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Effect of chronic intake of liquid nutrition on stomach and duodenum morphology

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ABSTRACT

Changes in the quantity and/or quality of food intake have been shown to be associated with morphological and functional alterations of the gastrointestinal system. To examine this, we investigated the effect of chronic liquid nutrition intake (Fresubin) on stomach and duodenum morphology in Wistar rats fed liquid nutrition during different developmental periods. We used four groups of rats: a) control group (CON) fed pelleted chow for 130 days; b) liquid nutrition group (LN) fed liquid nutrition for 130 days; c) liquid nutrition juvenile group (LNJ) fed liquid nutrition for 70 days and then pelleted food for 60 days; d) liquid nutrition adult group (LNA) fed pelleted chow for 70 days and then liquid nutrition for 60 days. We found that LN and LNA rats showed a significant reduction of empty stomach mass compared to CON animals, while stomach and duodenal longitudinal muscle layer thickness did not differ between groups. Villus height was increased only in LNA animals, while villus width was increased in both LN and LNA rats. Crypt depth was reduced in LNJ. However, liquid nutrition intake did not affect villus height/crypt depth ratio, nor number of goblet cells. We found that chronic intake of liquid nutrition affects some morphological parameters of the stomach and duodenum but these changes were not homogenous between experimental groups. Interestingly, transition from liquid nutrition to solid food reversed the alterations of stomach weight as well as villus width induced by intake of liquid nutrition in LNA rats. Our data indicate that morphological and functional changes in the gastrointestinal system induced by qualitative and quantitative changes in food intake are at least partially reversible. Therefore, specific diets may be used potentially as adjuvant treatment for modulating the progression of gastrointestinal diseases by affecting stomach and small intestine morphology.

1. Introduction

The morphological and functional properties of the gastrointestinal tract are sensitive to the quantity and/or quality of provided food as decreased food intake reduces the absorptive surface of the small intestine, while long-term overconsumption also affects the morphology and function of the gastrointestinal tract (Dameto et al., 1991; Mao et al., 2013). For example, hyperphagia has been found to stimulate proliferation of the intestinal mucosa in rats (Ivanova et al., 2009; Wongdee et al., 2013). Furthermore, Dameto et al. (1991) found that intake of cafeteria diet increases intestinal length but shortens overall transit time in Wistar rats. Interestingly, faster gastric transit is also observed in obese patients and is associated with shorter satiety periods (Mushref and Srinivasan, 2013; Zahorska-Markiewicz et al., 1986). It is believed that these modifications of gastrointestinal morphology and function may contribute to the development of various diseases, including obesity (Wright et al., 1983).

Various types of liquid diets are widely used in the clinical setting. Liquid nutrition delivered to the stomach either orally *per vias naturales* or thru nasogastric tube is frequently used for its specific composition and better digestibility as well as for its beneficial adjuvant therapeutic effects. For example, liquid nutrition is used for the adjuvant treatment of diseases such as Crohn disease, esophageal cancer, and obesity (Day and Burgess, 2013; Johnson et al., 2006; Lean et al., 2013). Moreover, it is also used for

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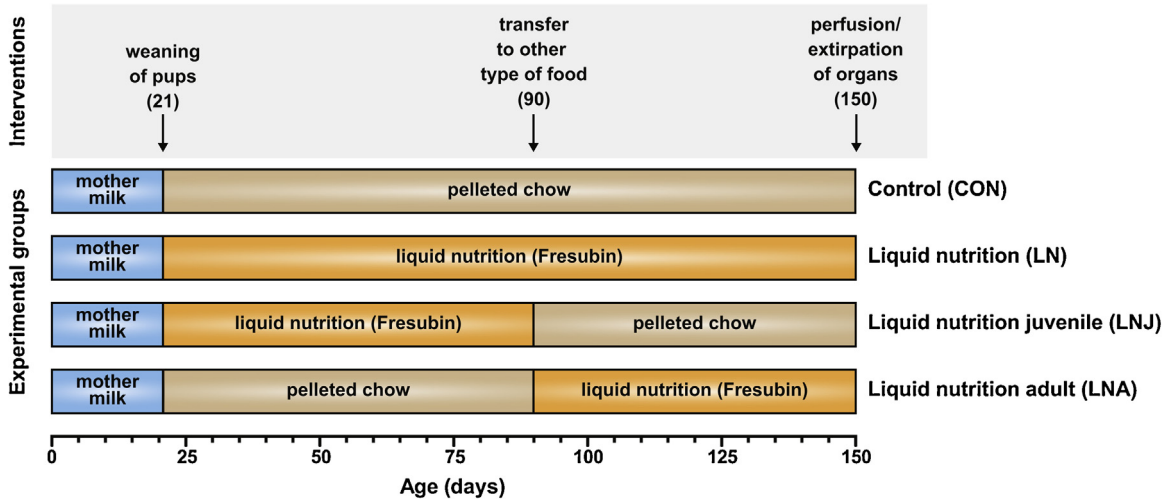

Fig. 1. Schematic illustration of the experimental design. At the age of 21st days pups were weaned and randomly separated into: (a) control group (CON) fed pelleted chow for the entire study; (b) liquid nutrition group (LN) fed liquid nutrition for the entire study; (c) liquid nutrition juvenile group (LNJ) fed 70 days by liquid nutrition and then 60 days by pelleted food; (d) liquid nutrition adult group (LNA) fed 70 days by pelleted chow and then 60 days by liquid nutrition. At the end of the study rats were perfused and gastrointestinal tissues were removed for further morphometric analyses.

Table 1
Body weight (bw) at the end of experiment and area under the curve (AUC) of energy intake, water intake and macronutrient intake in rats fed pelleted chow (CON), liquid nutrition (LN), liquid nutrition in juvenility (LNJ), or liquid nutrition in adulthood (LNA). Each value is displayed as mean ± SEM; n = 20 for each group.

	Groups			
Parameters	CON	LN	LNJ	LNA
Body weight (g)	493.15 ± 7.16	571.63 ± 19.25***	463.55 ± 9.69	619.05 ± 13.81***
AUC Energy intake (kJ/100 g bw/day)	1532.41 ± 20.11	1903.49 ± 19.16$^{###}$	1814.95 ± 29.47$^{###}$	1690.18 ± 26.49^{+++}
AUC Water intake (ml/100 g bw/day)	270.69 ± 2.94	424.16 ± 4.09$^{###}$, ~~~	377.18 ± 5.10$^{###}$	325.30 ± 3.94^{+++}
AUC Protein intake (g/100 g bw/day)	29.82 ± 0.41	17.69 ± 0.17$^{###}$, ~~~	21.79 ± 0.33$^{###}$	26.39 ± 0.42^{+++}
AUC Saccharide intake (g/100 g bw/day)	10.99 ± 0.15	64.22 ± 0.70$^{###}$, ~~~	47.34 ± 0.84$^{###}$	29.73 ± 0.74^{+++}
AUC Lipid intake (g/100 g bw/day)	3.51 ± 0.02	15.84 ± 0.15$^{###}$, ~~~	11.93 ± 0.19$^{###}$	7.88 ± 0.18^{+++}

*** $P < 0.001$ compared with CON and LNJ groups.
$^{###}$ $P < 0.001$ compared with CON and LNA groups.
$^{+++}$ $P < 0.001$ compared with CON group.
~~~ $P < 0.001$ compared with LNJ group.

acceleration of recovery from mild acute pancreatitis or abdominal surgery, as well as in controlling glycaemia of diabetic patients (Rajkumar et al., 2013; Stenvers et al., 2013). Therefore, it is not surprising that the beneficial effects of liquid diets are well known and documented. However, there is less documentation of their potential negative effects. For example, there is evidence that liquid diets can induce apoptosis of some cell types of the gastrointestinal tract, potentially resulting in atrophy of whole organs, including the major salivary glands and colon (Johnson et al., 1986; Scott and Gunn, 1991; Takahashi et al., 2012).

Compared to solid foods, liquids are more easily digested and reduce demands on the activity of the stomach and intestines (Hellstrom et al., 2006). However, intake of liquid diets is associated with low satiating effect and therefore increased food intake (Cuomo et al., 2011; Hellstrom et al., 2006; Malik et al., 2006). It has also been shown that liquid food promotes hyperplasia of the intestinal villi and crypts, in addition to increasing intestinal enzyme activity, nutrient absorption, and microbial growth (Deprez et al., 1987; Yang et al., 2001). Previously we have shown that chronic intake of liquid nutrition (Fresubin), a standard, nutritionally complete liquid diet designed for patients suffering from malnutrition or obstructions of the gastrointestinal tract, leads to marked hyperphagia and development of obesity as well as metabolic alterations in rats (Mikuska et al., 2013, 2016b). Fresubin contains 84 mL water per 100 mL of liquid nutrition. Therefore rats fed liquid nutrition showed approximately twofold water intake compared to rats fed by standard pelleted food (Mikuska et al., 2013). Increased volume of ingested food, especially during early developmental period, may potentially exert long-lasting effect on morphological and functional features of several organs systems. We have shown that chronic intake of liquid nutrition significantly affected kidney and heart morphology as well as blood pressure. Interestingly, observed alterations of metabolism, uropoetic and cardiovascular system were reversible (Mikuska et al., 2016a,b). Therefore, in the present study we investigate the effect of chronic liquid nutrition intake on gastrointestinal tract morphology, particularly of the stomach and duodenum in Wistar rats. Additionally, we also investigated the relationship between the developmental stages when liquid nutrition was provided and stomach and duodenum morphology. This experimental setting enables to determine also reversibility of potential changes induced by chronic liquid nutrition intake.

2. Materials and methods

2.1. Animals

Male pups with Wistar rats dams were purchased from Charles River (Germany). The rats were housed 4 per cage and were maintained under controlled laboratory conditions (12 h light/dark cycle, lights on at 6:00 a.m., ambient temperature 22 ± 1 °C and humidity 55 ± 10%). All experiments were performed between 08:00–12:00 h and all external noise or other stressful stimuli were strictly avoided. The experiments were approved by the Ani-
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