PURE Insights

Volume 1 Article 6

2012

Nutrition and Cognitive Functioning: Multifaceted Analysis of Physiological and Psychological Components

Lindsey M. King
Western Oregon University, lking09@mail.wou.edu

Nutrition and Cognitive Functioning: Multifaceted Analysis of Physiological and Psychological Components

Abstract
Although the human brain only represents about two percent of the body's total weight, it uses 20 percent of the total calories consumed each day. Calories are vital for proper cognitive function and development. Previous research has reported a wide array of cognitive deficits associated with malnutrition in early childhood and delayed development in children whose mother consumed inadequate nutrition during pregnancy. Previous research has also reported a wide array of cognitive deficits associated with calorie restriction, as well as demonstrated increased cognitive performance after the administration of nutrients. Lastly, research is beginning to more thoroughly examine the relationship of preoccupying cognitions surrounding body image and cognitive deficits to better understand this component of thought and its effect on cognitive performance. In the current analysis, it is suggested that the association between nutrition and cognition is multifaceted, with both physiological and psychological components implicated.

Keywords
cognitive ability, preoccupying cognitions, fasting, malnutrition, calorie restriction, development, protein energy malnutrition

Cover Page Footnote
The author wishes to express her deepest gratitude to her supervisor Dr. Ethan McMahan for his guidance, support, insight, advice, suggestions, and comments throughout the writing process.

Nutrition and Cognitive Functioning: Multifaceted Analysis of Physiological and Psychological Components

Lindsey M. King Western Oregon University
Faculty Sponsor: **Dr. Ethan McMahan**

Although the human brain only represents about two percent of the body's total weight, it uses 20 percent of the total calories consumed each day. Calories are vital for proper cognitive function and development. Previous research has reported a wide array of cognitive deficits associated with malnutrition in early childhood and delayed development in children whose mother consumed inadequate nutrition during pregnancy. Previous research has also reported a wide array of cognitive deficits associated with calorie restriction, as well as demonstrated increased cognitive performance after the administration of nutrients. Lastly, research is beginning to more thoroughly examine the relationship of preoccupying cognitions surrounding body image and cognitive deficits to better understand this component of thought and its effect on cognitive performance. In the current analysis, it is suggested that the association between nutrition and cognition is multifaceted, with both physiological and psychological components implicated.

Keywords: cognitive ability, preoccupying cognitions, fasting, malnutrition, calorie restriction, development, protein energy malnutrition

There are clear cognitive impairments associated with inadequate nutrition related to malnutrition, fasting, and dieting (Green & Rogers, 1995). There are also clear cognitive impairments observed in people who are ingesting adequate nutrition, yet have high preoccupying cognitions surrounding food, weight, and body image (Kemps & Tiggermann, 2005). Preoccupying cognitions are thoughts that one is fixated on. These cognitions demand excessive time and energy to think about and are usually accompanied by anxiety. Numerous factors play a role in these cognitive impairments which are both physiological and psychological in nature. For example, research that has examined the physiological component has found deficits in cognitive functioning caused by Protein Energy Malnutrition (PEM; Kar, Shobini, & Chandramouli, 2008). Further research examining the physiological component has found that administration of glucose following fasting produces a positive effect on subsequent cognitive functioning and attention span (Sünram-Lea, Foster, Durlach, and Perez, 2001).

Concerning the psychological component of nutrition and cognition, research suggests that this correlation could be due to a mood imbalance that is the direct result of decreased calorie intake. This mood imbalance may manifest in the form of anxiety or depression (Widenhorn-Müller, Hille, Klenk, and Weiland, 2007). It is also proposed that a decrease in one's ability to maintain attention, which is related to inadequate glucose levels, could affect the participants' ability to perform cognitive assessment tasks (Green, 1992). Lastly, the variable of preoccupying cognitions surrounding food and body image has been examined as another possible reason for these findings (Green, Rogers, Elliman, & Gatenby, 1992; Green & Rogers, 1998; Kemps & Tiggemann, 2005; Kemps, Tiggemann, & Marshall, 2005; Vreugdenburg, Bryan, & Kemps, 2003). The above studies suggest that preoccupying cognitions concerning food and associated anxiety may negatively impact many aspects of cognition and working memory.

In general, people who are not eating well-balanced meals at least three times a day, are engaging in dieting practices, fasting rituals, frequently missing breakfast, or are generally malnourished, are unable to perform at the same cognitive level as those that are eating regularly (Green, Rogers, Elliman, & Gatenby, 1992). It is thus the purpose of the current article to review research on the physiological and psychological mechanisms that play a role in the association between nutrition and cognitive functioning.

Physiological Component

In an attempt to understand the specific macromolecules that effect cognitive ability in cases of malnutrition, Martin and Benton (1998) examined the influence of a glucose drink on short-term memory scores. The participants consumed either a glucose or placebo drink after having their initial glucose levels tested. Following this, a test measuring aspects of short-term memory was administered. Results indicated that a glucose drink improved the short-term memory scores of those who had not eaten breakfast, but had no effect on

the group who had eaten breakfast. Those in the group who fasted and consumed the glucose drink had short-term memory scores that were comparable to the group who ate breakfast, suggesting that blood glucose is associated with short-term memory.

To further examine the impacts of glucose levels in the body, Sünram-Lea, Foster, Durlach, and Perez (2001) investigated the administration of glucose at different times of the day, as opposed to only breakfast. A group of 60 participants were randomly assigned to one of six conditions: glucose, placebo, control, fasting, breakfast, and lunch. Results showed that blood glucose levels were significantly higher under the breakfast and lunch condition than the fasting condition, and glucose was seen to affect performance on long-term verbal memory and spatial memory assessments. These results further support the idea that adequate glucose levels allow for optimum cognitive functioning.

Another aspect of cognition was examined by Morris and Sarll (2001) in their study on listening span in students who miss breakfast. In this study, 80 college students missed breakfast and then completed a listening span test. The Listening span test provides a measure of verbal memory capacity for spoken material, and predicts overall school performance and testing ability. Once this test was completed, 40 of the participants were given a glucose drink, while the other 40 participants were given a sugar free drink. Each of the groups waited 20 minutes and then completed a post-test. Results indicated that the participants who consumed the glucose rich drink had better scores than the control group, suggesting that listening span does have a physiological component. Short term low glucose levels may thus be related to an inability to pay attention and to listen, which may cause decreased test scores.

Further research suggests that calorie restriction during dieting may have physiological consequences that could negatively impact cognitive functioning. In one study, Green, Rogers, Elliman and Gatenby (1992) used the Dutch Eating Behavior Questionnaire (DEBQ) to assess subject's level of dietary restraint. Subjects were divided into three groups based on their current level of dietary restraint. Measures of dietary intake from the previous 24-hours were also collected. These measures indicated that the subjects in the dieting group were only consuming 70% of their maintenance energy requirement. The results further indicated that the dieting group demonstrated lower processing capacity and slower reaction times, suggesting that people who are under eating experience associated cognitive impairments.

Examining extreme calorie restriction, Bhoomika, Rao and Chandramouli (2008) discuss the effects of chronic protein energy malnutrition (PEM) on children's cognitive development. A comparison was made between a group of naturally occurring malnourished and nourished children. The malnourished group was selected by measurements of height for age (stunting), and weight for height (wasting). The children were given a set of neuropsychological tests that analyzed motor speed, attention, executive functions, visuo-spatial relationships, comprehension, learning and memory. The data shows that the PEM group scored significantly lower from the adequately nourished group on tests of higher cognitive functions. The PEM group also showed lower test performance on tasks that used executive functions, such as working memory and spatial intelligence. This study further found that some cognitive functions were delayed by PEM but improved at a constant rate through development. However, other PEM-related cognitive deficits did not improve over time.

Psychological Component

A common behavior that is pivotal in the discussion of nutrition and the psychological component of cognitive deficit is dieting. Dieting refers to a purposeful attempt to lose weight by means of calorie restriction (Green & Rogers, 1998). Though there are notable health benefits to fasting or calorie restriction for individuals who are overweight, there are also negative consequences of dieting practices that can lead to possible health risks. Calorie restriction can easily lead to negative consequences when conducted in a manner that includes lowering calories below basic metabolic needs or skipping meals entirely. When baseline caloric needs are not met, a variety of cognitive impairments are seen (Bhoomika, Rao, & Chandramouli, 2008). Interestingly, cognitive impairments are not only seen in the extremes of malnourished subjects, but also in dieting participants with normal glucose levels (Jones & Rogers, 2002) and students who skip breakfast or meals altogether (Sünram-Lea, Foster, Durlach, & Perez, 2001).

Research is beginning to show that these cognitive impairments may be caused by the preoccupying cognitions that are involved in the dieting process. For example, research has found that cognitive functions are impaired for dieters regardless of weight loss (Green & Rogers, 1995). This implies that the stress involved with dieting has the ability to negatively impact our cognitive processing (Kemps & Tiggemann, 2005). These preoccupying cognitions surrounding food and body image are thought to have the ability to negatively impact working memory potential by reducing one's processing capacity (Green et al., 1992; Green & Rogers, 1998; Kemps & Tiggemann, 2005; Kemps et al., 2005; Vreugdenburg et al., 2003).

To demonstrate the validity of preoccupying cognitions involved in the dieting process, Jones and Rogers (2002) used a chocolate bar, or a "diet-threatening" food to arouse preoccupying cognitions in a group of participants. Each participant completed a hunger and mood questionnaire and cognitive performance task prior to consumption of the chocolate bar. They were then told that they were required to eat a chocolate bar containing approximately 310 calories. After 15 minutes, the experimenter returned, and the hunger and mood questionnaire survey was filled out again by the participant. The cognitive portion of the test was also repeated. Results indicate that performance on a memory task was impaired after food consumption in the self recorded dieting group. Additionally, dieters experienced an increase in preoccupying cognitions surrounding food and body image. This study controlled for the possibility of physiological deficits by selecting participants that were screened for possible health complications and giving everyone a high calorie chocolate bar with adequate time for the glucose to be absorbed by the body. When the dieters were asked why they thought that they performed poorer after consumption of the chocolate bar, many of them attributed their performance to the distracting thoughts about diet and body image. This study demonstrates the power of preoccupying cognitions and how our thoughts have the ability to impact our cognitive processes.

In an additional study examining preoccupying cognitions, Vreugdenburg, Bryan, and Kemps (2003) examined cognitive function during a six month trial. In this study, preoccupying cognitions were measured by filling out a survey that was comprised of 20 statements related to the intensity of food-related thoughts, body shape, and diet over the past month. Following this, several tasks measuring different aspects of working memory were completed by each participant. Results indicated that self-reported dieters had clear impairments in the central executive and phonological loop of working memory compared with non-dieters. Current dieters had a much higher degree of preoccupying cognitions surrounding food, diet, and body shape. The authors of this study concluded that preoccupying cognitions are likely tapping into the mental resources required for other cognitive tasks and is thus playing a role in the association between dieting and cognitive function. In other words, excessive worrying may impair cognitive performance because worry takes away from one's ability to focus on the test at hand.

Kemps, Tiggermann, Wade, Ben-Tovim, and Breyer (2006) examined the impacts of disordered eating behaviors on cognition. The purpose of this study was to analyze aspects of cognitive ability affected by Anorexic Nervosa (AN) and to examine preoccupying cognitions as a mechanism underlying working memory impairment in extreme malnutrition. The participants of this study included a total of 27 inpatient AN patients, 24 self-identified dieters, and 24 non-dieting participants. Several tasks were administered on a laptop computer to all three groups. These tests examined aspects of the central executive (cognitive processing ability) as well as crystallized intelligence (knowledge and skills). A measurement of preoccupying cognitions surrounding food, weight, and body shape was recorded for all three groups. The results indicated that there was an impairment in cognitive functioning for both the dieters and the AN patients when compared with the non-dieting participants, however, the cognitive deficits were more extreme for the AN group compared to the dieting group. This study suggests that preoccupying cognitions can account for cognitive impairment when examining healthy subjects, who have no physiological reason to perform poorly. However, when looking at medically unhealthy subjects, more specifically, malnourished subjects, physiological factors outweigh the preoccupying cognitions. Greater difficulties in processing complex information are seen in groups who suffer from physiological consequences of malnutrition compared with groups who suffer from the psychological component of preoccupying cognitions.

Addressing another psychological component, Widenhorn-Müller, Hille, Klenk, and Weiland (2007) examined the influence of nutrition on mood in high school students. One of the groups was assigned as the fasting group and the other was assigned as the control, non-fasting group. On the day of the test, the fasting group received no breakfast while the non-fasting group received a controlled breakfast. Seven days later the groups were reversed. A mood questionnaire was completed. Those who consumed breakfast showed higher ratings of positive feelings, processing capacity, alertness, and a decrease in negative affect. It is possible that these psychological effects of fasting are a contributing factor to impacted cognitive performance.

Summary

The relationship between nutrition and cognitive functioning is multifaceted and complex. There are many physiological and psychological factors that concurrently play a role in these deficits. Some of the contributing factors include significantly higher levels of depressed mood (Kemps, Tiggemann, & Marshall, 2005), preoccupying cognitions (Vreugdenburg, Bryan, & Kemps, 2003), decreased ability for processing capacity and decreased attention span, (Widenhorn-Müller, Hille, Klenk, & Weiland, 2007), slower reaction times (Green, Rogers,

Elliman & Gatenby 1992) and decreased listening ability (Morris & Sarll, 2001).

For practical purposes, the current article clearly separates the potential physiological and the psychological mechanisms of this relationship. However, it should be noted that these components are intertwined and directly affect one another. For example, malnutrition is associated with many negative physiological effects including decreased ability to synthesize neurotransmitters, decreased velocity of nervous conductions and decreased myelination (Medina, 2008). All of these effects of malnutrition directly affect one's psychological functioning and are associated with high levels of anxiety and depression. It is currently unclear whether the physiological component of one's poor diet causes psychological consequences, or rather, one's poor psychological health that causes one to engage in disordered eating behavior and experience associated physiological consequences. What is clear is that proper nutrition and a healthy mindset surrounding nutrition is vital for one to perform at their optimum cognitive capacity.

Findings from this area of research challenge the status quo and demonstrate the need to address nutrition at all levels, including government, school, media, and health care providers. Benefits to nutrition and correspondingly, cognitive functioning may be seen if governmental agencies placed a greater emphasis on nutrition awareness campaigns, updated the food pyramid, increased FDA regulations on diet supplements, and increased funding for programs aimed at meeting the nutritional needs of child. Increased nutrition and higher levels of cognitive functioning in children may be achieved if schools hired registered dietitians to evaluate their breakfast and lunch options to ensure that they are providing well-balanced and healthy meals to school children. Nutrition courses could also be implemented into schools addressing issues surrounding nutrition, with the goal of decreasing the high levels of dieting and negative body image-related preoccupying cognitions. Lastly, it may be beneficial for both physical health and associated cognitive functioning if health care providers emphasized nutrition-related issues as a regular part of every check-up and mental health evaluation. Based on the vast research examining the many cognitive impairments associated with inadequate nutrition related to malnutrition, fasting, and dieting, perhaps our society should emphasize proper nutrition as a main contributor to a healthy lifestyle and optimal cognitive functioning.

References

Brockman, L. M., & Ricciuti, H. N. (1971). Severe protein-calorie malnutrition and cognitive development in infancy and early childhood. *Developmental Psychology*, 4(3), 312-319. doi:10.1037/h0030953.

Goggin, J. E., Holmes, G. E., Hassanein, K., & Lansky, S. B. (1978). Observations of postnatal developmental activity in infants with fetal malnutrition. *The Journal of Genetic Psychology: Research and Theory on Human Development*, 132(2), 247-253.

Green, M., & Rogers, P. (1995). Impaired cognitive functioning during spontaneous dieting. *Psychological Medicine: A Journal of Research in Psychiatry and the Allied Sciences*, *25*(5), 1003-1010. doi:10.1017/S0033291700037491.

Green, M., & Rogers, P. (1998). Impairments in working memory associated with spontaneous dieting behaviour. *Psychological Medicine: A Journal of Research in Psychiatry and the Allied Sciences*, *28*(5), 1063-1070. doi:10.1017/S0033291798007016.

Green, M., Rogers, P., Elliman, N., & Gatenby, S. (1992). Impairment of cognitive performance associated with dieting and high levels of dietary restraint. *Physiology & Behavior*, *55*(3), 447-452. doi:10.1016/0031-9384(94)90099-X.

Ingwersen, J., Defeyter, M., Kennedy, D. O., Wesnes, K. A., & Scholey, A. B. (2007). A low glycaemic index breakfast cereal preferentially prevents children's cognitive performance from declining throughout the morning. *Appetite*, 49(1), 240-244 doi:10.1016/j.appet.2006.06.009.

Kar, B., Rao, S., & Chandramouli B. (2008). Cognitive development in children with chronic protein energy malnutrition. *Behavioral and Brain Functions 4(31),* 1-12. doi:10.1186/1744-9081-4-31.

Kemps, E., & Tiggemann, M. (2005). Working memory performance and preoccupying thoughts in female dieters: Evidence for a selective central executive impairment. *British Journal of Clinical Psychology*, *44*(3), 357-366. doi:10.1348/014466505X35272.

Kemps, E., Tiggemann, M., & Marshall, K. (2005). Relationship between dieting to lose weight and the functioning of the central executive. *Appetite*, *45*(3), 287-294. doi:10.1016/j.appet.2005.07.002.

Martin, P. Y., & Benton, D. (1999). The influence of a glucose drink on a demanding working memory task. *Physiology & Behavior*, 67(1), 69-74. doi:10.1016/S0031-9384(99)000402.

Medina, M. T. (2008). *Neurologic consequences of malnutrition*. New York: Demos.

Morria, N., & Sarll, P. (2001). Drinking glucose improves listening span students who miss breakfast. *Educational Research*, 43(2), 201-207. doi:10.1080/00131880010021311.

Muhammad, A. (2011). Nutritional factors in mental health: Does 'Epigenetics' provide a road map? *Journal of Pakistan Medical Association*. Vol. 61, No. 8.

Odebode, T., & Odebode, S. (2005). Protein Energy Malnutrition and the Nervous System: the Impact of Socioeconomic Condition, Weaning Practice, Infection and Food Intake, an Experience in Nigeria. *Pakistan Journal of Nutrition*, *4*(5), 304-309.

Sünram-Lea, S. I., Foster, J. K., Durlach, P., & Perez, C. (2001). Glucose facilitation of cognitive performance in healthy young adults: Examination of the influence of fast-duration, time of day and pre-consumption plasma glucose levels.

Psychopharmacology, 157(1), 46-54 doi:10.1007/s002130100771.

Vreugdenburg, L., Bryan, J., & Kemps, E. (2003). The effect of self-initiated weight-loss dieting on working memory: The role of preoccupying cognitions. *Appetite*, *41*(3), 291-300. doi:10.1016/S0195-6663(03)00107- 7.

Wesnes, K. A., Pincock, C., Richardson, D., Helm, G., & Hails, S. (2003). Breakfast reduces declines in attention and memory over the morning in schoolchildren. *Appetite*, 41(3), 329-331. doi:10.1016/j.appet.2003.08.009.

Widenhorn-Müller, K., Hille, K., Klenk, J., & Weiland, U. (2008). Influence of having breakfast on cognitive performance and mood in 13- to 20-year-old high school students: Results of a crossover trial. *Pediatrics*, 122(2), 279-284. doi:10.1542/peds.2007-0944.