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Effect of acute high-intensity interval cycling while viewing a virtual natural scene on mood and eating behavior in men: A randomized pilot trial

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SUMMARY

Background and aim: This study examined the effect of using virtual reality glasses during high-intensity interval exercise (HIIE) on mood and eating behaviour in men.

Methods: Twenty-three healthy young men (age 20.5 ± 1.2 years, BMI 22.1 ± 3.4 kg/m², VO_{2peak} 34.6 ± 6.5 ml/kg/min) participated in the study. Augmented green environment virtual reality while performing HIIE (VR) compared with HIIE (CON) at 90 % VO_{2peak} were performed for 20 min. Mood was assessed using the Subjective Exercise Experiences Scale (SEES), which consists of three domains including positive well-being, psychological distress, and fatigue. Eating behaviour was assessed and included appetite sensations, food preferences, and food intake.

Results: Results showed that there was no significant differences between VR and CON on mood and eating behaviour. The interaction of preference (implicit wanting) for high fat food showed a tendency to increase from pre-post VR compared to CON ($P = 0.052$). A secondary analysis of tertiles of the three domains of SEES showed no interaction effect of VR vs CON on appetite sensations. However, there was a general group effects of psychological distress on desire to eat ($P = 0.049$).

Conclusions: In conclusion, VR-augmented HIIE did not have a differential effect on mood or eating behaviour compared to HIIE alone, except a potential negative impact on fat preference.

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Psychological distress may lead to greater desire to eat during VR-augmented HIIE.

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1. Introduction

High-intensity interval exercise (HIIE) has received attention in recent years as a promising exercise regime with an impact on several health outcomes [1]. HIIE at intensity near to maximal aerobic power has been previously used among obese and non-active individuals [2]. Some studies have suggested that HIIE does not increase post-exercise appetite hormones, energy intake [3], subjective hunger or nutrient preferences. [4] However, exercise intensity has a strong influence on the enjoyment of exercise. For example, subjective pleasure reduced at higher intensities above ventilatory threshold [5]. Thus, examining the effect of HIIE on psychological responses has to be considered when it is incorporated into weight management programs.

Mood state has been shown to affect the tendency to engage in emotional eating [6]. For example, overweight individuals were found to eat relatively more during negative emotional states and situations [7]. High emotional eaters tended to eat more sweet foods after experimentally-induced sadness [8]. Different theories have been used to explain the effect of mood on food choice. A review by Gardner [9] concluded that negative emotion invokes proximal and short-term preferences to palatable foods in order to repair mood, which put more emphasis on taste and sensory experience, whereas positive emotion encourages healthy lifestyle to maintain positive experience in the long-term.

Training outdoors in natural environments is associated with greater engagement and decreases in tension, confusion and anger compared to training indoors [10]. This could be attributed to better self-perceived general and mental health, particularly in green spaces, whereas blue spaces may not have this advantage [11]. Training in green spaces reduced state anxiety, independent of exercise intensity and duration [12]. Different physical activities were examined in green spaces, and all these activities improved self-esteem and reduced total mood disturbance [13].

Virtual reality (VR) has been successfully used in the treatment of addiction, flying phobia and many behavioural psychological conditions such as mild depression, anxiety and food cravings [14–17]. It can be used to examine the relationship between perception and emotion because VR techniques rely on the selection of perceptual stimuli to activate emotions [18]. Using VR, while exercising, decreased ratings of perceived exertion (RPE) and increased enjoyment [19–21]. In addition, VR can be used to enhance healthy eating habits as a treatment tool for supporting behaviour modification goals by strengthening these goals in life-like circumstances [14]. Moreover, VR-induced exercise improves mood and energy, reduces tiredness and enhances enjoyment [22]. Hence, the hypothesis of current study is that manipulations that can improve mood during HIIE may improve control over eating behaviour. Thus, the context of an exercise bout and the scene within the VR environment can differentially affect emotion and eating behaviour. The current hypothesis is speculation, and requires running a pilot trial to investigate the responses of participants into the use of VR glasses because there is no direct evidence yet to support this hypothesis.

Given the increased affordability of VR technology, this can be considered as a promising technology used at home to exercise in continuity with conventional treatment under the supervision of the clinician. It is important to examine whether the use of VR can help to induce positive emotion and reduce stress that individuals might experience during HIIE, and to examine the interactions between emotional state and eating behaviour. This will help exercise training instructors who are considering using this technology as part of weight management programs.

2. Methods

2.1. Participant characteristics

Twenty-three healthy young men (age 20.5 ± 1.2 years, BMI 22.1 ± 3.4 kg/m²) were recruited from '[removed for blind peer review]' through announcement in student's advertisement boards and website and from '[removed for blind peer review]' City through announcement in social media. Exclusion criteria included diabetes, hypertension or any other health complications, injuries, vestibular and balance disorders. All participants had a familiarization session using VR viewing different video from the experiment, and participants who did not feel comfortable with using VR were excluded. The Dutch Eating Behaviour Questionnaire (DEBQ) was used to exclude restrained eaters, and this measurement has been validated and gained a good reliability in measuring the emotional and external components of eating behaviour [23].

2.2. Study design

The experiment was set at the Exercise Physiology Laboratories at the '[removed for blind peer review]'. The laboratory is air-conditioned with the temperature held constant at 21 °C.

The current study was a cross-over randomized pilot trial, where all participants underwent the two exercise bouts of the experiment. The study procedure consisted of three exercise tests, the first exercise test was a maximal exercise graded test to determine the intensity of exercise sessions, and two exercise tests were 20-min HIIE with and without VR in counterbalanced order.

All participants were instructed to arrive at the laboratory, between 8 am and 11 am, following an overnight fast. Upon their arrival, height and weight were measured. Participants were asked to maintain their normal dietary intake between tests, and were asked to abstain from strenuous exercise and the consumption of caffeine in the previous 24 h [24]. All participants signed informed consent forms before the participation. Study design was approved by Ethics Committee at '[removed for blind peer review]'.

2.3. Data management of study measures

2.3.1. Exercise tests

2.3.1.1. HIIE intensity determination. The test started at 40 W for 2 min on cycling ergometer (Lode, Germany), and incremental loads was 20 W for 2 min each stage, until participants reached maximal volitional aerobic capacity (VO_{2peak}). Automated gas exchange was collected and analysed throughout the test using Parvo Medics Analyser (TrueOne®2400, Metabolic Measurement System, Parvo Medics Inc., USA). The workload at 90 % VO_{2peak} was determined as the workload of HIIE bouts.

2.3.1.2. HIIE bouts. 20-min HIIE control bout, without VR (CON).

The exercise test consisted of 30 s cycling at 90 % VO_{2max} followed by 30 s passive interval rests, for 20 min, without using VR (CON).

20-min HIIE experimental bout, with augmented green environment VR while cycling (VR).

The exercise test consisted of 30 s cycling at 90% VO_{2peak} followed by 30 s passive interval rests, for 20 min, with natural view (VR).

The VR scene was a view of a natural green environment while cycling, which was selected from YouTube website based on the best natural green view and the best quality of resolution. This video was montaged using Vegas Pro 12.0 (MAGIX Software GmbH, MAGIX Computer Products International Co., NV, USA). Camtasia Studio 8.0 (TechSmith Corporation, Michigan, USA) was used to manipulate the sound which was varied between 30-s high beat music and 30-s slow music to match the interspersing effort and rest during interval exercise. Samsung Gear VR Oculus and Galaxy smartphone were used to

view the video during exercise. Participants were allowed to remove the VR glasses at the middle of exercise bouts for 30 s to avoid cyber sickness.

2.3.2. Mood test: subjective exercise experience scale (SEES)

Subjective Exercise Experiences Scale (SEES) is a psychological scale that was developed based on 3 factors including positive well-being, psychological distress and fatigue, and consisted of 12 questions [25].

SEES was provided pre and post exercise bouts of HIIE, and differences between VR and CON were analysed to examine the effect of HIIE on mood.

2.3.3. Eating behaviour tests

2.3.3.1. *Subjective appetite using visual analogue scale (VAS)*. Subjective appetite sensations including hunger, desire to eat and fullness were measured using a paper-based VAS in pre- and post-exercise bouts, which has been previously proved to assess motivation to eat in human [26]. Scoring data followed the same procedure of the original instrument using the measure by millimetre (mm) to indicate participants' responses.

2.3.3.2. *Food preferences using leeds food preferences questionnaire (LFPQ)*. The Leeds Food Preferences Questionnaire (LFPQ) is a computer-based paradigm using the E-Prime experiment generator. The procedure uses 16 photographic food stimuli chosen to vary along two major dimensions: fat (high or low) and taste (sweet or non-sweet), such that there were four categories including high-fat sweet, high-fat non-sweet, low-fat sweet and low-fat non-sweet.

The Arab-version of the LFPQ was translated and validated among Arab men, and the procedure of examining explicit liking, explicit wanting, and implicit wanting followed the original procedure as explained elsewhere [27].

2.3.3.3. *Food intake*. After completing all post-exercise eating behaviour tests, an ad libitum test meal was provided. The test meal consisted of 750 g (\approx 1800 kcal) of cheese and tuna pies, 200 ml (120 kcal) fruit juice and 300 mL water. The test meal was fixed at the same amount for all participants. Participants were instructed to freely consume as much as they wanted of the meal.

2.3.3.4. *Secondary analysis: moderation of mood on appetite sensations*. Post-exercise SEES was subtracted from pre-exercise SEES during VR condition (Δ SEES). Participants were ranked from the highest to the lowest according to each domain of SEES (positive well-being, psychological distress, and fatigue), and were sub-grouped to 3 tertiles (Group 1 included 8 participants of the top tertile, group 2 included 8 participants of the middle tertile, and group 3 included 7 participants of the bottom tertile).

2.4. Statistical analysis

Data were analysed using Statistical Package of the Social Science (SPSS Inc., IBM Corporation, version 21, New York, USA). Continuous data were presented as mean \pm standard deviation (SD) & standard error of the mean (SEM). All continuous variables were checked for normality using Kolmogorov–Smirnov test, if not normal then Non Gaussian variable transform to log transform. Pair t test were used to check mean difference between pre & post in Gaussian variables, and Wilcoxon tests were used for non-Gaussian variables even it transform but again it is not normal. Univariate and repeated measurement analysis was applied to check the group (VR & CON), time (Pre & Post) effects and interaction effects for appetite sensations, LFPQ and the three domains of SEES. The same analysis was used to examine the group and time effects and interaction effect of different tertiles of SEES on appetite sensations. P value < 0.05 was considered statistically significant.

Power calculation using α level of 0.05 and power of 0.8 from previous studies showed that 16 and 20 participants were required to reach significant differences in food intake and food preferences respectively between medium-term high and moderate intensity concentric exercise intervention [28].

3. Results

Descriptive data included HR_{max} (181 ± 12 beats/min), VO_{2peak} (34.6 ± 6.5 ml/kg/min), and 90 % VO_{2peak} (31.2 ± 5.9 ml/kg/min). Mean scores for restrained, external and emotional eating were 2.4 ± 0.8 , 2.7 ± 0.6 and 2.2 ± 0.6 respectively, which demonstrated that participants were healthy and did not have any eating disorder.

Heart rate were respectively 73 ± 9 , 139 ± 13 , 148 ± 15 , 151 ± 15 and 155 ± 15 beats/min at rest, minute 5, 10, 15 and at the end of exercise. It significantly increased with time ($P = 0.001$), with no significant differences between VR and CON ($P = 0.78$).

The examination of the effect of HIIE on mood showed that there were no significant differences between CON and VR in the three domains of the scale (positive well-being, psychological distress, and fatigue) (Table 1).

There were no significant differences in liking and wanting variables between VR and CON, except the boarder significant effect in the interaction of condition * fat * time ($F = 4.24$, $P = 0.052$). Implicit wanting for HF increases from pre-post exercise during VR condition; and decreases from pre-post exercise during CON condition (Table 2).

There were no significant group and time effects on appetite sensations, except for hunger ($P = 0.04$) which increased in the post-exercise (Table 2), and the interaction effect for appetite sensations were not significant.

Further, there was no significant difference between CON (1078.3 ± 603.9 kcal) and VR (1044.3 ± 494.1 kcal) in the post-exercise food intake ($F = 0.06$, $P = 0.8$).

The analysis of the moderation of mood on appetite sensations is shown in Table 3. There were no interaction effects on appetite sensations. Group effects of positive well-being on hunger was $P = 0.09$, and for fatigue on satisfactory was $P = 0.054$, and for psychological distress on desire to eat was statistically significant ($P = 0.049$).

4. Discussion

VR is a newly advanced technique that helps to imitate different scenarios and change behaviours. While a natural environment scene has been proposed to induce positive emotion, the hypothesis of

Table 1

Subjective Exercise Experience Scale (SEES) responses during HIIE with and without augmented green environment Virtual Reality (VR) ($n = 23$).

SEES	condition	Pre-exercise	Post-exercise	Mean Diff (95%CI)	P value
		Mean \pm SEM	Mean \pm SEM		
Positive Well Being	VR	5.36 ± 0.27	4.68 ± 0.37	0.69 (-0.10–1.5)	0.079
	CON	5.16 ± 0.23	4.65 ± 0.31		
Group effect				<0.001	
Group*time effect				0.903	
Psychological Distress	VR	1.95 ± 0.15	2.05 ± 0.26	-0.26 (-0.84–0.32)	0.363
	CON	1.80 ± 0.23	1.95 ± 0.28		
Group effect				<0.001	
Group*time effect				0.944	
Fatigue	VR	2.27 ± 0.24	3.82 ± 0.34	-1.54 (-2.38–-0.71)	0.001
	CON	2.27 ± 0.29	3.48 ± 0.36		
Group effect				0.003	
Group*time effect				0.505	

VR: exercise bout while using virtual reality glasses; CON: exercise bout without using virtual reality glasses. P value < 0.05 was considered statistically significant.

Table 2

Responses of appetite sensations and food preferences (implicit wanting) in pre- and post-HIIE bouts during VR and CON (n = 23).

Variable	Treatment	Pre	Post	Mean Diff (95%CI)	P value
		Mean ± SEM	Mean ± SEM		
Hunger	VR	53.6 ± 5.7	71.4 ± 5.0	-6.3 (-17.7–5.1)	0.264
	CON	66.4 ± 3.9	72.7 ± 5.4		
Group effect				0.010	
Group*time effect				0.205	
Satisfactory	VR	25.5 ± 4.2	24.5 ± 4.8	1.0 (-8.5–10.5)	0.829
	CON	24.9 ± 3.4	26.1 ± 5.6		
Group effect				0.975	
Group*time effect				0.753	
Fullness	VR	20.2 ± 3.9	20.2 ± 3.4	0.09 (-9.6–9.8)	0.985
	CON	19.8 ± 3.7	15.8 ± 3.1		
Group effect				0.474	
Group*time effect				0.434	
Desired to eat	VR	66.7 ± 5.3	69.2 ± 5.7	-2.5 (-18.6–13.6)	0.753
	CON	70.7 ± 4.3	66.6 ± 4.7		
Group effect				0.495	
Group*time effect				0.513	
Implicit wanting of high fat food	VR	5.5 ± 4.1	14.1 ± 6.1	-8.6 (-23.3–6.1)	0.238
	CON	8.8 ± 4.5	2.1 ± 5.1		
Group effect				0.322	
Group*time effect				0.052	

VR: exercise bout while using virtual reality glasses; CON: exercise bout without using virtual reality glasses. P value < 0.05 was considered statistically significant.

current study is that the impact of VR-augmented cycling on emotion could influence post-exercise appetite and food choice. Our current data showed no significant differences between VR and CON condition on mood, and there was a negative effect of VR-augmented HIIE on the preference of high fat food stimuli, although the effect of VR alone on food preferences is unknown and has not been examined. The secondary analysis showed that psychological distress might be the trigger of increased desire to eat when using VR. This secondary analysis of mood on eating behaviour has some limitations due to subgroup sample size, and further studies in this topic are warranted.

The preference to high fat food stimuli increased after VR-augmented HIIE. It was reported that using VR alone increased tension, tiredness and lower energy level, but it reduced tiredness and enhanced enjoyment when it was paired with moderate-intensity cycling session [22]. It was recommended that VR condition showed better than the imagination condition in terms of decreasing of emotional eating for women as a part of reducing weight and obesity [29]. However, the exposure to real food enhances food craving to greater extent than VR food image stimuli, and the later enhances food craving to a greater extent than neutral cues [30]. The mechanism of food craving could partially be attributed to emotion. It was reported that when women with food addiction was exposed to an emotional video that increases sad mood they increased their attention to unhealthy food images compared to healthy and non-food images [31]. The association between emotional eating and the preferences of sweet fatty food was reported in most categories studied in a large web-based study [32]. Different scenarios of projected VR food stimuli were displayed for healthy women, and BMI and eating disorder did not associate with food craving [33]. Apparently, the responses of individuals to emotion can determine the degree of appetitive responses [34].

While food exposure can enhance food craving, with different degree between real food and food image stimuli, it is unclear whether VR natural green stimuli can trigger/suppress food craving. Natural green scene increases relaxation, enjoyment and positive emotion. Most previous studies examined outdoor training in a natural green environment, which have multifactorial effects that enhance mental health and positive mood (e.g. [35–38]). The effects of colours (green, red, gray) on mood while indoor cycling were examined using projected video footage. Although lower total mood disturbance and ratings of perceived exertion were found during green-coloured natural view, there were no differences between colours in feeling of tension, depression, fatigue, vigour and confusion [39]. Thus, the

Table 3
Effect of subgroup tertiles of SEES domains on appetite sensations during VR-augmented HIIE (n = 23).

Parameters	Positive Well being			Psychological Distress			Fatigue		
	Pre	Post	Mean Chang (95% CI)	Pre	Post	Mean Chang (95% CI)	Pre	Post	Mean Chang (95% CI)
VR									
Hunger	63.3 ± 11.2	61.3 ± 11.9	2.0 (-37.4–41.4)	46.6 ± 10.2	67.0 ± 10.3	-20.4(-52.7–11)	50.3 ± 9.4	80.0 ± 4.9	-29.8(-49–10)**
	52.3 ± 6.3	71.1 ± 4.7	-19 (-29–7.6) **	61.8 ± 9.0	73.9 ± 8.2	-12.1(-33.5–9.3)	51.1 ± 9.5	61.4 ± 8.0	-10.3(-31.7–11)
	44.0 ± 11.9	83.4 ± 6.7	-39 (-57–21.1)**	52.1 ± 11.1	73.7 ± 8.1	-21.6(-59.4–16)	60.1 ± 12.1	73.1 ± 12.4	-13 (-59.9–33.9)
Con									
	77.4 ± 5.3	0.3 ± 9.8	7.1 (-16–30.3)	67.0 ± 5.3	76.9 ± 9.7	-9.9(-34.7–14.9)	60.4 ± 6.5	69.1 ± 34.3	-8.9(-31.7–14.2)
	57.9 ± 4.7	69.6 ± 9.2	-11.8 (-34.7–11.2)	64.0 ± 8.1	67.3 ± 9.4	-3.3(-12.1–5.6)	65.9 ± 6.8	77.0 ± 6.1	-11.1(-27.7–5.5)
	63.6 ± 8.8	79.0 ± 9.9	-15.4 (-33.7–2.8)	68.4 ± 7.5	74.1 ± 9.8	-5.7(-39.8–28.4)	73.9 ± 6.9	71.9 ± 9.9	2.0 (-28.5–32.5)
Group Effect		0.09			0.91			0.78	
Group*time effect		0.69			0.78			0.36	
Satisfactory									
	13.6 ± 6.6	18.3 ± 9.9	-4.6(-28.6–19.4)	34.8 ± 8.5	36.8 ± 10.2	-2 (-29.6–25.7)	29.3 ± 6.4	28.6 ± 7.5	0.6 (-10.5–11.7)
	34.9 ± 8.2	32.4 ± 6.1	2.5 (-9.7–14.7)	17.1 ± 4.4	20.5 ± 7.6	-3.4(-16.4–9.7)	32.6 ± 8.2	26.0 ± 8.4	6.6 (-12.9–26.2)
	28.4 ± 5.4	22.7 ± 9.4	5.7 (-14.6–24.0)	24.6 ± 8.5	15.1 ± 5.5	9.4 (-1.2–20.1)	13.1 ± 6.4	18.1 ± 10.6	-5.0 (-31.7–21.7)
	24.0 ± 6.8	27.8 ± 12.7	-3.7(-31–23.5)	21.5 ± 5.9	27.5 ± 10.3	-6(-35–23)	21.4 ± 6.5	25.8 ± 22.3	-4.4(-18.9–10.2)
	33.5 ± 4.7	29.6 ± 6.0	3.9(-7.1–14.9)	23.8 ± 6.2	19.3 ± 7.6	4.5(-6–14)	30.1 ± 5.0	12.5 ± 5.0	17.6 (8.7–26.5)**
	16.1 ± 5.4	20.3 ± 10.9	-4.1(-31.5–23.2)	30.1 ± 6.5	32.4 ± 12.5	-2.3(-25–21.4)	23.0 ± 18.5	42.1 ± 14.1	-19.1(-10.5–11.7)
Group Effect		0.91			0.57			0.054	
Group*time effect		0.92			0.51			0.21	
Fullness									
	13.0 ± 7.1	15.6 ± 6.9	-2.6(-23.9–18)	26.5 ± 8.1	19.9 ± 5.6	6.6 (-7.9–21.2)	21.9 ± 7.3	19.8 ± 4.1	2.0(-11–15.2)
	29.3 ± 7.8	25.8 ± 4.4	3.4(-11.3–18.7)	10.6 ± 3.3	21.0 ± 6.5	-10.4 (-25–5.2)	28.6 ± 21.5	24.4 ± 6.9	4.3 (-20.3–28.8)
	18.4 ± 5.0	19.0 ± 7.0	-0.6 (-25–23.9)	24.3 ± 8.4	19.7 ± 7.1	4.6 (-22.6–31.7)	9.0 ± 4.1	15.9 ± 7.6	-6.9 (-27.1–13.3)
	12.1 ± 3.6	13.1 ± 5.1	-1.0(-13–11.2)	20.4 ± 7.9	10.4 ± 4.4	10 (-7.5–27.5)	18.9 ± 7.4	17.3 ± 5.6	1.6 (-17–20.2)
	29.4 ± 6.9	24.5 ± 5.4	4.9(-7.4–17.1)	19.6 ± 18.1	18.6 ± 6.1	1.0 (-9.4–11.4)	19.1 ± 5.9	11.4 ± 4.4	7.8 (-1.4–16.9)
	17.8 ± 7.7	9.1 ± 4.4	8.7(-13.3–30.7)	19.5 ± 5.7	19.0 ± 5.7	0.6 (-16.9–18.1)	21.9 ± 7.2	19.4 ± 6.6	2.4 (-15.4–20.2)
Group Effect		0.33			0.39			0.39	
Group*time effect		0.72			0.75			0.63	
Desired to eat									
	63.5 ± 11.1	63.4 ± 11.9	0.01 (-38.6–38.6)	64.6 ± 10.9	66.0 ± 11.6	-1.4 (-49.8–27)	74.5 ± 9.0	74.3 ± 11.3	0.3 (-35.5–36)
	70.1 ± 7.9	77.8 ± 4.9	-7.8(-19.4–3.9)	69.4 ± 6.9	65.4 ± 10.6	4 (-18.4–26.4)	62.4 ± 23.5	61.5 ± 9.7	0.9 (-24.6–26.4)
	66.6 ± 10.4	65.9 ± 12.9	0.7 (-43.9–45.4)	66.1 ± 11.6	77.3 ± 7.9	-11 (-49.8–27.6)	62.9 ± 11.9	72.3 ± 9.8	-9.4 (-48.7–29.8)
	81.4 ± 7.7	65.8 ± 7.9	15.6 (-0.9–32.1)	73.9 ± 5.3	67.6 ± 8.7	6.3(-12–24.5)	65.4 ± 8.3	65.6 ± 10.3	0.13(-17.7–17.9)
	65.4 ± 4.5	61.0 ± 7.9	4.4 (-12.3–21.1)	60.8 ± 8.8	60.9 ± 9.6	-0.2(-12.2–11.9)	72.1 ± 7.1	66.3 ± 8.3	5.9 (-16.2–27.9)
	64.9 ± 9.3	74.0 ± 10.1	-9.1 (-23.7–5.4)	78.7 ± 7.4	72.0 ± 7.2	6.7 (-17.9–31.4)	75.0 ± 7.9	68.1 ± 7.1	6.9 (-5.1–18.9)
Group Effect		0.67			0.049			0.79	
Group*time effect		0.45			0.62			0.86	

Data represented Mean ± SE; VR: exercise bout while using virtual reality glasses; CON: exercise bout without using virtual reality glasses; * & ** significance at P-value 0.05 & 0.01 level for pre and post exercise.

simulation of natural green project VR on mood might be different from outdoor natural environment, which may have lower impact on eating behaviour and food preferences.

The secondary analysis of current study showed that psychological distress has an effect on desire to eat, with a tendency of increase while using VR although this was not observed in all subgroup tertiles and there was no significant interaction between group and time effect. The current finding is in agreement with the hypothesis that negative emotion leads to increased food intake and/or desire to eat. It was previously suggested that poor responses of typical reduction of hunger and high inhibitory control can moderate distress-induced food intake [40]. On the other hand, positive and negative emotion may associate with eating behaviour and increase food intake in different pathways [41–45]. For example, Bongers et al. [46] found that emotional eaters increased food intake after four different conditions including neutral, negative and positive mood manipulation, which means each condition has different food-signalling cue, and emotional eating does not explain all change in eating behaviour. A recent meta-analysis suggested that negative mood is associated with increased food intake in clinical patients, whereas positive mood is associated with increased food intake in the general population [47], and undereating during negative emotions may contribute to low body weight [7]. In conclusion, our current study found an effect of negative emotion on desire to eat, with a tendency of increase while during VR-augmented HIIE.

Some limitations should be reported in the current study. For example, this study only examined a specific view of a natural green environment while cycling, and a specific HIIT protocol. Support technologies associated with virtual reality can help to generate synthetic environments in which users can navigate as if they were in real life, thus ensuring a high sense of perceived control on the environment itself [14]. Participants' heads, eyes, body movements can be recorded while they are performed, which allows the tracking of participants' behaviour during the execution of even complex tasks. This, unfortunately, was not included in the current study. Moreover, it is hard to capture and reproduce discrete single emotions in a non-natural environment, such as the laboratory. Individuals' responses into different emotional stimuli are mediated by different signalling cues, and the strength of signalling cues of the current study was not examined. Lastly, our secondary analysis of the moderation of mood on eating behaviour should be interpreted with caution due to small sample size in each subgroup. In fact, the majority of acute exercise studies have been limited to a single gender [23] or are of insufficient cohort size [48].

5. Conclusions

The current experiment of augmented green environment VR while performing HIIE either does not have an effect on mood and eating behaviour or may have a negative impact on food preference, and psychological distress intuitively were the trigger of desire to eat during VR-augmented HIIE. There is a need for a progressive studies leading to new technologies and potentially effective products in addition to study that offers a place for well-designed significant investigations of new interferences [49]. Thus, further research need to examine the psychological effects of exercise that might be improved when paired with VR.

Authorship declaration

All authors contributed to the study design. Assel Eisa and Jawad Gannas collected the data and contributed in data acquisition. Shaea Alkahtani supervised statistical analysis and wrote the first draft of manuscript. Ghalia Shamlan wrote and revised some sections of the manuscript. All authors approved the final draft, and are in agreement with the manuscript and declare that the content has not been published elsewhere.

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Ethics committee

Study design was approved by the Standing Committee for Research Ethics on Living Creatures at King Saud University (KSU-SE-17-1).

Conflicts of interest

Authors declare no conflicts of interest.

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