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**Laidlaw Undergraduate Research and Leadership Programme
Research Report**

**Effectiveness of game-based oromotor exercises on laryngeal elevation in
healthy adults**

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Introduction

The larynx is heavily involved in the pharyngeal phase of swallowing (Owens et al., 2015). During this stage, the larynx rises up and forward, helping to close the laryngeal vestibule and divert the bolus laterally around it to prevent the food bolus from entering the trachea (Logemann et al., 2000; Vandaele et al., 1995). In individuals with dysphagia, the most frequent cause of aspiration is either delayed laryngeal elevation or failure to raise the larynx. (Lundy et al., 1999) Dysphagia has a major negative impact on quality of life and may lead to serious complications such as pneumonia, malnutrition, and dehydration (González-Fernández et al., 2013).

Swallowing exercises like effortful pitch glide are supported by studies to have effect in strengthening muscles that supports laryngeal elevation (Milorio et al., 2014). Nonetheless, for swallowing exercises to reach their full effect, strict adherence to them is crucial. It is discovered that patients who can consistently perform swallowing exercises have a lower risk of developing stenosis, receiving a G-tube, or worsening their diet (Duarte et al., 2013).

Despite the importance of adhering to swallowing exercises, Shinn et al (2013) showed patient compliance to long-term swallowing exercises is only 40%. It appeared that forgetting, the effort needed and a lack of awareness of the significance of the swallowing exercise were common causes of nonadherence.

Gamification is a promising solution to increase patient adherence to exercise-based intervention. Gamification techniques have been used in the healthcare industry to increase patient motivation and involvement, encourage good lifestyle choices, and assist patients in managing chronic illnesses, among other goals (Rodriguez et al., 2023). Game-based exercises are shown to be satisfactory and superior to traditional exercises in terms of their effectiveness, efficiency, learnability, and satisfaction (González-González et al., 2019). Although the field of gamification is still in development, there is increasing evidence in support of gamified exercises throughout all stages of outcome research and withstand scientific assessment of their claims (Constantinescu et al., 2017).

The purpose of this study was to examine the pitch glide exercise game developed by the Swallowing Research Laboratory's effectiveness in improving participant's laryngeal functions and their adherence to the exercise routine. Although there might not be significant improvement in laryngeal elevation in healthy adults given the short period of practice, it is anticipated that participants in the group with game-based oromotor exercise (OME) will have higher adherence in carrying out OME at home than participants in group with traditional OME.

Methods

24 healthy participants aged 18 - 88 were recruited from the community. (Game-based OME: N = 14, 18–81 yr, mean 49.07 ± 21.95 yr, 11/3 females/males; Traditional OME: N = 10, 20–88 yr, mean 56.4 ± 26.26 yr, 7/3 females/males) Participants were recruited based on the following inclusion criteria: i) Do not have self-reported or diagnosed with speech problems or swallowing problems or impaired oromotor function; ii) aged 18 or above; iii) no previous diagnosis of diseases in the head and neck or any dental deformities; iv) no previous diagnosis of neurological diseases (e.g. stroke, Parkinson's disease and multiple sclerosis), chronic respiratory diseases or heart disease; v) no difficulties in following the assessment procedures.

Participants were randomly assigned to either the game-based oromotor exercise (OME) group or the traditional OME group. Both groups were assessed on their laryngeal functions through a range of oromotor tasks and instrumental assessments. Afterwards, participants in the game-based OME group were given an iPad with the swallowing exercise app installed. Participants were asked to play the game 15 minutes per day, and their adherence is tracked via in-app log record. On the other hand, the traditional OME group was taught the pitch glide exercise after the assessment and asked to perform the exercise 15 minutes per day as well. Adherence tracked by participants self-recording their practice process and submitting the self-recorded videos to the investigators. Both groups have a practice dose of 5 sets of exercise per day. At the end of the training period, participants were asked to fill in a printed or online questionnaire to rate their OME experiences regarding comfort level, enjoyment and motivation.

Participant ID	Age	Gender
G01	74	Male
G02	69	Male
G03	44	Female
G04	54	Female
G05	48	Female
G06	20	Female
G07	24	Female
G08	77	Female
G09	81	Female
G10	19	Female
G11	52	Female
G12	55	Male
G13	18	Female
G14	52	Female

Table 1.

Details of participants in the game-based OME group. The table included participant's identifying number, age and gender.

Participant ID	Age	Gender
T01	87	Female
T02	88	Male
T03	55	Male
T04	56	Female
T05	25	Female
T06	60	Female
T07	25	Female
T08	20	Female

T09	61	Male
T10	87	Female

Table 2.

Details of participants in the traditional OME group. The table included participant's identifying number, age and gender.

Q1	I feel motivated to complete the oromotor exercises every day.
Q2	I am willing to continue doing oromotor exercises of this mode (i.e., game-based / traditional) for a long period of time.
Q3	I have paid a significant amount of physical effort when doing the oromotor exercises.
Q4	I feel physical pain or discomfort during / after the oromotor exercises.
Q5	Overall, I have enjoyed doing oromotor exercises of this mode (i.e., game-based / traditional).
Q6	<p>(Applicable to the game-based oromotor exercise group only) What component(s) of the game has/have motivated you the most to do the oromotor exercises? (Please tick the appropriate boxes below)</p> <p><input type="checkbox"/> Incorporation of games into oromotor exercises</p> <p><input type="checkbox"/> The reward system</p> <p><input type="checkbox"/> Provision of encouragements</p> <p><input type="checkbox"/> Others (please specify: _____)</p>

Table 3.

Questions included in the questionnaire. Participants were asked to indicate to what extent they agree with each of the following statements by circling the corresponding number. Note: 1 = Strongly disagree 10 = Strongly agree

Result

Four participants in the game-based OME group were accidentally given instructions to perform more sets of exercises than other participants. They were excluded from data analysis to ensure finding accuracy.

Participant ID	Pre training min	Pre training max	Pre training pitch range	Post training min	Post training max	Post training pitch range	Difference	Adherence	Adherence averaged with training days
G05	50	773.6181	723.6181	50	800	750	26.3819	85.71%	85.71%
G06	50	788.6935	738.6935	50	788.6935	738.6935	0	85.71%	85.71%
G07	98.99497	724.6231	625.62813	50	800	750	124.37187	57.14%	57.14%
G08	50	784.9246	734.9246	76.38191	713.3166	636.93469	-97.98991	385.71%	235.71%
G09	72.61307	792.4623	719.84923	57.53769	747.2361	689.69841	-30.15082	100.00%	85.71%
G10	50	800	750	50	660.5527	610.5527	-139.4473	42.86%	42.86%
G11	68.84422	796.2311	727.38688	65.07538	735.9296	670.85422	-56.53266	100.00%	100.00%
G12	57.53769	781.1558	723.61811	80.15076	792.4623	712.31154	-11.30657	71.43%	71.43%
G13	65.07538	800	734.92462	95.22614	800	704.77386	-30.15076	57.14%	57.14%
G14	50	739.6985	689.6985	91.45729	800	708.54271	18.84421	128.57%	114.29%
T01	91.45729	735.9296	644.47231	83.9196	800	716.0804	71.60809	0.00%	0.00%
T02	61.30653	773.6181	712.31157	68.84422	788.6935	719.84928	7.53771	0.00%	0.00%
T03	80.15076	800	719.84924	87.688	800	712.312	-7.53724	71.43%	71.43%
T04	91.4573	717.0854	625.6281	80.15076	766.0804	685.92964	60.30154	85.71%	85.71%
T05	50	792.4623	742.4623	53.76884	781.1558	727.38696	-15.07534	85.71%	41.43%
T06	91.45729	679.397	587.93971	80.15076	743.4673	663.31654	75.37683	100.00%	100.00%
T07	50	735.9296	685.9296	50	796.2311	746.2311	60.3015	34.29%	60.00%
T08	50	751.005	701.005	50	702.0101	652.0101	-48.9949	111.43%	71.43%
T09	80.15076	758.5427	678.39194	68.84422	762.3116	693.46738	15.07544	100.00%	105.71%
T10	65.07538	766.0804	701.00502	83.9196	792.4623	708.5427	7.53768	100.00%	100.00%

Table 4

Summary of pre- and post- pitch assessment result and adherence percentage of participants.

Participant in the game-based OME group have a smaller pitch range after home practice than participant in traditional OME group (game-based $M = -19.60$, $SD = 72.16$, traditional $M = 22.61$, $SD = 42.15$). However, this difference was not statistically significant; $t(18) = 1.597$, $p = .13$; and represented a large-sized effect ($d=.71$).

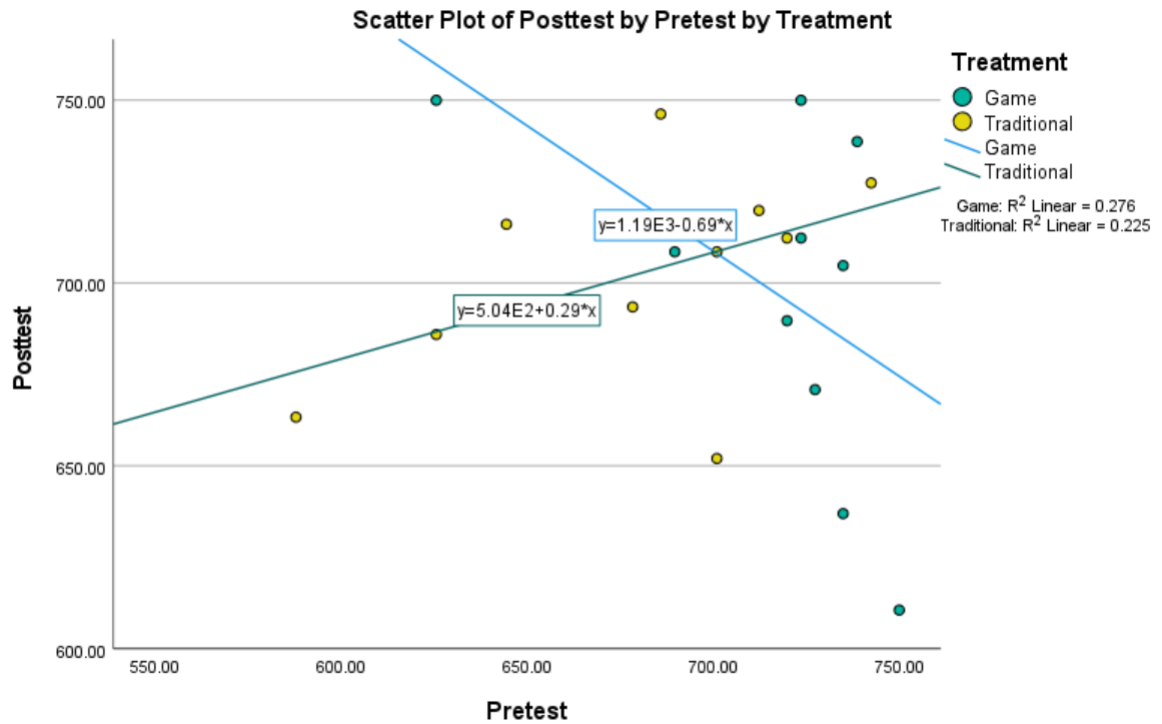


Figure 1.

Scatter plot of pretest and posttest pitch range of participants. The graph presents the pretest and posttest pitch range of participants in game-based OME group and participants in traditional OME group. Participants in game-based OME group's pitch range decreased after training and participants in traditional OME group's pitch range increased after training.

For adherence, the game-based OME group reported higher adherence than the traditional OME group (game-based $M = 1.11$, $SD = 1$, traditional $M = 0.69$, $SD = 0.42$). This difference was not statistically significant; $t(18) = 1.25$, $p = .23$; and represented a medium-sized effect ($d = .56$).

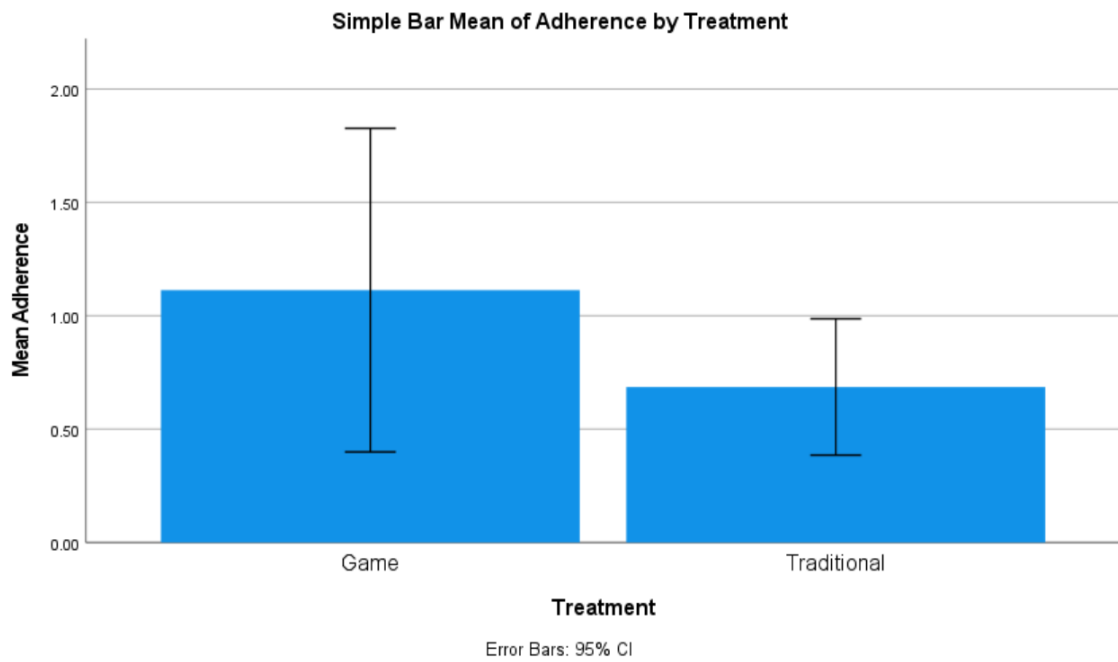


Figure 2.

Adherence rate of participants in game-based OME group and traditional OME group. The graph presents mean differences between adherence rate of participants doing game-based oromotor exercise and traditional oromotor exercise.

It was noted that some participants would stop practice for one day and practice double the dose the next day as compensation, therefore, participants' adherence averaged with practice days were calculated with the following formula: $(\text{days of practice}/7 + \text{number of sets completed}/35) * 0.5$. In this regard, the game-based OME group continued to have higher adherence than the traditional OME group (game-based $M = 0.91$, $SD = 0.55$, traditional $M = 0.63$, $SD = 0.39$). This difference was not statistically significant; $t(18) = 1.31$, $p = .21$; and represented a medium-sized effect ($d = .58$).

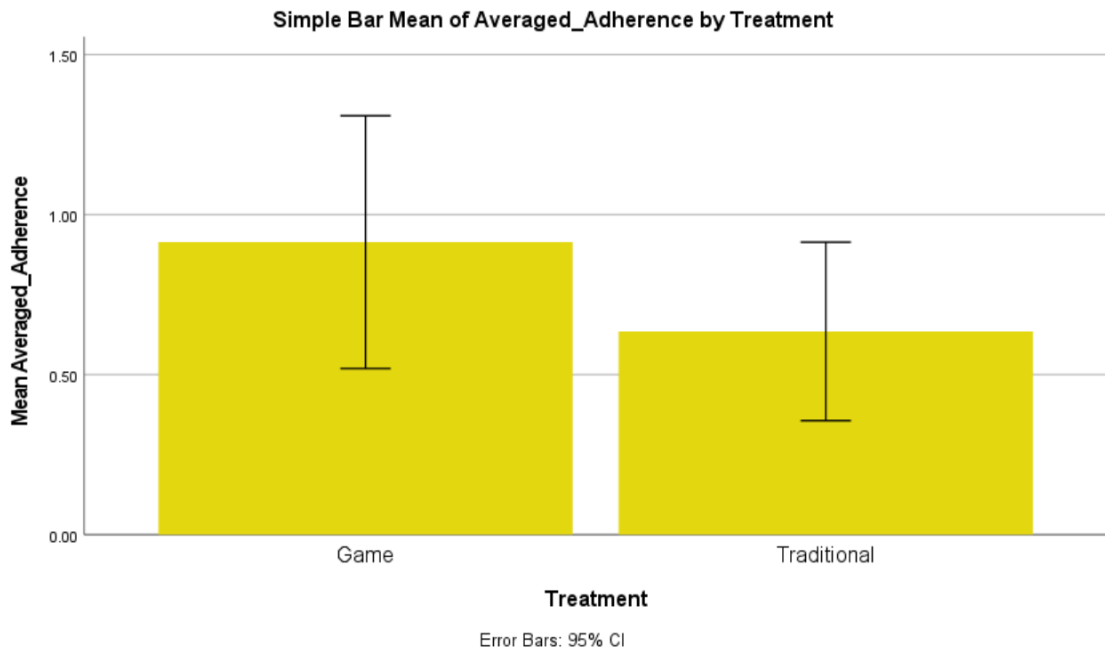


Figure 2.

Adherence rate averaged with practice days of participants in game-based OME group and traditional OME group. The graph presents mean differences between adherence rate of participants doing game-based oromotor exercise and traditional oromotor exercise.

The results of the questionnaire Q1-5 were summarized in table 5.

Questions	Game-based OME group		Traditional OME group	
	Mean	SD	Mean	SD
Q1	6.90	2.13	5.10	3.17
Q2	6.10	3.07	4.80	1.87
Q3	4.40	2.67	5.40	2.71
Q4	2.50	2.07	3.60	2.88
Q5	8.10	1.52	6.00	2.00

Table 5.

The mean and standard deviation of participants' responses to the questionnaire.

The game-based OME group reported the incorporation of games into exercises, the reward system, provision of encouragements and points system as major motivators to completing the oromotor exercises.

Conclusion

It was observed that participants in the game-based OME group were found to have a smaller pitch range after training compared to participants in the traditional OME group despite having higher adherence in general. Since the mean adherence percentage of the game-based OME group exceeds 100%, and examination of the raw data revealed one participant practiced up to 3.8 times the instructed dose, it is possible that the reduced pitch range was due to vocal fatigue after over-practice (de Oliveira Lemos et al., 2023). It is also possible that the observed result was influenced by other miscellaneous factors such as hydration levels, which may cause fluctuations in their pitch range (Vermeulen et al., 2021). Still, the result is not conclusive as the recorded result is not statistically significant. Further investigation on this topic is warranted.

The result suggested that game-based oromotor exercise may lead to higher adherence rate among participants, which can be due to higher motivation, a greater willingness to undertake long-term rehabilitation using this treatment mode, higher enjoyment level and lower perceptual fatigue and discomfort level.

Difficulties encountered and how they were resolved

Regarding difficulties encountered during my research, the first that came to mind was writing consent forms and ethical approval forms with no prior experience. Although I had experience in data collection when I worked as an intern in other research labs before, compiling the necessary documents to start my project from scratch was foreign to me. Thankfully, I have my supervising professor and other members of the Swallowing Research Laboratory to guide me. By referencing old consent forms and successful ethical applications provided by them, I was able to commence data collection in July.

Another challenge was finding participants to join my study. My research requires a high degree of commitment, therefore my mass email to the entire University of Hong Kong only received two replies. To overcome this, I decided to be more proactive and started reaching out to

my family and friends, who helped me contact potential participants. Thanks to them, I ended up exceeding my goal of 15 participants and found 24 participants.

Scheduling conflict with participants also presented an issue. I usually try to schedule the same day of week for two consecutive weeks for assessment, but scheduling conflict made this impossible for some participants. In order to have the post-training assessment be done as soon as possible after the one week training period, the post-training assessment was scheduled at the soonest possible date.

Improvements that could be made if the project were to be repeated

If the project were to be repeated, I would file the ethical approval application form in May instead of filing it in June. I originally decided to file my ethical approval form at the official start of my project, but I now realized I cannot begin recruiting participants until my ethical application is approved. Therefore, beginning it earlier will allow more time for the actual investigation phase of the project.

It was also learned that three participants in the game-based OME group thought the daily practice dose was higher than it should be. This is a mistake that could potentially invalidate experimental results. Upon discovery of this issue, I have immediately changed the way I deliver instructions and confirm participants' understanding of practice requirements by asking them to tell me how much they should practice per day. If the project were to be repeated, I will implement this change from the start and avoid this mistake.

The current research brings impact beyond the classroom by aiding in the development of a swallowing exercise game by the HKU swallowing research lab. This project allows us to evaluate the game's effectiveness as well as collect participants' perspectives on this game for further improvement. Once research on the game is complete, it will be available for download on Apple Store. This game can be utilized by dysphagia patients to improve their oromotor functions, also for clinicians to use in intervention with their clients.

In addition, this research brings insight on a new promising rehabilitation method. In the current study, it was recorded that participants in the game-based OME group have higher adherence but negative pitch range improvement, which could be attributed to participants exceeding the recommended practice dose and resulting in vocal fatigue. To mitigate this risk, it is recommended that clinicians suggest an upper limit for exercise sets to prevent excessive strain on the laryngeal muscles. Still, game-based oromotor exercises offer numerous benefits in clinical setting, including increasing client adherence, motivation and enjoyment of the swallowing exercise. As such, the method holds great potential for clinical use.

For future research on this topic, participants with swallowing disability can be recruited for investigation. The current study is only a preliminary investigation on a newly developed game, therefore healthy participants are recruited to test out the protocol. However, for future studies on this topic, it is recommended that participants with conditions such as stroke, Parkinson's disease and head and neck cancer that led to dysphagia be seek out for investigation. Since swallowing exercises are typically recommended for these patients, recruiting them in the study can help us gain insight on gamified swallowing exercise's effect in clinical use.

Furthermore, future studies should aim to recruit more participants. Due to time constraints, the current study only recruited 24 participants, which limit the possibility of recording statistically significant results and generalizing the study effect to a larger population. Recruiting more participants can increase the study's power and accuracy, and allow us to put more confidence in the study result.

Lastly, a longer training period for the participants is recommended for future studies. Although the intervention dosage for different dysphagia patients varies, studies have noted that swallowing intervention was often provided five times per week for 4 weeks (Choy et al., 2022). The training period in the current study is only one week, which may not reflect intervention use in typical clinical practice. Research has also suggested that a longer training period may lead to greater improvement in swallowing functions (McCullough & Kim, 2013). The current study recorded no significant difference between the oral motor performance before and after swallowing

exercising exercise for both groups of participants. But a longer training period may allow us to see a stronger difference pre- and post-training, which may help us better understand the effect of effort pitch glide swallowing exercise, also to compare the effects of traditional oromotor exercises and gamified oromotor exercise on participants' oromotor functions.

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