



Original article

## Experiences with using e-learning tools in orthopedics in an uncontrolled field study application



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### ARTICLE INFO

#### Article history:

Received 23 April 2018

Accepted 7 January 2019

#### Keywords:

Uncontrolled e-learning

Podcast

Digital text

Knowledge

Evaluation

### ABSTRACT

**Background:** E-learning is widely used in undergraduate medical education and often in blended learning settings for students learning at home. This study should assess the educative value of e-learning tools in orthopedics and traumatology when used under “field” conditions, in comparison with a controlled laboratory-like setting.

**Materials and methods:** Medical students were invited for their voluntary online participation in an uncontrolled study (UCS). They were randomly exposed to digital book chapters or podcasts on four different orthopedic diseases, and then filled in pre-/post-tests and evaluations. Test results indicating insufficient study participation were not included in the subsequent analysis. Results in a gain of knowledge and student’s satisfaction were compared to existing data of a randomized controlled trial with the same tools in a laboratory environment (RCT).

**Results:** Among 84 included UCS students and 130 RCT students, podcast learners showed a significantly higher gain of knowledge compared to text learners independent of the learning setting (UCS  $p < 0.011$ ; RCT  $p < 0.001$ ). There were no significant differences in the gain of knowledge for the two different learning tools when comparing each the UCS and RCT settings. Evaluations showed positive ratings for both tools, while podcasts were on the average rated higher than texts were. Significantly more UCS participants ( $n = 46$ ) compared to the RCT ( $n = 34$ ) showed signs of disengagement with the study ( $p < 0.05$ ).

**Discussion:** The findings suggest that it is possible to achieve a similar gain of knowledge with e-learning tools in uncontrolled settings and in RCTs. The role of e-learning materials in voluntary and formative learning settings is of value and should be explored in future studies.

**Level of evidence:** III, case-control study.

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## 1. Introduction

Digitally supported forms of learning (e-learning) have become a firm component of undergraduate teaching in orthopedics and traumatology [1–3], giving students the possibility to use them anywhere and anytime [4]. When integrating e-learning into curricula, blended learning concepts are highly appreciated by students [5]—rarely reported as mandatory [6], but mostly as

voluntary supplement to teaching [2,7,8]. To analyze the efficacy of e-learning tools and concepts, many studies used written tests before and after interventional exposure [1,9,10] to gain insights about their impact on students’ knowledge. Among these studies, the design of one category can be described as laboratory-like settings [1,9], up to randomized controlled trials (RCT) [11]. Another category can be subsumed as rather uncontrolled utilization of e-learning where students use tools without any further supervision or limitation (e.g. exposure time) [6,10]. The latter approach can be regarded as a limitation for obtaining reliable study results due to multiple bias possibilities of the uncontrolled character. However, as many medical e-learning or blended learning concepts are based on the utilization of online tools by the participants at home [6,8,10], this approach still seems to represent the most common

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academic use of e-learning [7,8,12] and cannot be reproduced exactly by the strict design of RCTs. Consequently, it could be important that medical teachers in undergraduate curricula know about the impact and value of acquired knowledge by the use of e-learning tools under uncontrolled conditions.

In this study, electronic textbook chapters and audio-visual podcasts were tested as examples of e-learning tools, which are used for orthopedic teaching [2,13]. Textbooks can be regarded as the backbone of self-directed learning when studying surgical topics [14] and digital texts were also among the first digitally offered learning features which are still very popular [13,15]. As an example of solely internet-based learning tools, audiovisual podcasts has been shown to be highly popular among students [2] and to sufficiently enhance users' knowledge in surgical teachings [1,9].

The aim of the field study presented here was to assess medical students' approval and gain of knowledge when learning uncontrolled online with randomly assigned digital book texts or podcasts about orthopedic diseases. These results were compared to existing data from a randomized controlled trial in a laboratory-like environment [16] and analyzed for differences.

## 2. Materials and methods

### 2.1. Study design

The uncontrolled field study was conducted with the program Survey Monkey® (SurveyMonkey Inc., Palo Alto, CA, USA). Participation was voluntary and possible with informed consent from March to April 2013. Students were recruited via existing email distributors of German medical schools and guided with a link to the study on Survey Monkey® (in Germany, all medical schools have to comply with the German approbation law, which defines and unifies the content to be covered and teaching formats in undergraduate medical education at the national level). First, every participant was introduced into the objectives of the study and asked not to use any other learning materials. The participants were asked to give in data like gender or age with ensured anonymity. They were then randomly assigned to one topic (Achilles tendon rupture, scoliosis, shoulder dislocation, radial head fracture) and presented randomly either an appropriate text chapter or a podcast via Survey Monkey®, after a topic-related pre-test. The users could individually define their processing time for the tools. Subsequently, an evaluation sheet was shown, followed by a final post-test. Data was saved online after submission. The results of this uncontrolled study group (UCS group) were compared to those from an already existing randomized controlled trial (RCT group) [16]. For both groups, contents and learning tools were exactly the same as were the procedures – except for a defined time to use the tools, and a granted exclusion of communication possibilities in the RCT [16] which was not given in the UCS group. The responsible local ethical committee of the medical school gave its consent (reference number: EA1/090/12).

### 2.2. Learning tools

Each podcast consisted of a PowerPoint™ (Microsoft Corp., Redmond, WA, USA) slideshow as visual component with a voice-over narrative, which were combined by the software Camtasia Studio® (TechSmith Corp., Okemos, MI, USA). Texts were derived from standard medical teaching books [17,18]. It was ensured that the processing time was similar for all podcasts and digital texts.

### 2.3. Evaluation questionnaires

The evaluations of the learning tools asked for clarity and comprehensibility of the digital texts or podcasts, as well as a personal

assessment whether the participants felt well prepared with their learning tool for the final post-tests (Figs. 1 and 2). All questions were 5-point Likert-scaled (1 = I totally agree, 2 = I agree, 3 = neutral, 4 = I disagree, 5 = I totally disagree).

### 2.4. Knowledge tests

In advance to the study, a list with clinically relevant focus areas (e.g. diagnostics, treatment options) for all topics was created with specialists of orthopedics and traumatology, who were blinded for the exact contents of the learning tools. Based on this list, questions were created for the pre- and post-tests to objectify the pre-knowledge of the participants and the final gain of knowledge (pre-tests: 10 to 12 questions; post-tests: 22 to 26 questions), following the recommendations of Haladyna [19]. These questions consisted of texts with different levels of difficulty (from simple knowledge item questions up to brief clinical case presentations), sometimes supplemented by anatomical or radiological figures and gave the participants the possibility to choose the only right answer out of five given options. The mean test results with standard deviation were calculated in % right answers. The absolute gain of knowledge was determined by subtracting the results of the pre-tests from those of the post-tests. As this was a study with voluntary participation where a lack of motivation may play a role, test results with signs of insufficient participant engagement were excluded from further analysis and the group comparison. This included incomplete answering or early termination of the test, and a negative gain of knowledge in alignment with procedures taken in formative knowledge assessment and the handling of unmotivated test-takers [20].

### 2.5. Statistics

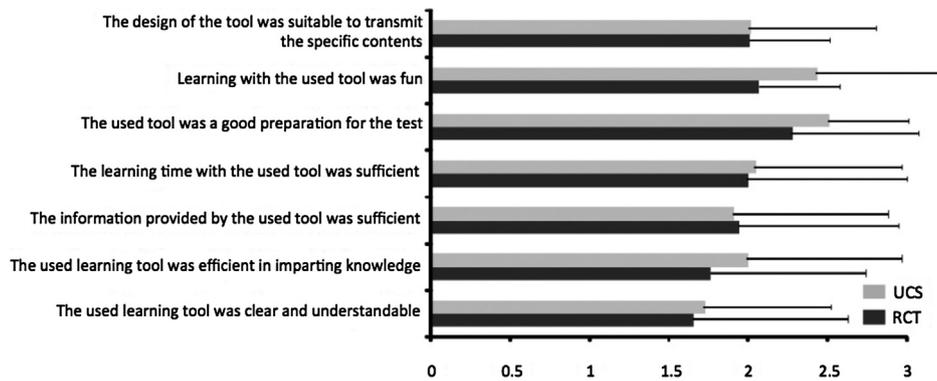
Data analysis was performed with SPSS® 21.0 statistics software (SPSS Inc., Chicago, USA). The normality of the distribution was assessed by the Kolmogorov-Smirnov test before applying parametrical testing. For group comparisons of the test results (digital text vs. podcast or UCS vs. RCT) Student's t-test was applied. Calculation of significant differences regarding the drop-out quote in both study settings was performed with a Chi-squared test. For analyzing personal data and evaluation questions, the correlation coefficients Spearman-Rho and Pearson were determined. A p-value of less than 0.05 was considered to be significant.

## 3. Results

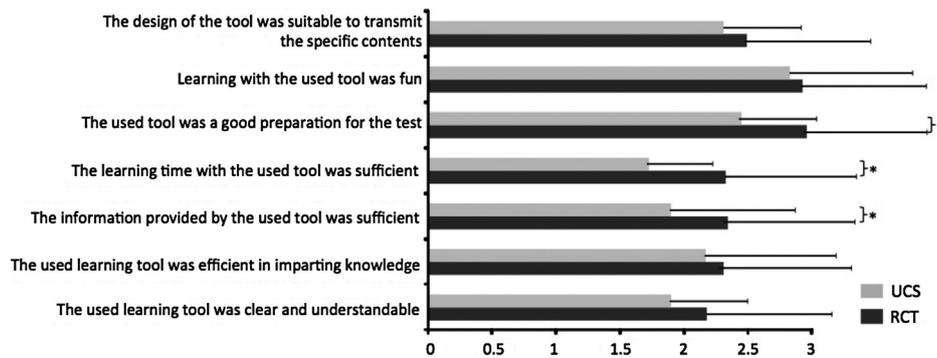
Altogether, 141 students participated voluntarily in the UCS group and filled in all forms (56 digital text, 85 podcast). Of those, 57 were not included (27 digital text, 30 podcast) due to a negative gain of knowledge. Out of 164 participants in the RCT group (71 digital text, 93 podcast), with 34 students (16 digital text, 18 podcast) significantly less were not included due to a negative gain of knowledge compared to the UCS group ( $p < 0.05$ ). Data analysis did not indicate any significant differences in the distribution of data sets omitted from the subsequent study analysis. The results of the 84 included UCS participants (29 digital text, 55 podcast) were compared to the 130 students in the RCT group (55 digital text, 75 podcast). The final participants were on the average in their 7th semester (UCS group) or in their 5th semester (RCT group).

### 3.1. Evaluations

Among the included UCS group participants, the majority was between 21 and 24 years old (55.95%), similar to the RCT group (60.77%). In both groups, a predominance of female participants could be noted (UCS: 77.38%; RCT: 60%). The Cronbach's Alpha for



**Fig. 1.** Comparison of the evaluation results for the podcast tests between the uncontrolled study (UCS) group and the randomized controlled trial (RCT) group observed without any significant differences (answering options were based on a 5-point Likert scale with 1=I totally agree, 2=I agree, 3=neutral, 4=I disagree, 5=I totally disagree).



**Fig. 2.** Comparison of the evaluation results for the digital texts between the uncontrolled study (UCS) group and the randomized controlled trial (RCT) group (\*  $p < 0.05$ ) (answering options were based on a 5-point Likert scale: 1=I totally agree, 2=I agree, 3=neutral, 4=I disagree, 5=I totally disagree).

**Table 1**

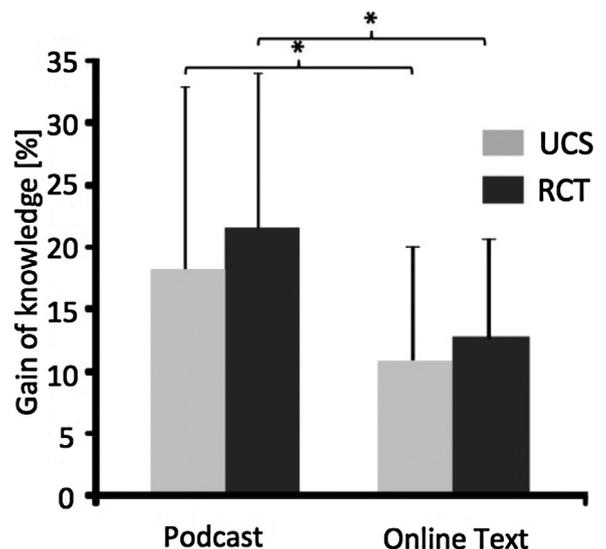
Pre-test and post-test results of the UCS and RCT. Analysis of the pre-tests and post-tests for the uncontrolled study (UCS) group and the randomized controlled trial (RCT) group after learning with digital texts (1a) or podcasts (1b) ( $p < 0.05$ ). There were significant differences in the podcast groups for the pre-tests (\*\*  $p < 0.001$ ) and the post-tests (\*\*  $p < 0.001$ ).

1a	N	Pre-test	Post-test
Digital text (UCS)	29	54.15 ± 13.34	65.54 ± 11.11*
Digital text (RCT)*	51	48.11 ± 12.59	60.97 ± 12.56*
1b	N	Pre-test	Post-test
Podcast (UCS)	55	56.36 ± 13.9**	74.67 ± 11.05**
Podcast (RCT)*	73	44.51 ± 12.44	66.16 ± 12.59*

the evaluation questionnaires among the UCS group was 0.84 for the text group and 0.87 for the podcast group (Cronbach's Alpha within the RCT group was 0.86 for the text group and 0.81 for the podcast group [16]). The mean answers of the Likert-scaled evaluation questions concerning handling and approval of the learning tools used in the UCS or RCT group did not differ significantly for podcasts (Fig. 1), but showed significant differences among digital text users regarding test-preparation, sufficiency of learning time or informative content ( $p < 0.05$ ) (Fig. 2). Both in the RCT and the UCS group it could be observed that the ratings for the digital texts were lower than in the corresponding groups using podcasts.

### 3.2. Knowledge tests

The results of the pre-tests and post-tests in the UCS and the RCT group are shown for digital texts and for podcasts in Table 1. In all of them, participants had a significant gain of knowledge ( $p < 0.001$ ).



**Fig. 3.** Gain of knowledge for both the observed e-learning tools digital text and podcast in the uncontrolled study (UCS) group and the randomized controlled trial (RCT) group ( $p < 0.05$ ).

When comparing the gain of knowledge for the tool digital text (UCS: 10.89 ± 10.74% versus RCT: 12.86 ± 8.38%) or the tool podcast (UCS: 18.31 ± 15.04% versus RCT: 21.66 ± 12.69%), there were no significant differences (digital texts UCS versus RCT:  $p = 0.396$ ; podcasts UCS versus RCT:  $p = 0.185$ ) (Fig. 3).

Direct comparison of the digital text and the podcast users in the UCS group revealed a significantly higher gain of knowledge

among the participants who had worked with podcasts ( $p < 0.011$ ) (equal to the RCT findings with a  $p < 0.001$ , [16]).

#### 4. Discussion

In the present study, two e-learning tools about orthopedic and traumatological diseases were compared between two groups, both of which used the tools either uncontrolled at home (UCS) or within the scope of an already published RCT [16]. Collected parameters were an evaluation of students' approval of the tools and written multiple-choice tests to detect their gain of knowledge. This investigation is, to our knowledge, the first approach of a crossover randomized comparison between controlled experimental "laboratory" learning results and "field" data, while using the same e-learning tools and analyzing methods.

The evaluation of the digital texts and podcasts showed positive ratings, which have already been revealed in other studies [2,15]. For the podcasts, the ratings in the UCS and RTC groups were without significant differences. On the other hand, the digital texts showed a higher satisfaction among UCS users for all items compared to the RCT users, with a significantly higher approval of sufficiently provided information, sufficient learning time with the tool and preparation for the post-test. One reason for these findings may be the missing time restriction in the UCS setting. Other than in the podcasts with their defined duration, the uncontrolled setting offered more possibilities to work with the text at a self-chosen speed, which might have better met the individual learning preferences of the participating students [21]. However, it should also be noted that both in the RCT and the UCS group, the ratings for the digital texts were lower than in the corresponding groups using podcasts.

Knowledge was increased significantly with both learning tools in the UCS and the RCT group. This was expectable after working with a defined and topic-oriented learning source, and has already been described for both tools [1,13]. Interestingly, the results also showed that the overall gain of knowledge achieved was for each of the two learning tools without any significant influence of being used in a controlled or uncontrolled setting. The reason for the significantly higher pre-test knowledge among the UCS podcast users might be explained by a selection bias. Consequently, the findings revealed here suggest that also an uncontrolled use of e-learning tools e.g. from home can lead to a sufficient gain of knowledge. This would be helpful for many study concepts, especially in blended learning curricular formats which are based on the use of e-learning components as a preparation for face-to-face teachings [3,10]. However, it must be stressed that such "field" studies are no real means to test the quality of e-learning tools – this should be done with RCTs, as only with these defined conditions can be achieved [11,16]. Still, our results here suggest that field studies can give helpful hints for the efficacy of those tools under "everyday" usage of students. The better results of podcast users compared to text users in the UCS group seem to support the advantages of podcasts as effective teaching tools for single orthopedic diseases, in accordance with the existing RCT results [16]. The enhanced podcasts which were used here addressed both visual and audio senses of the users [22]. This and the timely compact defined form of knowledge transfer might have supported the better learning outcome.

A critical discussion is needed for the significantly higher number of drop-outs in the UCS compared to the RCT group. This may be based on the fact that the students in UCS group were engaged less in the utilization of the tools or worked with less concentration in the tests. The time commitment, which is necessary when dealing with e-learning offerings, might be an influencing factor when using the online tools voluntarily from home [23]. As long as

the use of online learning materials is not directly linked to grade-relevant tests, it might be assumed that students would use those tools rather superficially [22]. Consequently, a gain of knowledge achieved by uncontrolled e-learning use must be treated with caution [1]. The results suggest that online-learning at home might be less advantageous than online-learning in a study room in the university, what might make it feasible for medical schools to provide enough possibilities for computer-learning when offering blended learning courses. To ensure the use of tools in blended learning settings when learning uncontrolled e.g. from home, mandatory self-tests could be an option [6]. Altogether, the issue of students learning with e-learning materials under non-controlled conditions (e.g. from home) and the influences on their individual willingness and the intensity to use those materials depending on given circumstances (kind of tool, time of use, length of necessary interaction) should be focused on in future studies.

This field study included several limitations. A well-known and accepted limitation was the fact that the use of additional help such as books or online search for completing the tests for the UCS participants could not be excluded. Furthermore, there was no control of the length of the working period or the time of day when the tools were used. Here, the evaluation questions could have been extended for assessing the conditions under which the students used the tools (daytime, stress, level of vigilance). The problem of a lack of control is present in many study designs of curricular blended learning concepts, where students are supposed to learn online on their own at home [7,8,12] or underway [24]. Another drawback was that the tools were not embedded into an ongoing curriculum. It can be assumed that students might use e-learning tools more when facing an exam, but less during an ongoing semester or without any corresponding face-to-face teachings as in this study [22].

#### 5. Conclusions

This study suggests that the use of e-learning tools such as digital texts or podcasts about orthopedic and traumatological topics will lead to a similar gain of knowledge among students no matter whether they learned in an uncontrolled manner online or in a controlled experimental environment. The same holds true for students' approval of podcasts as learning tools, while digital texts were preferred in aspects like learning time, test-preparation or informative content by the uncontrolled learners. The role of e-learning materials in voluntary and formative learning settings is of value and should be explored in future studies.

#### Disclosure of interest

The authors declare that they have no competing interest.

#### Funding source

There was no funding of the study.

#### Authors' contribution

D.B., J.M., K.S. and E.H. made substantial contributions to the conception and design. J.M. performed the acquisition of data. All authors analyzed and interpreted the data and have been involved in drafting the manuscript. D.B., H.P., R.H. and E.H. revised it critically. All authors read and approved the final manuscript.

## Acknowledgements

The authors would like to thank Mr. Florian Behringer and Mrs. Mira Céline Klein for their kind support in statistical analyses.

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