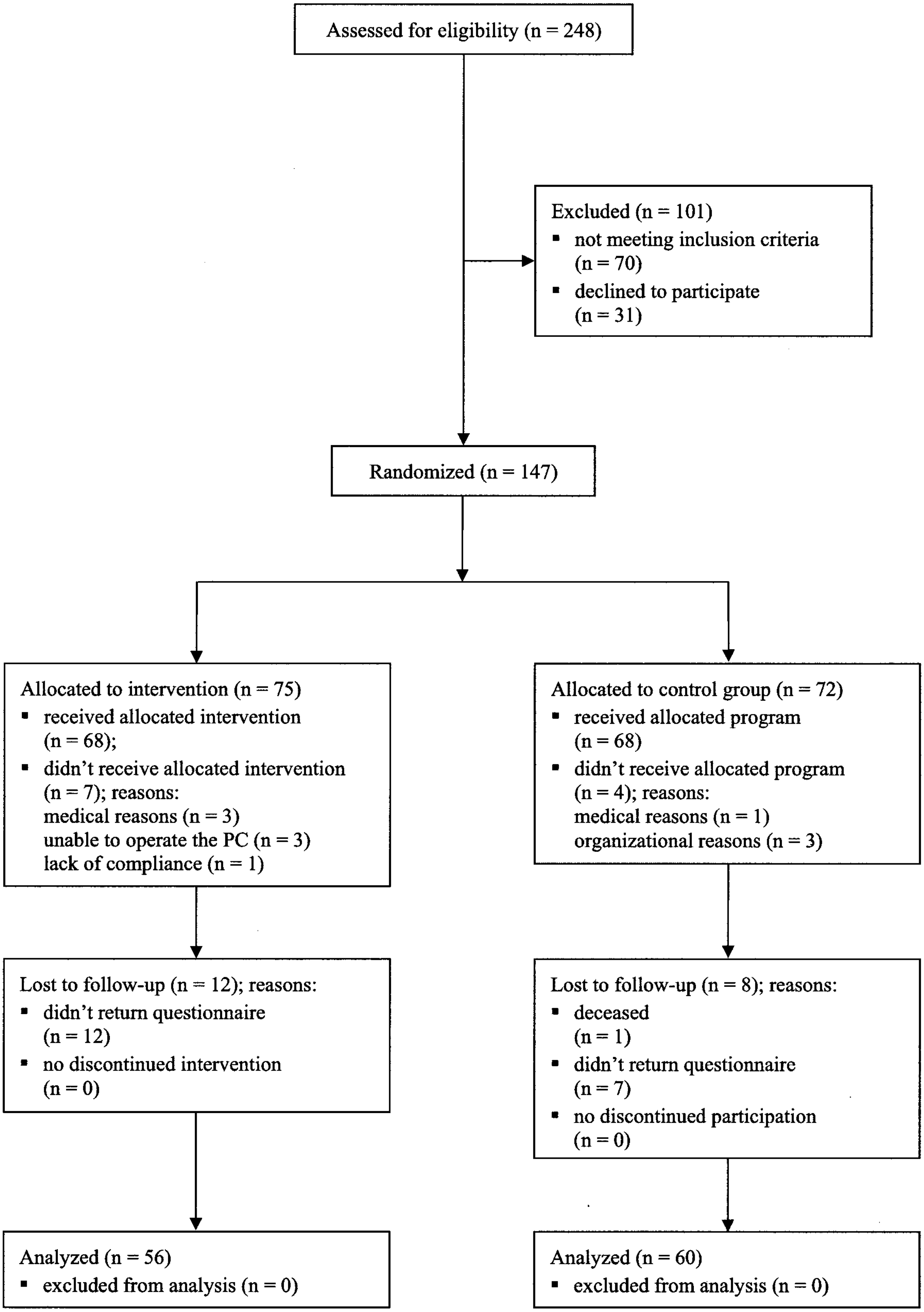


**Figure 5:** Recruitment of patients with total knee replacements.

tients as evaluated by the physicians and therapists).

The first subject discussed was the course of training, which was assessed positively by the physicians and therapists. They were able to operate the Training Assistant and to confirm that the patients were able to handle the program. As far as validity is concerned, this confirmation must be examined in detail to be certain that the patients were indeed able to operate the Training Assistant and that the criterion "course of training" in the on-line questionnaire has been correctly evaluated in terms of their abilities.

The arrangement of training was also assessed positively. Physicians and therapists alike regarded the arrangements in general as attractive and the movement descriptions as vivid. They emphasized the importance of the video animations and the audio sequences. However, it should be mentioned that for some of the patients, the movement descriptions were not adequate.

Assessment of the training's effectiveness was similar throughout, to the extent that all regarded the computer-aided training as being just as effective as conventional training. In fact, three participants (one physician, two therapists) thought that the computer-aided training was more effective because the patients were more meticulous and conscientious in carrying out the multimedia exercises led by a computer-animated trainer moving in real time. The physicians and therapists confirmed the patients' self-assessments. The great majority of the patients described the computer-aided training as helpful for their performance and recovery.

Training supervision was also regarded positively in the respect that preparation of patients for the computer-aided training was unproblematic and with duration of 30 mins claimed no more time than the preparation required for conventional training. Admittedly, it might be helpful for the training if the therapist carrying out the patient's preparation were the same one who was available during the training or supervising it.

Corresponding with the positive trend of enthusiasm for the training shown by the patients, the physicians and therapists would also continue to make use of the Training Assistant, for their in-, out-, and ambulatory patients.

**TABLE 1**
*Baseline characteristics of patients with total hip replacements*

| | Cases ($n$ = 74) | Controls ($n$ = 64) | Comparison ($P$ Value) |
|---|---|---|---|
| Sex | 60.8% women | 70.3% women | NS |
| Age, yrs | 67.8 | 69.3 | NS |
| Employed | 9.5% | 6.3% | NS |
| Living alone | 31.1% | 31.3% | NS |
| No. of days from operation to rehabilitation admission | 22.5 | 23.5 | NS |
| Rehabilitation length of stay, days | 19.8 | 19.8 | NS |
| Median admission HHS | 62 | 65 | NS |
| Median admission FIM™ score | 117 | 116.5 | NS |
| Median admission FFbH score | 35.7 | 33.3 | NS |

NS, not significant ($P > 0.05$); HHS, Harris Hip Score; FFbH, Hanover Functional Ability Questionnaire.

## Randomized, Nonblinded, Controlled Trial

***Patients with Total Hip Replacements.*** Patients with total hip replacement who fulfilled the inclusion criteria were randomized to receive either computer-aided training or conventional training during their inpatient rehabilitation. Table 1 shows that the baseline characteristics of these patients were similar in the two groups.

Both forms of training showed significant improvements in scores used for the result evaluation until discharge. Effect sizes[15,16] ranged from 0.67 to 1.34 (cases), respectively, from 0.76 to 1.34 (controls) (Table 2). There was no statistically significant difference between these two groups on Harris Hip Score, Staffelstein Score, FIM score, and FFbH.

At the 6-mo follow-up, all patients with total hip replacement who had completed the inpatient rehabilitation program were mailed a questionnaire and asked to report their functional status using the FFbH for patients with osteoarthritis. Nine patients did not return the questionnaire (Fig. 4).

Six months after the program, the average functional capacity of the case group was 72.7 (SD = 22.8) compared with a rating of 37.4 (SD = 16.8) in the same patients before treatment. This was a statistically significant improvement (Wilcoxon's $Z = -6.6$, $P < 0.001$). The control group score increased in a very similar way from 38.3 (SD = 19.2) to 74.8 (SD = 23.0). There was no effect and no statistically significant difference in improvement between groups (Kolmogorov-Smirnov $Z = 0.639$, $P = 0.809$).

Looking back on their training program during the inpatient rehabilitation, patients marked very good on a 5-point rating scale (2 = very good; −2 = very bad) for both computer-aided training using the Training Assistant and conventional training. The average case group rating was 1.26 (SD = 0.59) compared with a rating of 1.21 (SD = 0.73) in the control group. Also, 22 of 65 cases and 22 of 57 controls indicated very good. There was no statistically significant difference between the two groups.

***Patients with Total Knee Replacements.*** Patients with total knee replacement who fulfilled the inclusion criteria were randomized to receive either computer-aided training or conventional training during their

**TABLE 2**
*Effect sizes for patients with total hip replacements*

| Scores/Measured Values | Cases ($n$ = 74) | | | Controls ($n$ = 64) | | |
|---|---|---|---|---|---|---|
| | Diff T2-T1[a] | SD T1[b] | ESpre[c] | Diff T2-T1[a] | SD T1[b] | ESpre[c] |
| StS hip | 14.8 | 11.3 | 1.31 | 17.1 | 12.8 | 1.34 |
| HHS | 14.8 | 13.1 | 1.13 | 16.2 | 15.2 | 1.07 |
| FIM™ | 2.6 | 3.9 | 0.67 | 3.4 | 4.5 | 0.76 |
| FFbH | 22.5 | 16.8 | 1.34 | 23.4 | 19.2 | 1.22 |
| Distancewalked | 640.8 | 269.9 | 2.37 | 671.3 | 224.1 | 3.00 |
| Flexion | 6.6 | 12.7 | 0.52 | 5.2 | 14.8 | 0.35 |

StS, Staffelstein Score; HHS, Harris Hip Score; FFbH, Hanover Functional Ability Questionnaire.
[a] Difference between discharge and admission scores.
[b] Standard deviation of admission scores.
[c] Effect size standardized with standard deviation of admission (pre) scores.

inpatient rehabilitation too. Table 3 shows that the baseline characteristics of these patients in the study were similar in the two groups.

Both forms of training showed significant improvements in scores and items used for the result evaluation until discharge. Effect sizes,[11,12] which were computed using the standard deviation of admission (pre) scores range from 0.73 to 1.40 (cases), respectively, from 0.96 to 1.16 (controls) (Table 4). There was no statistically significant difference between these two groups on Hospital for Special Surgery Score, Staffelstein Score, FIM score, and FFbH.

At the 6-mo follow-up, as was done for patients with hip arthroplasty, all patients with knee arthroplasty who had completed the inpatient rehabilitation program were mailed a questionnaire and asked to report their functional status using the FFbH for patients with osteoarthritis. One patient was deceased, and five patients did not return the questionnaire (Fig. 5).

Six months after the program, the average functional capacity of the case group was 76.9 (SD = 16.8) as compared with a rating of 46.4 (SD = 14.4) in the same patients before treatment. This was a statistically significant improvement (Wilcoxon's Z = −6.0, $P < 0.001$). The control group score also increased significantly from 48.3 (SD = 16.7) to 70.6 (SD = 20.6). Differences between follow-up and admission scores showed a small effect to the credit of the case group (effect size = 0.38). However, statistically speaking, there was no significantly better improvement for the case group (Kolmogorov-Smirnov Z = 1.134, $P = 0.153$).

At the 6-mo follow-up, patients with total knee replacement marked very good on a 5-point rating scale (2 = very good) for both computer-aided training and usual training. The average case group rating was 1.26 (SD = 0.81) compared with a rating of 1.28 (SD = 0.74) in the control group. Also, 23 of 54 cases and 27 of 60 controls indicated very good. There was no statistically significant difference between the two groups.

**TABLE 3**
*Baseline characteristics of patients with total knee replacements*

| | Cases ($n$ = 68) | Controls ($n$ = 68) | Comparison ($P$ Value) |
|---|---|---|---|
| Sex | 66.2% women | 79.4% women | NS ($P$ = 0.061) |
| Age, yrs | 70.2 | 69.7 | NS |
| Employed | 4.4% | 2.9% | NS |
| Living alone | 36.8% | 35.3% | NS |
| No. of days from operation to rehabilitation admission | 21.6 | 24.1 | NS |
| Rehabilitation length of stay, days | 20.1 | 19.9 | NS |
| Median admission HSS | 59.5 | 58.5 | NS |
| Median admission FIM™ | 118 | 118 | NS |
| Median admission FFbH | 47.2 | 48.6 | NS |

NS, not significant ($P > 0.05$); HSS, Hospital for Special Surgery Score; FFbH, Hanover Functional Ability Questionnaire.

***Relationship of Demographic Variables to Functional Gain.*** One purpose of our analysis was to understand the influence of basic demographic variables on change in functional ability within the case group. For this analysis, FFbH change was made the dependent variable, whereas sex, age, educational level, and indication where designated as the independent variables.

**TABLE 4**
*Effect sizes for patients with total knee replacements*

| Scores/Measured Values | Cases ($n$ = 68) Diff. T2-T1[a] | SD T1[b] | ESpre[c] | Controls ($n$ = 68) Diff. T2-T1[a] | SD T1[b] | ESpre[c] |
|---|---|---|---|---|---|---|
| StS knee | 16.4 | 12.2 | 1.34 | 15.7 | 14.2 | 1.11 |
| HSS | 14.8 | 10.7 | 1.38 | 14.2 | 12.2 | 1.16 |
| FIM™ | 2.9 | 4.0 | 0.73 | 2.6 | 2.7 | 0.96 |
| FFbH | 20.1 | 14.4 | 1.40 | 16.1 | 16.7 | 0.96 |
| Distance walked | 569.7 | 263.1 | 2.17 | 571.9 | 166.7 | 3.43 |
| Flexion | 10.4 | 18.3 | 0.57 | 9.4 | 18.3 | 0.51 |

StS, Staffelstein Score; HSS, Hospital for Special Surgery Score; FFbH, Hanover Functional Ability Questionnaire.
[a] Difference between discharge and admission scores.
[b] Standard deviation of admission scores.
[c] Effect size standardized with standard deviation of admission (pre) scores.

Table 5 shows that there were no significant or clinically meaningful differences in the change of the average functional ability measure.

## DISCUSSION AND CONCLUSIONS

Computer-aided training is a new tool in orthopedic rehabilitation. The patient trains and transmits training variables to the therapist. The therapist analyzes, adapts and transfers new training configurations to the patient. They communicate with each other by mutual exchange of certain kinds of data. Little is known about practicability and effectiveness of tele-rehabilitation systems or to what extent the patients would accept them as an alternative to conventional therapy. This study was performed to evaluate just such a program—the Universal Training Assistant—implemented in the everyday operation of a rehabilitation clinic.

The computer-aided training should at least lead to equal treatment results when compared with a self-training program in groups supervised by a therapist as part of the rehabilitation setting. The findings of our present study demonstrate that treatment with the Training Assistant improves functional status, activities of daily living, functional independence, and range of motion and reduces pain just as well as conventional training. Training was effective and safe. Adverse events were not reported across the groups. For patients with total hip replacement or total knee replacement, the computer-aided training can be regarded as equivalent to the conventional training relating to the results of the rehabilitation program.

Regarding acceptance, the computer-aided training was assessed in a positive manner. For all criteria, only average values between good and very good were seen. All patients, regardless of sex, age, and educational level were able to use the system without major problems and were compliant. The result of the group discussion was that both physicians and therapists recognize the Training Assistant as a new instrument to assist rehabilitation.

Overall, the study showed that this new approach is feasible and practicable in principle. It has led to results that correspond to those that

**TABLE 5**
*Average functional ability measure change by sex, age, educational level, and indication in the case group*

| Variables | Pretreatment to Posttreatment Change in Hanover Functional Ability Questionnaire: Mean | Standard Deviation | Comparison ($P$ Value) |
|---|---|---|---|
| Sex | | | 0.109 |
| Female ($n$ = 90) | 19.8 | 16.7 | |
| Male ($n$ = 52) | 23.9 | 14.6 | |
| Age, yrs | | | 0.418 |
| <65 ($n$ = 38) | 23.6 | 15.6 | |
| 65–74 ($n$ = 72) | 19.8 | 15.5 | |
| >74 ($n$ = 32) | 22.1 | 17.9 | |
| Education level | | | 0.922 |
| 9-yrs of elementary school ($n$ = 121) | 21.6 | 16.2 | |
| Higher levels ($n$ = 16) | 22.2 | 16.0 | |
| Indication | | | 0.327 |
| Total hip replacement ($n$ = 74) | 22.5 | 17.7 | |
| Total knee replacement ($n$ = 68) | 20.1 | 14.1 | |

can be achieved by self-training. Therewith, reported findings from recently published exploratory trials[2–4] were confirmed.

It calls for complementary research in inpatient and outpatient settings to determine whether these results are sufficient to justify a widening of the system. In addition, further studies would have to examine which particular patient groups would profit most by employing such a tele-rehabilitation system.

According to the authors, the Universal Training Assistant has a great deal of potential in outpatient applications. In an ideal set-up, the patient learns to operate the system as an inpatient and continues to use it after dismissal. The patient completes the specified training program and is analyzed by the therapist regarding performance of training. The patient then offers the therapist feedback based on objective achievements and subjective assessments. Additional tools like Web cams or accelerometers for controlling the exercises during outpatient rehabilitation have to be developed and integrated in the system. The existence of such tools would increase the compliance levels of the patients and, at the same time, reduce the risk that the system will be put in the closet like many ortheses. Experiences made with cardiologic patients have shown that computer-supported, remote-controlled training has a very positive effect on the patients' motivation.[17,18] Therefore, future studies should test the effects that orthopedic tele-rehabilitation systems have on motivation levels.

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