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Research paper

Eating on nightshift: A big vs small snack impairs glucose response to breakfast

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ABSTRACT

Shift work is a risk factor for chronic diseases such as Type 2 diabetes. Food choice may play a role, however simply eating at night when the body is primed for sleep may have implications for health. This study examined the impact of consuming a big versus small snack at night on glucose metabolism. N = 31 healthy subjects (21–35 y; 18 F) participated in a simulated nightshift laboratory study that included one baseline night of sleep (22:00 h-07:00 h) and one night awake with allocation to either a big snack (2100 kJ) or small snack (840 kJ) group. The snack was consumed between 00:00–00:30 h and consisted of low fat milk, a sandwich, chips and fruit (big snack) or half sandwich and fruit (small snack). Subjects ate an identical mixed meal breakfast (2100 kJ) at 08:30 h after one full night of sleep and a simulated nightshift. Interstitial glucose was measured continuously during the entire study using Medtronic Continual Glucose Monitors. Only subjects with identical breakfast consumption and complete datasets were analysed (N = 20). Glucose data were averaged into 5-minute bins and area under the curve (AUC) was calculated for 90 min post-breakfast. Pre-breakfast, glucose levels were not significantly different between Day1 and Day2, nor were they different between snack groups ($p > 0.05$). A snack group by day interaction effect was found ($F_{1,16} = 5.36$, $p = 0.034$) and post-hocs revealed that in the big snack group, AUC response to breakfast was significantly higher following nightshift (Day2) compared to Day1 ($p = 0.001$). This translated to a 20.8% (SEM 5.6) increase. AUC was not significantly different between days in the small snack group. Consuming a big snack at 00:00 h impaired the glucose response to breakfast at 08:30 h, compared to a smaller snack. Further research in this area will inform dietary advice for shift workers, which could include recommendations on how much to eat as well as content.

1. Introduction

Some 20% of the population are required to work outside the regular 09:00–17:00 h working day, and this number is likely to increase as economic demands push work hours into the night for many industries (Rajaratnam and Arendt, 2001). These irregular schedules mean workers often have to sleep during the day and be awake at night. This causes a misalignment between normal day-light entrained internal physiological processes, such as metabolism and digestion, and the external environment (Van Cauter et al., 1991; Banks and Dinges, 2007). As a consequence, shift workers have poorer health than day workers, even after controlling for lifestyle and socioeconomic status, with increased risk of obesity and Type 2 diabetes (Banks et al., 2014).

Night shift workers tend to redistribute meals from the day to night hours (Banks et al., 2014). Humans are biologically primed to eat during the daytime, with lower hunger ratings (Heath et al., 2012), slower gastric emptying (Goo et al., 1987), reduced glucose tolerance (Van Cauter et al., 1992), increased insulin resistance (Morgan et al., 1999) and impaired insulin secreting β-cell function (Rakshit et al., 2015) during night-time hours. Eating during night hours may therefore have negative consequences for metabolism. Indeed, studies have shown that eating late in the day reduces the effectiveness of weight loss programs independent of energy intake, dietary composition or sleep duration (Garaulet et al., 2013), and that meals consumed after 20:00 h predicted higher body mass index (BMI) even after controlling for sleep timing and duration (Baron et al., 2011).

Preliminary laboratory work by our research group has compared glucose response to a standard breakfast meal across four simulated nightshifts in a group of young healthy males (Grant et al., 2017). Participants were randomised to two conditions. In one condition participants received a large meal in the middle of the night (01:00 h), and in the other, food intake was redistributed to daytime hours, keeping

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total 24-hour energy intake constant. In the group who ate at night, glucose area under the curve (AUC) significantly increased across the nightshifts, but remained relatively stable for those who only ate during the day. These results suggest that refraining from eating during the night may limit impairments to glucose metabolism (Grant et al., 2017). Therefore, recommending that night-workers avoid eating during their shifts may reduce risk of metabolic disturbance for this group. A clear limitation to this approach is the potential that workers will not tolerate complete redistribution of food intake to outside work hours. However, it may be possible to limit changes in glucose metabolism by simply reducing, rather than eliminating food at night. Therefore, the aim of this study was to examine the impact of consuming a big versus small snack during a simulated night shift on glucose response to a standard breakfast meal the next morning.

2. Materials and methods

2.1. Subjects

Thirty-two healthy adult volunteers were recruited. One subject withdrew due to illness part-way through the study. The mean age (± SD) of the remaining 31 subjects was 24.3 (± 3.4) years (range: 21–35 years; 18 female). The average body mass index (BMI) was 22.2 ± 3.0 kg/m^2; participants with a BMI of over 25 kg/m^2 were excluded from participation. To meet inclusion criteria subjects were required to sleep a minimum of 7 h per night with bedtime no later than midnight and wake time before 09:00 h for the week prior to the laboratory phase of the study. This routine was confirmed using sleep diaries, wrist actigraphy and time-stamped messages each morning. During this period, subjects were not allowed to nap, consume caffeine nor alcohol.

Subjects were excluded from the study if they reported: being a smoker; drinking more than two cups of caffeinated drinks or two standard drinks of alcohol per day; trans meridian travel in the past three months; shift work in the past two years; a BMI above 25 kg/m^2; current medication (apart from the contraceptive pill) or recreational drug use (illicit drugs confirmed by urine test); and any medical, psychological or sleep disorders. Blood chemistry analysis was conducted to confirm general health. The study was approved by the University of South Australia Human Research Ethics Committee. Subjects gave written, informed consent and were reimbursed for their time.

2.2. Protocol

Subjects resided in a windowless and sound-attenuated sleep laboratory. Ambient room temperature was maintained at 22 ± 1 °C. Light intensity was set to < 50 lx at head height (dim light) during all wake periods of the protocol, and < 0.03 lx (darkness) during all scheduled sleep periods.

Subjects spent two nights and three days in the sleep laboratory: one day for adaptation and training, one baseline day and night, one experimental night of sleep deprivation, and one recovery day. Subjects arrived at the laboratory at 13:00 h and spent the adaptation day practicing various performance tasks. They had a 9-hour sleep opportunity from 22:00 h to 07:00 h on the first night (Fig. 1).

On the second night, subjects participated in a simulated night shift. All subjects had an identical dinner meal at 18:00 h (~3400 kJ). Subjects were then randomly allocated to either a big snack (~2100 kJ, n = 15) or small snack (~840 kJ, n = 5) group. The snack was consumed between 00:00–00:30 h and consisted of low fat milk, a sandwich, chips and fruit (big snack) or half sandwich and fruit (small snack). The macronutrient composition of the snacks is presented in Table 1. Subjects ate an identical mixed meal breakfast (2100Kj; Table 1) at 08:30 h after a full night of sleep (Day1) and a simulated nightshift (Day2). All food was prepared and monitored by qualified research staff, and subjects were not permitted to eat outside of set meal times. Interstitial glucose was measured continuously during the entire study using Medtronic Continual Glucose Monitors, with sensors placed in the subcutaneous layer of the participants' medial abdominal area. Glucose levels were extracted in mg/dL using Medtronic CareLink Pro 3.3 software (Medtronic MiniMed) and converted to mmol/L by dividing values by 18.

As part of a larger study (Centofanti et al., 2016; Centofanti et al., 2015; Hilditch et al., 2015; Hilditch et al., 2015), participants were assigned to one of three groups: a control group (NO-NAP, n = 6); a 10 min "on-shift" nap ending at 04:00 h plus a 10 min "top-up" nap at 07:00 h (10-10-NAP, n = 5, mean combined sleep time = 16.6 min, SE = 0.9); or a 30 min "on-shift" nap ending at 04:00 h (30-NAP, n = 9, mean sleep time = 26.3 min, SE = 0.9).

On the final day of the study, subjects were allowed a 6-hour daytime recovery sleep opportunity between 10:00 h and 16:00 h. Sleep was measured using polysomnography (PSG) during all sleep periods with the Compumedics Grael Sleep System and Compumedics Profusion PSG 3 Software (Melbourne, Australia). Placement of electrodes was in line with the 10/20 system of electrode placement (Carskadon and Rechtschaffen, 1994). Sleep data were scored in 30-second epochs in accordance with the criteria of Rechtschaffen and Kales (1968) and total sleep time (TST) was derived.

During wake periods, subjects performed neurobehavioral test batteries approximately every 2 h and were permitted to read books, play card/board games, watch DVDs, interact with each other and study staff, or listen to music between test sessions. Subjects did not have access to any clock-bearing or telecommunication devices. Subjects were not allowed to perform any vigorous activities during the study.

2.3. Statistical analysis

Analyses were performed using SPSS Statistics Version 21.0 (IBM Corp., Armonk, NY, USA). Only subjects with identical breakfast consumption and complete glucose datasets were analysed (n = 20). Glucose data were averaged into 5-minute bins and area under the curve (AUC) was calculated for 90 min post-breakfast, with baseline (BL) glucose values calculated as the average of the three pre-breakfast points: 08:15 h, 08:20 h, and 08:25 h. AUC was computed using the trapezoidal estimation method (Venn and Green, 2007) to demonstrate overall glucose response to breakfast. A linear mixed model ANOVA (Van Dongen et al., 2004) was conducted to assess the effects of snack group (big snack [NO-NAP N = 4, 10-10-NAP N = 4, 30-NAP N = 7]; small snack [NO-NAP N = 2, 10-10-NAP N = 1, 30-NAP N = 3]), and day (Day1 = following one full night of sleep; Day2 = following

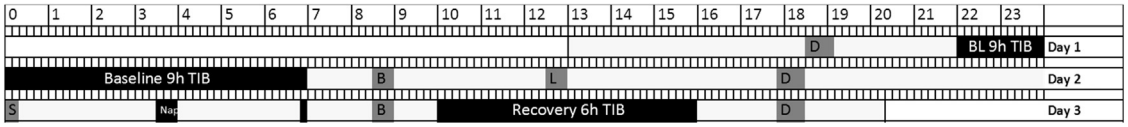

Fig. 1. Schematic represents study protocol. Time of day is presented across the X-axis, from midnight to midnight on Study Days 1, 2, and 3. Black boxes represent time in bed opportunities (TIB). The TIB opportunity ending at 04:00 h represents the 30-minute and 10-minute night time nap for each nap condition respectively (30-NAP; 10-10-NAP). The TIB opportunity ending at 07:00 h represents the 10-minute morning nap opportunity for the 10-10-NAP condition. Meals are shown in the grey boxes (B = breakfast, L = lunch, D = dinner, S = Snack). Across both snack conditions, each breakfast comprised of ~2100 kJ, lunch comprised of ~2700 kJ and each dinner comprised of ~3400 kJ. The big snack condition comprised of ~2100 kJ and the small snack condition comprised of ~840 kJ.