NeuroImage: Clinical 12 (2016) 262–268

Contents lists available at ScienceDirect

NeuroImage: Clinical

journal homepage: www.elsevier.com/locate/ynicl

Disrupted functional connectivity in adolescent obesity

Laura Moreno-Lopez[a], Oren Contreras-Rodriguez[b,c], Carles Soriano-Mas[b,c,d], Emmanuel A. Stamatakis[a], Antonio Verdejo-Garcia[e,f,g,*]

[a] Division of Anaesthesia, University of Cambridge, Cambridge, UK
[b] Department of Psychiatry, Bellvitge Biomedical Research Institute-IDIBELL, Barcelona, Spain
[c] Centro de Investigación Biomédica en Red de Salud Mental (CIBERSAM), Barcelona, Spain
[d] Department of Psychobiology and Methodology of Health Sciences, Universitat Autònoma de Barcelona, Barcelona, Spain
[e] Red de Trastornos Adictivos, University of Granada, Granada, Spain
[f] Instituto de Neurociencias F. Olóriz, University of Granada, Granada, Spain
[g] School of Psychological Sciences & Monash Institute of Cognitive and Clinical, Neurosciences, Monash University, Melbourne, Australia

ARTICLE INFO

Article history:
Received 6 May 2016
Received in revised form 21 June 2016
Accepted 11 July 2016
Available online 12 July 2016

Keywords:
fMRI
Resting state
Functional connectivity
Obesity
Adolescents

ABSTRACT

Background/objective: Obesity has been associated with brain alterations characterised by poorer interaction between a hypersensitive reward system and a comparatively weaker prefrontal-cognitive control system. These alterations may occur as early as in adolescence, but this notion remains unclear, as no studies so far have examined global functional connectivity in adolescents with excess weight.
Subjects/methods: We investigated functional connectivity in a sample of 60 adolescents with excess weight and 55 normal weight controls. We first identified parts of the brain displaying between-group global connectivity differences and then characterised the extent of the differences in functional network integrity and their association with reward sensitivity.
Results: Adolescent obesity was linked to neuroadaptations in functional connectivity within brain hubs linked to interoception (insula), emotional memory (middle temporal gyrus) and cognitive control (dorsolateral prefrontal cortex) (pFWE < 0.05). The connectivity between the insula and the anterior cingulate cortex was reduced in comparison to controls, as was the connectivity between the middle temporal gyrus and the posterior cingulate cortex and cuneus/precuneus (pFWE < 0.05). Conversely, the middle temporal gyrus displayed increased connectivity with the orbitofrontal cortex (pFWE < 0.05). Critically, these networks were correlated with sensitivity to reward ($p < 0.05$).
Conclusions: These findings suggest that adolescent obesity is linked to disrupted functional connectivity in brain networks relevant to maintaining balance between reward, emotional memories and cognitive control. Our findings may contribute to reconceptualization of obesity as a multi-layered brain disorder leading to compromised motivation and control, and provide a biological account to target prevention strategies for adolescent obesity.
© 2016 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Obesity is the most important health concern in the world today, as it contributes to diseases such as type-2 diabetes, cardiovascular disease, musculoskeletal conditions, some cancers and dementias (Guh et al., 2009; Whitmer et al., 2008). When obesity manifests during adolescence, the risk of developing these medical conditions during lifetime is significantly increased (Inge et al., 2013; Reis et al., 2013). Obesity has been traditionally defined as a *physiological* imbalance between energy consumption and energy expenditure, and thus most research on its neural underpinnings has been limited to homeostatic centres, such as the hypothalamus (Horvath, 2005). However, obesity is arguably linked to abnormal communication between multiple brain areas implicated in perception of homeostatic signals, reward related motivation and cognitive control (Berthoud, 2011; Jensen and Kirwan, 2015; Mata et al., 2015). Given that adolescence is characterised by a unique brain network organisation linked to a *psychological* imbalance between enhanced reward sensitivity and reduced cognitive control, (Paus et al., 2008; Van Leijenhorst et al., 2010) and thus to sensitised reactivity towards highly appetising food, (Stice et al., 2011) research on brain network organisation can provide important insights for understanding and prevention of adolescent obesity.

Resting-state connectivity approaches have successfully identified alterations in functional brain networks within populations with obesity: obese individuals compared to normal weight controls show increased connectivity between regions involved in metabolic sensing

* Corresponding author at: School of Psychological Sciences, Monash University, 18 Innovation Walk, 3800 Clayton Campus, Melbourne, Australia.
E-mail address: antonio.verdejo@monash.edu (A. Verdejo-Garcia).

http://dx.doi.org/10.1016/j.nicl.2016.07.005
2213-1582/© 2016 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

and interoception (i.e., hypothalamus, insula) and regions involved in reward processing (i.e., striatum and orbitofrontal cortex or OFC) (Coveleskie et al., 2015; Kullmann et al., 2014; Wijngaarden et al., 2015). Moreover, obese individuals display decreased connectivity in brain regions involved in interoceptive processing and cognitive control (Kullmann et al., 2012). However, these studies have exclusively assessed adult samples, and therefore it remains unknown if brain connectivity alterations are manifest in adolescent populations. Only one study has previously assessed resting-state functional connectivity in obese adolescents through magnetoencephalography (MEG), showing that obese adolescents display increased connectivity in frontal, temporal and occipital regions compared to normal weight controls (Olde Dubbelink et al., 2008). However, the application of novel functional magnetic resonance imaging (fMRI) methods for measuring both global and regional connectivity can provide substantially more precise mapping of the connectivity alterations that characterises adolescent obesity.

In this study, we apply (i) a large-scale global connectivity approach to identify the key brain hubs that distinguish adolescents with obesity from normal weight controls, and (ii) data driven seed-based connectivity analyses to describe specific alterations between these networks, and their correlation with sensitivity to reward. We hypothesise that obese adolescents will have abnormal global connectivity in brain hubs implicated in interoception (insula), motivation (striatum, limbic regions, OFC) and cognitive control (dorsolateral prefrontal cortex or DLPFC), and that increased seed-based functional connectivity between regions involved in interoception and motivation, and decreased functional connectivity between regions involved in interoception/motivation and cognitive control would be associated with higher sensitivity to reward.

2. Materials and methods

2.1. Subjects

One hundred and fifteen adolescents participated in this study: 55 with normal weight (32 females, 23 males) and 60 with excess weight (38 females, 22 males) based on standard BMI cut-offs (Cole and Lobstein, 2012). Both groups had statistically similar distributions in terms of age, years of education and biochemical measures (Table 1). Participants were recruited through the Hospital Virgen de las Nieves (Granada, Spain) and through educational and community services in the same geographical area. The eligibility criteria were age between 12 and 17 years old, and BMI between 18 and 40. The exclusion criteria were as follows: (i) chronic medical conditions (i.e., diabetes, hypertension) indicated by self-reports and blood count and blood pressure measures, (ii) mental health problems indicated by the Millon Adolescent Clinical Inventory, (Aguirre, 2004) (iii) history of head trauma indicated by self-reporting, and (iv) contraindications to MRI scanning, such as claustrophobia and implanted ferromagnetic objects. This study was approved by the Human Research Ethics Committee of the University of Granada and all subjects and their parents provided written informed consent.

2.2. Procedure

Assessments were conducted during two different sessions at least 7 days apart. During the first session the participants were screened and completed the self-report questionnaires. The second session involved resting-state fMRI scanning.

2.2.1. Self-report questionnaire

The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ) (Torrubia et al., 2001) is a 48 items self-report questionnaire comprising two subscales: Sensitivity to Punishment (e.g., “Are you often afraid of new or unexpected situations?”), and Sensitivity to Reward (e.g., “Do you sometimes do things for quick gains?”). Participants respond using a dichotomous scale (“yes” or “no”), and the score of each subscale is the result of the sum of the affirmative responses. This questionnaire has showed adequate internal consistency, and its scores hold adequate validity (Caseras et al., 2003). The outcome measure of interest was the score of sensitivity to reward, which was correlated with brain connectivity measures.

2.2.2. MRI data acquisition

All the MRI scans took place between 4 and 6 p.m., after the main meal of the day (lunch is the main meal of the day in Spain and typically occur between 2 and 3 p.m.). The resting-state sequence lasted 6 min, and participants were instructed to keep awake with their eyes closed. We used a 3.0 Tesla clinical MRI scanner, equipped with an eight-channel phased-array head coil (Intera Achieva Philips Medical Systems, Eindhoven, The Netherlands). A T2*-weighted echo-planar imaging (EPI) was obtained (TR = 2000 ms, TE = 35 ms, FOV = 230 × 230 mm, 96 × 96 pixel matrix; flip angle = 90°, 21 4-mm axial slices, 1-mm gap, 180 whole-brain volumes). The sequence included four additional dummy volumes to allow magnetization to reach equilibrium.

2.3. Imaging analyses

2.3.1. Preprocessing

Functional imaging data were preprocessed and analyzed using statistical parametric mapping (SPM8) (http://www.fil.ion.ucl.ac.uk/spm/software/spm8/) implemented in MATLAB R2007b (MathWorks, Natick, MA, USA). Preprocessing steps involved motion correction,

Table 1
Demographics, blood count based biochemical indices and self-report scores of excess weight and normal weight groups.

	Normal weight (n = 55)		Excess weight (n = 60)		Test	
	Mean	SD	Mean	SD	t	p
Age (years)	15.11	1.82	14.67	1.70	1.345	0.181
Height (m)	164.17	9.34	163.62	8.85	0.327	0.744
Weight (kg)	56.60	10.68	78.69	13.93	9.482	0.000*
BMI (kg/m^2)	20.84	2.39	29.26	3.84	−14.242	0.000*
Biochemical parameters						
Insulin	57.12	119.88	49.76	59.53	0.279	0.781
Basal glucose	92.00	6.92	93.26	5.108	−0.832	0.409
Triglycerides	63.89	27.91	71,37	29.81	−1.013	0.315
Cholesterol	145.97	19.66	158.00	28.35	−1.990	0.051
Sensitivity to punishment and reward questionnaire						
Sensitivity to reward	10.18	5.10	9.95	5.09	0.244	0.808
Sensitivity to punishment	11.44	4.15	9.58	3.72	2.527	0.013*

* $p < 0.05$.

Download English Version:

https://daneshyari.com/en/article/3074812

Download Persian Version:

https://daneshyari.com/article/3074812

Daneshyari.com