Original Article

Effectiveness of E-Learning with Fifth-Year Medical Students Studying Metabolic Bone Diseases

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Background: E-learning is a tool for enhancing knowledge which can potentially increase medical students' ability to learn and understand complex subjects.

Objective: To assess the effectiveness of e-learning in increasing understanding of metabolic bone diseases by medical students during their orthopaedic rotation.

Materials and Methods: A retrospective cohort study was conducted at the Department of Orthopaedics, Faculty of Medicine, Ramathibodi Hospital. Fifth-year medical students doing their rotation in the Orthopedics Department between August 2012 and July 2013 were enrolled in the study. All participants were instructed to study metabolic bone diseases using a lesson plan, handouts, and a textbook. They were also given the opportunity to volunteer to participate in an e-learning class prior to attending a one-hour case-based lecture. Students who missed the class were excluded from the present study. Baseline characteristics, in-class scores, multiple choice question [MCQ] grades, and orthopaedic grades of the participants were collected. Associations between study factors and outcomes were analyzed using multiple regression analysis.

Results: A total of 154 medical students were included in the study. Their average age was 23 years, and 57% were female. Only 12 (8%) participated in the voluntary e-learning class. The e-learning group had higher in-class scores (9.00$\pm$0.95) compared to the non e-learning group (7.70$\pm$1.30) with *p*-value = 0.001. Cumulative GPA and participation in the voluntary e-learning class were factors included in the multiple regression analysis. After adjusting for cumulative GPA, attendance at the e-learning class was significantly associated with in-class scores (coefficient 1.20, 95% confidence interval 0.43, 1.96, *p*-value = 0.002). Participation in the e-learning class was not significantly correlated with either MCQ grades or orthopaedic grades.

Conclusion: E-learning as an adjunct to traditional teaching methods can increase knowledge about metabolic bone disorders among medical students, but it does not affect either MCQ grades or orthopaedic grades.

Keywords: Metabolic bone, Diseases, E-learning, Medical students, Effectiveness

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Metabolic bone diseases are an important subject in the undergraduate medical curriculum. The metabolic bone disease course content includes calcium and phosphorus metabolism, bone formation and resorption, and common metabolic bone disorders such as rickets, osteoporosis, and osteogenesis imperfecta. The necessary integration of this information with basic science, pathophysiology, and clinical applications makes this topic complicated and thus difficult to understand. Even though classes on this topic are scheduled for the last two weeks of the orthopaedic rotation, some medical students still

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cannot absorb all the required knowledge which is provided in the classroom.

To alleviate the aforementioned problem, alternative or supplemental learning strategies should be explored. Over the years, several innovative learning measures have been proposed. Among them is e-learning, a method that has been proven to be helpful for medical students[1,2]. With that method, students can study anywhere, anytime, and any segment of the subject matter in their own way. A study by Ruiz JG et al[1] reported that e-learning helped medical students arrange their learning styles by content and sequence, leading to greater understanding and improved knowledge and performance. Citak M et al[3] found that nearly 80% of medical students preferred using internet-based learning for the subject orthopaedic trauma surgery; the students gave positive feedback and provided constructive, practical suggestions. On the other hand, Ruesseler M et al[4] reported that only 39% of the orthopaedic curricula in Germany included e-learning. The application of an e-learning process in the study of metabolic bone diseases may increase student competency. However, the study of metabolic bone diseases involves a large volume of quite specific information. Additionally, currently there is only limited data available on e-learning strategies, especially strategies for low- and middle-income countries[5]. We hypothesized that including e-learning in the metabolic bone diseases segment of the curriculum would encourage medical students to independent study, achieving additional knowledge on their own both before and after formal classes. This study attempted to evaluate the effect of e-learning on the level of knowledge and understanding of the topic of metabolic bone diseases among fifth-year medical students in orthopaedic rotation. The evaluation focused on in-class scores, multiple-choice question [MCQ] grades, and orthopaedic grades.

Materials and Methods

A retrospective cohort study was conducted at the Department of Orthopaedics, Faculty of Medicine, Ramathibodi Hospital, Mahidol University from January to December 2013. All fifth-year medical students who enrolled in the orthopaedic rotation between August 2012 and July 2013 were included. They were also given the opportunity to voluntarily participate in an e-learning class prior to attending a one-hour case-based lecture. Students who missed the class or who were unwilling to participate the study were excluded. This study was approved by Ramathibodi Hospital Ethical Committee.

All participants were instructed to study metabolic bone diseases using the lesson plan, handouts, and a specified chapter in the Ramathibodi Orthopaedic Textbook prior to attending the class. A one-hour case-based lecture covering rickets, renal osteodystrophy, and osteoporosis was given by the orthopaedic attending (PW) during the fourth week of the five-week rotation. Baseline characteristics and academic ratings included age, gender, academic year, and cumulative GPA from the first to the fourth year. All data were retrieved from the medical student database. The participants who attended metabolic bone diseases e-learning class were categorized as the e-learning group and those who did not were categorized as the non e-learning group (Figure 1).

Metabolic bone diseases e-learning lecture

The metabolic bone disease e-learning class was an internet-based presentation available at www.ramaortho.com. It was prepared (by PW and WW) as a PowerPoint presentation and was published by an orthopaedic e-learning educator (BN) using Articulate Presenter E-learning Authoring Tools & Software. All members of the e-learning group voluntarily participated in this e-learning course during the five weeks of their orthopaedic rotation. Topics covered by the e-learning course included bone development, calcium and phosphate metabolism, hormonal regulation (vitamin D, parathyroid hormone, and calcitonin) followed by common metabolic bone disorders (rickets, renal osteodystrophy, osteogenesis imperfecta, and osteoporosis), and a course summary. The total duration of the e-learning presentation was 25 minutes.

Outcomes

The primary outcome measure was in-class score (Figure 1) which was comprised of pre-test and

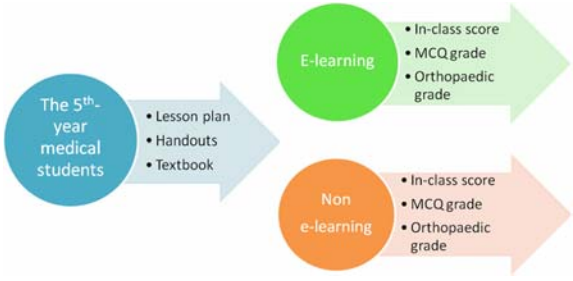

Figure 1. A retrospective cohort study of learning about metabolic bone diseases.

post-test evaluations. The pre-test evaluation included five questions about embryogenic bone formation, cells for bone formation and resorption, calcium metabolism, phosphate metabolism, and parathyroid hormone. The post-test evaluation consisted of five questions regarding clinical application of metabolic bone; rickets, renal osteodystrophy, secondary hyperparathyroidism, and the diagnosis and prevention of osteoporosis. Each question had five multiple choice answers. Together, the ten questions gave a maximum of ten points. Evaluation was done using a radiofrequency-based Power Vote System (KV Electronic Assembly Co., Ltd., Samutprakan, Thailand).

Secondary outcomes were MCQ grade and orthopaedic grade. MCQ grade contributed 40% of the overall orthopaedic assessment score. Five out of the 100 MCQ questions assessed knowledge of metabolic bone disorders. The orthopaedic grade was used as an indirect assessment of e-learning. That grade was composed of a multi-tasking evaluation, i.e., MCQ, constructed-response questions [CRQ], an objectively structured clinical examination [OSCE], continuous professional skills, and skill in asking for informed consent.

Data collection

All baseline characteristics and study factors of participants were obtained from the medical student database by a senior orthopaedic instructor (PO). Following the pre-test and post-test evaluations conducted in the classroom, the in-class scores were retrieved from the Power Vote System in Excel format by an orthopaedic information technologist (NO).

Statistical analysis

Continuous variables are presented as mean and standard deviation (SD). Categorical data are presented as percentages. Between-groups comparisons of in-class scores and other continuous variables were performed using unpaired t-tests and categorical data was analyzed using Fisher's exact test. The relationships between study factors and outcomes were analyzed by univariate analysis using multiple regression. Factors that had a p-value <0.1 were added into the multivariate analysis. The final model was retrieved using backward-stepwise selection with the p-value >0.2 for factor removal. The residual-versus-fitted plot and Cook-Weisberg heteroskedasticity test were performed for explanatory variables of the fitted regression model. Adjusted R-square with p-value from the F-test estimated the ability of factors to explain in-class score. All statistical analyses were performed using STATA 12.0 Program (StataCorp, College Station, Texas, USA). Statistical significance was set at $p \leq 0.05$.

Sample size estimation

Sample size was calculated using the Power and Sample Size Program, Vanderbilt 3.0.43, based on an alpha error of 0.05 and a power of the study of 0.8. A pilot study was conducted with the first rotation (20 participants). We found the average in-class score among the e-learning group was 8.0, and the average in-class score of the non e-learning group was 6.4. The SD in both groups was 1.2. The estimated sample size was 12 for each group. The sample size was calculated based on multiple regression with alpha error 0.05, a power of the study of 0.8, SD of a potential predictor (cumulative GPA) from 20 participants from the pilot study of 0.39, SD of the regression errors of 0.3, an expected true slope of the line of 0.3, and estimated total sample size of 149.

Results

Between August 2012 and July 2013, 157 fifth-year medical students enrolled in the orthopaedic rotation. Three students missed the metabolic bone class, one due to diarrhea, one to a common cold, and one other absence. The remaining 154 students were included in the study. Baseline characteristics were similar between the participants and the non-participants (Table 1). The average age of the participants was 23 years (range 22 to 24 years). Eighty-eight (57%) were female. The average cumulative GPA was 3.14. Twelve (8%) of the participants joined the e-learning session, and 142 (92%) participants did not attend the e-learning session and did not use the e-learning material during the rotation.

Among the e-learning group, 8 (67%) were female, the average cumulative GPA was 3.34±0.12 (Table 2), and the average in-class score was 9.00±0.95. Among the non e-learning group, 82 (56%) were female and the average cumulative GPA was 3.12±0.38. Their average in-class score was 7.70±1.30. The e-learning group had significantly higher in-class evaluation scores when compared with the non e-learning group (p-value = 0.001). At the end of the orthopaedic rotation, there were no significant differences in either MCQ grade or orthopaedic grade between the two groups.

Factors identified as potentially related to in-class score by univariate regression analysis were cumulative GPA and e-learning (p-value <0.1) (Table 3).

The cumulative GPA coefficient was 0.59, 95% confidence interval [CI]: 0.03, 1.13, with *p*-value = 0.037. The e-learning group had a GPA coefficient of 1.30, 95% CI: 0.53, 2.06 with *p*-value = 0.001. After adding factors potentially related to in-class scores into the multivariate analysis, backward stepwise included both cumulative GPA and e-learning in the final model with a normally distributed residual-versus-fitted plot and no heteroskedasticity (*p*-value from Chi-square = 0.1419). Coefficients of cumulative GPA and e-learning were 0.45 (95% CI: -0.09, 0.99), and 1.20 (95% CI: 0.43, 1.96), respectively (Table 4). The equation from the final regression model was as follows:

In-class score = 6.30+0.45 (cumulative GPA)+1.20 (E-learning group)

Note: actual cumulative GPA was used; e-learning group = 1, and non e-learning group = 0.

Cumulative GPA and e-learning explained 7% of in-class scores (adjusted R-square from this model was 0.07 with *p*-value from the F-test = 0.001). Both

Table 1. Baseline characteristics of participants and non-participants

Variables	Total (n = 157)	Participants (n = 154)	Non-participants (n = 3)	*p*-value*
Female (%)	90 (57.3)	88 (57.1)	2 (66.7)	1.000
Academic year (%)				
2012	59 (37.6)	58 (37.7)	1 (33.3)	1.000
2013	98 (62.4)	96 (62.3)	2 (66.7)	
Cumulative GPA, mean (SD)	3.14 (0.38)	3.14 (0.38)	3.14 (0.64)	0.997
MCQ grade, mean (SD)	2.86 (0.51)	2.87 (0.51)	2.50 (0.43)	0.280
Orthopaedic grade, mean (SD)	3.15 (0.31)	3.15 (0.02)	3.02 (0.15)	0.468

SD = standard deviation

* *p*-value from the comparison of baseline characteristics between respondents and non-respondents

Table 2. Comparison between the e-learning and non e-learning groups

Variables	E-learning (n = 12)	Non e-learning (n = 142)	*p*-value
Female (%)	8 (66.7)	82 (56.3)	0.557
Academic year (%)			
2012	4 (33.3)	54 (38.0)	1.000
2013	8 (66.7)	88 (62.0)	
Cumulative GPA, mean (SD)	3.34 (0.35)	3.12 (0.38)	0.056
In-class score, mean (SD)	9.00 (0.95)	7.70 (1.30)	0.001
MCQ grade, mean (SD)	2.92 (0.53)	2.86 (0.51)	0.729
Orthopaedic grade, mean (SD)	3.15 (0.31)	3.20 (0.30)	0.574

SD = standard deviation

Table 3. Univariate regression of factors related to in-class score

Variables	Coefficient	95% CI	Standard error	*p*-value
Female	-0.31	-0.36, 0.51	0.21	0.145
Academic year 2013	0.07	-0.36, 0.51	0.22	0.736
Cumulative GPA	0.59	0.03, 1.13	0.28	0.037
E-learning group	1.30	0.53, 2.06	0.39	0.001

CI = confidence interval

factors demonstrated a positive correlation with in-class score, i.e., for every incremental increase of one unit in cumulative GPA, in-class score increased by 0.45. For students who attended the e-learning class, the increase in in-class score was 1.20 for each one unit increase in GPA.

Discussion

E-learning was conducted electronically, usually on the internet. Successful e-learning has been shown to depend on the self-motivation level of the student. Our study used e-learning as an adjunct to case-based lectures on metabolic bone diseases. We proposed that medical students who voluntarily attended e-learning would have higher in-class scores when compared with those who did not attend. Our cohort study results showed that the e-learning group had significantly higher in-class evaluation scores than the non e-learning group (average 9.00 and 7.70, respectively with *p*-value = 0.01). Factors related to in-class score were cumulative GPA and e-learning participation. After adjusting for cumulative GPA, the e-learning group had significantly higher in-class scores with a coefficient of 1.20, 95% CI: 0.43, 1.96, and *p*-value = 0.002. Cumulative GPA did not show a significant relationship with in-class scores with a coefficient of 0.45 (95% CI: 0.43, 0.99) and *p*-value = 0.102, even though the students who had a high cumulative GPA could be expected to be good learners, to be diligent, and to be more likely to access learning resources. There was no association between e-learning participation and either MCQ grade or orthopaedic grade.

Our study found a low incidence (8%) of voluntary e-learning participation. Medical students who participated in e-learning achieved higher in-class scores than medical students who did not. This finding underscores the effectiveness of e-learning in improving knowledge of metabolic bone diseases. However, it might be necessary to make participation in e-learning mandatory for medical students in order to achieve the potentially greater learning outcomes. In the orthopaedic curriculum, one study found a mandatory policy to be more effective than a voluntary option, not only for knowledge improvement but also for increased ability to deal with clinical problems[6].

The case-based lecture integrated with e-learning represents a potentially successful platform for improving knowledge of metabolic bone disorders. This blended system has been applied mostly in curricula among central European universities[7]. Various e-learning methods included in a systematic review[8], i.e., online video series, computer-based learning modules, and virtual patients, were also shown to enhance medical students' competencies in terms of knowledge, clinical skills, and psychomotor skills[9]. However, the authors suggest that further exploration of knowledge retention after using e-learning is needed. Our study correlated MCQ grade and orthopaedic grade with voluntary e-learning participation, but we found that knowledge with e-learning was not significantly associated with these outcomes at the end of the orthopaedic rotation. One explanation is the subject of metabolic bone evaluation represented only 5% of the MCQ score and less than 5% of the overall orthopaedic score.

E-learning interactivity is another aspect for study. Our e-learning was integrated with more concise case-based lectures and the provision of essential knowledge. Nevertheless, there were no interactive tasks to enliven the topic which may have reduced the students' attention. Back DA et al[10] reported that teaching-related content, user-friendliness, and being less time-consuming contributed about 85 to 93% to learning from online materials. Our study found that e-learning was related to teaching contents but that faculty Wi-Fi access and individual topics that exceed 10 minutes duration may compromise the effectiveness of e-learning as well as the number of participants completing a given module.

Table 4. Multiple regression of factors related to in-class score

Variables	Coefficient	95% CI	Standard error	*p*-value
Cumulative GPA	0.45	-0.09, 0.99	0.20	0.102
E-learning group	1.20	0.43, 1.96	0.39	0.002
Constant	6.30	4.60, 8.00	0.86	<0.001

Adjusted R-square 0.07, *p*-value = 0.001
CI = confidence interval

Our study recruited two consecutive cohorts of fifth-year medical students from 2012 and 2013, an adequate sample size. The primary outcome was objectively measured based on the Power Vote System. Limitations of the study are the low participation rate in the e-learning class and the fact that the study did not include other factors related to outcomes such as infrastructure support, internet accessibility, time, frequency of attendance, self-management, and availability of other learning resources. Moreover, the adjusted R-square from the final model was 0.07 with a *p*-value from the F-test = 0.001 which means both factors together could explain only 7% of in-class scores. Other factors not included in this study may have contributed to in-class score prediction. Further research is need to explore other predictors of in-class score.

More e-learning should be included in the orthopaedic curriculum to help students understand and apply complex knowledge. Possible methods to enhance the effectiveness of e-learning are mandatory participation, integration with in-class activities, inclusion of interactive features, and reduced duration of individual e-learning lessons.

Conclusion

E-learning in metabolic bone disease courses significantly increases in-class scores measuring medical students' knowledge of the topic. E-learning is not related to MCQ or orthopaedic grades. Compulsory participation and infrastructure support could potentially increase the effectiveness of e-learning about metabolic bone.

E-learning as an adjunct to traditional teaching methods can increase knowledge about metabolic bone disorders among medical students, but it does not affect either MCQ grades or orthopaedic grades.

What is already known on this topic?

E-learning generally facilitates students' learning abilities and enhances both their knowledge and their performance. There is only limited evidence regarding the effectiveness of e-learning with complex modules.

What this study adds?

This study shows that e-learning can significantly increase in-class scores on a complex topic like metabolic bone disease, demonstrating that e-learning can increase both basic knowledge and clinical application skills.

Potential conflicts of interest

The authors declare no conflict of interest.

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