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Running head: INFORMATION ON ENERGY EXPENDED DURING EXERCISE AFFECTS SUBSEQUENT ENERGY INTAKE

Licence to eat: Information on energy expended during exercise affects subsequent energy intake

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Abstract

An acute bout of exercise, compared with no exercise, appears to have little influence on subsequent energy intake (EI), resulting in short-term negative energy balance. Whereas the labelling of food is evidenced to influence EI, little research has focused on how EI is affected by framing acute exercise in different ways. To explore this, 70 healthy, mostly lean, male and female participants in the current study completed a set amount of exercise (estimated energy expenditure (EE) 120 kcal), but were informed on three occasions before and after the exercise that they had expended either 50 kcal or 265 kcal. An *ad libitum* test meal, comprising orange juice, tortilla chips and chocolate chip cookies, was then presented after a 10-minute break to assess subsequent EI. Measures of hunger and dietary restraint were also completed. Greater EI, primarily driven by chocolate chip cookie consumption ($p=.015$), was observed in participants receiving 265 kcal EE information. Hunger ratings were significantly lower in the 265 kcal EE information group than in the 50 kcal group following the test meal ($p=.035$), but not immediately after the exercise. These results support an interpretation that higher EE information (265 kcal) provides participants with a greater 'license to eat' when palatable foods are accessible. Tentative evidence for a moderating effect of dietary restraint was observed, indicating a greater influence of EE information in participants with lower restraint. The findings of the current study suggest that the provision of EE information (e.g., through mobile device apps) could be counter-productive to healthy weight management.

Key words: Appetite; Energy balance; Exercise; Compensation

1. Introduction

Physical activity has been suggested to influence weight by altering the balance between energy expenditure (EE) and energy intake (EI) (Martins, Morgan, & Truby, 2008). In this context, it is significant that the effects of an acute bout of exercise on subsequent EI and appetite are variable, but on average very small (Schubert, Desbrow, Sabapathy, & Leveritt, 2013). A greater understanding of this relationship is therefore important due to its implications for weight control (King, Hopkins, Caudwell, Stubbs, & Blundell, 2008).

A recent meta-analysis concluded that acute exercise has a trivial effect on absolute EI (Schubert et al., 2013). The reason for this is contended to be that the energy expended in acute exercise is trivial compared with the total energy stored in the body (Rogers & Brunstrom, 2016). A negative energy balance is induced due to this lack of compensation, and reflects a lower EI relative to the expenditure. However, Schubert and colleagues' conclusion masks considerable variability in the research findings. One review indicated that 65% of studies reported no change in EI following exercise, whereas 16% observed a reduction and 19% an increase (Blundell & King, 1999). This variability may be partly due to differences between studies, such as gender, exercise intensity and macronutrient composition of the test foods (Martins et al., 2008).

Research suggests the relationship between EE and EI is influenced by dietary restraint (Hawks, Madanat, & Christley, 2008a). Overall, evidence indicates that high dietary restraint is associated with a larger negative energy balance following acute exercise (King et al., 2012; Lluch, King, & Blundell, 2000). This larger effect may occur due to exercise assisting restrained individuals in controlling their eating behaviour (King, 1999). According to the goal conflict model of eating, restrained eating behaviour is determined by two opposing goals, eating enjoyment and weight control (Stroebe, Mensink, Aarts, Schut, & Kruglanski, 2008; Stroebe, van Koningsbruggen, Papies, & Aarts, 2013). The more active goal is argued to inhibit the other, and consequently exerts greater influence over eating behaviour. For example, if the eating enjoyment goal is more active, a restrained eater may violate their

weight control goal and overeat. Goals are proposed to become more or less active when primed by relevant cues (e.g., eating enjoyment activated by palatable foods). Therefore, cues that prime weight control should inhibit eating enjoyment. This could explain the large negative balance observed in restrained individuals following exercise, which may prime the weight control goal.

This proposed priming effect reflects how external stimuli can influence EI (Martins et al., 2008). Research has indicated that the way in which food is labelled or framed can influence intake. For example, higher EI has been reported for foods labelled as 'low-fat' and 'fitness' (Koenigstorfer, Groeppel-Klein, Kettenbaum, & Klicker, 2013; Wansink & Chandon, 2006). Exercise-related primes (e.g., posters, videos) have also been indicated to influence subsequent EI, although the direction of this effect is ambiguous. Specifically, EI has been shown to both increase (Albarracin, Wang, & Leeper, 2009) and decrease (Stein, Greathouse, & Otto, 2016; van Kleef, Shimizu, & Wansink, 2011) following exercise-related primes. Furthermore, individual differences are suggested to play an important role in this effect (e.g., self-reported exercise levels) (Stein et al., 2016).

Dietary restraint is also argued to influence how susceptible consumers are to the way in which a food is presented (i.e., labelled). For example, restrained participants have been found to consume more at a subsequent meal when a drink was described as having a high energy content, despite containing the same energy as a comparison (Mills & Palandra, 2008; Polivy, 1976). This pattern of eating is referred to as 'counter-regulatory eating' and is argued to occur once a restrained eater's dietary goal is violated (Herman & Polivy, 1984). In the example above, restrained eaters may have evaluated their weight control goal to have been violated due to the drink's high energy content label. As a result of having already violated this goal, it is suggested that the restrained eaters had less reason to further control their EI, and therefore they overate.

The aim of the current study is to draw together the previously detailed research which investigated two factors that are argued to influence subsequent EI – i.e., an acute bout of

exercise, and labelling. Specifically, the current study aims to explore whether the way in which exercise is framed influences subsequent EI. Two recent studies have investigated this by framing exercise in qualitatively distinct ways (Fenzl, Bartsch, & Koenigstorfer, 2014; Werle, Wansink, & Payne, 2014). Participants in Werle and colleagues' study consumed less dessert and fewer hedonic snacks when a walk was framed as fun rather than exercise. This was interpreted as participants having a reduced need to compensate after the fun walk, due to experiencing greater enjoyment. In Fenzl and colleagues' study, cycling framed as 'fat-burning' – rather than 'endurance' – was associated with an increase in subsequent EI in participants who exercised due to externally imposed self-regulation. Associations of 'fat-burning' with greater EE were argued to give these participants a greater license to eat. These two studies provide evidence that the connotations evoked from the way exercise is framed can influence compensatory eating behaviour.

The current study aims to develop the findings of these studies and to explore whether quantitatively distinct, but qualitatively comparable labels influence subsequent EI. Due to the ubiquity of wearable devices that estimate calorie-expenditure during exercise, the effect of this information on subsequent EI warrants investigation. In order to explore the effect of this labelling, all participants completed an acute bout of cycling until the same calorimetric target was reached (estimated EE 120 kcal). However, they were informed as having expended either 50 kcal or 265 kcal. Therefore, both labels represent EE, but of different quantities. The influence of these EE information labels on hunger ratings and subsequent EI was then assessed. Based on Fenzl and colleagues' findings, it was predicted that participants would have greater subsequent EI in the 265 kcal condition – which represented higher EE – compared with the 50 kcal condition.

The moderation by dietary restraint in the relationship between EE information and EI was also investigated. From the perspective of the goal conflict model of eating (Stroebe et al., 2013), completing any amount of exercise could be conceptualised as assisting restrained eaters by priming their weight control goal (and inhibiting eating enjoyment). This could explain

the aforementioned findings that higher restraint is associated with a greater negative energy balance following acute exercise (King et al., 2012; Lluch et al., 2000). As such, it was predicted that restrained participants would not differ between the EE information conditions (50 kcal, 265 kcal). In contrast, less restrained participants were predicted to have higher subsequent EI in the 265 kcal EE information condition, in line with the findings of the previous exercise-labelling research.

2. Methods

2.1. Participants

Seventy healthy, mostly lean people (24 male, 46 female) participated in the study. Inclusion criteria were 18 to 65 years old, non-smoker or light smoker (≤ 5 cigarettes a day), no history of eating disorders, no food allergies or intolerances, not vegan, not taking drugs which may influence appetite (except oral contraceptives), and willing and able to complete 15-25 minutes of cycling. Ethical approval was obtained from the University of Bristol's Faculty of Science Human Research Ethics Committee. Participants provided informed, written consent and were reimbursed £10 for their time and expenses.

2.2. Experimental design and sample size

2.2.1. Experimental design. The experiment was a single-blind, between-subjects design, with EE information for an acute bout of exercise as the experimental manipulation (50 kcal, 265 kcal). Dependent variables included *ad libitum* EI for the three test items (orange juice, tortilla chips, chocolate chip cookies), and self-rated measures of hunger. Dietary restraint and other participant characteristics (e.g., gender, BMI) were also assessed. The research was presented as an investigation into *The Effects of Exercise on Taste Perception and Food Reward*. Randomisation to experimental conditions (50 kcal, 265 kcal) occurred on the test day in a 1:1 ratio using stratification by experimenter (DM, LH), gender (male, female) and test session time (08:30, 10:00, 17:30).

2.2.2. Sample size calculation. The sample size calculation was based on unpublished data (L.A. Kyle). In this study, a preload energy content difference of 200 kcal resulted in a 162 kcal ($SD=196$) mean difference in *ad libitum* EI between conditions, which represented a large effect size ($d=.83$). As the current study's manipulation involved information rather than actual manipulation of energy density, a lower expected mean difference in EI (100 kcal) was used to calculate sample size. This indicated that 32 participants were required in each condition

($N=64$) to have 82% power at $p=.05$ (2-tailed). 6 additional participants were tested ($N=70$) as they had already registered for the study.

2.3. Materials

2.3.1. EE information manipulation. Participants completed an acute bout of exercise on a stationary indoor cycle (Duke H925, BH: Staffordshire, United Kingdom). Calorimetric feedback, exercise duration and revolutions-per-minute were monitored by the experimenter from behind a screen, with participants receiving no specific feedback about these during the experiment. The exercise was standardised between participants by keeping the resistance of the bike the same for all participants. The resistance load corresponded to a mild to moderate level of intensity, so that all participants were able to complete the bout of exercise. Participants were also asked to maintain a speed between 60 and 90 revolutions-per-minute, which the experimenter asked them to adjust accordingly. Due to the target range of revolutions-per-minute, the duration of the exercise was able to vary, lasting no longer than 15 minutes.

The experimenter asked all participants to continue cycling until the same calorimetric target of 120 kcal was reached. Although all participants were instructed to stop cycling after the calorimetric target had been reached, they were provided with different EE information depending on their condition allocation – either 50 kcal or 265 kcal. Participants were provided with this information at 3 points: 1) before exercising, when asked to cycle until either 50 kcal or 265 kcal had been expended, 2) when the calorimetric target had been reached (120 kcal for all participants), 3) when presented with a paper response booklet with the EE information visible on the front. The information on the front of the booklet included an extra 3 kcal – i.e., 53 kcal or 268 kcal – to reflect energy expended while gradually stopping the bike. To account for differences between participants in calorie-literacy, at point 2) the experimenter casually approximated the EE information in Kit-Kat fingers (Nestle: York, United Kingdom) – i.e., 1 or

5 Kit-Kat fingers in the 50 kcal and 265 kcal conditions, respectively. Kit-Kat was selected due to it being an internationally recognisable product.

The 215 kcal difference between conditions was based on the manipulation used in the previously mentioned unpublished data (L.A. Kyle). In Kyle's study, the preload energy content differed by 200 kcal between conditions and a 162 kcal ($SD=196$) mean difference in EI was indicated at a subsequent meal. This current study increased the 200 kcal difference to 215 kcal to represent an EE difference equivalent to 4 Kit-Kat fingers.

2.3.2. *Ad libitum* test meal. *Ad libitum* EI was assessed by presenting participants with orange juice, tortilla chips and chocolate chip cookies (Sainsbury's Basics range, Sainsbury's Supermarkets Ltd.: London, United Kingdom). After tasting each item, participants rated their liking, desire to eat or drink, and enjoyment for each of the test items on 100mm visual analogue scales. Participants then had 15 minutes in which they could consume the remaining test meal items *ad libitum*. The weight and energy content for the test meal portions are provided in Table 1. Large portion sizes were selected to avoid consumption of all of an item. Items were reweighed afterwards to calculate the amounts consumed. Two 250-gram glasses of water were also provided during the experiment, one when participants arrived and the other during the test meal. Participants were free to drink water whenever they desired.

Table 1

Test meal item portions.

Test meal item	Amount (g)	Energy density (kcal/100g)	Energy per portion (kcal)
Orange juice	450	40	189
Tortilla chips	200	480	960
Chocolate chip cookies	250	493	1233

2.3.3. *Dutch Eating Behaviour Questionnaire* (van Strien, Frijters, Bergers, & Defares, 1986). Participants completed the Dutch Eating Behaviour Questionnaire (DEBQ) sub-scale of restraint (10 items). Each item required participants to rate their agreement with a statement

from 1 ('never') to 5 ('very often'). Reliability of the restraint sub-scale was excellent (Cronbach's $\alpha = .91$).

2.3.4. Appetite and mood ratings. Participants rated their current hunger, fullness and other aspects of appetite and mood on 100 mm visual analogue scales at four points during the experiment. Each set comprised 24 items (single or groups of descriptors – e.g., 'I feel HUNGRY', 'I feel TENSE/ANXIOUS/NERVOUS/ON EDGE').

2.4. Procedure

Participants attended a single test session at the University of Bristol's Nutrition and Behaviour Unit laboratories. The session lasted approximately 90 minutes and began at 08:30 a.m., 10:00 a.m. or 17:30 p.m.

Before attending a session, participants completed an online questionnaire in which they reported their gender and age, and completed the DEBQ-restraint sub-scale. Participants also indicated willingness to abstain from consuming calorie-containing foods and drinks in the 3 hours before their test session to standardise hunger levels.

On arrival, participants were asked to give informed consent and completed baseline appetite and mood ratings. They then completed an acute bout of exercise, as detailed above. Immediately after the exercise, participants completed the second appetite and mood ratings, rested for 10 minutes, then completed the third appetite and mood ratings. Following this, participants were presented with the *ad libitum* test meal. Participants then completed the fourth appetite and mood ratings, indicated their beliefs about the purpose of the experiment, and their height and weight was measured. At the end of experiment participants were asked to provide final written consent.

Participants were fully debriefed by email about the purpose of the experiment after all data had been collected.

2.5. Data Analysis

EI values for each test meal item (overall, orange juice, tortilla chips, chocolate chip cookies) were analysed with between-subjects ANCOVAs to investigate the effects of EE information (50 kcal, 265 kcal) and gender (female, male) on EI. EE information and gender were entered as between-subject factors, and baseline hunger (i.e., hunger measured before exercise) as a covariate. Gender was included due to evidence of variability in EI between males and females (Martins et al., 2008).

PROCESS for SPSS (Hayes, 2014) was used to explore whether the relationship between EE information and EI was moderated by restraint for each test meal item. Test meal items were entered separately as outcome variables, with EE information (50 kcal, 265 kcal) as the independent variable, DEBQ-restraint as a moderating variable, and baseline hunger as a covariate. Simple slopes analyses (Aitken & West, 1991) assessed the influence of EE information on EI at three levels of restraint (low, mean, high). Low restraint represented one *SD* below mean (centred) restraint, and high restraint represented one *SD* above. Because women are found to be higher in dietary restraint than men (Hawks, Madanat, & Christley, 2008b), the inclusion of both variables could lead to collinearity. An independent-samples *t*-test confirmed this in the current sample (mean difference = -.47, $t(68) = -2.58$, $p = .012$), reflecting a higher level of restraint in females (mean = 2.72, *SD* = .74) than males (mean = 2.25, *SD* = .69). Due to this relationship between the two variables, and to keep the number of predictor variables commensurate with the sample size, only dietary restraint was included in the moderation analyses.

Hunger values (after exercise, after test meal) were analysed with between-subjects ANCOVAs to investigate the effects of EE information (50 kcal, 265 kcal) on hunger at different time points. EE information was entered as a between-subjects factor, and baseline hunger was entered as a covariate. The 'after exercise' hunger value was an average of the two

INFORMATION ON ENERGY EXPENDED DURING EXERCISE AFFECTS SUBSEQUENT ENERGY INTAKE

hunger ratings completed between the exercise and taste test – i.e., immediately after cycling, and immediately before eating.

All data were analysed using SPSS v.21.0 for Windows (SPSS Inc.: Chicago).

3. Results

3.1. Participant characteristics

Participant characteristics are summarised by EE information group in Table 2. Participants in both conditions were well-matched for key characteristics, including age, gender, BMI, restraint and baseline hunger. Exercise duration was also very similar between groups.

Table 2. Participant characteristics by level of EE information.

Participant characteristic	EE information	
	50 kcal	265 kcal
<i>n</i>	34	36
Age (years)	28 ± 12	28 ± 12
Gender (female/male)	23/11	23/13
BMI	23.92 ± 4.99	23.16 ± 3.20
Restraint (DEBQ)	2.44 ± .67	2.67 ± .82
Baseline hunger (%)	57 ± 29	51 ± 27
Test session time (08:30/10:00/17:30)	12/11/11	12/13/11
Exercise duration (minutes)	13:47 ± 1:24	13:57 ± 1:19
Experimenter (DM/LH)	18/16	18/18

Data are means ± *SD*, or *n* for gender, test session and experimenter

All participants completed the required exercise and were included in subsequent analyses.

3.2. EE information and gender effects on subsequent EI

As shown in Fig. 1, participants consumed more overall, and of each test item, when presented with 265 kcal EE information compared with 50 kcal. A small effect of EE information on overall EI was indicated, which approached statistical significance ($F_{(1,65)}=3.70$, $p=.059$, $\eta_p^2=.05$). This trend was primarily driven by cookie EI, which represented a statistically significant medium-sized main effect ($F_{(1,65)}=6.24$, $p=.015$, $\eta_p^2=.09$). No main effects were indicated for juice or tortilla EI.

Fig. 1. Mean (± 1 SEM) EI for test meal items by EE information condition.

A statistically significant small main effect of gender on overall EI was indicated ($F_{(1,65)}=4.63$, $p=.035$, $\eta_p^2=.07$), with men consuming more overall ($M=571$, $SD=243$ kcal) than women ($M=367$, $SD=290$ kcal). This trend was primarily driven by a statistically significant medium main effect for tortilla EI ($F_{(1,65)}=8.60$, $p=.005$, $\eta_p^2=.12$), indicating higher consumption in males ($M=220$, $SD=129$ kcal) than females ($M=114$, $SD=113$ kcal). No gender main effects were indicated for juice or cookie EI.

No statistically significant interaction effects between EE information condition and gender were indicated overall, or for any test item.

3.3. Moderation by restraint on the relationship between EE information and EI

Dietary restraint was not indicated to significantly moderate the relationship between EE information and EI, overall or for any test item (EE information $\times$ restraint interaction). Although the interaction effect was not statistically significant for cookie EI, simple slopes

analysis indicated a significant effect of EE information on EI for low restraint, but not high. As shown in Table 3 and Fig. 2, for all three levels of dietary restraint, more cookies were consumed in the high EE information condition than the low condition. Specifically, this relationship was statistically significant ($p=.025$) for participants with a low level of restraint (1.81), i.e., 1 *SD* below mean restraint, with a difference of 128 kcal between conditions. For a mean level of restraint (2.56), the difference was 80 kcal and the relationship approached statistical significance ($p=.061$). For a high level of restraint (3.31), i.e., 1 *SD* above mean restraint, the difference was 32 kcal and the relationship failed to reach statistical significance.

Table 3. Moderated regression analyses for EE information, restraint and cookie EI.

($R^2=.17$, $F=3.33$, $p=.015$)		<i>b</i>	<i>SE</i>	<i>t</i>	<i>p</i>
Constant		94.58 [11.66,177.49] ^b	41.52	2.28	.026
EE information					
	Low restraint (-1 <i>SD</i>)	.59 [-.08,1.11]^b	.26	2.29	.025
	Mean restraint ^a	.37 [-.17,.76] ^b	.19	1.91	.061
	High restraint (+1 <i>SD</i>)	.15 [-.40,.70] ^b	.27	.54	.589
Restraint		-7.58 [-61.95,46.78] ^b	27.22	-.28	.78
EE information x restraint interaction		-.30 [-.78,.19] ^b	.24	-1.22	.23

Note. Baseline hunger included as covariate.

Note. Significant effects ($p<.05$) are in boldface.

^aMean restraint ($n=70$, mean=2.56, $SD=\pm.75$)

^bValues in square brackets are 95% CIs

Fig. 2. Simple slopes analysis investigating the conditional effect of EE information on cookie EI at low, mean and high levels of restraint. The plotted data represent mean centred restraint ± 1 SD. Low restraint represents one SD below the mean, and high restraint represents one SD above the mean. p -values indicate whether the regression coefficients significantly differ from 0.

3.4. EE information effects on hunger

As shown in Fig. 3, hunger ratings after exercise did not differ statistically ($F_{(1,67)}=1.00$, $p=.32$, $\eta_p^2=.02$) between the 50 kcal and 265 kcal groups. However, hunger ratings after the test meal were significantly lower ($F_{(1,67)}=4.62$, $p=.035$, $\eta_p^2=.07$) in the 265 kcal EE information group than in the 50 kcal group.

Fig. 3. Mean (± 1 SEM) hunger ratings after exercise and test meal. * $p=.035$

4. Discussion

This novel research provides evidence that information about the energy expended during exercise affects subsequent EI. A small effect of EE information on overall EI, which approached statistical significance, supported the initial prediction and reflected greater consumption in participants who received high (265 kcal) EE information compared with those who received low EE information (50 kcal). A statistically significant medium effect of EE information on cookie EI revealed that compensation varied between the test meal foods. There was also tentative evidence for the hypothesised moderation by dietary restraint, although more research is needed to explore this and to separate its effects from those of gender.

Participants consumed more overall – and of each test item – when presented with high EE information compared with low. On average, 92 kcal more was consumed overall by participants receiving 265 kcal information. This was supported by a small effect, which approached statistical significance. Although this is a relatively small difference, such an increase in EI could lead to changes in body weight over time (Wansink, 2010). This overall effect was primarily driven by a larger cookie intake, which was supported by a medium, statistically significant main effect. This indicated that participants consumed an average of 67 kcal more cookies in the 265 kcal information condition.

These results complement previous exercise-labelling studies (Fenzl et al., 2014; Werle et al., 2014), which indicated that the way in which exercise is framed can influence subsequent EI. Werle and colleagues reported that less dessert and fewer hedonic snacks were consumed following a walk when it was labelled as fun rather than exercise. This was proposed to be due to less compensation – i.e., lower hedonic snack consumption – being needed when the walk was framed as fun. Compared with these qualitatively different labels, the current study provided the same EE information, but varied its level between groups (50 kcal, 265 kcal). As such, this can be interpreted as participants simply altering their

compensatory behaviour in response to the amount of calories believed to have been expended.

As evidenced by a recent meta-analysis, subsequent EI is minimally affected by acute EE (Schubert et al., 2013). This is argued to be due to the actual amount of energy expended in acute exercise being trivial in comparison with the body's total energy stores (Rogers & Brunstrom, 2016). As such, Rogers and Brunstrom contend that EI ought to be little affected by acute EE. As the current study found that EE information affected subsequent EI, it can be argued that, in an acute bout of exercise, people are more influenced by the amount of energy thought to have been expended, rather than the actual amount. In the current study, 215 kcal greater EE information resulted in an average increase in overall EI of 92 kcal between conditions. As 215 kcal represents a relatively small amount in terms of the body's total energy stores, further research would help elucidate whether subsequent EI continues to increase as a function of higher EE information.

In relation to food, a reliance on labels has been suggested to reduce the monitoring of intake, as internal control mechanisms are externalised (Koenigstorfer et al., 2013). This is argued to lead to overeating if labels (e.g., 'low-fat') appear to assist consumers in reaching health-related goals. A similar reliance on EE information labels could offer an explanation of the current findings. Participants provided with high EE information may have felt more deserving of a reward, and consequently experienced a greater license to consume. However, the lack of a difference in hunger between the groups before the test meal foods were presented or tasted suggests that, at that point, participants were not expecting or planning to eat more. Only when given access to the palatable test meal did the EE information have a differential effect on their licence to eat (after which hunger declined more in the group that ate more – i.e., the high EE information group).

In contrast to the current study, Fenzl and colleagues (2014) reported no main effect of exercise-labelling on EI. A possible explanation for this difference is the use of different test meal items. Whereas Werle and colleagues (2014) reported an effect in chocolate pudding

and cola (sweet items), Fenzl and colleagues assessed consumption of pretzels (a savoury item). The current study is consistent with both these findings as an effect of EE information was indicated for sweet cookies, but not savoury tortillas. This is in line with compensation for exercise being more commonly observed with sweeter, and perhaps more liked, foods (Bellisle, 1999), although it is also possible that these foods differ in their metabolic effects and that this could account for the pattern of results across these studies. Additionally or alternatively, priming towards sweet foods may have been a factor. To account for differences between participants in calorie-literacy, EE was approximated in the current study as the equivalent number of Kit-Kat fingers. As such, participants may have been primed toward consumption of the sweeter rather than the savoury test food. No significant effects were observed regarding orange juice, despite it being a sweet item. This may reflect the food and drink items being viewed differently in terms of reward, although this would not explain the effect demonstrated for cola in previous research (Werle et al., 2014). Alternatively, orange juice may have been viewed as more utilitarian and consequently less rewarding for exercise, whereas cola was perceived as more hedonic.

Dietary restraint was not indicated to significantly moderate the relationship between EE information and EI for any test item, which is in line with Fenzl and colleagues' study. However, simple slopes analyses revealed that EE information significantly influenced cookie consumption at a low level of restraint. This indicated that participants with low restraint consumed 128 kcal more cookies when provided with high rather than low EE information. In contrast, participants with higher restraint were less influenced by calorie-expenditure information, consuming only 32 kcal more in the high EE information condition. Due to no moderation of restraint being indicated, the simple slopes analyses can only provide tentative evidence. However, this suggests that less restrained individuals compensated in accordance with the amount of energy they believed to have been expended, which is in line with initial hypothesis. Regarding the goal conflict eating model (Stroebe et al., 2008; Stroebe et al., 2013), this could be interpreted as the actual exercise in both conditions priming the weight

control goal in restrained individuals. Consequently, the eating enjoyment goal may have been inhibited, leading to reduced consumption. In contrast, as these goals are more salient in restrained individuals, participants with lower restraint may have altered their consumption in accordance with the level of EE information, reflecting a greater license to eat following an ostensibly higher amount of exercise.

A complicating factor for determining the moderation by restraint is that females had a significantly higher level of restraint than males, which is consistent with the majority of research (Hawks et al., 2008b). Although gender was removed from the subsequent analyses in order to avoid collinearity and minimise the number of variables in the model, the tentative evidence for a moderation of restraint cannot be separated clearly from an effect of gender. Recruitment of men and women scoring on either extreme of the restraint scale would help to elucidate the role of restraint and to separate its effect from gender.

The results of this study must be considered with regard to its limitations. One limitation is that a control condition was not included and, as such, no conclusions can be drawn regarding how the reported effects compare with no provision of EE information. Specifically, the 50 kcal information condition may have offered a greater license to eat than no information, but to a lesser extent than the 265 kcal information condition. Another limitation is that baseline fitness was not assessed and, as such, the effort required to complete the exercise may have influenced the results. However, due to the groups being highly comparable in terms of age, gender, BMI and exercise duration, there is no reason to assume large differences between them in terms of fitness. Furthermore, all participants indicated that they were willing and able to take part in the exercise, so it is likely that people who would have found the exercise highly effortful did not register for the study.

The findings from this novel research carry with them important implications that have not been raised previously. These relate to weight control and conducting research into the effects of exercise on EI. First, due to the ubiquity of wearable devices that estimate calorie-expenditure, the current study indicates that the accuracy of these is highly important. As high

EE information can lead to greater EI following exercise, any overestimation made by these devices could result in overeating and consequently undermine dietary goals. Although slight variations in EI may not be perceptible on a day-to-day basis, these could lead to significant changes in body weight over a longer period (Wansink, 2010). Therefore, longer-term assessment of the effect on EI presents an important avenue for future research. Second, differences in the way that exercise is framed (e.g., low or high EE) may account for some of the variability in research findings concerning the effects of acute exercise on EI (Martins et al., 2008). As such, future investigations into this relationship should detail how the exercise was framed to avoid biasing results and to enable better inter-study comparison.

The true purpose of the study was carefully disguised, with the cover story that the study was measuring the effects of exercise on taste perception and food reward. Debriefing interviews indicated that participants believed this story, and that they were not aware of the manipulation of the EE information, or the actual study hypotheses. In this respect, it is notable that on average acute exercise (mean EE = 490 kcal) has been found to have a negligible effect on EI (mean increase is only 47 kcal) (Schubert et al., 2013), even though in such studies the manipulation of level of exercise cannot be disguised. For acute bouts of exercise, this would appear to indicate an absence of a metabolically driven increase in EI (Rogers & Brunstrom, 2016) and the presence of a variable cognitively driven effect, including licence to eat and/or strengthening of dietary/body weight goals. Additionally, exercise may acutely inhibit perceived hunger – i.e., ‘exercise-induced anorexia’ (Schubert et al., 2013) – which is partly outweighed by the licence to eat given by knowing one has exercised. Notwithstanding these complexities, over the longer-term, it would appear that exercise does help with healthy weight management (Donnelly et al., 2014; Donnelly et al., 2003; King et al., 2012; King, Lluch, Stubbs, & Blundell, 1997).

5. Conclusions

This novel research indicated that EE information relating to an acute bout of exercise can influence subsequent EI. This was interpreted as high EE information providing a greater license to eat. The findings strongly support the need for further investigation, as they have important implications for weight control and conducting research into the effects of exercise on subsequent EI.

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Disclosure

The authors have no conflict of interests to disclose.

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