



Profile of Educational Technology Use by Medical Students and Evaluation of a New Mobile Application Designed for the Study of Human Physiology

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Abstract

Nowadays, smartphones represent an invaluable tool to access educational material; however, the available information is not always accurate or evidence-based. Therefore, we aimed to evaluate the use of technology by medical students and assess the effect of a newly developed mobile app for the study of human physiology. We used a standardised questionnaire to assess the profile of educational technology use, from which a mobile app (PhysioQuiz) was developed. The effectiveness and user opinion were assessed in a randomised controlled study ($n = 110$). Of 1022 students enrolled in medical school, 489 (47.9%) participated in the study. Of the respondents, 96.7% used mobile applications, with the main purpose being entertainment (94.7%) and study (81.9%). Only 6.1% reported use of physiology apps. PhysioQuiz use did not yield higher average grades ($p = 0.48$); however, user opinion demonstrated that it was useful for assisted learning (82.1%) and identification of non-learned content (78.6%) and considered a tool for self-assessment (89.3%). Mobile app use is widespread among medical students but there is a lack of human physiology education apps. A newly developed app for the study of human physiology was useful for assisted learning and considered a tool for self-assessment.

Keywords Mobile applications · Physiology · Technology · Education · Students

Introduction

The development of the personal computer and the advent of the internet made information readily available to a large proportion of the world's population. Nowadays, smartphones represent an invaluable tool to access information in a fast and comfortable manner. This includes the use of electronic

educational tools for academic purposes; however, the available information is not always formatted, accurate, or evidence-based for educational needs [1, 2]. Furthermore, there is a scarcity of studies assessing the frequency and impact of the use of innovative technology for education, especially in the medical field.

There is a growing use of portable devices, such as tablets and smartphones, in universities [1–3]. Studies have demonstrated that 80–85% of medical students have smartphones and use them at least once a day as a study tool, on average, having between one and five medical applications (apps) installed [4, 5]; nevertheless, few apps are developed with the main goal of improving students' learning [6, 7].

Among the software and apps for medical educational purposes, there are reports of successful approaches, such as the use of apps in the development of surgical skills [8, 9] or the use of virtual reality for training procedures [9]. There are also promising reports within the study of biological sciences, specifically physiology [10–13]. Data regarding the evaluation of the specific use and efficacy of mobile apps in higher level education are scarce; therefore, there is no clarity whether the

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impact of its use is positive with respect to students' academic achievement [14, 15].

Therefore, we sought to evaluate the expectation and frequency of use of technological resources by medical students, with an emphasis on available mobile apps for the advancement of learning biological and medical sciences. Moreover, we sought to develop a new mobile app for the complementary study of human physiology and to test the usefulness of this tool in a randomised controlled trial.

Materials and methods

The present study was carried out in three stages: 1) evaluation of the use of technological resources by medical students; 2) development of a mobile app for the study of human physiology; 3) assessment of the impact of use of the newly developed mobile app on medical students' learning and user experience in a randomised controlled trial.

Assessment of medical students' use of technology

A cross-sectional study was carried out by the application of a questionnaire addressing the use of technology by medical students. The sample consisted of medical students from the Federal University of Paraná (UFPR) in different curriculum years (of a six-year medicine program), totaling 1022 students. The questionnaire consisted of 8 questions (some conditional with subitems) assessing the use of technology, with a focus on frequency of use, type of operating system, type of technology, time spent, purpose of use and user experience.

Data from this stage were analysed using the Fisher exact test for serial evaluation of the difference between two proportions.

Development of an android mobile application for the study of physiology

We developed a mobile app in the format of a "quiz" including human physiology questions equivalent to the course content of Human Physiology I from the UFPR Medical School curriculum (students study Human Physiology for three semesters) and based on its recommended bibliography. The course has emphasis on cellular, nerve-muscle, cardiovascular, and respiratory physiology. A total of 151 questions addressed the topics of "cellular physiology" (26 questions), "cardiovascular physiology" (77 questions), and "respiratory physiology" (48 questions). All questions were subdivided into three difficulty levels: easy, medium, and difficult, each with different times for resolution (30, 90, and 120 s, respectively).

The questions and the correct answers were randomised every time the subject accessed the app. Questions were derived from a databank given by the supervising professor

(FALD) or developed by two medical students (EYO, NIC) who had concluded all Physiology courses from the curriculum. New questions were assessed and validated by a PhD student in Physiology (CTDR) and the supervising professor (FALD). All questions provided feedback (citing the references) for the student, irrespective of whether the question was answered correctly.

The app was built by a biomedical informatics student (ALMS). The Android application was created using JAVA programming language in conjunction with XML interface and the development of a database stored in the cloud using LINUX, APACHE, MySQL, and PHP (LAMP package). In addition to the questions, the app has the following features: user profile (showing the frequency of use; number of questions answered by module; and number of correct, incorrect, or missed questions in each module), ranking, and recommended reading. All questions are, thus far, in the Portuguese language, and the app is now available free of charge in the official Android store under the name *PhysioQuiz* (<https://play.google.com/store/apps/details?id=br.ufpr.physioquiz>, more than 2980 downloads, accessed on January 27th, 2019).

Assessment of the impact of application use on grades and user experience

A randomised controlled trial was performed to assess the impact of app use on grades. Selected participants were enrolled in the "Human Physiology I" course, either on the first ($n = 97$) or second ($n = 92$) semester of 2016. Inclusion criteria were first-time enrollment on the "Medical Physiology I" course during the year of 2016, older than 18 years, and acceptance of participation in the research. Exclusion criteria included not installing or using the app, answering less than 10 questions using the app during the length of the study, discontinuation of the course, or voluntary request for exclusion. In this study, there was no blinding of participants or outcome assessor.

The students included in the study ($n = 110$) were randomized (by software, Microsoft Excel) into two groups: one that used the mobile app ($n = 39$ in the first semester and $n = 21$ in the second semester) and a control group ($n = 29$ in first semester and $n = 21$ in second semester). Students who did not use any apps or who did not have an Android system on their cell phones (which prevented the use of the app) were allocated to the control group. Following randomization, the groups presented similar academic indices (the academic performance index, calculated by the institution and tested using the Wilcoxon test). The use of the app was voluntary and intended to be complementary to other methods of study.

For data analysis, the average numerical grades (scale from 0 to 100) obtained by the students (recorded on exams only, not including scores obtained by any other means, such as

seminars or essays that were later added to final grade) were tested for normality using Shapiro-Wilk test and compared between groups using the unpaired t-test. A *p* value less than 0.05 is considered statistically significant.

For assessment of user experience, students who used the app answered a questionnaire composed of seven statements to assess their level of agreement using a Likert scale.

Results

Assessment of medical students' use of technology

Of the 1022 students enrolled in the medical course in the first half of 2016, 489 (47.9%) volunteered to participate in the study; 225 (46%) males and 264 (54%) females. The mean age was 21.8 years old (standard deviation of 3.1), with a minimum of 18 and a maximum of 40 years old. Regarding the use of cell phones by the students ($n = 487$), 291 (59.8%) reported Android as the operating system, 177 (36.4%) used IOS, and 11 (2.3%) used Windows. The distribution of operating systems was homogeneous among students in different periods ($p = 0.73$). With respect to the use of tablets ($n = 400$), 159 (39.8%) of the students reported IOS as the operating system, 93 (23.3%) reported Android, and 11 (2.8%) Windows, again with a homogeneous distribution between periods ($p = 0.62$).

Regarding the use of apps ($n = 486$ respondents), 470 (96.7%) students reported use. Other technological resources ($n = 418$) were also used; 316 (65.0%) reported using video classes, 271 (55.8%) educational websites, 246 (50.6%) e-books, and 27 (5.6%) podcasts.

The specific purpose of app use ($n = 470$) involved entertainment in 445 cases (94.7%), learning in 407 cases (86.6%), and personal organisation in 312 cases (66.4%). The influence of apps on learning was evaluated by a Likert scale, as summarized in Fig. 1.

The use of mobile apps for learning purposes during the first two years (of a total of six) of the medical school curriculum in Brazil, which includes basic science courses, corresponded to 213 individuals. When questioned regarding which apps they used for study during the basic science courses, of 191 respondents, 121 (63.4%) reported using some type of application for human anatomy study. The students considered that the strengths of such apps were the possibility to visualise anatomical structures, practicality, a complementary tool for learning, and portability. As weaknesses, students reported content limitation and cost.

When questioned specifically regarding the use of any mobile app for human physiology study, only 17 students reported use, which represented 3.6% of students who completed the questionnaire. Although the 17 students who used these

apps cited names, only three of the described apps were exclusive for physiology study.

The use of apps during clinical science courses or clinical practice ($n = 382$ respondents to this question) was reported by 140 (36.6%) students. When asked which apps were used, students cited mainly those that were not specific to a single area of medicine but covered different content used by the general practitioner. Other apps used included those of medical semiology ($n = 30$), mainly cardiac and pulmonary auscultation, and pharmacology ($n = 14$), drug interactions and others. Reported strengths of apps were practicality ($n = 51$) and complementarity to studies ($n = 15$). Reported weaknesses included incomplete content ($n = 8$) and cost ($n = 7$).

When asked what they considered essential in a mobile app ($n = 390$), students cited the ease or practicality of app handling as the main requirement (52.6%, $n = 205$). Other points raised were the quality and updating of content (21.3%, $n = 83$), simplicity (15.6%, $n = 61$), appearance (11.3%, $n = 44$), objectivity (10.5%, $n = 41$), organisation (10.3%, $n = 40$), and didactic (10.5%, $n = 41$).

Development and assessment of the impact of app use on grades and user experience

A mobile app (Android platform) was designed for physiology study and allowed the students to answer questions and review topics after answering (Fig. 2). We tested the impact of app use on grades using a randomised controlled trial providing the app to students who were attending the Medical Physiology I course ($n = 189$). Overall, 110 students were randomised and divided into students that received the app ($n = 60$) and controls ($n = 50$). Figure 3 presents a flowchart (following CONSORT recommendations, 2010) demonstrating the flow of participants along the study. The adherence was low for app use in the first semester (20.5%) due to technical problems that delayed app delivery to students, which did not happen in the second semester (95.3% adherence).

Regarding the performance of students, there was no significant difference in test grades between groups ($p = 0.48$). The mean (standard deviation) final grade (average of three exams) for the app group was 6.76 (1.04) as compared with 6.60 (0.97) for the control group (Fig. 4). There was also no significant difference when scores from each test were compared between groups. Mean grades (standard deviation) for test 1 to 3 from app group compared to control were as follows: test 1 – app group 6.01 (1.01), control 5.63 (1.13), $p = 0.132$; test 2 – app group 7.07 (1.96), control 7.13 (1.32), $p = 0.87$; test 3 – app group 7.20 (0.83), control 7.04 (1.13), $p = 0.50$.

The results from user experience assessed by a questionnaire are presented in Fig. 5.

When asked about the improvements to the app that they would like to see ($n = 15$ respondents), the main points raised by the users were the need for a greater number of questions

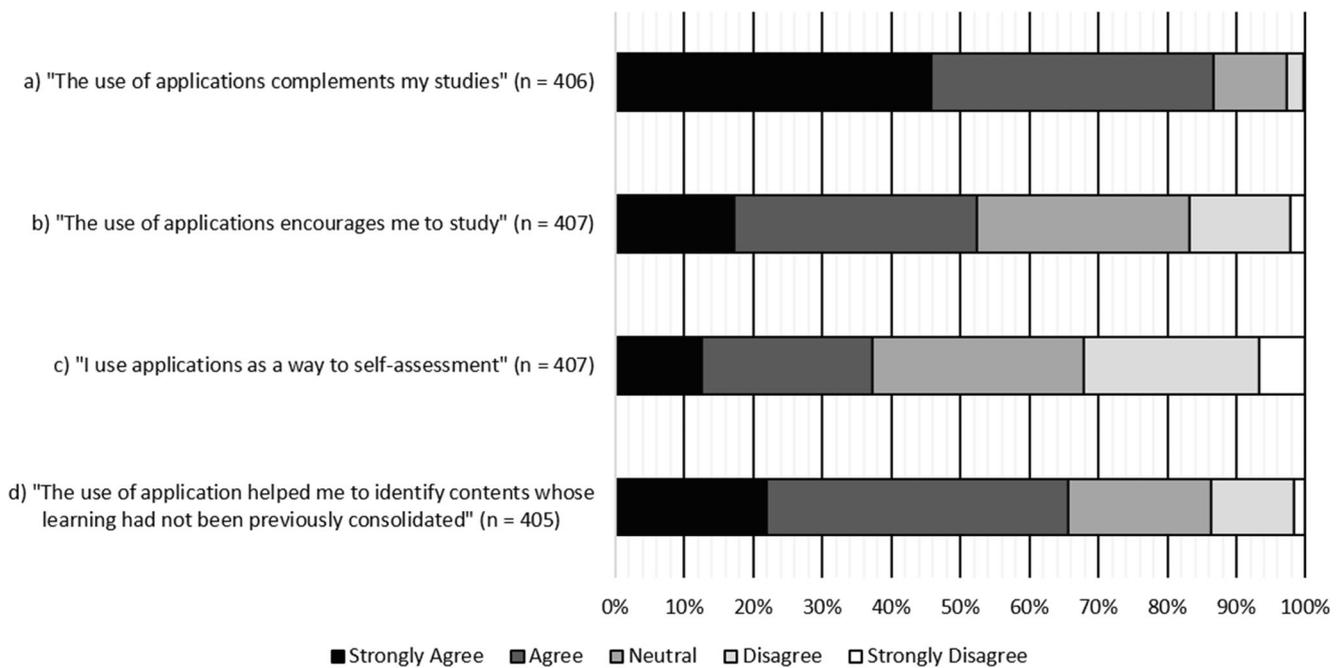


Fig. 1 Assessment of users' opinion on the role of mobile application use in learning. The diagram shows the level of agreement (five-point Likert scale) for four statements related to the use of applications in the learning process

(40%, $n = 6$), more questions on the difficult level (20%, $n = 3$), more questions with graphs (20%, $n = 3$), and a longer time to solve the questions (20%, $n = 3$).

Discussion

The present study was innovative in identifying the use of technological resources among medical students and developing an educational instrument for the study of human physiology based on the needs and technical specifications described by the students themselves. Data demonstrated high use of apps for study, although there was a scarcity of apps for the study of physiology, and users reported content adequacy problems. The newly developed app presented here was useful in assisting the study of human physiology by identifying deficits in the user's knowledge, besides serving as a form of self-evaluation.

Evaluation of the use of technology by medical students

The use of technological resources, such as cell phones and tablets, was highly prevalent among medical students, which is in accordance with data from other institutions, such as the University of Salamanca (Salamanca, Spain), where 93.6% ($n = 124$) of medical students have a smartphone and 47.6% have a tablet [16]. The rate of use of portable devices in higher education is very high among both students (99%) and teachers (95%); thus, the widespread use of these resources

among academics makes them relevant for exploration as a learning tool [2, 17].

With respect to operating systems (OS), the present study indicates that Android is prevalent in mobile phones, while iOS is mostly used on tablets, a result that diverges when compared with other countries, likely due to socioeconomic issues. A study from a University in Nebraska (United States) indicated that 84.9% of their students have an iOS smartphone or tablet, while only 12.8% use Android [18]. On the other hand, China, similar to Brazil, has a higher prevalence in the market of smartphones with an Android operating system (approximately 70%), as described by Hsu et al. [6]. The predominance of the Android system in Brazil steered our decision to initially create an app on this platform. The choice to develop an app and not another tool took into account what was highlighted by Taktorova et al., [2]; apps can be free, content can be updated and added with upgraded versions, and high-quality graphics and sound can be used [2].

Regarding the use of apps, most interviewees revealed they used it as a tool for study, surpassing other technological resources such as podcasts, e-books, video-classes, and websites. No articles were found that contained this type of data for comparison. The reported time spent using apps for study was mostly around two hours per week. When questioned about the influence of study applications, 65.7% of students agreed that "Application use helped me identify content whose learning had not previously been consolidated" and 86.5% that "Application use complements my studies". Therefore, in the opinion of the users, this tool would be important in the teaching-learning process. Other studies on the

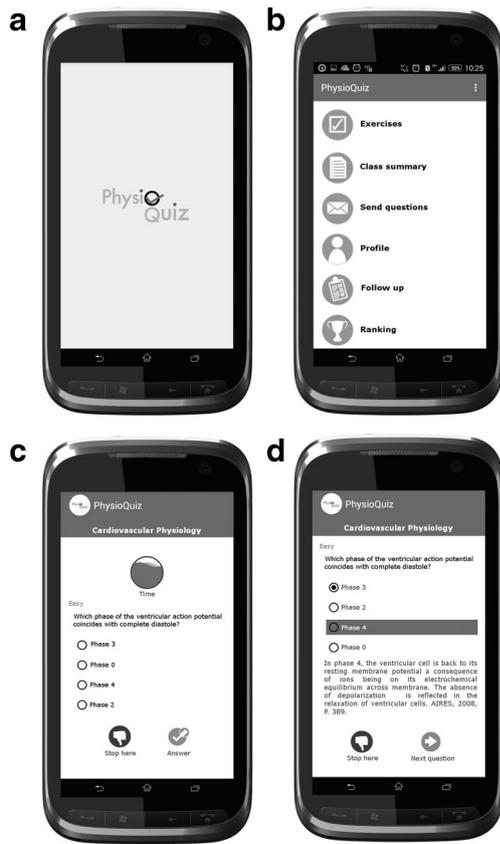


Fig. 2 Screenshots from the mobile application PhysioQuiz. (A) App launch screen; (B) Initial screen of the app, where the user has the possibility to access the following resources (some still in the development phase): Exercises, Class Summary, Send Questions, Profile, Follow-up, Ranking, Recommended reading, and Evaluate questions; (C) Example of a question, at the top of the screen we have the colour-coded difficulty (green for easy, orange for medium, red for difficult); (D) Example of the feedback provided following the questions, the text explaining the topic and correct option was based on the recommended bibliography used in Medical Physiology I

pattern of use of these technologies for study have not yet been performed.

Although the majority of students claimed to use study apps, when considering the use of apps for physiology study, the prevalence was very low (3%). One of the possibilities that explains low use of physiology apps is that, although there are many apps available, their quality remains low, discouraging student use. This can be supported by the fact that the main negative point mentioned in the questionnaire involved the content, since this was the main quality sought by the students. Another possibility for the low use of apps has been suggested by other studies, which highlighted that the majority operated only on the iOS system, limiting their access by Brazilian students, and that there were few apps available exclusively for education [6, 7].

During the basic science curriculum years, the apps most used were related to human anatomy. During the clinical curriculum years, the applications most cited were the ones

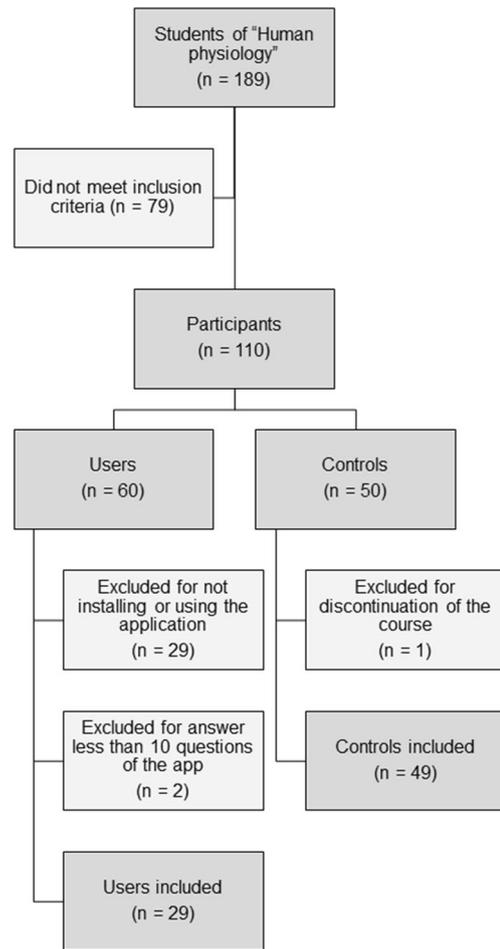


Fig. 3 Flowchart of study participants

providing general medical information, such as those covering diseases of various specialties, followed by apps for medical semiology and pharmacology. These data are in partial accordance with data collected in a study involving 81 medical

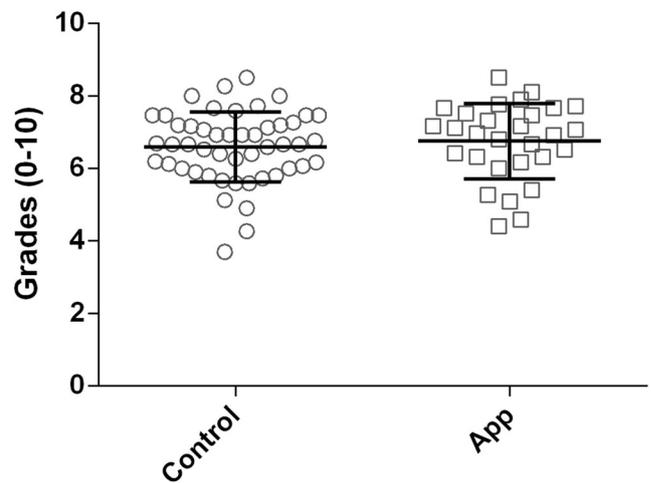


Fig. 4 Distribution of test grades of users in the control and app groups. Bars represent the mean and standard deviation

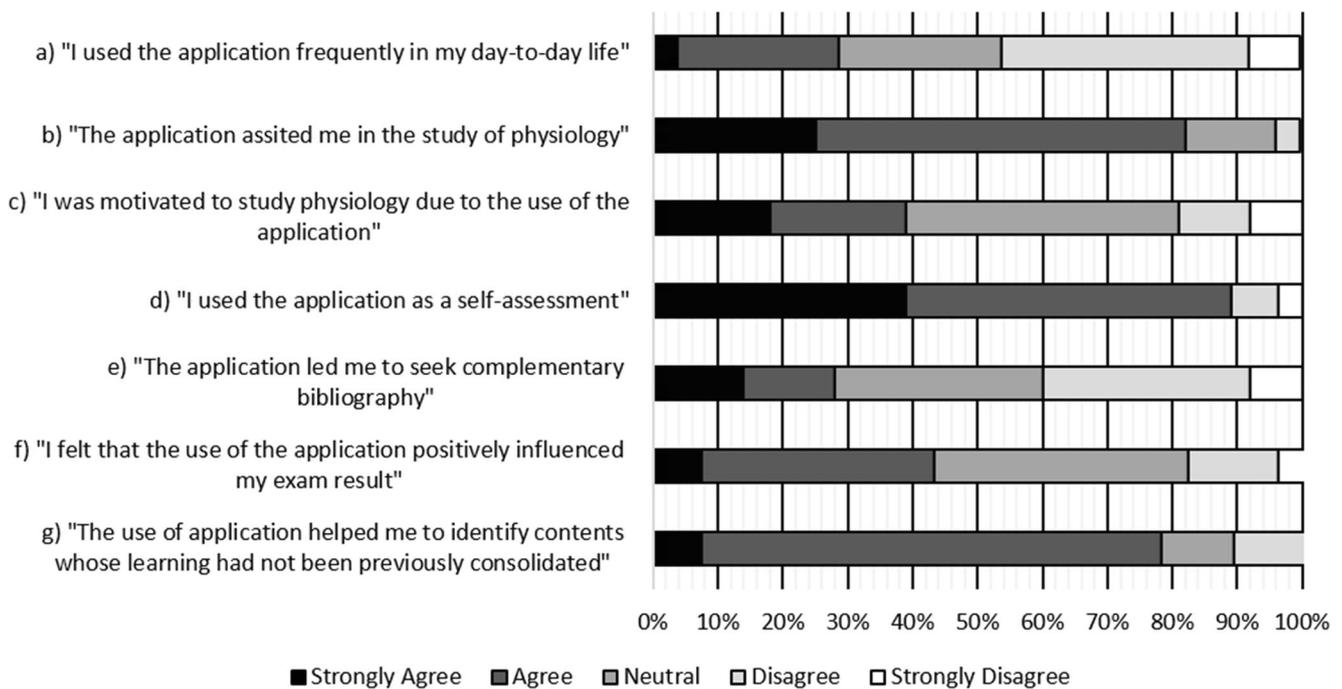


Fig. 5 Assessment of users' opinion on the role of the mobile application PhysioQuiz

students at the University of Alberta (Canada), where the most commonly used apps were for pharmacology (77.4%), drug consultation followed by book searches (49.1%) [19]; even though the investigation was performed in a personal digital assistant (PDA) (popular at the time).

When asked what students considered essential in an application, students cited ease and practicality in application handling, content quality and update, and simplicity and attractive design. Some of these features have already been pointed out in the study "One Educational Laptop Per Child" (OELPC) [2, 20] and were taken into account in the development of the PhysioQuiz app.

Evaluation of physioquiz app usage

Although the adjunct use of the app did not result in a statistically significant change in grades, users' opinions were positive, since 89.3% agreed with the statement "I use applications as a way to self-assessment", 82.1% agreed that "The application assisted me in the study of physiology", and 78.6% agreed that "The use of this application helped me to identify contents whose learning had not been previously consolidated". Therefore, even without modifying the final grade of the users, the app proved useful for both the study of physiology and identification of knowledge deficits and was also considered as a tool for self-assessment. It is believed that this may have been due to the fact that the application replaced other conventional methods of study, such as flashcards, study handouts, or time spent training answering questions by hand.

It is important to point out that the use of the app was not imposed by the investigators. It is possible that different results would have occurred if the users were obligated to spend a predefined amount of time using the app. However, we consider the use of apps as an adjunct tool for learning; therefore, we did not design a study that required exclusive use of the app or a predefined amount of use time. Different from our findings, a study by Briz-Pounce et al. [16] found an improvement in the performance of students who used an app in comparison with traditional speech of an anatomy class; however, in this case, app use was exclusive, the outcome was a post-test of only one topic and not the entire course topics as in our study, and furthermore, the study was quasi-experimental, whilst ours was a randomised controlled trial. A limitation of our study was the assessment of a single set of students belonging to the same course in a single year. A broader, multi-centre investigation using a full version of the app, including a full range of topics in human physiology, could yield different conclusions. Future research should also consider the collection of information representing app usage such as time spent on app and number of questions answered, to precisely infer about the impact of the app on test scores and learning.

Conclusion

The use of mobile apps is widespread among medical students and most have used apps for educational purposes. We identified a lack of apps designed for human physiology education and developed and tested a new app for study, which was

demonstrated to be useful in assisting the study of human physiology, by identifying deficits in the user's knowledge, besides serving as a form of self-assessment.

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Compliance with ethical standards

Conflict of interests None to declare.

Research involving human participants and/or animals All procedures involved in the present study were conducted in accordance with the Declaration of Helsinki 1975, updated in 2013, and Brazilian legislation. The study protocol was approved by the Ethics Committee of the Health Sciences Centre (#1.343.302/2015).

Informed consent Informed consent was obtained from all individual participants included in the study.

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