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Research report

Breakfast consumption and exercise interact to affect cognitive performance and mood later in the day. A randomized controlled trial ☆

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ABSTRACT

The current study assessed the interactive effect of breakfast and exercise on cognition and mood. Twelve active males completed four trials; no breakfast-rest, breakfast-rest, no breakfast-exercise or breakfast-exercise in a randomized, cross-over design. The trials consisted of; breakfast or fast, a 2 h rest, exercise (treadmill run) or equivalent rest, a chocolate milk drink, a 90 min rest and an *ad libitum* lunch. Cognitive performance and mood were recorded frequently throughout each trial. Data was analysed as pre-exercise/rest, during and immediately post exercise/rest and post-drink. No effects were found prior to consumption of the drink. Post-drink, fasting before exercise increased mental fatigue compared to consuming breakfast before exercise and fasting before rest. Tension increased when breakfast was consumed at rest and when exercise was undertaken fasted compared to omitting breakfast before rest. Breakfast before rest decreased rapid visual information processing task speed and impaired Stroop performance. Breakfast omission improved Four Choice Reaction Time performance. To conclude, breakfast before exercise appeared beneficial for post-exercise mood even when a post-exercise snack was consumed. Exercise reversed post-breakfast cognitive impairment in active males.

Introduction

Past research has explored the effects of pre-exercise nutrition on physical performance, forming a set of guidelines for athletes and the active population to follow. For example, it is recommended that carbohydrate is consumed prior to exercise to improve endurance capacity (American Dietetic Association, 2009). However, achieving optimal physical performance is often not the sole motivation for exercise. Performance is a multi-dimensional paradigm, which also encompasses aspects of cognition and mood. An acute bout of sub-maximal exercise has been shown to improve some facets of cognitive performance, such as reaction time (Etnier et al., 1997) and decision making (Adam, Teeken, Ypelaar, Verstappen, & Paas, 1997; McMorris & Graydon, 1996), as well as mood (Scully, Kremer, Meade, Graham, & Dudgeon, 1998), an effect often thought to be caused by increased arousal during the recovery period (Lambourne & Tomporowski, 2010). Many of the general population exercise regularly for these additional health benefits instead of, or in addition to, physical performance enhancement. It has been found that consuming CHO during exercise can enhance these cognitive (Ali & Williams, 2009; Collardeau, Brisswalter, Vercruyssen, Audiffren, & Goubault, 2001) and mood (Lieberman, Falco, & Slade, 2002) effects demonstrating an interaction between nutritional state and exercise on post-exercise cognitive performance.

The timing of exercise likely influences pre-exercise nutritional intake. When exercise is undertaken in the morning, it is perhaps more common to remain fasted due to lack of time. Some individuals may choose to exercise in a fasted state due to the associated increase in fat oxidation (Backhouse, Williams, Stevenson, & Nute, 2007; Gonzalez, Veasey, Rumbold, & Stevenson, 2013). Although this may be beneficial if weight loss is a main goal of exercise, if breakfast is ommitted to achieve this, dietary guidelines which state that breakfast consumption is important for health and well-being are contradicted (NIfHaC, 2006). The positive health benefits of consuming breakfast include mood enhancement (Kral, Heo, Whiteford, & Faith, 2012) and improvement in some aspects of cognitive performance, in particular, memory [for review see (Marangoni et al., 2009)]. These benefits have been attributed to its timing, consumed first thing in the morning, breaking the overnight fast and it is thought that breakfast may be vital for optimum cognitive function at this point (Benton & Parker, 1998; Pollitt & Mathews, 1998). Although the acute mood-enhancing effects of breakfast do tend to diminish after a few hours (Smith, Clark, & Gallagher, 1999), consuming a mid-morning snack has been shown

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to improve declining mood following a large breakfast (Benton, Slater, & Donohoe, 2001). Even if guidelines for exercise recovery are followed and energy is replaced immediately following exercise [for example, by consuming chocolate milk (Karp et al., 2006; Thomas & Stevenson, 2009)], omitting breakfast and inducing a further energy deficit through exercise following an overnight fast may have detrimental cognitive and mood effects later in the day.

Trials which have investigated the effect of consuming or omitting breakfast prior to exercise on cognitive performance and mood are uncommon in the literature and have produced diverse results (Hill, Whitehead, & Goodwin, 2011; Paul, Rokusek, Dykstra, Boileau, & Layman, 1996; Vermorel, Bitar, Vernet, Verdier, & Coudert, 2003). In a cross-sectional study by Vermorel et al. (2003), it was suggested that when adolescents have a morning physical education lesson they require a substantial breakfast for cognitive benefits later in the day (Vermorel et al., 2003). Recently, there was no difference identified in the mood state of swimmers who either consumed or omitted CHO before a morning training session (Hill et al., 2011) although Paul et al. (1996) reported an increase in mental fatigue during the recovery period following a 90 min cycle if breakfast was omitted rather than consumed beforehand, but found no effect on cognition. However, no study to date has looked at the interactive effect of breakfast consumption or omission prior to exercise or rest on cognitive performance and mood in the same sample, which may be an important factor (Hubert, King, & Blundell, 1998). Therefore the focus of the present paper was to assess the effect of breakfast consumption and breakfast omission prior to rest or exercise, followed by a post-exercise recovery drink to assess cognitive performance and mood response. It was hypothesized that consuming breakfast prior to exercise would elicit the most beneficial cognitive performance and mood effects following a morning run.

Methods

Initial screening/preliminary measurements

Ethical approval for the study protocol was granted by the Ethics Committee from the School of Life Sciences at Northumbria University. Prior to participation volunteers gave written informed consent. All participants confirmed that they were non-smokers, in good health and free from social drugs, medication and herbal and dietary supplements at an initial screening visit. Participants had no history of, or current, head trauma, learning difficulties, attention deficit hyperactivity disorder (ADHD), dyslexia, migraines or gastric problems, a good standard of English, equivalent to that of a native English speaker and were not high caffeine consumers (<600 mg per day). A further criterion for inclusion in the study was that participants were at least moderately physically active, exercising for at least 30 min 5 times per week (confirmed using the International Physical Activity Questionnaire [IPAQ; (Craig et al., 2003)] and were able to run for 1 h continuously.

Screening also comprised the collection of demographic information and training and familiarisation with the cognitive tasks and experimental procedures. The battery of cognitive tasks was repeated 3 times during this session to decrease the chance of learning effects during main trials. Participants undertook two preliminary tests to establish (1) the relationship between $V\,O_2$ and running speed on a flat treadmill using a 16-min test, and (2) their $V\,O_2$max using an incremental treadmill test whereby the gradient was increased by 1%·min^{-1} to exhaustion as previously described in full detail (Williams, Nute, Broadbank, & Vinall, 1990). The running speed equivalent to 60% of each participant's $V\,O_2$max was then determined and the duration of exercise needed at this intensity to expend 2.9 MJ was calculated for each individual. The within subjects design with matched energy expenditure during exercise intended to eradicate any significant effects that varying exercise durations may have had on the results. On the day preceding the first trial, participants were required to keep a record of their food intake and physical activity which was replicated the day preceding subsequent trials. All 12 participants who attended the screening visit also successfully completed the study.

Participants

Twelve, healthy, active men participated in the study. Their mean ± SD age, height, body mass (BM), Body Mass Index (BMI) and maximal oxygen uptake ($V\,O_2$max) were 23.2 ± 2.4 y, 177.6 ± 7.0 cm, 77.2 ± 5.3 kg, 24.5 ± 2.0 kg/m^2 and 50.7 ± 1.2 mL kg^{-1} min^{-1}, respectively. Participants abstained from alcohol and vigorous exercise for 24 h and fasted for 12 h, prior to the start of each trial.

Cognitive and mood measures

The cognitive tasks and mood measures selected had shown previous sensitivity to nutritional and/or exercise interventions. All tasks and visual analogue scales were administered using the Computerised Mental Performance Assessment System (COMPASS, Northumbria University), a programme used to present computerised standard psychometric tests. COMPASS has been used in several previous nutritional intervention studies and has been shown to be sensitive to acute cognitive enhancement and impairment with a variety of substances [e.g. (Haskell, Kennedy, Wesnes, & Scholey, 2005; Jackson, Deary, Reay, Scholey, & Kennedy, 2012; Kennedy et al., 2010; Kennedy et al., 2011; Scholey et al., 2010; Wightman, Haskell, Forster, Veasey, & Kennedy, 2012)]. Presentation of tasks and mood scales was via a laptop computer. All responses were recorded via a button response box (comprising buttons for Yes/No, Left/Right, Blue/Green/Yellow/Red and a central reaction time button). Each set of tasks took approximately 13 min to complete. Participants were tested individually and were required to wear ear defenders throughout the cognitive tasks to minimise noise distraction.

Simple reaction time (SRT; ~90 s)

An arrow pointing upwards appeared in the centre of the computer screen at irregular intervals (between 1 and 3.5 s). The participant was instructed to press the centre button on the response pad when the arrow appeared, responding as quickly and as accurately as possible. The task was scored for overall reaction time (RT) to 30 stimuli.

Stroop task (~2 min)

Words describing one of four colours ('RED', 'YELLOW', 'GREEN', 'BLUE') were presented in different coloured fonts in the centre of the computer screen. The participant pressed one of four coloured response buttons in order to identify the font colour (e.g., if the word 'GREEN' was presented in a blue font, the correct response would be to respond with the blue button). The presented words were either 'congruent' (word and font are the same colour) or 'incongruent' (word and font are different colours) and were presented in a random order. In total, 120 words were presented. The task was scored for RT and accuracy of responses to 'congruent' and 'incongruent' words.