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An online game-based intervention using quizzes to improve nutrition and physical activity outcomes in university students

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Introduction

Emerging adulthood, defined as the period from late teens through early adulthood (18–25 years) has been described by Arnett (2000) as a distinct period of life course characterised by higher independency, exploration and experimentation that may determine life choices in later adulthood.[1] For many, it is also a period for weight-related behaviour changes as pooled evidence from longitudinal studies have shown shifts in physical activity[2-3] and dietary behaviour.[4-5] The Project EAT showed a decrease in fruit and vegetable (FVI) intake (by >½ serving/day)[6] and an increase in fast-food consumption (by 0.4 times per week in girls)[7] during the transition from high school to adolescence. The same cohort also showed a decline in weekly hours of moderate-to-vigorous activity (from 5.1 to 3.5 hours/week for girls) and an increase time in computer use (from 10.4 to 14.2 hours/week for boys).[8]

Adopting unhealthy eating and physical activity habits in early adulthood can have long-term health implications. The Adolescent Health study, which followed high school participants for five years, found a two-fold increase in obesity prevalence (from 13.3% to 22.6%) which remained high 12 years later from baseline.[9] The CARDIA Study showed that participants with poor diets (e.g., high intakes of fast-food, meat and snacks) had higher incidence of cardiometabolic risk over a 20-year study period when compared with participants following a diet closer to guidelines.[10] Engaging in regular physical activity also has long-term benefits, including reduced risks of obesity, coronary heart disease, type 2 diabetes and mental health conditions[11] while long-term benefits have been found in adults who became active in early adulthood and remained active over time despite being inactive as adolescents.[12]

About 58% of emerging adults are expected to enter tertiary education[13] with evidence suggesting unfavourable changes in weight-related behaviours during the

transition from high school to tertiary education.[2,14] Epidemiological studies have found that two out of three university students failed to meet the recommended levels of physical activity,[15] about one third consumed confectionary and fast-food once to twice per week and less than 10% consumed more than two portions of fruit and vegetable per day.[16] In addition, the meta-analysis by Vadeboncoeur et al., (2015) demonstrated that students gained on average of 1.36 kg during their first year of studies[17] with similar individual studies indicating that weight gain[18] and unhealthy weight-related behaviours remained throughout university years.[19] University students have reported that a cluster of personal (e.g., previous habits, self-efficacy), social (e.g., behaviour and support of peers or close ones) and environmental factors (e.g., availability and accessibility of food or exercise facilities, living arrangements) impact their eating and physical activity behaviour.[20-22] Increased nutrition knowledge in students has also been associated with healthy eating behaviours,[23-24] however, cross-sectional data indicate gaps in students' knowledge in relation to foods containing fat, salt and fibre and optimal weight-management behaviours.[25]

Digital interventions have been used in non-clinical populations targeting dietary and physical activity behaviour.[26] Examples include the use of mobile phones (e.g., texting), digital devices (e.g., pedometers) or internet-based interventions. Gamification refers to the use of game-elements such as videos, rewards and social features in non-gaming systems to enhance user experience, motivation and engagement.[27-28] In the UK, emerging adults are peak users of video games[29] while the time users spent on gaming has been associated with adverse health indicators such as increased caffeine and junk food intakes[30] and higher body mass index.[31] Universities are influential settings towards shifting emerging adults' behaviour [32] and therefore can favourably use the time young adults spend on gaming to deliver health-promoting interventions.[33] Digital interventions

have the potential to improve diet and physical activity outcomes, however, more research is needed targeting specific populations and using designs that enhance motivation and adherence to the intervention.[26] Due to its' underpinning characteristics, gamification can be used in health-related contexts and as part of online interventions to make the learning process more appealing and increase participation.[34-35]

Considering the weight-related behavioural changes occurring in emerging adulthood and the associated long-term health implications, emerging adulthood is an important timeframe for health promotion. The primary objective of this study was to investigate the short-term effect of an online intervention using game-elements (quiz-games) on nutrition knowledge, diet quality and physical activity in a sample of university students. Quiz-games characteristics including adherence (frequency) and performance (score) of games played and the effect of time (days) on performance after repeating a quiz-game were also investigated.

Materials and methods

Design and Study Population

A single-blind randomised controlled trial (RCT) with two data collection points and two parallel arms was used to address the research questions and test the hypotheses, that university students' engagement with playing the quiz-games as part of the online intervention would improve their nutrition knowledge, diet quality and physical activity behaviour. A detailed description of the study methodology can be found elsewhere.[36] Eligible students were those enrolled at the time of the study (2017-2018) at two London-based universities, aged 18 to 34 years, and free of any medical or other condition that required special dietary treatment. Recruitment was open throughout the academic year. Students were screened for their readiness to perform a safe level of physical activity[37]

and their potential risk of having an eating disorder[38] and those at risk were excluded from the study (n=0). The sample size was calculated based on nutrition knowledge score as presented by Kliemman et al. (2016).[39] Mean scores in nutrition knowledge were 79.3 (SE=0.51, SD=5) for students studying Dietetics and 67.7 (SE=0.97, SD=9) for students studying English, and the overall score difference was 11.5 point (95% CI: 9.3–13.7). Additional evidence suggests that an 8–9% (7.0–8.0 points) increase on the initial knowledge score significantly improves diet quality.[40] As students from all Faculties would be invited to participate in this study, a standard deviation between 7 and 9 was expected in the mean scores of this population. Setting the power at a 90% level and significance threshold at $p<0.05$, a sample size of at least 35 participants in each group would satisfy the preceding criteria. Considering a 25% dropout rate, the overall sample size needed for this study was 88 participants. A convenient sample of 88 participants entered the study and were randomly assigned to the intervention or the control group (Figure 1). Computer-generated random numbers[41] based on a 4:3 allocation ratio (intervention: control) were used for randomisation as a higher dropout rate was expected from participants in the intervention group. Written consent was provided before students entered the study. The data collection points were at baseline and after a 10-week interventional period. Participants in the intervention group received access to the intervention while the control group had no access and did not receive any other educational materials. The study obtained approval by the Faculty Research Ethics Committee of Kingston University , and St George's, University of London (FREC 2017-12-009) and it was registered in the ClinicalTrials.gov database (identifier NCT03028714). Students who completed the study received a £10 Amazon voucher token at the end.

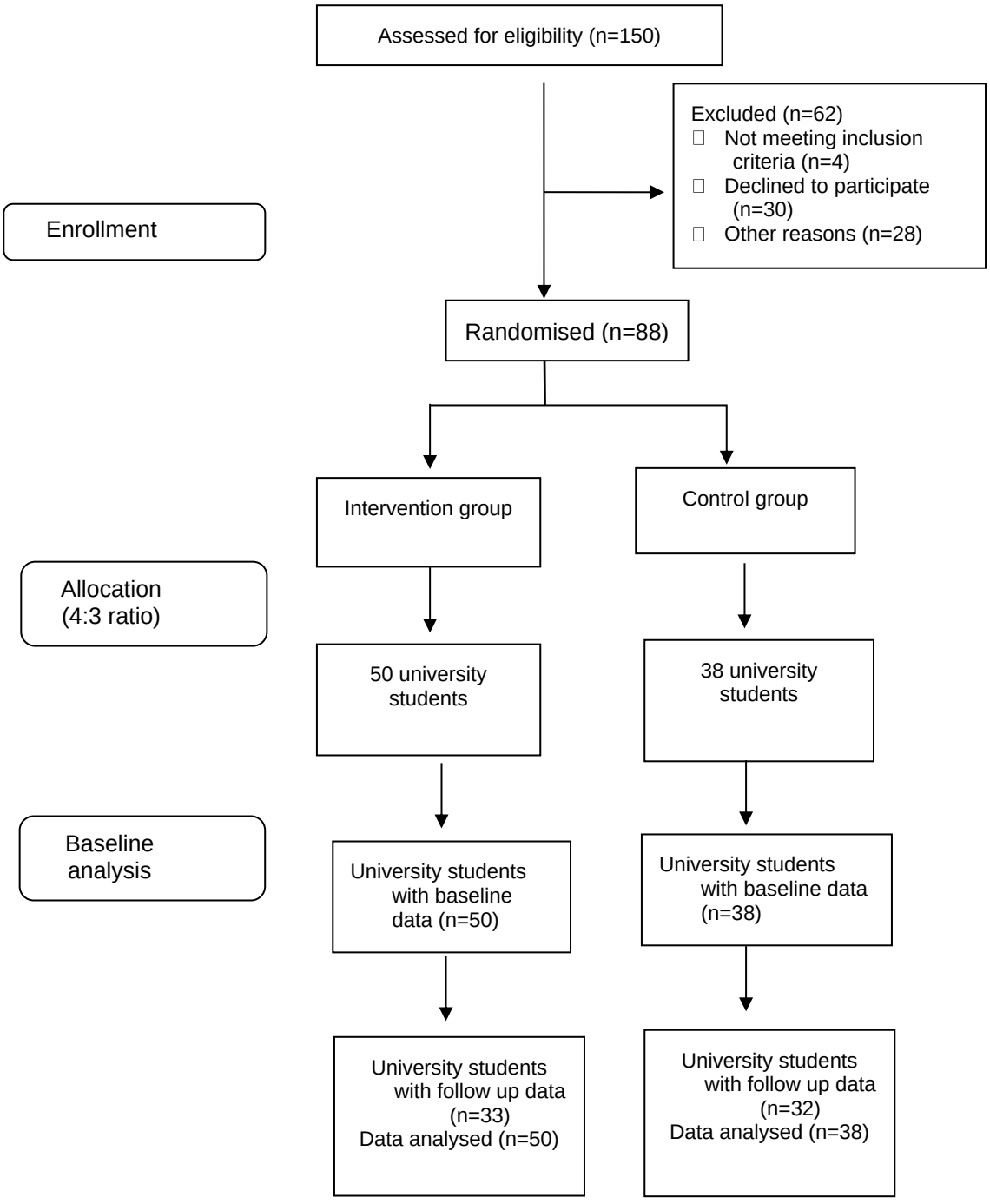

Figure 1. CONSORT flow diagram of the randomised controlled trial.

Intervention

The intervention included access to a website which contained information about the following topics: Activity and Exercise, Alcohol, Body weight, Eating on a budget, Fast-food, Fat, Food labels, Fruit and Vegetables, Meals and Snacks, Meat, Salt, Sugars and Sugary Drinks. Ten quiz-games relevant to the website content (one quiz for each topic except for Body weight and Eating on a Budget topics) were also included.[36] Each quiz-game included ten multiple-choice questions with a range of two to four correct answer options with only one correct response (Supplemental Table 1). The Kahoot! Game-based learning platform was used to develop the online quiz-games.[42] The gamification theory was applied,[35] as the quizzes included the following game elements: *time* - students had 30 seconds to answer each question; *reward* - students received points which increased their score when choosing the right answer; *feedback* - right and wrong answers appeared at the end of the quiz-game; *social interaction* - students could compete with each other when playing the same game (invited by the same host); *replay* - students could repeat the quiz-game to improve their scores. Students were encouraged to play as many times as they wished to improve their knowledge and scores, as well as use the website as a reference tool to look for the correct answers. Music, videos and animated pictures were added to make the games more entertaining and engaging. Any electronic device was able to host the quizzes and HTML iframes were used to pinch the quizzes to the website for easy access. Customised usernames and passwords were provided to students to access and play the games. Prior to the study, the quiz-games were piloted in a class of undergraduate students to test their feasibility. Electronic messages were sent twice per month to encourage students to play and improve their scores.

Outcome measures

Nutrition knowledge was assessed using the revised validated General Nutrition Knowledge Questionnaire (GNKQ-R).[39] The GNKQ-R tool includes questions in relation to dietary recommendations, food groups, healthy food choices, diet, disease and weight associations and overall nutrition knowledge score ranging from 0 to 88. Each correct answer accounts for one point (otherwise null) and a higher score indicates higher nutrition knowledge.

Diet quality was assessed using a validated semi-quantitative food frequency questionnaire (FFQ) which calculates an index of diet quality (IDQ).[43] The FFQ includes 18 questions about frequency and amount of intake of whole grain products, fat-containing foods, dairy products, vegetables and fruits, sugary foods and number of main meals skipped during the week. The IDQ score ranges from 0 to 15 points, with a higher score indicating higher diet quality.

Physical activity was assessed using the short form of the validated International Physical Activity Questionnaire (IPAQ-SF).[44] The IPAQ-SF includes questions about the frequency (days per week) and duration (minutes per day) of different types of activities (vigorous, moderate, walking) as well as sitting time (minutes per day). Physical activity was measured as total metabolic equivalent task (MET-min per week) from all types of activities (vigorous, moderate, walking).

Demographic and academic characteristics including age, gender, ethnicity, studying status (undergraduate/postgraduate), Faculty of study, being on a special diet (e.g., yes/no and type of diet if answered 'yes'), and holding a nutrition qualification (yes/no and specific qualification if answered 'yes'), were collected at baseline. Body mass (kg) and stature (m) were also measured by the principal investigator and body mass index (BMI) (kg/m^2) was calculated at baseline.

Engagement with the quiz-games

Engagement was based on the frequency of playing the quiz-games (n). As the total number of quiz-games was ten, participants who played at least five quiz-games were considered adherent to the intervention. Because students were given the choice to play (or not) any quiz-game, as many times they wished, n (times playing) was calculated by adding the total number of quiz-games played, irrespective of whether it was the same or a different quiz-game.

Statistical analyses

The IBM SPSS Statistics version 24 was used for the analyses of the data.[45] The significance level was set at $p<0.05$. Descriptive statistics were used to describe the main characteristics of the study population and chi-square tests (or the Fisher's exact test) or t-tests to explore significant differences between the two groups of the study at baseline. Descriptive statistics were also used to calculate the number of participants who played each quiz-game, the number of times each game was played and the mean scores (% of correct answers) of each quiz-game. A receiver operating characteristic (ROC) analysis was undertaken to estimate the cut-off point (time in days) where the differences in scores ceased to improve for participants who played a quiz-game twice. Normality of variables were tested using the Kolmogorov-Smirnov test. The Mann-Whitney test was applied to test for differences in outcomes between the two groups over time and the Wilcoxon signed rank test was performed to test for differences in outcomes within each group over time, using an intention to treat analysis. A mixed-design two-way repeated measures

analysis of variance (ANOVA) using a per protocol analysis was applied to investigate the effect of engagement rate with the quiz-games on the outcomes of measure over time.

Results

At baseline, participants of the two groups of the study did not significantly differ according to age, gender, ethnicity, studying status, Faculty of study, BMI and following a special diet (Table 1). However, a higher number of participants holding a nutrition qualification was assigned to the control group (p=0.033). Nutrition knowledge (p=0.861), diet quality (p=0.958), physical activity (p=0.667) and sitting time (p=0.237) also did not significantly differ between the two groups at baseline.

Table 1. Baseline demographic, academic and anthropometric characteristics of study participants

Variables	**Control group (n=38)**	**Intervention group (n=50)**	**p-value for difference between groups**
Age (years) (mean ± SD)	22.53 (3.28)	23.38 (4.14)	0.284
Gender, n (%)			
Male	15 (39.5)	14 (28.0)	0.257
Female	23 (60.5)	36 (72.0)	
Ethnicity, n (%)			
White	25 (67.6)	27 (54.0)	0.585
Black	2 (5.4)	5 (10.0)	
Asian	7 (18.9)	14 (28.0)	
Mixed	3 (8.1)	4 (8.0)	
Missing=1			
Studying status, n (%)			
Undergraduate	27 (76.3)	38 (76.0)	0.973
Postgraduate	9 (23.7)	12 (24.0)	
Faculty of study, n (%)			
Science, Engineering and Computing	17 (44.7)	21 (42.0)	0.426
Arts and Social Sciences	5 (13.2)	6 (12.0)	
Art, Design and Architecture	2 (5.3)	7 (14.0)	
Business and Law	0	4 (8.0)	

Health, Social Care and Education	8 (21.1)	7 (14.0)	
Medicine	4 (10.5)	3 (6.0)	
Biomedical Sciences	2 (5.3)	2 (4.0)	
Has a nutrition qualification, n (%)			
No	30 (81.1)	48 (96.0)	**0.033**
Yes	7 (18.9)	2 (4.0)	
n=1 missing			
Being on a special diet, n (%)			
No	31 (86.1)	45 (90.0)	0.736
Yes	5 (13.9)	5 (10.0)	
n=2 missing			
BMI (kg/m^2) (mean ± SD)	23.09 (3.32)	24.70 (5.31)	0.085
Nutrition knowledge (median, IQR) (maximum score 88)	66.60 (17)	63.50 (12)	0.861
Index of diet quality (median, IQR) (maximum score 15)	8.00 (3.94)	8.44 (3.40)	0.958
Physical activity (MET-min/week) (median, IQR) (n=10 missing)	3217.50 (3096.88)	3238.48 (2525.25)	0.667
Sitting time (minutes per day) (median, IQR) (n=9 missing)	431.56 (255)	405.00 (180)	0.237

IQR: interquartile range

Of the 50 participants in the intervention group, 15 did not play any game and 35 were engaged to some extent with the quiz-games. On average, students played 6 out of 10 games with the Activity quiz-game being played by almost all students (n=34) (Figure 2). Fast-food and Alcohol quiz-games were also played by a high number of students (n=24), while Food labels and Salt quiz-games were played by the lowest number of participants (n=16). Among the 35 game-players, 15 played at least one quiz-game. Activity was the most frequently played quiz-game being played 43 times in contrast with Food labels and Fruit & Vegetables quiz-games which were only played 17 times each

(Figure 2). The mean scores (% of correct answers) of the quiz-games ranged from 82% (Meals & Snacks) to 55% (Salt) (Figure 2). In total, 35 quiz-games were played twice, 6 quiz-games were played three times, one quiz-game was played four times and one quiz-game was played five times.

[insert Figure 2]. Number of times each quiz-game was played (on the left) and mean scores (% of correct answers) of each quiz-game (on the right) from participants in the intervention group who played each game (n).

Only the quiz-games which were played twice were used in the ROC analysis due to the low number of quiz-games played more than twice. The change in scores (score at second time minus score at first time) was converted into a new binary variable. When the second score was higher the variable was coded as 'positive'. When the second score was lower or remained the same, the variable was coded as 'negative'. Based on this coding scheme, 18 students had a 'negative' change in scores and their average number of days before repeating the quiz-game was 21.2 (SD=21.3) while 17 students had a 'positive' change in scores and their average number of days before repeating the quiz-game was 5.9 (SD=9.3). The ROC curve analysis showed that 8 days was the cut-off point with the higher true positive rate (0.67) and lower false positive rate (0.29) (Figure 3), meaning that when participants played a quiz-game for the second time within 8 days, their performance (score) improved, while after that point their performance remained the same or decreased.

[Insert Figure 3] ROC curve showing the accuracy of the test to estimate the cut-off point for the number of days where it is expected that when a player repeated the quiz-game

after these days the score would remain the same or decreased. The cut-off point of 8 days seems to have the optimal sensitivity and 1-specificity in this test.

No significant differences were found between the intervention and the control group over time on any of the outcomes of measure (Table 2). At the end of the intervention, students of both groups had significantly improved their nutrition knowledge compared to baseline (Table 2).

Table 2. Comparison of nutrition knowledge, diet quality and physical activity outcomes of participants in the control and intervention groups over the study period

		Time interactions						**Group x time interactions**	
		Control group (n=38)			**Intervention group (n=50)**				
Outcome		Median (IQR)	Difference (95% CI)	p-value	Median (IQR)	Difference (95% CI)	p-value	Test statistic	p-value
Nutrition knowledge (max score 88)[a]	Baseline	64.00 (16)	2.50 (0.50, 4.50)	**0.011**	63.00 (11)	2.00 (1.00, 4.00)	**<0.001**	0.262	0.793
	At 10 weeks	66.50 (13)			67.00 (12)				
Index of diet quality (max score 15)[b]	Baseline	8.00 (4.00)	0.00 (-0.50, 0.50)	0.863	8.00 (2.80)	0.00 (0.00, 0.50)	0.193	0.616	0.538
	At 10 weeks	7.00 (3.56)			8.92 (3.06)				
Physical activity (MET-min/week)	Baseline	3217.50 (3096.88)	0.00 (-514.0, 774.50)	0.959	3238.48 (2525.25)	120.00 (0.00, 703.50)	0.126	-0.46	0.643
	At 10 weeks	3363.50 (4578.75)			3505.50 (4066.50)				
Sitting time (minutes per day)	Baseline	431.56 (255)	-30.00 (-90.00, 13.99)	0.135	405.00 (180)	-0.13 (-65.51, 0.00)	0.333	-0.24	0.812
	At 10 weeks	375.00 (180)			375.00 (180)				

[a] Those holding a nutrition qualification (n=9) and missing values (n=1) were excluded from the analysis

[b] Those on a special diet (n=10) and missing values (n=2) were excluded from the analysis

IQR: interquartile range

The engagement rate of the quiz-games had no effect on any of the outcomes of measure as no significant differences were found at the end of the intervention in nutrition knowledge, diet quality, physical activity, nor sitting time among adherent participants in the intervention group compared with those in the control group (Table 3).

Table 3. The effect of engagement with the quiz-games on nutrition knowledge, diet quality, physical activity and sitting time over the study period[a]

	Post-intervention			
Outcome	Control group vs. adherents to quiz-games			
	Sample (n)	*F* statistic	Partial η^2	p-value
Nutrition knowledge (scores)[b]	44 (27 controls, 17 adherents)	1.474	0.034	0.232
Index of diet quality index (scores)[c]	42 (27 controls, 15 adherents)	1.474	0.031	0.268
Physical activity (MET-min/week)	43 (26 controls, 17 adherents)	0.301	0.007	0.586
Sitting time (minutes per day)	41 (25 controls, 16 adherents)	0.174	0.004	0.679

[a]A mixed-design two-way repeated measures analysis of variance (ANOVA) per protocol analysis was applied. The assumptions of normality, homoscedasticity and independence of samples were fulfilled in all models.

[b] Those holding a nutrition qualification were excluded from the analysis.

[c] Those on a special diet were excluded from the analysis.

Discussion

The current study found no significant impact of the online quiz-games on nutrition knowledge, diet quality and physical activity between the two groups of the study over time. The outcomes remained non-significant even when engagement rates with the quiz-games were considered. Similar digital interventions among non-clinical populations targeting both physical activity and dietary outcomes showed small positive effects, however, digital interventions targeting diet or exercise alone were found ineffective.[26] With regards to the study population, a RCT that used a structured online intervention to improve fruit and vegetable intake (FVI) and physical activity among US university students found a small but significant increase in daily FVI intake at follow-up, however, no improvements were found in physical activity.[46] These findings are in line with a RCT among Chinese students who also received a structured web-based intervention targeting FVI and physical activity with significant improvements in FVI only[47] suggesting that the structured and focused design of the interventions might have facilitated the positive dietary outcomes. The same study also found that baseline stage of behavioural change, motivational indicators and social support played a significant role in actual behaviour change. This is consistent with an intervention using online quizzes to increase physical activity where only students inactive at baseline significantly increased their physical activity at the end of the intervention and follow-up period.[48] In this current UK-based study, students from both groups did not have very low scores of nutrition knowledge, diet quality and physical activity at baseline. As a result, ceiling effects might have influenced the effect of the intervention on study outcomes.

Among the 50 students in the intervention group, 15 did not play any game and only 35 students played at least one quiz-game. When comparing the frequency of playing a quiz-game with the performance of the same quiz-game (Figure 2), one can assume that

increasing knowledge to collect points was the main motive of students as the most frequent played games (e.g., Activity) had high performance and vice versa (e.g., Salt). As a result, the quiz-games seemed to have promoted surface learning in this study. Surface learning is characterised by accepting new information without processing them as opposed to deep learning which is characterised by critical thinking of the acquired knowledge, connecting to previous knowledge and integration of knowledge into real life.[49-50] The speculation that students memorised the information for a short period of time without processing in depth the learning material is also confirmed by the ROC analysis and the fact that scores decreased when repeating a quiz-game after eight days. These outcomes are in line with other studies that have used the same platform (Kahoot!) to enhance learning of university students.[51-52] The studies found positive changes in the learning outcomes and students reported positive experiences with the platform, indicating the potential to use game-based quizzes as an auxiliary tool to recall a high amount of information in the short term. However, none of the studies assessed the learning outcomes in the long-term or whether and how students used the gained knowledge in practice.

Motivation may also impact adherence to the intervention. Despite evidence suggesting a positive correlation between adherence to digital interventions and improved weight-related outcomes,[53] many studies fail to report adherence data.[26] In this study, adherence was estimated by measuring the number of times games played with those playing at least five games considered as adherents. However, exposure to the website was not measured and adherence might have been underestimated as students who did not play any game could still have increased their knowledge by visiting the website. In addition, none of the students made use of the social feature of competing with each other and all chose to play the quiz-games individually. Competition is important to keep motivation and

engagement high with many studies arguing that gamification contexts need to be enhanced with game-design elements and tailored characteristics to increase their effectiveness.[28] Moreover, the voluntary nature of the intervention and the fact that students who did not play any game still received the financial compensation at the end of the study might also explain the low engagement rates with the quiz-games.

The short duration of the intervention and the lack of follow-up assessment are another study limitations as participants might needed more time to engage with the intervention and process the given information before a measurable impact presents itself. The intention to treat analysis approach used in this study tends to de-emphasise the magnitude of the intervention on outcomes and the use of self-reported questionnaires may have decreased the accuracy of the collected data. Despite the small sample size, an effort was made to recruit participants throughout the academic year to consider seasonal factors that have been found to affect weight-related behaviours of students.[17,20-21] Finally, although positive associations have been found between knowledge and dietary changes[54], dietary, physical activity and sedentary behaviour in university students is affected by a cluster of factors not considered in this study (e.g., social, financial and environmental)[20-21] and therefore, multicomponent interventions may be more appropriate to achieve substantial lifestyle behaviour changes in this population.[55]

Conclusions

Online quiz-games seem to be well-accepted and easy to implement in student populations, however, they might not be sufficient to provide robust changes in knowledge and weight-related behavioural outcomes. Therefore, further investigation is needed to identify the specific gamification features that have the potential to promote dietary and physical activity outcomes. Researchers should further evaluate students'

motivation to change their lifestyle behaviours as well as their motivation to engage with the games to get a better understanding of the characteristics of successful game-based interventions. Adding social and interactive activities (e.g., cooking classes, workshops), adjusting the university environment (cafeterias, gyms) and using game-based learning with social features might be the key elements of successful interventions to improve knowledge and promote healthy weight-related behaviours in university students.

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