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ACKNOWLEDGEMENTS. We thank the Department of Science and Technology, New Delhi for providing funds through a research project and a Junior Research fellowship to R.B. We also thank Prof. Stephen Mann, University of Bristol, UK for help.

Received 5 August 2010; revised accepted 23 March 2011

Money handling and obesity: a test of the exaptation hypothesis

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The food reward centres in the brain play a central role in the regulation of food intake and thereby obesity. In the modern lifestyle, a number of artificial rewards such as money have been introduced and brain areas evolved for handling food rewards appear to be exapted to handle money and other rewards. This implies that the changing behaviour related to these rewards could influence obesity. Considering money as a reward, we conducted a survey of 211 full-time cashiers to test whether ownership over cash, amount of cash handled and duration of cash-handling work correlated with obesity parameters. Body mass index was significantly affected by sex, ownership, amount of money handled and duration of cash-handling service. Waist-to-hip ratio was significantly affected by sex, amount of money handled and marginally by ownership. The results are compatible with the exaptation hypothesis. It is possible that increasing importance of non-food rewards may play a significant role in the obesity epidemic.

Keywords: Body weight, economics of obesity, exaptation hypothesis, money handling.

OBESITY has become a major health concern worldwide[1]. Since obesity is associated with adverse health outcomes, increased health expenditures and increased risk of numerous co-morbidities[2], efforts are being made to understand the factors that are responsible for the prevalent obesity epidemic. Several genetic, metabolic, socio-economic and behavioural explanations are now available to account for the observed patterns of global increase in obesity. A large number of genes appear to influence body weight[3,4]. However, it is unlikely that the sudden rise in the proportion of obese people in many societies is due to increase in the frequency of any of the genes. A classical metabolic theory suggests that genetic or acquired 'thriftiness' in metabolism is a predisposing factor for obesity[5,6]. However, this view has been challenged

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recently[7,8]. It is also suggested that obesity represents a positive energy balance, i.e. energy intake consistently exceeds energy expenditure. However, whether the current obesity epidemic is because of increased energy intake or reduced energy expenditure or both, is seriously debated. Energy expenditure measurements using doubly labelled water have revealed that there is little difference in the total daily energy expenditure across societies, across lifestyles and over time[8,9]. This implies that increased energy intake might have a greater contribution.

It is becoming clear that adipose tissue has other active roles apart from being an energy-storage tissue alone, as it is an active endocrine organ affecting metabolism, immunity, sex, reproduction and cognitive brain functions[7,10–13]. Therefore, obesity and behaviour can be expected to interact mutually. O'Rahilly and Farooqi[14] argued that obesity is more of a neurobehavioural than a metabolic phenomenon. Christakis and Fowler[15] demonstrated that obesity spreads through social networks. Obesity is also suggested to work as a social signal[16] and is further linked to aggression suppression and accompanying behavioural and physiological changes[17]. These studies point to the behavioural aspects of obesity, raising the possibility that the missing links in metabolic interpretations of obesity may be found in behaviour.

Recent studies in the neuronal basis of reward anticipation can possibly explain some of the behavioural causes of obesity. The reward centres are known to play a central role in regulating food intake, although the exact mechanism by which this happens is debated. Repeated stimulation of reward centre is a suspected cause of overeating[18]. Three hypotheses have been proposed to understand how the reward centre regulates eating[19]. (1) Obese individuals experience greater activation of the meso-limbic reward system in response to food intake, which may increase risk for overeating. (2) Obese individuals experience less activation of the meso-limbic reward system in response to food intake, which leads them to overeat to compensate for this deficiency. (3) Greater anticipated reward from food intake increases risk for overeating.

We extend this line of thought to hypothesize that in modern lifestyle, and social and economic structure the importance of non-food rewards such as money is increasing. Frequent stimulation of the reward system by non-food rewards may eventually desensitize the reward centre which gives a subnormal response to food, and greater quantity of food is needed for generating adequate response. The most important non-food reward in modern life is money. Also, money reward is easier to quantify and therefore we focus on monetary reward, although other social and psychological rewards are also likely to have comparable effects. Neuroimaging studies have shown that brain regions responsive to money reward overlap extensively with those responsive to food reward[20–24]. The reward recognition response has qualitative and quantitative components. Elliott *et al.*[20] showed that regions responsive to monetary reinforcement overlap extensively with those responsive to primary reinforces such as food. They also distinguished the type of response given by different parts of the brain involved. Amygdala, dopaminergic midbrain and striatum respond to the presence of reward regardless of the value. Premotor cortex shows linearly increasing response with increasing reward value. Orbitofrontal cortex shows strong response at lower and higher values of reward, rather than the middle range. Wang *et al.*[21] demonstrated that orbitofrontal cortex is highly sensitive to food stimulus, while an independent study carried out by Elliot *et al.*[22] showed that the same region plays an important role in mediating the incentive value of the financial reward. Amygdala and striatum show heightened response when post stimulus movement is required, whereas no such change was observed within the orbitofrontal cortex.

Money is a recent phenomenon in the evolutionary history of man, and hence no separate brain centres are likely to have evolved for money handling. The brain centres evolved to handle food-related information and emotions appear to be involved in handling money-related information and emotions as well. This can be said to be a process of exaptation, which refers to features that are now utilized for a useful purpose but were not built by natural selection for their current role[25]. For example, the human hand evolved for tree climbing and tool making, but it can be used now for operating a computer keyboard.

The hypothesis being tested here is that due to exaptation, there is a neuronal crosstalk between money and food-related responses. Since increasing attention is being paid to the reward system as a possible seat of the problem, it is possible that the rapidly changing importance of money in human behaviour may be one of the factors contributing to the current obesity epidemic. In an attempt to test the hypothesis experimentally Briers *et al.*[26] demonstrated that food intake affected money-related decisions and thoughts about money affected food intake. Watve and Yajnik[7] speculated further that the desire for accumulating wealth may give a neuronal signal for accumulating fat.

While neuroimaging studies and controlled experiments raise the possibility that attitude towards money and wealth may affect food intake and fat accumulation, it is not known whether these factors have a detectable effect on an epidemiological scale. We decided therefore to test whether there is any significant association between money handling and fat accumulation on a population scale. We test here a proposed prediction of the exaptation hypothesis that people who handle more money and spend more time and energy in perceiving money as reward should show higher body mass index (BMI) and/or waist-to-hip ratio (W/H). One can think of a comparative study of cashiers versus other table jobs

that do not handle money. The potential problem here is that the different nature of work may involve different physical activity. For example, cashiers have greater restrictions on leaving their place during duty hours and this job may be more sedentary than other table jobs. Therefore, we took a different approach. We focused on people working as full-time cashiers. Assuming the nature of job of all full-time cashiers to be homogenous with respect to physical activity, we looked for factors that could affect qualitatively and quantitatively the physical and mental process of handling money. We identified three factors that were easy to objectively categorize or quantify, viz. (i) ownership over the money, which can be assumed to affect the attitude and involvement in the money being handled, (ii) the amount of money handled per day, and (iii) the duration of service as a cashier. Predictions of the exaptation hypothesis are that owner cashiers should have higher BMI and/or W/H ratio than salaried cashiers, since the cash being handled has a greater reward value for owners. The amount of money handled and duration of the cashier's job should be positively correlated with BMI and/or W/H ratio after adjusting for age, sex and exercise.

Data were collected by interviewing cashiers from three cities in Maharashtra, India, viz. Pune (18°31′N, 73°55′E), Mumbai (18°55′N, 72°54′E) and Nagpur (21°09′N, 79°09′E). All respondents were asked their verbal consent for participation in the survey, but were kept unaware of the hypothesis being tested. We avoided asking for written consent since a substantial fraction of the respondents were from crowded busy markets and generally reluctant to spend time for survey questionnaires. Signing any document with a quasi-legal language would have added to the reluctance and thereby biased the sample. Since the survey did not involve any drug, invasive procedure, phlebotomy, biopsy or any other biological sample collection, psychiatric questionnaires or the like, we kept the formal ethical procedures to a minimum.

BMI, waist circumference and W/H ratio were recorded as measures of obesity. A questionnaire was designed to collect information about (i) personal history (age, sex and routine exercise, if any), (ii) job history (years of service in current position and previous jobs, if any and years of service in each), and (iii) body parameters (height, weight, hip circumference and waist circumference). Self-reported routine exercise was categorized in four categories, viz. no exercise (designated with an index 0); low exercise (walking less than 3 km per day and no other exercise with an index 1); moderate exercise (walking more than 3 km per day, yoga or light health-club exercises, index 2); vigorous sports (aggressive games or other rigorous exercises, index 3).

To account for the effect of ownership, we divided the cashiers into salaried cashiers working on fixed salaries that did not vary with the fluctuations in the amount of daily cash handled, and owner cashiers who had partial or complete ownership over the money and for whom the fluctuations in daily amounts were proportionate to fluctuations in income. Most of the salaried cashiers in the sample were employees of banks, shops or other private establishments. There were problems in getting honest information on cash turnover from the private sector owing to the fear of taxation enquiries. We therefore decided not to treat the cash turnover as a continuous variable, but categorized it as low (less than Rs 50,000 per day) and high (greater than Rs 50,000 per day) turnover.

We performed ANCOVA analysis to account for intergroup variation associated with sex, ownership, cash-amount category and exercise categories as factors, and age, duration of sedentary service and duration of cashier service as covariates.

Classification of individuals in obesity classes according to their BMI showed that in both sexes owner cashiers had more pre-obese and obese individuals than salaried cashiers (Table 1). ANCOVA (Table 2) showed that BMI was significantly affected by sex, ownership, years of service as cashier, amount of money handled and diabetes. Females had a significantly greater mean BMI (25.12) than males (24.45, $P = 0.039$) and mean BMI (25.78) of owner cashiers was highly significantly greater than salaried cashiers (23.7, $P = 0.001$) (Figure 1). The amount of money handled positively affected BMI significantly (high turnover 25.26, low turnover 24.35, $P = 0.034$) and the effect of duration of cash-handling service was marginal ($P = 0.054$). Age, duration of service in sedentary job and exercise did not show significant effects. W/H ratio was significantly affected by sex, amount of money handled and exercise. Males had greater mean W/H ratio (0.933) than females (0.86, $P < 0.0001$). Cashiers handling greater amounts of money per day had significantly greater W/H ratio (0.942 and 0.905 respectively for males and females, $P < 0.001$; Figure 1). W/H ratio was significantly positively associated with exercise (for exercise categories in increasing order 0.914, 0.903, 0.947 and 0.957 respectively, $P = 0.004$) possibly owing to reverse causation (i.e. obese individuals having greater motivation and social pressure to take up exercises). Owners had higher W/H ratio (0.921) than salaried cashiers (0.912), but significance was marginal ($P = 0.068$). Although the three money-related factors had significant effects on obesity parameters, the predictability of the model was low. It explained 18% of variance in BMI and 25% in W/H ratio.

Compatible with the exaptation hypothesis, all the three money-related factors, viz. ownership over money, amount of money handled and duration of cashier service had detectable effects on the obesity parameters. Three possible alternative explanations may be able to account for the differences. (i) Owner cashiers may be said to experience a greater stress than salaried cashiers. This explanation suffers from a problem commonly encountered by all stress-related hypotheses; that of defining and

Table 1. Distribution of body mass index (BMI) categories among salaried and owner cashiers

		Percentage of individuals in a category*				
	Number of individuals	Under weight	Normal range	Pre-obese	Obese class I	Obese class II
Male						
Salaried cashiers	79	6.33	69.62	20.25	3.80	0.00
Owner cashiers	84	2.38	41.67	40.48	13.10	2.38
Female						
Salaried cashiers	36	11.11	58.33	19.44	5.56	5.56
Owner cashiers	12	0.00	25.00	58.33	16.67	0.00

*Categories according to the World Health Organization[1].

Table 2. ANCOVA table for factors associated with BMI and waist-to-hip (W/H) ratio

Parameter	Model value (SD)	*t*	*P*
BMI			
Intercept	29.662 (5.345)	10.948	< 0.0001
Age	–0.194 (0.227)	–1.692	0.092
Years of service as cashier	0.059 (0.060)	1.937	0.054
Total years of sedentary job	0.193 (0.241)	1.580	0.116
Sex	–1.349 (1.281)	–2.076	0.039*
Ownership	2.374 (1.411)	3.320	0.001*
Amount of money handled	–1.809 (1.674)	–2.133	0.034*
Exercise	–0.746 (1.228)	–1.198	0.233
Diabetes	3.124 (2.861)	2.154	0.033*
Heart disease	–2.721 (4.542)	–1.182	0.239
Blood pressure	1.505 (1.651)	1.798	0.074
W/H ratio			
Intercept	0.830 (0.114)	14.403	< 0.0001
Age	0.001 (0.005)	0.610	0.542
Years of service as cashier	–0.001 (0.001)	–1.138	0.256
Total years of sedentary job	–0.001 (0.005)	–0.283	0.778
Sex	0.081 (0.027)	5.868	< 0.0001*
Ownership	0.028 (0.030)	1.835	0.068
Amount of money handled	–0.065 (0.036)	–3.604	0.000*
Exercise	0.057 (0.038)	2.939	0.004*
Diabetes	–0.003 (0.061)	–0.100	0.920
Heart disease	–0.049 (0.097)	–0.993	0.322
Blood pressure	0.001 (0.035)	0.049	0.961

*Significant effect.

quantifying stress. In the absence of an objective measure, the stress hypothesis becomes non-falsifiable and therefore should be considered with a lower priority, although it cannot be completely ruled out. (ii) Since most high-turnover salaried cashiers were from banks and low-turnover salaried cashiers from shops and private establishments, the difference could be argued to be due to other unidentified factors in the two types of environment. This is an inherent bias in the data, which could not be removed. However, there is no perceivable a priori reason for the two job settings inducing the difference. (iii) The effect of duration of cashier service could be argued to be an effect of sedentary job. Here the absence of a significant association with the total duration of sedentary job suggests that this explanation is inadequate. Thus although other explanations are not completely ruled out at this stage, the effect of money is the only single and most parsimonious explanation for all the three effects. Therefore, we can argue that the data are in support of, or at least compatible with the exaptation hypothesis, if not a convincing proof of it. The relatively low explained variance, in spite of high levels of significance, indicates the limits to the influence of money on obesity. For a phenomenon like obesity which is influenced by a large number of genetic and environmental factors[3], a single potential causal factor explaining 18% variance in BMI and 25% in W/H ratio is certainly not negligible. Genome-wide association studies have identified a large number of loci associated with obesity. Although the associations are statistically highly significant, they together explain not more than 2% of population variance in obesity[27–31]. With this background, if three

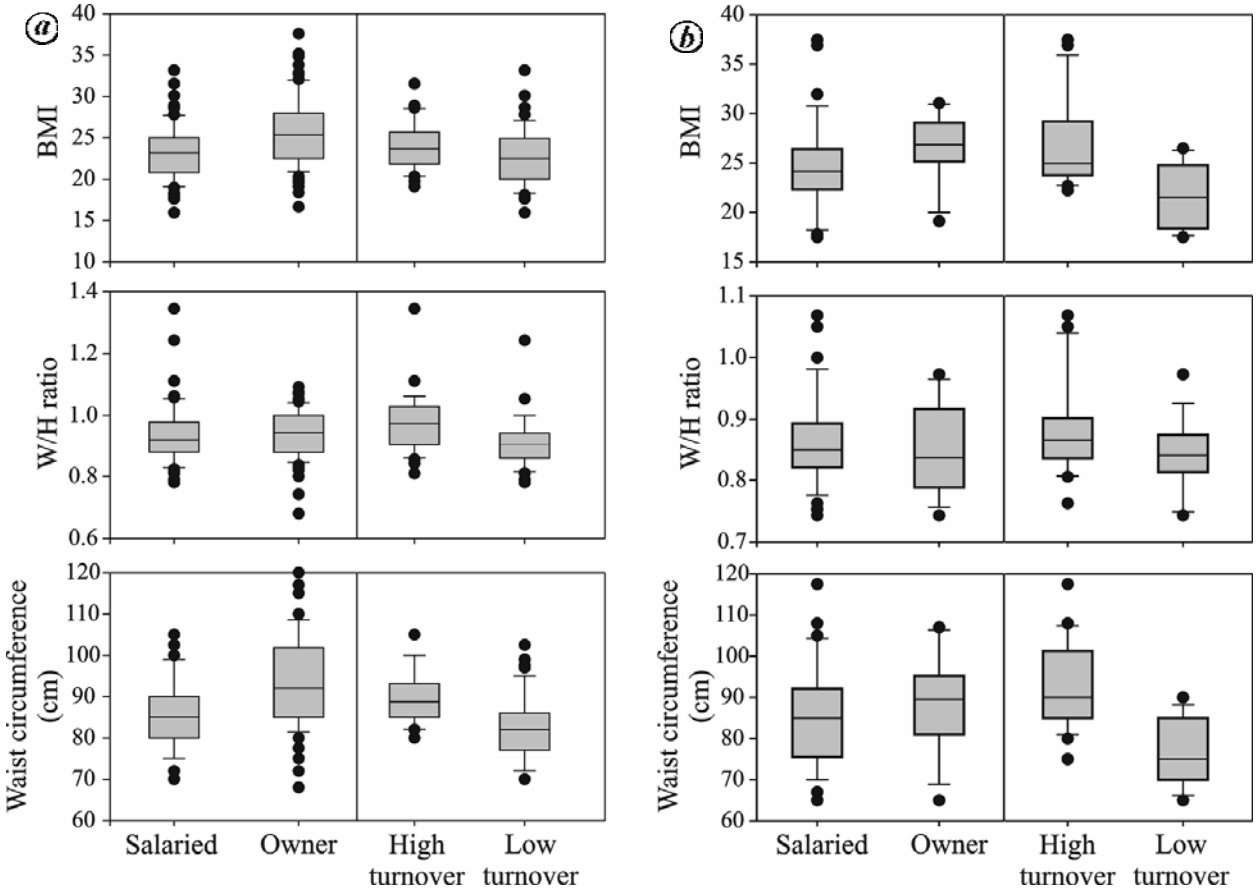

Figure 1. Box plots of body mass index (BMI), waist-to-hip (W/H) ratio and waist circumference of (***a***) male and (***b***) female salaried and owner cashiers, and among the high and low turnover salaried cashiers.

parameters of a single behavioural trait explain 18–25% variance, it is highly intriguing and should trigger more studies across cultures with different ethnic and economic backgrounds.

Although the data were only about cashiers, the principle should be applicable more widely. We collected data about cashiers because it was easier to get objective and measurable parameters related to money. Being the owner of money may imply greater involvement in the money being handled and greater intensity of perceiving money as reward, and there is no ambiguity in the distinction between owner and salaried. For other people it would be more difficult to quantify how much time, mental space or intensity is given to money-related thoughts. However, there is no reason why any neurobehavioural phenomenon implied by a cashier study should not be applicable to others. The implications may go beyond money and apply to other non-food rewards as well, although objectivity and quantifiability could be more difficult in those cases.

Most of the current theories of obesity revolve around increased food intake and reduced energy expenditure. There are some glaring gaps in this thinking. For example, any data on the efficiency of assimilation are conspicuously lacking. The differential allocation of energy within a body has also not received sufficient attention. Even if we restrict ourselves to food intake, all the reasons for increase in food intake are not completely clear. Increased food availability might explain an increased intake only in the lower range of food availability. Satiety mechanisms are expected to make the relationship saturating and therefore, any factor that tampers with the satiety signals could be a more likely cause of obesity. Our results support the view that the changing economic aspirations and changing reward values are likely to be one of the neuronal causes of overeating since they can interfere in the reward recognition and satiety mechanisms.

It is already well documented that the obesity epidemic has some relation to the economics of different societies. Across nations there is a positive correlation between income and BMI[32]. Within less developed countries, those with higher socio-economic status are more likely to be obese. In cross-sectional data there is a negative correlation between income and BMI in some of the developed countries[32,33]. However, longitudinal studies on American women showed that after correcting for race, education and reverse causation (i.e. obese women are less likely to get high-paying jobs), there remains a

causal relationship of high income with increase in body weight[32].

Obesity is certainly a complex phenomenon and a number of different factors ranging from virus infections[34] to psychosocial factors must be contributing to it. Although at this stage we do not know to what extent exaptation contributes to it, it appears a promising hypothesis raising a number of questions and should trigger neurobiological, psychological, endocrinological as well as epidemiological studies.

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ACKNOWLEDGEMENT. We thank Krystal Philip and Bangari Haldipur for help during data collection.

Received 1 July 2010; revised accepted 5 April 2011