International Journal of School and Cognitive Psychology

Völgyi, Int J Sch Cog Psychol 2015, 2:2
DOI: 10.4172/2469-9837.1000124

Research Article Open Access

Physical Activity, Body Composition and Resting Cortical Activity in Preschool Children

Völgyi E[1,2,3*], Rezaie R[1,4], Hare ME[1,3], Tylavsky FA[3] and Papanicolaou AC[1,4]

[1]Department of Pediatrics, University of Tennessee Health Science Center, Memphis, TN 38103, USA

[2]Children's Foundation Research Institute, Le Bonheur Children's Hospital, Memphis, TN 38103, USA

[3]Department of Preventive Medicine, University of Tennessee Health Science Center, Memphis, TN 38163, USA

[4]Neuroscience Institute, Le Bonheur Children's Hospital, Memphis, TN 38103, USA

[*]**Corresponding author:** Eszter Völgyi, PhD, Department of Pediatrics, University of Tennessee Health Science Center, Memphis, TN 38103, USA, Tel: +1 901-287-5360; Fax: +1 901-287-4478; E-mail: evoelgyi@uthsc.edu

Rec date: Dec 9, 2014, **Acc date:** Apr 16, 2015, **Pub date:** Apr 20, 2015

Abstract

In this study, we explored the relationship between physical activity, body composition and cortical function in a cohort of preschool children.

All participants underwent resting magnetoencephalography (MEG), a non-invasive measure of direct neuronal activity, and estimates of physical activity and body composition were obtained using accelerometer and dual-energy X-ray absorptiometry, respectively.

In contrast to previous studies in adults, we found no association between measures of resting neuronal activity and body composition or body mass index (BMI) percentile. However, time spent performing moderate- ($r=0.905$, $p<0.0001$), moderate-vigorous ($r=0.886$, $p<0.0001$) physical activity and overall activity counts ($r=0.889$, $p<0.0001$) were significantly correlated with increased power in the alpha band (8-12 Hz) in left and right central brain regions.

These results are suggestive of a complex relationship between physical activity and resting brain function, believed to underlie the organization of sensorimotor and higher cognitive functions, critical to later academic success.

Keywords: Brain function; Magnetoencephalography; Physical activity; Body composition; Preschoolers

Introduction

The notion that aerobic physical activity during childhood has a significant impact on the development of higher cognitive functions has gained wide support in recent years [1]. From a neurobiological perspective there is evidence to suggest that, in preadolescent children, aerobic fitness is strongly associated with the integrity of brain structures associated with various aspects of cognition, namely relational memory and executive functions [2,3], in addition to neurophysiological indices of cortical activity related to the latter [4-8]. In view of the strong correlation between habitual physical activity and adiposity in children and adolescents [9,10], several studies - albeit in young adults have already noted a relationship between higher body mass index and diminished structural integrity of cortical regions believed to be critical in the reward system and taste regulation [11,12], as well as abnormalities in resting brain activity necessary for arousal and vigilance, among other functions [13]. This is important, because it has been speculated that resting state alpha-band oscillations reflect one of the most basic cognitive processes [14]. Literature describing physical activity, obesity and brain function in the pediatric population is scarce, in part due to the difficulties of neuroimaging assessments in children. An earlier study on adolescent girls also strengthened the hypothesis that obesity may have a major impact on human brain function, based on an altered resting-state functional connectivity in severely obese adolescents [15]. These findings highlight the need for more pediatric research in this area to further investigate the onset of this phenomenon.

Considering that the incidence of obesity has more than doubled in children in the last 30 years [16], the influence of physical activity and excess body weight on brain functional architecture during early development may be an important factor in accounting for differences in cognitive function and academic achievement between healthy and overweight children. In the current study, we further explored this relationship in a sub-sample of preschoolers. Specifically, we examined the association between resting brain function, obtained using a non-invasive measure of direct neuronal activity known as magnetoencephalography (MEG), and estimates of physical activity and body composition based on accelerometry and dual-energy X-ray absorptiometry (DXA), respectively.

Materials and Methods

Participants: Individuals were recruited through the Conditions Affecting Neurocognitive Development and Learning in Early Childhood (CANDLE) study at their clinical visit. The study's primary aim is to identify factors from in utero through early childhood that contribute to cognitive development by age 3. A detailed description of the study is given elsewhere [17]. Briefly, healthy pregnant (16-28 weeks of gestation) women (between the ages of 16 and 40) were enrolled in the CANDLE study between December 2006 and July 2011. CANDLE children were considered to be developing normally on the basis of: (1) full term (i.e., >37 weeks gestation) based on ultrasound data or on the mother's report of her last menstrual cycle; (2) no history of frank neurological damage or diagnosed seizure disorder; (3) no history of serious psychopathology resulting in psychiatric hospitalization (e.g., a psychotic episode); (4) no history of autism spectrum disorder or hyperactivity disorder; (5) no history of neonatal drug exposure; (6) and body mass index (BMI) not less than the age- and sex-appropriate 3rd percentile [18]. The age of the children who fully completed the study (n=17) ranged from 3.8 to 5.2 years. Participants who were under deep sleep during MEG testing (n=4), or were extreme outliers (±3 SD) in either the body composition measures (n=1) or cortical spectral power values (n=1) were excluded from analysis. All subjects were right-handed and every participant completed two separate study visits within 2 months.

The study was performed in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of the University of Tennessee Health Science Center.

Anthropometric measurements: Participants were weighed while wearing light clothes and without shoes. Height was determined using a fixed wall-scale measuring device to the nearest 0.1 cm. The average of two measurements that were within 1 cm was used as the participant's height. Weight was determined to within 0.1 kg for each subject using an electronic scale that was calibrated weekly. The average of two measurements within 0.2 kg of each other was used as the participant's weight. Body mass index was calculated as weight (kg) per height (m^2), and age- and gender-specific percentile scores were calculated based on the CDC (Centers for Disease Control) growth charts.

Body composition assessment: Dual-energy X-ray absorptiometry [Hologic Discovery A (Bedford, MA) software version 8.3 and analyzed using APEX software 2.3] was used to measure whole body fat mass (FM), percentage of FM (FM%), and lean mass (LM). Subtotal FM, FM% and LM are reported in this paper. All metal items were removed from the participants and a certified technician performed the DXA measurements using a standardized protocol. The subjects were positioned in the center of the table and they were scanned using the default scan mode. The coefficient variation was 0.02% for LM, 0.05% for FM, 0.04% for total mass, and 0.03% for FM%. All DXA scans were reviewed for quality assurance by one of the study co-investigators (F.A.T.).

Physical activity monitoring: Each child was asked to wear an accelerometer (ActiGraph GT1M; The ActiGraph, Fort Walton Beach, FL) attached to an elastic band on the right hip for seven consecutive days (except bathing, napping and sleeping). The monitor was programmed to collect 15 sec epoch (interval) motion counts. Accelerometry has been shown to provide valid estimates of physical activity among young children [19] and it has been used extensively by other investigators. Each child included in the analysis met the criteria of wearing the accelerometers for a minimum of 10 hours for at least two days [20].

Accelerometer data were processed and cleaned in Microsoft EXCEL (Microsoft Inc, Redmond, WA). Missing data, which were defined as sequences of ≥10 minutes consecutive zero counts, were deleted before analysis. The total volume of physical activity was expressed as total counts divided by three days registered with most wearing time. Cut-off points for moderate- and vigorous-intensity physical activity were defined according to Pate et al. [21]. Daily activity count, step count, and daily time spent in sedentary-light physical activity (SLPA), moderate physical activity (MPA), vigorous physical activity (VPA), and moderate and vigorous physical activity (MVPA) are reported in this paper.

Magnetoencephalography and fast fourier transformation: For each subject, 5 minutes of resting MEG data (sampling rate of 1017.25 Hz, and 0.1-200 Hz band-pass filter) was recorded using a 248-channel whole-head neuromagnetometer (WH 3600, 4D Neuroimaging Inc., San Diego, CA, USA) housed in a sound-damped and magnetically shielded room. Participants were asked to keep their eyes closed and avoid blinking or otherwise moving during the recordings. A minimum of 5 segments of resting MEG data (5 seconds duration) not affected by the presence of biogenic or environmental artifacts were selected after visual inspection for digital fast Fourier transformation (FFT) power spectrum analysis, previously described by Castillo et al. [22]. The FFT was computed using a 0.19 Hz frequency resolution, and spectral power was summarized using the standard frequency bands of delta (0-4 Hz), theta (4-7 Hz), alpha (8-12 Hz) and beta (12-20 Hz). To characterize regional differences in spectral power, MEG sensors in the left and right hemispheres, excluding sensors in the midline, were grouped into anterior, temporal, central and posterior regions as shown in Figure 1. These groupings were chosen to approximate coverage of the frontal lobes (anterior), temporal lobes (temporal), central-parietal cortex (central) and occipital lobes (posterior).

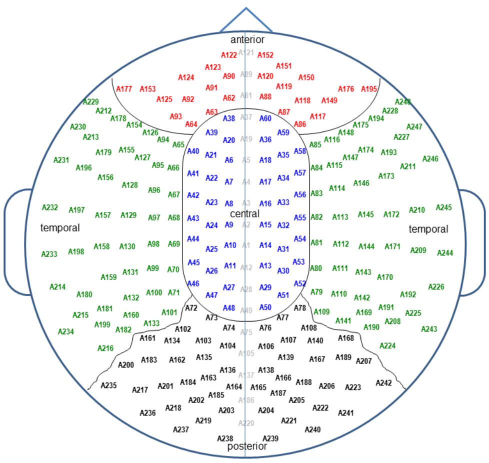

Figure 1: Grouping of the 248 MEG sensors.

Analyses: All continuous data were checked for normality using Shapiro-Wilk's W test. Descriptive results are reported as mean ± SD. Pearson correlation was used to test the relationship between average spectral power for each of the four areas and four frequency bands, and physical activity and body composition outcomes. Bonferroni correction was applied for all correlations. All analyses were performed using Statistica v12 (StatSoft Inc., Tulsa, OK, USA).

Results

The characteristics of the study participants are presented in Table 1. There were 11 participants included in the analysis (4 boys), with an

Citation: Völgyi E, Rezaie R, Hare ME, Tylavsky FA and Papanicolaou AC (2015) Physical Activity, Body Composition and Resting Cortical Activity in Preschool Children. Int J Sch Cog Psychol 2: 124. doi:10.4172/2469-9837.1000124

average age of 4.6 years; 73% were African American. The participants' BMI percentiles and subtotal FM% represented a large range; 24.2-97.7 and 12.6-38.9%, respectively. Two participants (18%) were above the 95th percentile on the CDC BMI for age chart.

Characteristics	Mean	SD	Min	Max
Age (years)	4.6	0.45	4	5.17
Gender	4 boys/7 girls			
Height (cm)	107	4.8	98.4	113.7
Weight (kg)	18.3	2.8	15	25.8
BMI (kg/m^2)	15.8	1.54	14.5	19.5
Height for age pct	58.5	26.5	24.2	94.5
Weight for age pct	55.6	25.2	24.2	97.1
BMI pct	55.2	23.7	24.2	97.7
Subtotal fat mass (kg)	3.96	21.86	1.86	8.63
Subtotal lean mass (kg)	11.4	1.77	8.7	13.6
Subtotal fat mass percent (%)	25.3	8.3	12.6	38.9
Steps taken a day	7870	2852	4077	15391
SLPA (hrs/day)	10.6	1.3	8	12.4
MPA (hrs/day)	1.2	0.4	0.7	1.9
VPA (hrs/day)	0.4	0.2	0.2	0.8
MVPA (hrs/day)	1.6	0.6	0.9	2.7

BMI: Body mass index, PCT: percentile, SLPA: Sedentary-light physical activity, MPA: Moderate physical activity, VPA; Vigorous physical activity, MVPA; Moderate and vigorous physical activity

Table 1: Basic characteristics of study participants (n=11).

On average, study participants were taking 7870 ± 2852 steps daily, and spent an average of 0.4 ± 0.2 hrs/day in vigorous activity, 1.2 ± 0.4 hrs/day in moderate activity and 10.6 ± 1.3 hrs/day in sedentary and light physical activities.

While strong correlations were observed for the right hemisphere between lean mass, fat mass % and theta activity in all four brain regions (range 0.52 to 0.74), and between lean mass and alpha activity in the temporal, central and posterior regions (range 0.67 to 0.76), these relationships did not remain significant following Bonferroni correction. In our sample, BMI percentile and body mass did not correlate with regional spectral power in any of the frequency bands.

On the other hand, as shown in Figure 2, following Bonferroni correction, alpha activity in the right central region was significantly correlated with moderate-level physical activity (r=0.898, p<0.0001). Furthermore, in the left hemisphere, alpha activity in the central region strongly correlated with time spent performing moderate (r=0.905, p<0.0001), moderate-vigorous (r=0.886, p<0.0001) and overall activity count (r=0.889, p<0.0001).

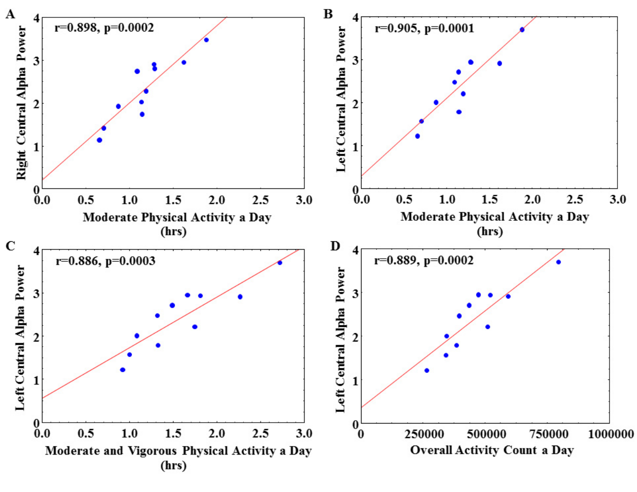

Figure 2: Relationship between regional spectral power and physical activity (significant correlation coefficients after Bonferroni correction (p<0.00014)).

Discussion

Using MEG, body composition assessment and accelerometry, we explored the relationship between resting brain function, fat mass and physical activity in preschoolers. While no significant association between resting brain activity and body composition or BMI was noted, mean power in the alpha band in central brain regions correlated significantly with moderate, moderate-vigorous and overall physical activity. Moreover, despite the modest sample size and the relatively large number of comparisons, we attempted to mitigate the possibility of spurious significant results, by removing extreme outliers and using correction for the multiple correlations.

With respect to body composition, BMI and brain activity, our findings are in contrast to recent studies. Babiloni, et al., [13] used electroencephalography (EEG) and reported that abnormal weight in healthy overweight/obese young adults was related to altered cortical neural synchronization based on resting state alpha rhythms. Yau, et al., [23] also reported that obese adolescents have subtle brain alterations, namely reduced thickness of the orbitofrontal and anterior cingulate cortices, two areas that are believed to be related to eating and food observation [24,25]. These abnormalities might have an impact on human brain function based on an increased resting-state functional connectivity. These studies - albeit performed with adolescents - highlight the need for more pediatric research in this area to further investigate the onset and mechanism of this phenomenon. However, these differences may attributable to a number of factors, including composition of the sample studied, as the present cohort consisted exclusively of preschool-aged children. Indeed, age-related changes in resting spectral power have been documented in several neurophysiological studies, with emphasis on the resting state [26-28]. Thus, associations or lack of associations seen in preschool children may not be comparable to those reported in young adults, because of potential factors such as chronic exposure to environmental variables and neuroplasticity. Furthermore, MEG employed in this study affords higher spatial resolution as compared to scalp EEG, and may thus more accurately capture the sources of neuronal activity.

An important feature of the findings in this study is the emphasis placed on exploring the relationship between physical activity and brain function, as opposed to body composition alone. It is a well-known theory in the field of exercise science that obesity or excess body weight is in part the consequence of decreased physical activity or an increasingly sedentary lifestyle [10,29]. Moreover, given the implications in the literature addressing the influence of exercise on brain function [1,30,31] and cognition [1,32], the possible modifying effect of physical activity cannot be overlooked when considering the relationship between body composition and brain outcomes. Due to acute and chronic exercise, changes in the endocrine system take place in various glands through the release of specific hormones, such as growth hormone, cortisol, and sex hormones [33]. It has been speculated by some [34] that alterations in brain function associated with increased physical activity may be due to elevated levels of brain-derived neurotrophic factor (BDNF), known to underlie the synaptic growth and differentiation. Indeed, it has been demonstrated that exercise increases the level of BDNF mRNA in the hippocampus [35,36], a structure that is associated with memory encoding and consolidation, suggesting that BDNF is a candidate for mediating the long-term benefits of exercise on the development of higher cognitive functions [37]. Moreover, this observation may have implications in the treatment of developmental disorders such as attention-deficit hyperactivity disorder (ADHD), where it has been speculated that reduced BDNF levels may play an important role in manifestation of the disorder [38]. Given that elevated BDNF levels associated with exercise may influence cognitive performance, increased physical activity in individuals with ADHD may alleviate neurocognitive deficits that characterize this population.

The relevance of the current findings to this area of research can be acknowledged in several ways. Firstly, given the practical limitations involved in studying pre-school aged children using brain imaging, the successful acquisition of MEG data in subjects in this category demonstrate the feasibility of undertaking neuroimaging studies in cooperative children 4-5 years of age. Second, the fact that physical activity data was obtained using an objective measure rather than a questionnaire, and dual energy x-ray absorptiometry is a reference method gave us a more valid estimate of the study participants' physical activity level and body composition. Moreover, to our knowledge, this is the first known study to examine both exercises and body composition in relation to brain function in pre-school children, an important point considering the emergence of evidence hinting at the complex interrelationship among these variables.

Our findings in preschool children contribute to the notion that elevated levels of physical activity are associated with neurophysiological activity, namely the alpha rhythm, believed to underlie the organization of sensorimotor and higher cognitive functions. The importance of these observations is further emphasized by evidence that aerobic fitness in early childhood significantly influences cognitive development, critical to later academic success [1]. Future studies may further elaborate on the associations explored in this study by considering the influence of environmental and gestational factors on the dynamic relationship between neurodevelopment, physical activity and body composition.

Acknowledgments

We gratefully acknowledge the participant recruitment, coordination and sample collection by CANDLE and Le Bonheur Children's Hospital staff, and particularly the parents and children who participated in the study.

Funding source: Funding for this study was provided by The Urban Child Institute, Memphis, TN, USA, Children's Foundation Research Institute, Le Bonheur Children's Hospital, Memphis, TN, USA.

References

1. Hillman CH, Erickson KI, Kramer AF (2008) Be smart, exercise your heart: exercise effects on brain and cognition. Nat Rev Neurosci 9: 58-65.
2. Chaddock L, Erickson KI, Prakash RS, Kim JS, Voss MW, et al. (2010) A neuroimaging investigation of the association between aerobic fitness, hippocampal volume, and memory performance in preadolescent children. Brain Res 1358: 172-183.
3. Chaddock L, Erickson KI, Prakash RS, VanPatter M, Voss MW, et al. (2010) Basal ganglia volume is associated with aerobic fitness in preadolescent children. Dev Neurosci 32: 249-256.
4. Chaddock L, Erickson KI, Prakash RS, Voss MW, VanPatter M, et al. (2012) A functional MRI investigation of the association between childhood aerobic fitness and neurocognitive control. Biol Psychol 89: 260-268.
5. Voss MW, Chaddock L, Kim JS, Vanpatter M, Pontifex MB, et al. (2011) Aerobic fitness is associated with greater efficiency of the network underlying cognitive control in preadolescent children. Neuroscience 199: 166-176.

6. Davis CL, Tomporowski PD, McDowell JE, Austin BP, Miller PH, et al. (2011) Exercise improves executive function and achievement and alters brain activation in overweight children: a randomized, controlled trial. Health Psychol 30: 91-8.
7. Hillman CH, Castelli DM, Buck SM (2005) Aerobic fitness and neurocognitive function in healthy preadolescent children. Med Sci Sports Exerc 37: 1967-1974.
8. Hillman CH, Buck SM, Themanson JR, Pontifex MB, Castelli DM (2009) Aerobic fitness and cognitive development: Event-related brain potential and task performance indices of executive control in preadolescent children. Dev Psychol 45: 114-129.
9. Sallis JF, Prochaska JJ, Taylor WC (2000) A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc 32: 963-975.
10. Jiménez-Pavón D, Kelly DJ, Reilly JJ (2010) Associations between objectively measured habitual physical activity and adiposity in children and adolescents: Systematic review. International Journal of Pediatric Obesity 5: 3-18.
11. Pannacciulli N, Del Parigi A, Chen K, Le DS, Reiman EM, et al. (2006) Brain abnormalities in human obesity: a voxel-based morphometric study. Neuroimage 31: 1419-1425.
12. Cole JH, Boyle CP, Simmons A, Cohen-Woods S, Rivera M, et al. (2013) Body mass index, but not FTO genotype or major depressive disorder, influences brain structure. Neuroscience 252: 109-117.
13. Babiloni C, Marzano N, Lizio R, Valenzano A, Triggiani AI, et al. (2011) Resting state cortical electroencephalographic rhythms in subjects with normal and abnormal body weight. Neuroimage 58: 698-707.
14. Klimesch W (2012) α-band oscillations, attention, and controlled access to stored information. Trends Cogn Sci 16: 606-617.
15. Olde Dubbelink KT, Felius A, Verbunt JP, van Dijk BW, Berendse HW, et al. (2008) Increased resting-state functional connectivity in obese adolescents; a magnetoencephalographic pilot study. PLoS One 3: e2827.
16. Ogden CL, Carroll MD, Kit BK, Flegal KM (2012) Prevalence of obesity and trends in body mass index among US children and adolescents, 1999-2010. JAMA 307: 483-490.
17. Völgyi E, Carroll KN, Hare ME , Smith KR, Piyathilake C, et al. (2013) Dietary patterns in pregnancy and effects on nutrient intake in the Mid-South: the Conditions Affecting Neurocognitive Development and Learning in Early Childhood (CANDLE) study. Nutrients,. 5: 1511-1530.
18. http://www.cdc.gov/nchs/
19. Trost SG, Sirard JR, Dowda M, Pfeiffer KA, Pate RR (2001) Calibration of the Computer Science and Applications, Inc., physical activity monitor in preschool children [abstract]. Med Sci Sports Exerc 5: 144.
20. Rich C, Geraci M, Griffiths L, Sera F, Dezateux C, et al. (2013) Quality control methods in accelerometer data processing: defining minimum wear time. PLoS One 8: e67206.
21. Pate RR, Almeida MJ, McIver KL, Pfeiffer KA, Dowda M (2006) Validation and calibration of an accelerometer in preschool children. Obesity (Silver Spring) 14: 2000-2006.
22. Castillo EM, Fletcher JM, Li Z, Hoskison MM, Hasan KM, et al. (2009) Transcallosal connectivity and cortical rhythms: findings in children with spina bifida. Neuroreport 20: 1188-1192.
23. Yau PL, Kang EH, Javier DC, Convit A (2014) Preliminary evidence of cognitive and brain abnormalities in uncomplicated adolescent obesity. Obesity (Silver Spring) 22: 1865-1871.
24. Davids S, Lauffer H, Thoms K, Jagdhuhn M, Hirschfeld H, et al. (2010) Increased dorsolateral prefrontal cortex activation in obese children during observation of food stimuli. Int J Obes (Lond) 34: 94-104.
25. Maayan L, Hoogendoorn C, Sweat V, Convit A (2011) Disinhibited eating in obese adolescents is associated with orbitofrontal volume reductions and executive dysfunction. Obesity (Silver Spring) 19: 1382-1387.
26. Orekhova EV, Stroganova TA, Posikera IN, Elam M (2006) EEG theta rhythm in infants and preschool children. Clin Neurophysiol 117: 1047-1062.
27. Babiloni C, Binetti G, Cassarino A, Dal Forno G, Del Percio C, et al. (2006) Sources of cortical rhythms in adults during physiological aging: a multicentric EEG study. Hum Brain Mapp 27: 162-172.
28. Balsters JH, O'Connell RG, Galli A, Nolan H, Greco E, et al. (2013) Changes in resting connectivity with age: a simultaneous electroencephalogram and functional magnetic resonance imaging investigation. Neurobiol Aging,. 34: 2194-2207.
29. Stensel DJ, Gorely T, Biddle SJH (2008) Youth Health Outcomes, in Youth Physical Activity and Sedentary Behavior. Challenges and Solutions, Human Kinetics: Champaign, IL 32-38.
30. Chaddock L, Pontifex MB, Hillman CH, Kramer AF (2011) A review of the relation of aerobic fitness and physical activity to brain structure and function in children. J Int Neuropsychol Soc 17: 975-985.
31. Chapman SB, Aslan S, Spence JS, Defina LF, Keebler MW, et al. (2013) Shorter term aerobic exercise improves brain, cognition, and cardiovascular fitness in aging. Front Aging Neurosci 5: 75.
32. Chaddock-Heyman L, Erickson KI, Voss MW, Knecht AM, Pontifex MB, et al. (2013) The effects of physical activity on functional MRI activation associated with cognitive control in children: a randomized controlled intervention. Front Hum Neurosci 7: 72.
33. Howlett TA (1987) Hormonal responses to exercise and training: a short review. Clin Endocrinol (Oxf) 26: 723-742.
34. Ferris LT, Williams JS, Shen CL (2007) The effect of acute exercise on serum brain-derived neurotrophic factor levels and cognitive function. Med Sci Sports Exerc 39: 728-734.
35. Neeper SA, Gómez-Pinilla F, Choi J, Cotman C (1995) Exercise and brain neurotrophins. Nature 373: 109.
36. Neeper SA, Gómez-Pinilla F, Choi J, Cotman CW (1996) Physical activity increases mRNA for brain-derived neurotrophic factor and nerve growth factor in rat brain. Brain Res 726: 49-56.
37. Cotman CW, Berchtold NC (2002) Exercise: a behavioral intervention to enhance brain health and plasticity. Trends Neurosci 25: 295-301.
38. Corominas-Roso M, Ramos-Quiroga JA, Ribases M, Sanchez-Mora C, Palomar G, et al. (2013) Decreased serum levels of brain-derived neurotrophic factor in adults with attention-deficit hyperactivity disorder. Int J Neuropsychopharmacol.