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Remote physiology practical: Viable alternative to in-person practical in health sciences education?

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Abstract

Introduction: Practicals are core components of an undergraduate health sciences curriculum to promote experiential learning and motivation in students. With restrictions on traditional forms of face-to-face practicals during the COVID-19 pandemic, we designed and investigated the efficacy of remote practicals as a viable learning strategy in exercise physiology teaching.

Methods: Student volunteers were instructed to perform a graded exercise test in a remote setting and provide their collected data for subsequent discussion in an online lecture. The effectiveness of this remote practical in promoting students' motivation and learning outcomes achievement was assessed via an anonymous questionnaire containing 29 closed-ended and 2 open-ended items. Continual Assessment (CA) results were also investigated. Unpaired student's t-tests were performed for comparisons between interventions with significance level set at $P<0.05$.

Results: Sixty-one (out of 81; 75%) students responded to the questionnaires and 49 (60%) consented to the use of their CA results for this study. Results revealed that students were moderately motivated and attained strong achievement of learning outcomes. When compared to students who did not volunteer for the hands-on component of the remote practical, students who participated in the hands-on component reported significantly higher self-efficacy ($P<0.05$) in explaining the practical procedures to their peers. Qualitative analysis further revealed that experiential learning and real-life data analysis were the central reasons supporting the effectiveness of the remote practical. Students were generally satisfied and would recommend the remote practical to future students.

Conclusion: Our study highlights the potential of remote practicals as viable alternatives to traditional practicals.

Keywords: *Remote Practical, Experiential Learning, Student Motivation, Learning Outcomes*

Practice Highlights

- Remote practical aids in promoting experiential learning in exercise physiology teaching.
- Remote practical can promote motivation by enabling students to see the relevance of their learning.
- Students perceived that they could achieve the necessary learning outcomes via remote practicals.

I. INTRODUCTION

Laboratory work or practical classes are considered as core components of health sciences curriculum in higher education (Colthorpe & Ainscough, 2021; Dohn et al., 2016; Hofstein & Lunetta, 2004). Past studies have revealed the strong educational value of practical classes in promoting student motivation (Bruce, 1988; Dohn et al., 2016), student learning outcomes achievement (Brinson, 2015) as well as the ability to draw theory to practical applications (Neves et al., 2017).

One of the key subjects in undergraduate health sciences education is human physiology, a discipline seeking to understand the underlying mechanisms and dynamics of the human body (Lellis-Santos & Abdulkader, 2020). The role of practical classes in the teaching and learning of physiology is highly valued by educators and students alike (Dohn et al., 2016; Neves et al., 2017). Experiential learning in physiology practicals commonly takes the form of interactive hands-on activities, real-time data collection and analysis of physiological responses. When such practicals are carried out in a traditional face-to-face manner, students are able to utilise laboratory equipment in an authentic experimental setting and generate real-time data from their peers and/or themselves (Colthorpe & Ainscough, 2021). Data analysis and discussion following the hands-on component of practicals can further promote contextualised learning and facilitate the understanding of the theoretical content (Lewis & Williams, 1994). It has been reported that such an interactive learning approach in physiology enhances the achievement of learning outcomes and increases the level of motivation for students (Dohn et al., 2016).

The emergence of the COVID-19 pandemic has led to increasing safety management restrictions being imposed on physical classes in higher education institutes around the world (Ali, 2020). As such, educators were faced with the sudden need to switch from face-to-face lessons to online and remote teaching (Ali, 2020; Lellis-Santos & Abdulkader, 2020). Amidst the uncertainty of this transition, traditional face-to-face practicals have seen a sharp decline (Ray & Srivastava, 2020; Vasiliadou, 2020). As we examine these educational trends during crises, it becomes apparent that harnessing creativity to adapt and invent novel solutions is vital to maintain and even advance current standards of teaching and learning. Lellis-Santos and Abdulkader (2020) rightfully exemplify this notion by proposing the use of smartphone applications as a creative teaching approach to enable scientific data collection and practical learning from home even during social isolation. Along similar lines, we have designed a remote practical for students to carry out hands-on experiments outside of a traditional laboratory environment as an innovative alternative to circumvent the restrictions on face-to-face practicals and to provide them with experiential learning opportunities on cardiovascular concepts in exercise physiology.

To the best of our knowledge, there are few studies conducted to date regarding the efficacy of such remote practicals, particularly in the field of life sciences and exercise physiology. Therefore, our study aims to address this research gap by evaluating the effectiveness of our remote exercise physiology practical on (1) student learning outcomes, (2) student motivation and (3) students' perceptions on the effectiveness and relevance of the remote practical. In addition, we also compared the quantitative and qualitative responses between students who participated and did not participate in the hands-on component of the remote practical. The Continual Assessment (CA) results from these two groups of students were also compared to assess if differences in academic performance existed between the two groups.

II. METHODS

A. Description of the Module

LSM3212 Human Physiology: Cardiopulmonary System is a third-year module in Life Sciences conducted by the Department of Physiology, Yong Loo Lin School of Medicine at the National University of Singapore. A total of 81 undergraduate Life Sciences students were enrolled in the module in the Academic Year 2020/2021, Semester 2. Traditionally, both lectures and practicals are carried out in a face-to-face manner for this module. However, due to restrictions imposed by the COVID-19 pandemic, lessons were forced to go online. As a result, a remote practical was designed and conducted as an innovative alternative for this batch of students.

B. Description of the Remote Practical

The remote practical was designed to provide students with experiential learning on cardiovascular concepts in exercise physiology. Conventionally, the practical involved a treadmill-based graded exercise test performed by a student volunteer equipped with specialised electrocardiogram-based heart rate monitors to illustrate how the cardiovascular system changes with increasing exercise stress. For the remote practical, however, students were given a set of practical handouts comprising a novel graded exercise protocol developed by the authors and could choose to perform it in their own time asynchronously, or not carry it out at all. In the graded exercise protocol, students were instructed to carry out a series of graded knee raise exercises and record their heart rate measured via a smartphone application together with other subjective exercise prescription ratings (ratings of perceived exertion and talk test ratings) after each set of exercise. The graded exercise protocol was developed with the intent to encourage contextualised learning from the practical content to real-life exercise routines. The consolidated data was subsequently used for discussion in a virtual lecture to illustrate how heart rate responses and cardiovascular adaptations may differ across individuals, as well as how the consolidated data may serve to guide exercise prescription. Participation in the hands-on component (knee raise exercises) of the remote practical was optional. However, participation in the analysis and discussion of the collated data in the virtual lecture conducted after the graded exercise was made compulsory. Via this design, the remote practical (comprising both the graded exercise and post-exercise discussion) not only replicated the pedagogy of the original in-class practical, but also augmented the opportunity for students to volunteer and take part in the graded exercise component of the practical.

C. Instruments

After the virtual lecture, students completed an anonymous (no informed consent required) questionnaire containing 29 closed-ended and 2 open-ended items. The purpose of this self-report questionnaire was to evaluate students' perceived effectiveness of the remote practical on their motivation and achievement of learning outcomes of the virtual lecture.

Student motivation was measured by the Lab Motivation Scale (Dohn et al., 2016) containing 21 closed-ended statements based on three aspects - student interest, effort and self-efficacy. Multiple instruments had previously been employed to assess dimensionality and reliability of the validated Lab Motivation Scale (Dohn et al., 2016). A set of six closed-ended items were employed to measure students' perception on whether they had achieved the intended learning outcomes of the remote practical. Lastly, two closed-ended items were included to elicit a general satisfaction score from students regarding the remote practical and/or the virtual lecture. All the closed-ended statements in the questionnaire were scored on a 5-point Likert Scale, ranging from 5 (strongly agree) to 1 (strongly disagree).

Furthermore, there were two open-ended questions focusing on the effectiveness of the remote practical and the relevance of the remote practical to students' daily lives. The first question was posed to uncover specific reasons supporting the analysis of the closed-ended items, while the second question aimed to encourage contextualisation of concepts learnt through the remote practical in students' daily lives.

Finally, the CA results of students who participated in the hands-on component of the remote practical were compared with students who did not participate. To ensure a fair comparison, we took into consideration only the CA result from the questions corresponding to the content covered in the remote practical and virtual lecture. The questions taken into consideration made up 40% of the entire examination score.

D. Analysis

A mixed method approach was employed in analysing the questionnaire responses. An initial 66 questionnaire responses were collected but five incomplete responses were excluded, leaving a total of 61 responses that were included in the final analysis. Responses to the closed-ended items were coded accordingly to a 5-point Likert scale, ranging from strongly agree (5) to strongly disagree (1). Scores were reversed for statements phrased in a negative manner (items 9, 15 and 18). All closed-ended responses were presented in the form of mean ± standard deviation. As a measure of internal consistency, Cronbach's α was used as an instrument and measured across all scales. Unpaired student's t-tests were carried out to find out if differences between students who participated and did not participate in the hands-on exercise component were significant with significance level set at $P < 0.05$. All data analysis and statistical tests were performed using Microsoft Excel 2016.

Open-ended responses were analysed in a 3-part process: informal reviewing, open coding and thematic analysis. Firstly, all responses were informally reviewed to familiarise with general ideas and main themes were identified. Next, open coding was performed where each response was analysed in detail and coded to the most appropriate theme (Braun & Clarke, 2006). Finally, thematic analysis was carried out through ranking themes according to frequency and analysing the results (Braun & Clarke, 2006). The open-ended questions were made optional, and all responses collected were subsequently analysed.

III. RESULTS

Out of the 61 participants, 29 (48%) participated in the hands-on exercise component of the remote practical while 32 (52%) did not participate. Both groups attended the compulsory virtual lecture conducted after the remote practical, where the data collected from the remote practical was consolidated and discussed with the entire class.

Internal consistency was calculated using Cronbach's α and the reliability coefficient was found to be 0.95 across all closed-ended items, indicating an excellent level of interrelatedness across the overall scale (Cronbach, 1951). Individual scales of learning outcomes and motivation were also subjected to the analyses of Cronbach's α. The alpha coefficient value was calculated to be 0.86 for perceived achievement of learning outcomes and 0.94 for motivation (Tables 1 & 2). Motivation was further divided into three individual subscales assessing student interest, effort and self-efficacy, with the reliability coefficients returning 0.85, 0.88 and 0.88 respectively (Table 1). These reliability coefficients correlate strongly with those of Dohn et al. (2016), hence providing support for the internal consistency of the Lab Motivation Scale. Data supporting these findings is openly available via Figshare at https://doi.org/10.6084/m9. figshare. 17170964 (Low, 2021).

A. Remote Practical and Learning Outcomes

In general, students rated between "Agree" and "Strongly Agree" for perceived achievement of learning outcomes, with an overall mean score of 4.16 ± 0.68 on a 5-point Likert scale (Table 1). Students who participated in the hands-on component reported a mean score of 4.20 ± 0.54, which was similar to that rated by students who did not participate in the hands-on component (4.13 ± 0.68, P = 0.567; Table 1). For the first closed-ended statement: I have gained a stronger understanding of how heart rate responds to increasing exercise intensity, students who participated indicated a higher mean score of 4.52 ± 0.51 as compared to the lower mean score of 4.09 ± 0.59 (P = 0.004) for students who did not participate in the hands-on exercise component (Table 1).

Statement	All	Participated	Did not participate	P-value	α
I have gained a stronger understanding of:*					
This can be based on either your personal experience from the remote practical, or through the analysis of data from others who have participated.					
1. How heart rate responds to increasing exercise intensity	4.30 ± 0.59	4.52 ± 0.51	4.09 ± 0.59	0.004**	
2. Physiological mechanisms regulating heart rate in response to changes in energy demand	3.95 ± 0.72	4.03 ± 0.68	3.88 ± 0.75	0.390	
3. How heart rate responses may differ between individuals of varying fitness levels	4.26 ± 0.63	4.24 ± 0.58	4.28 ± 0.68	0.807	
4. How heart rate data can be used to prescribe exercise intensity	4.23 ± 0.59	4.24 ± 0.44	4.22 ± 0.71	0.880	0.86
5. How ratings of perceived exertion (RPE) can be used to prescribe exercise intensity	4.10 ± 0.60	4.00 ± 0.53	4.19 ± 0.64	0.224	
6. How the talk test can be used to prescribe exercise intensity	4.12 ± 0.61	4.14 ± 0.52	4.10 ± 0.70	0.798	
Overall	**4.16 ± 0.68**	**4.20 ± 0.54**	**4.13 ± 0.68**	**0.567**	

Table 1. Students' perceived achievement of learning outcomes in cardiovascular physiology

n = 61. Responses were coded from 1 (Strongly Disagree) to 5 (Strongly Agree). All means are shown with ±SD of the mean. **P < 0.01.

B. Remote Practical and Student Motivation

Students generally rated between "Agree" and "Somewhat Agree/Somewhat Disagree" for student motivation, with an overall mean score of 3.66 ± 0.71 (Table 2). Students who participated in the hands-on component reported a mean score of 3.70 ± 0.64, which was similar to that rated by students who did not participate in the hands-on component (3.62 ± 0.78, P = 0.187; Table 2). Students rated between "Agree" and "Somewhat Agree/Somewhat Disagree" regarding the three aspects of student motivation, with a score of 3.92 ± 0.69 for interest, 3.66 ± 0.75 for effort and 3.50 ± 0.68 for self-efficacy respectively (Table 2). For statement 23, students who participated indicated a higher mean score of 3.68 ± 0.61 as compared to the lower mean score of 3.29 ± 0.71 (P = 0.031) for students who did not participate in the hands-on component (Table 2).

Statement	All	Participated	Did not participate	P-value	α
Practical does not solely refer to the act of performing the graded exercise test, it can also include the collection, interpretation and analysis of the data contributed by others.					
		Interest			
7. I really enjoyed the practical* very much.	4.00 ± 0.66	4.00 ± 0.61	4.00 ± 0.72	1.000	
8. The practical work was fun to do.	4.00 ± 0.66	4.14 ± 0.59	3.83 ± 0.72	0.090	0.85
9. I thought the practical was boring. (reversed)	3.94 ± 0.77	4.11 ± 0.57	3.76 ± 0.93	0.113	

10. The practical was interesting.	4.00 ± 0.62	4.00 ± 0.67	4.00 ± 0.58	1.000	
11. The practical was exciting.	3.68 ± 0.73	3.68 ± 0.72	3.68 ± 0.75	0.994	
Average Score	3.92 ± 0.69	3.99 ± 0.63	3.85 ± 0.74	0.203	
Effort					
12. I think I was pretty good at the practical work.	3.50 ± 0.77	3.50 ± 0.79	3.50 ± 0.76	1.000	
13. I think I did pretty well at the practical work.	3.52 ± 0.68	3.50 ± 0.64	3.55 ± 0.76	0.806	
14. I am satisfied with my performance at the practical work.	3.52 ± 0.62	3.43 ± 0.57	3.65 ± 0.67	0.225	
15. The practical work was an activity that I could not do very well. (reversed)	3.56 ± 0.92	3.71 ± 0.76	3.35 ± 1.09	0.207	
16. I was very engaged in the practical work.	3.72 ± 0.71	3.81 ± 0.68	3.60 ± 0.75	0.313	0.88
17. It was important for me to do well at the practical work.	3.54 ± 0.80	3.50 ± 0.69	3.60 ± 0.94	0.673	
18. I did not try to do well for the practical work. (reversed)	3.98 ± 0.79	4.04 ± 0.64	3.89 ± 0.99	0.589	
19. I attempted the practical work seriously.	3.89 ± 0.70	4.04 ± 0.51	3.68 ± 0.89	0.130	
Average Score	3.66 ± 0.75	3.69 ± 0.66	3.60 ± 0.86	0.388	
Self-efficacy					
20. After completing the practical, I felt pretty competent.	3.55 ± 0.65	3.50 ± 0.64	3.62 ± 0.67	0.530	
21. I feel sure that I have learned from the practical.	4.07 ± 0.54	4.14 ± 0.45	4.00 ± 0.62	0.331	
22. I feel confident to tutor another student on the practical.	3.20 ± 0.67	3.21 ± 0.69	3.18 ± 0.67	0.844	
23. I feel confident to explain the procedures of the practical.	3.48 ± 0.69	3.68 ± 0.61	3.29 ± 0.71	0.031**	
24. I feel confident to conduct the practical from a manual.	3.63 ± 0.71	3.70 ± 0.67	3.56 ± 0.75	0.447	
25. I feel confident to explain the results of HR response to graded knee raise exercises.	3.56 ± 0.66	3.57 ± 0.57	3.56 ± 0.75	0.930	
26. I feel confident to write the conclusion of this practical work in a report.	3.13 ± 0.82	3.14 ± 0.71	3.11 ± 0.93	0.887	0.88
27. I feel confident to do well in an assessment on topics related to this practical.	3.39 ± 0.71	3.21 ± 0.63	3.57 ± 0.74	0.057	
Average Score	3.50 ± 0.68	3.52 ± 0.62	3.48 ± 0.73	0.560	
Overall	**3.66 ± 0.71**	**3.70 ± 0.64**	**3.62 ± 0.78**	**0.187**	**0.94**

Table 2. Students' perceived motivation towards the remote practical

n = 61. Adapted from the Lab Motivation Scale (Dohn et al., 2016). Responses were coded from 1 (Strongly Disagree) to 5 (Strongly Agree). Scores were reversed for statements phrased in a negative manner. All means are shown with ± SD of the mean. **P < 0.05.

C. Qualitative Explanations on Perceived Effectiveness and Relevance of Remote Practical

The first open-ended item sought to investigate the reasons underlying the perceived effectiveness or ineffectiveness of the remote practical in enhancing students' learning. Of the 37 responses, 34 (92%) felt that the remote practical was effective while 3 (8%) felt it was ineffective and of little to no added value to them (Table 3). Experiential learning and real-life data emerged as the most common themes cited across all responses (n = 12), followed by reinforc(ing) concepts taught in lecture (n = 10; Table 3). Experiential learning was reflected as the most common response among students who participated in the hands-on component (n = 10) in comparison to real-life data indicated by students who did not participate in the hands-on component (n = 8; Table 3).

The aim of the second open-ended item was to investigate the relevance and application of the remote practical to students' daily lives. Of the 36 responses, 29 (81%) felt the remote practical was relevant while 7 (19%) felt that it was irrelevant to their daily lives (Table 3). Overall, the remote practical was found to be most relevant in improving current exercise routine (n = 12), followed by understanding one's own fitness level (n = 10) and understanding the importance of exercise (n = 7; Table 3). This trend was similar for both students who participated and did not participate in the hands-on component of the remote practical (Table 3).

Theme	All	Participated	Did not participate
Effectiveness of the remote practical (n=37)			
Experiential learning	12	10	2
Real-life data	12	4	8
Reinforces concepts taught in lecture	10	3	7
(Ineffective) Little to no added value	3	1	2
Relevance of the remote practical to daily life (n=36)			
Improving current exercise routine	12	6	6
Understanding one's own fitness level	10	5	5
Understanding the importance of exercise	7	3	4
(Irrelevant) to daily life	7	3	3

Table 3. Themes identified from the open-ended responses, ranked by frequency

D. Remote Practical and Satisfaction Score

Students rated close to "Agree" for satisfaction, with an overall mean score of 3.95 ± 0.75 (Table 4). Those who participated in the hands-on component reported a mean score of 4.11 ± 0.70, which was similar to that rated by students who did not participate in the hands-on component (3.81 ± 0.77, P = 0.054; Table 4).

Statement	All	Participated	Did not participate	P-value
28. I felt that the practical was an additional academic burden. (reversed)	3.92 ± 0.84	4.11 ± 0.83	3.74 ± 0.82	0.094
29. I would recommend this remote practical to future LSM3212 students.	3.98 ± 0.66	4.11 ± 0.57	3.87 ± 0.72	0.170
Overall	**3.95 ± 0.75**	**4.11 ± 0.70**	**3.81 ± 0.77**	**0.054**

Table 4. Students' satisfaction score

n = 61. Responses were coded from 1 (Strongly Disagree) to 5 (Strongly Agree). All means are shown with ± SD of the mean. **P < 0.05.

E. Remote Practical and Academic Performance

Out of the 49 students who consented to the use of their CA results for this research study, 30 (61%) participated in the hands-on component of the remote practical while 19 (39%) did not (Table 5). Only the questions corresponding to the content covered in the remote practical and relevant virtual lecture were taken into consideration for this study. The overall mean mark was 7.3 ± 1.64 out of 10 (Table 5). Students who participated in the hands-on component (7.3 ± 1.84) and did not participate in the hands-on component (7.3 ± 1.32) exhibited similar mean marks as well (P = 0.940; Table 5).

Statement	All	Participated	Did not participate	T-test (P-value)
Number of students	49	30	19	-
CA Score/10	7.3 ± 1.64	7.3 ± 1.84	7.3 ± 1.32	0.940

Table 5. Students' CA results

n = 49. CA scores are shown as mean ± SD, with $^*P < 0.05$ considered significant.

IV. DISCUSSION

This study sought to evaluate if remote physiology practicals could be viable alternatives to traditional face-to-face practicals, especially during emergency remote teaching in a pandemic. Our results demonstrated that the students who participated in the remote practical perceived that they could achieve the learning outcomes in cardiovascular and exercise physiology teaching with reasonable satisfaction, regardless of whether they participated in the hands-on component of the remote practical. However, students who had actively participated in the hands-on component (graded exercise) reported that the remote practical had particularly benefitted them in better achieving certain learning outcomes as compared to their classmates who did not participate in the graded exercise. Specifically, students indicated that their participation in the graded exercise allowed them to have a better grasp of the concepts concerning heart rate response to increasing exercise intensity. This finding was not unexpected as the remote graded exercise was specifically designed to provide experiential learning opportunities to better comprehend the concepts underlying this particular learning outcome.

Perceived scores for the achievement of learning outcomes were otherwise similar between the participated and non-participated group. This could be attributed to the fact that the remote practical was used as a complement to the virtual lecture, wherein the interpretation and analysis of data collected from the optional graded exercise was discussed with the whole class during the compulsory virtual lecture. The perception scores of learning outcome achievement were well supported by the students' academic performance as all of them shared similar mean CA marks regardless of their participation in the remote practical. This similarity is especially prominent as the CA questions were set based on the principle of constructive alignment (Biggs, 1996; Bloom, 1956; Stamov Roßnagel et al., 2020).

Interestingly, open-ended responses revealed "experiential learning" as the key reason supporting the efficacy of the remote practical in students who participated in the graded exercise while "having real-life data which reinforces concepts taught in lecture" were key reasons indicated by students who did not participate in the hands-on component of the remote practical. These findings are in line with studies recommending experiential learning as one of the seven "principles of good practice" to achieve excellence in higher education (Chickering & Gamson, 2006). This is accomplished by generating real-life data to allow students to draw the link between theoretical content and practical applications, before applying it to analyse real-life situations in view of course material (Lewis & Williams, 1994). This suggests that the remote practical is able to foster environments which could encourage hands-on learning and real-time data generation to enhance student learning, even if not conducted in a traditional laboratory setting.

Overall, students were satisfied with the remote practical and/or virtual lecture, with those who participated in the hands-on component generally being more satisfied. Even though the remote practical was not compulsory, those who took part in the hands-on component generally did not view it as an additional academic burden and instead would recommend it to future batches of students. This reinforces the potential of such remote practicals in helping students to achieve learning outcomes without imposing unnecessary pressure on them.

With motivation being a strong indicator of self-directed learning and academic achievement (Cortright et al., 2013), it is crucial for educators to assess and understand the importance of motivating students. In fact, educators play a critical role in determining the motivation levels of their students through the nature of their classes and assignments (Cortright et al., 2013). Specifically, Dohn et al. (2016) states that students' motivation could be negatively impacted by limited equipment or restricted time for practicals. Majority of students face similar limitations for a graded exercise test carried out in a traditional face-to-face practical. Typically, only one volunteer would carry out the actual exercise experimental protocol due to equipment and time constraints, while other students would passively watch and learn from the data collected. The novel remote practical proposed in this study could potentially overcome these limitations as students are able to personally experience the hands-on exercise component within their own spaces at home and at their own convenience, thereby possibly enhancing their motivation levels.

Our results indicated that overall motivation towards the remote practical and/or the virtual lecture ranged from 3 to 5, corresponding to “somewhat agree” and “strongly agree”, with a mean value of 3.62 ± 0.78. This is comparable to the motivation scores previously reported by Dohn et al. (2016) for in-class biomedical laboratory classes. The positive motivation score could be explained by the fact that majority of students (81%) could see the relevance (Table 3) of the remote practical in their daily lives. Learning activities which guide students towards finding ‘personal meaning and value’ in the educational content is known to positively influence their motivation levels (Cortright et al., 2013). By providing opportunities for students to reflect on, find meaning and draw relevance to their personal lives, such remote practicals can potentially address common limitations of traditional practicals and boost student motivation and learning.

Delving further into the three aspects of student motivation – interest, effort and self-efficacy, students rated the highest scores for interest, followed by effort and lastly self-efficacy. The score for effort placed into the practical could have been understandably affected due to the non-compulsory nature of the graded exercise. The exercise component of the practical could not be made compulsory as not all students were medically/physically fit enough to undergo a graded exercise test. Nonetheless, the similarity in perceived learning outcomes and academic results between students who did and did not participate in the graded exercise suggests that the follow up analysis and peer-based discussion of the tabulated data involving the entire class was sufficient to bridge the learning gap between the two groups of students. Overall, the favourable perceived learning outcomes (ranging from “agree” to “strongly agree”) and academic scores (corresponding to a grade of “A-” to “A”) reinforces the value of the remote practical as a teaching strategy to promote learning in exercise physiology, regardless of the students’ ability or interest to participate in strenuous physical activity. However, whether the remote practical is more effective than a conventional face-to-face practical or no practical at all remains an interesting question which necessitates future research as this cannot be addressed given the limitations of our current study design.

Notably, self-efficacy scores were rated the lowest amongst the three aspects of motivation. This could be due to the fact that students are not closely supervised during a remote practical, unlike face-to-face practicals. Without the physical presence and continuous guidance of an instructor, students could have faced uncertainty as to whether instructions were properly executed. Thus, strategies to enhance pre-practical instructions using asynchronous video instructions or the incorporation of remote supervision methods may aid to further enhance the effectiveness of the remote practical. Interestingly, participation in the hands-on component of the remote practical appeared to have nonetheless enhanced the confidence of students in explaining the procedures of the practical to their peers (Table 2). This finding is of particular importance, as the ability to teach and explain is an indication of higher order learning corresponding to the second and third levels of the Bloom’s taxonomy (Bloom, 1956).

A. Limitations

Our study sought to evaluate the effectiveness of a remote exercise physiology practical in promoting student motivation and learning in a cohort of Life Sciences undergraduates. However, the current study design does not permit immediate comparison with conventional face-to-face practicals as students could not be randomly allocated into different comparison groups (remote or face-to-face) owing to pandemic restrictions and ethical reasons. Also, we could only investigate the effects of practical participation on the effectiveness of the remote practical in enhancing student motivation and learning outcomes achievement using a quasi-experimental approach. This is so, for we were unable to randomly allocate students into two comparison groups given that not all students were medically/physically fit enough to undergo a graded exercise test for the hands-on component of the remote practical. Based on this study design, some degree of self-selection bias could have been present as physically active students who had volunteered to take part in the exercise component of the remote practical could have seen greater relevance to their daily lives and could have been more intrinsically motivated to partake and learn from the practical session. In spite of that, the overall student motivation score appeared comparable between the two groups of students who participated and did not participate in the exercise component of the practical, suggesting that the degree of self-selection bias may not be of significant concern in the present study.

V. CONCLUSION

Overall, students reported that experiential learning and real-life data were the main reasons supporting the effectiveness of the remote practical. With experiential learning and real-life data as key components of traditional practicals (Dohn et al., 2016; Randall & Burkholder, 1990), the present study demonstrates the potential of remote practicals as viable and innovative alternatives for face-to-face practicals in exercise physiology teaching. In cases of sudden shifts to emergency remote education, such alternatives offer the possibility of incorporating experiential learning even during social isolation.

Notes on Contributors

C. Tan conducted the study, analysed and interpreted the data, and drafted the manuscript. I.C.C. Low was involved in experimental conception and design, as well as critically reviewed and revised the manuscript. All authors have read and approved the final version of the manuscript.

Ethical Approval

All students were provided with a participant information sheet containing the purpose and details of the research study. The questionnaire was made completely anonymous. Informed consent was obtained from students for use of their CA results only after the release and confirmation of their results. Circulation of research materials was done virtually and students were never approached directly for recruitment. The study was approved by the National University of Singapore - Institutional Review Board (NUS-IRB) with study code NUS-IRB-2020-631.

Data Availability

Data supporting these findings is openly available via Figshare at DOI: https://doi.org/10.6084/m9.figshare.17170964.

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Declaration of Interest

No potential conflict of interest was reported by the authors.

References

Ali, W. (2020). Online and remote learning in higher education institutes: A necessity in light of COVID-19 pandemic. *Higher Education Studies, 10*(3), 16-25. https://doi.org/10.5539/hes.v10n3p16

Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education, 32*(3), 347-364. https://doi.org/10.1007/BF00138871

Bloom, B. S. (1956). *Taxonomy of educational objectives. Vol. 1: Cognitive domain.* David McKay.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers & Education, 87*, 218-237. https://doi.org/10.1016/j.compedu.2015.07.003

Bruce, R. H. (1988). Enhancing student motivation and learning: Experiences with a simple simulation. *Higher Education Research & Development, 7*(2), 103-110. https://doi.org/10.1080/0729436880070201

Chickering, A., & Gamson, Z. (2006). Seven principles of good practice in undergraduate education. *New Directions for Teaching and Learning, 1991*, 63-69. https://doi.org/10.1002/tl.37219914708

Colthorpe, K., & Ainscough, L. (2021). Do-it-yourself physiology labs: Can hands-on laboratory classes be effectively replicated online? *Advances in Physiology Education, 45*(1), 95-102. https://doi.org/10.1152/advan.00205.2020

Cortright, R. N., Lujan, H. L., Blumberg, A. J., Cox, J. H., & DiCarlo, S. E. (2013). Higher levels of intrinsic motivation are related to higher levels of class performance for male but not female students. *Advances in Physiology Education, 37*(3), 227-232. https://doi.org/10.1152/advan.00018.2013

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*(3), 297-334. https://doi.org/10.1007/BF02310555

Dohn, N. B., Fago, A., Overgaard, J., Madsen, P. T., & Malte, H. (2016). Students' motivation toward laboratory work in physiology teaching. *Advances in Physiology Education, 40*(3), 313-318. https://doi.org/10.1152/advan.00029.2016

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science education, 88*(1), 28-54. https://doi.org/10.1002/sce.10106

Lellis-Santos, C., & Abdulkader, F. (2020). Smartphone-assisted experimentation as a didactic strategy to maintain practical lessons in remote education: Alternatives for physiology education during the COVID-19 pandemic. *Advances in Physiology Education, 44*(4), 579-586. https://doi.org/10.1152/advan.00066.2020

Lewis, L. H., & Williams, C. J. (1994). Experiential learning: Past and present. *New Directions for Adult and Continuing Education, 1994*(62), 5-16. https://doi.org/10.1002/ace.36719946203

Low, I. C. C. (2021). *Remote physiology practical: Viable alternative to in-person practical in health sciences education?* [Data set]. Figshare. https://doi.org/10.6084/m9.figshare.17170964

Neves, B. S., Altermann, C., Goncalves, R., Lara, M. V., & Mello-Carpes, P. B. (2017). Home-based vs. laboratory-based practical activities in the learning of human physiology: The perception of students. *Advances in Physiology Education, 41*(1), 89-93. https://doi.org/10.1152/advan.00018.2016

Randall, W. C., & Burkholder, T. (1990). Hands-on laboratory experience in teaching-learning physiology. *Advances in Physiology Education*, *259*(6), S4-S7. https://doi.org/10.1152/advances.1990.259.6.s4

Ray, S., & Srivastava, S. (2020). Virtualization of science education: A lesson from the COVID-19 pandemic. *Journal of proteins and proteomics, 11*, 77-80. https://doi.org/10.1007%2Fs42485-020-00038-7

Stamov Roßnagel, C., Fitzallen, N., & Lo Baido, K. (2020). Constructive alignment and the learning experience: Relationships with student motivation and perceived learning demands. *Higher Education Research & Development*, *40*(4), 838-851. https://doi.org/10.1080/07294360.2020.1787956

Vasiliadou, R. (2020). Virtual laboratories during coronavirus (COVID-19) pandemic. *Biochemistry and Molecular Biology Education*, *48*(5), 482-483. https://doi.org/10.1002/bmb.21407

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