ISSN 2250-3153

Association between Body Mass Index and Cognitive Performance in Rugby Players

Mohamed Ali Baccouche[1], Ichraf Arous[1], Hanen Sellami[2], Ali Elloumi[3]

[1]Research Unit, High Institute of Sport and Physical Education, University of Sfax, Tunisia.
[2]Department of Microbiology and Research Laboratory "Microorganismes et Pathologies Humaines", Habib Bourguiba University Hospital, Medical School of Sfax, University of Sfax, Tunisia.
[3]Labortory SYFACTE , Faculty of Letters and Humanities, University of Sfax, Tunisia.

Abstract- Poor cardiovascular fitness has been implicated as a possible mechanism for obesity- related cognitive decline, though no study has examined whether BMI is associated with poorer cognitive function in persons with excellent fitness levels. The aim of this study is to investigate the relationship between body mass index and cognitive performance in rugby players. Thus, fifteen rugby players male aged 24.7 ± 0.9 voluntarily participated in this study, whose body mass index (BMI) was greater than 30. The intercorrelations matrix between BMI and the five ImPACT composite scores showed that BMI is negatively correlated with verbal memory (r= -0.181; p<0.01), visual memory (r= -0.172; p<0.01) and visual motor speed (r= -0.103; p<0.05). Also, the results showed that there was no significant correlation between BMI and reaction time or between BMI and impulse control. The findings of the current study indicate that BMI is negatively associated with cognitive function in a sample expected to have better than average cardiovascular fitness. BMI was found to be associated with reduced cognitive performance in rugby players, but only in specific areas of functioning. Notably, measures of memory had the greatest associations with BMI while no association was found on measures related to executive function and attention.

Index Terms- Body mass index, cognitive performance, rugby players

I. Introduction

Overweight and obesity are a major public health issue. Despite increased awareness, the prevalence of obesity continues to rise in many countries. In 2008, an estimated 1.5 billion people worldwide were overweight (BMI ≥ 25–29.9 kg/m^2), with 500 million considered obese (BMI ≥ 30 kg/m2) [1].

Overweight and obese individuals are at elevated risk for numerous health problems, including cardiovascular disease, type 2 diabetes, musculoskeletal disorders, and even some forms of cancer [1, 2].

There is growing evidence that obesity is also associated with adverse neurocognitive outcomes including Alzheimer's disease [3], stroke, and vascular dementia [4]. Research also demonstrates an association between obesity and impaired cognitive functioning long prior to the onset of these conditions. Even after controlling for comorbid medical conditions, obese individuals exhibit deficits in multiple cognitive domains, including attention, executive function, and memory [5, 6].

The mechanisms for obesity-related cognitive dysfunction remain poorly understood. Neuroimaging studies link obesity to structural and functional changes, including greater atrophy, development of white matter hyperintensities [7], reduced neural connectivity [8], and decreased blood flow in frontal brain regions [9]. Other work demonstrates aspects of glycemic controls, including altered insulin sensitivity and insulin resistance, as important contributors to obesity-related cognitive dysfunction [10, 11].

Another likely contributor to obesity-related cognitive dysfunction is reduced cardiovascular fitness. Many obese individuals have poor cardiovascular fitness, perhaps attributable to low levels of physical activity found in this population [12, 13]. In turn, low levels of cardiovascular fitness are associated with reduced cognitive function in a variety of healthy and patient samples [14, 15], and improvements in cardiovascular fitness correspond to improved neuropsychological test performance [8, 14, 16, 17]. Similarly, a weight loss program combining diet and exercise was associated with improved neurocognitive functioning in obese adults [18].

The regular practice of physical activity is now recognized as an important element of good physical and mental health and this for all ages. The effect of physical activity on the brain, particularly on cognitive function is a recent approach. The most obvious benefits are observed in the elderly in whom physical activity helps people to slow cognitive decline associated with aging [19, 20, 21].

Childhood is a critical period in the development of certain cognitive functions [22, 23] and young people are confronted daily with learning situations. Thus, determining the effects of physical activity on cognitive functioning in children appears an important public health issue. However, a deterioration of the physical condition of young observed in recent decades [24].
Thus, further knowledge about the relationship between physical activity, cognitive functioning and physiological mechanisms underlying this relationship could guide the development of public health policy and education.

The effects of physical activity induce a transient modification of the cognitive performance in children and adolescents [25].

This is the case of Pesce et al. [26] who examined the short-term memory and long term memory in students of 11 and 12 years who participated in either circuit training or a team sport. The two types of physical exercise were similar intensity and duration, that is to say approximately 40 minutes at an average of about 140 bpm FC. This research reveals that team sport has been beneficial to both types of memory while circuit training has only been beneficial to the long-term memory. Budde et al. [27] found a race of 12 minutes at an average intensity (between 50 and 65% of maximum heart rate) was beneficial for adolescents who initially showed a low capacity of working memory. The execution of same exercise at a higher intensity (between 70 and 80% of maximum heart rate) was not effective. Some recent studies have examined executive functions in schools have also been documented. First, Kubesch et al. [28] examined the effect of physical exercise two conditions on the performance of an inhibition test in older adolescents between 13 and 14 years. The results suggest that physical education classes of 30 minutes are beneficial for executive functions, but not a short session of aerobic exercise class in five minutes. Furthermore, Hill et al. [29, 30] have shown that 10-15 minutes of moderate-intensity aerobic exercises were beneficial to executive functions in children aged between 8 and 12 years, even if the cognitive tests were completed nearly an hour after cessation of exercise. However, it should be noted that the benefits were only observed in children who had previously been exposed to the tests used.

Physical exercise does not seem to systematically induce positive effects on cognitive functioning. Thus, some research suggests differential effects depending on the age of the participants [31], nature [32, 26] and the amount of exercise [33, 34, 27, 28].

However, obesity is defined as overweight with excess body fat has adverse consequences for health. The measurement of body fat is difficult to achieve in clinical practice, estimates of overweight is used to define obesity: body mass index (BMI), which is equal to the weight (in kilograms) divided by height (in meters) squared. According to the classification adopted by the World Health Organization [35]: underweight is defined as a BMI less than or equal to 18.5 ; normal is defined by a BMI greater than or equal to 18.5 but less than or equal to 24.9 ; overweight is defined as BMI greater than or equal to 25 but less than or equal to 29.9 ; obesity is defined as a BMI greater than or equal to 30.

Obesity itself is divided into three classes: class I or moderate obesity ($30 \leq$ BMI ≤ 34.9); class II or severe obesity ($35 \leq$ BMI ≤ 39.9); class III or morbid obesity (BMI ≥ 40). In children and adolescents (<18 years) [36, 37], underweight is defined as BMI <3rd percentile; the normal weight is defined by the 3rd $\leq$ BMI <97th; overweight is defined as BMI $\geq$ 97th and obesity is defined by a threshold $\geq$ IOTF-30 [38].

Despite these findings, the contribution of physical fitness to obesity-related cognitive function remains unclear as risk factors often comingle. For example, rugby players often have cardiovascular risk factors and type 2 diabetes [38], despite excellent fitness levels. No study to date has examined the association between body composition and cognitive function in a sample of persons expected to have better than average fitness levels. To do so, we examined BMI and cognitive function in a sample of rugby players.

Based on the independent effect of obesity on cognition in past work, we expected that higher BMI would be associated with poorer cognitive function.

Thus the aim of this study is to investigate the relationship between body mass index and cognitive performance in rugby players

II. METHODS

2.1. Subjects

Fifteen rugby players male aged from 21 to 26 years voluntarily participated in this study, whose body mass index (BMI) was greater than 30.

None of the subjects were using drugs or other therapy for obesity, and none had prior histories of disease or injury that would prevent daily exercise.

All of these players selected at random and did not receive at any time a special diet instruction. Before enrolling in the study, subjects were informed of the experimental procedures, as well as the potential risks and benefits associated with the study. However, they were not informed of the study's purpose. To be included in the study, each subject provided written consent in accordance with the Declaration of Helsinki.

Table 1: Characteristics of study subjects.

	Obese
Age (Years)	24.7 ± 0.9
Body mass (kg)	109.84 ± 7.2
Height (m)	1.82 ± 0.09
Body mass index (kg/m^2)	33.16 ± 3.7

2.2. Procedures

Subjects were asked to be alone and away from any other person so that there is no communication during the experiment. Encouragement, criticism or any other form of investment have been banned.

2.2.1. Immediate Post Concussion Assessment and Cognitive Testing (ImPACT)

The ImPACT is a computerized neuropsychological test battery designed to assess attention, memory, and processing speed. After completion of the test, five composite scores as well as a total score are generated, including verbal memory, visual memory, visual motor speed, reaction time, and impulse control [39]. The ImPACT has high convergent validity [40] as well as excellent sensitivity and specificity [41] in college athlete populations.

2.2.2. BMI Calculation

BMI was calculated from self-report of height and weight collected during the demographic section of the ImPACT. Weight and height were measured among participants in an upright position, wearing light clothing and bare foot. The size of the subjects was measured using a stadiometer, to the nearest centimeter. Subjects were also weighed on scales Seca (alpha model 770), 100 grams. Overweight was defined as a body mass index (BMI [weight/height^2] $\geq$ 25).

2.3. Statistical analyses

All statistical tests were processed using STATISTICA Software (StatSoft, France).

To check whether a higher BMI was associated with lower performance on composite scores of the ImPACT. A Pearson correlation study was conducted to identify the relationship between BMI and composite scores of the ImPACT.
Statistical significance was set at $p < 0.05$.

III. RESULTS

Table 2. Correlations between BMI and composite scores for rugby players

	BMI	Verbal memory	Visual memory	Visual motor speed	Reaction time	Impulse control
BMI	-	–0.181**	–0.172**	–0.103*	0.015	0.024
Verbal memory		-	0.527***	0.318***	–0.141*	–0.082
Visual memory			-	0.372***	–0.186**	–0.350***
Visual motor speed				-	–0.384***	–0.276***
Reaction time					-	–0.187**
Impulse control						-

*Significant at $p \leq 0.05$.
**Significant at $p \leq 0.01$.
***Significant at $p \leq 0.001$.

The intercorrelations matrix between BMI and the five ImPACT composite scores showed that BMI is negatively correlated with verbal memory (r= -0.181; p<0.01), visual memory (r= -0.172; p<0.01) and visual motor speed (r= -0.103; p<0.05).

Also, the results showed that there was no significant correlation between BMI and reaction time or between BMI and impulse control.

IV. DISCUSSION

The aim of this study is to investigate the relationship between body mass index and cognitive performance in rugby players.

The findings of the current study indicate that BMI is negatively associated with cognitive function in a sample expected to have better than average cardiovascular fitness. BMI was found to be associated with reduced cognitive performance in rugby players, but only in specific areas of functioning. Notably, measures of memory had the greatest associations with BMI while no association was found on measures related to executive function and attention.

One factor that may be responsible for these differential effects is cardiovascular fitness. Cardiovascular fitness is known to have a beneficial effect on cognitive functioning [42], including measures of executive function [43] and attention [44]. Such findings raise the possibility that fitness helps to moderate the effects of BMI on some aspects of cognitive function (i.e. memory) but not others (i.e. executive function).

The results of the current study indicate that BMI is related to poor cognitive function but the exact mechanisms for this association are unclear. It is possible that athletes with a high BMI who over exert themselves are more likely to exhibit impaired performance on testing.

Other possibilities include the known physiological effects of higher BMI, including reduced glycemic control [45] and even reduced perfusion to the frontal brain regions [46]. Future prospective studies are needed to clarify the underlying mechanisms which may be at work, especially studies quantifying physical activity level.

The current study is limited in several ways. An important limitation for the current study involves the manner in which BMI was quantified. BMI is known to be limited in several ways, including poor adjustment for demographic factors (e.g. age, sex), concerns regarding the cut-points for BMI groups, and failure to directly measure body fat [47]. As a result, an individual can be lean with high muscle mass and may still be classified as obese according to BMI. This concern may be particularly relevant in a sample of athletes. However, it is noteworthy that greater BMI was still associated with poorer cognitive function in the current sample, despite these concerns.
The majority of studies, both in adults and children, found that overweight/obesity was associated with reduced cognitive ability and school outcomes [48, 49, 50, 51]. In a large group of children and adolescents between 8 and 16 years of age, overweight children performed poorly in tests measuring visuospatial organization and general mental ability even after adjusting for a number of potential confounders [51].

However, some studies show a continuous relationship between BMI and cognitive performance that is not limited to overweight players. Alternatively, obesity could have some adverse effect on brain function, possibly due to the secretion of hormones, pro-inflammatory cytokines or growth factors by adipose tissue that can cross the blood brain barrier [52].

Cournot et al. [53] showed that the performance of individuals with high body mass index were lower than those of low BMI individuals. For example, when the memory test, subjects whose BMI was 20 kg / m² retained an average of 9 out of 16 words, while those with a BMI ≥ 30 kg / m² or remembered only 7 words. In addition, high BMI appear to be associated with a slight decline in memory over 5 years. These results were obtained after elimination of many potential biases, including the level of education of the subjects, the presence of diabetes or high blood pressure, factors that could affect the results.

However, available evidence suggests that obesity among adults in the general population is associated with decreased cognitive performance [53], independent of age and comorbid metabolic disorders (e.g., hypertension, diabetes type 2) [54, 55]. Notwithstanding the longitudinal progression of cognitive decline, decreased cognitive performance has been reported to occur more rapidly among individuals with metabolic abnormalities (e.g., metabolic syndrome) when compared to individuals with normal metabolic profiles [56, 57].

Physical exercise does not seem to systematically induce positive effects on cognitive functioning. Thus, some research suggests differential effects depending on the age of the participants [31], nature [32, 26] and the amount of exercise [33, 34, 27, 28].

V. CONCLUSION

In summary, the results of the present study indicate that higher BMI is associated with reduced verbal and visual memory in rugby players.

Further work is needed to identify the mechanisms by which obesity adversely impacts cognitive function, particularly studies involving neuroimaging.

Physical activity has beneficial effects on the vascular system, including reduction of atherosclerotic plaque accumulation [58], decreased blood pressure [59], and subsequent reduction of cardiovascular disease risk [60].

However, a sporting activity is necessary to limit the diseases related to obesity and improve cognitive performance.

ACKNOWLEDGMENTS

The authors thank all subjects for their voluntary participation in this study. The authors wish to express their sincere gratitude to all the participants for their cooperation. This study did not involve any financial external support.

REFERENCES

[1] World Health Organization: Obesity and overweight. Published March, 2011. www.who.int/mediacentre/factsheets/ fs311/en/index.html (last accessed April 8, 2013).

[2] Bray GA: Medical consequences of obesity. J Clin Endocrinol Metab 2004; 89: 2583–2589.

[3] Gustafson D, Rothenberg E, Blennow K, Steen B, Skoog I: An 18 year follow-up of overweight and risk of Alzheimer disease. Arch Intern Med 2003; 163: 1524–1528.

[4] Fitzpatrick AL, Kuller LH, Lopez OL, Diehr P, O'Meara ES, Longstreth WT Jr, Luchsinger JA: Midlife and late-life obesity and risk of dementia. Arch Neurol 2009; 66: 336–342.

[5] Gunstad J, Paul RH, Cohen RA, Tate DF, Spitznagel MB, Gordon E: Elevated body mass index is associated with executive dysfunction in otherwise healthy adults. Compr Psychiatry 2007; 48: 57–61.

[6] Sellbom KS, Gunstad J: Cognitive function and decline in obesity. J Alzheimers Dis 2012; 30(suppl 2):S89–S95.

[7] Gustafson D, Rothenberg E, Blennow K, Steen B, Skoog I: An 18 year follow-up of overweight and risk of Alzheimer disease. Arch Intern Med 2003; 163: 1524–1528.

[8] Stanek KM, Grieve SM, Brickman AM, Korgaonkar MS, Paul RH, Cohen RA, Gunstad JJ: Obesity is associated with reduced white matter integrity in otherwise healthy adults. Obesity (Silver Spring) 2010; 19: 500–504.

[9] Willeumier KC, Taylor DV, Amen DG: Elevated BMI is associated with decreased blow flow in the prefrontal cortex using SPECT imaging in healthy adults. Obesity (Silver Spring) 2011; 16: 1–3.

[10] Gonzales MM, Tarumi T, Miles S, Tanaka H, Shah F, Haley AP: Insulin sensitivity as a mediator of the relationship between BMI and working memory-related brain activation. Obesity (Silver Spring) 2010; 18: 2131–2137.

[11] Stephan BC, Siervo : Does the improvement in insulin sensitivity mediate the beneficial effects of weight loss on cognitive function? Hypertension 2010; 55: 1331–1338.

[12] Haennel RG, Lemire F: Physical activity to prevent cardiovascular disease. How much is enough? Can Fam Physician 2002; 48: 65–71.

[13] Stunkard A: Physical activity, emotions, and human obesity. Psychosom Med 1958; 20: 366–372.

[14] Aberg MA, Pedersen NL, Torén K, Svartengren M, Bäckstrand B, Johnsson T, Cooper-Kuhn CM, Aberg ND, Nilsson M, Kuhn HG: Cardiovascular fitness is associated with cognition in young adulthood. Proc Natl Acad Sci U S A 2009; 106: 20906–20911.

[15] Okonkwo OC, Cohen RA, Gunstad J, Poppas A: Cardiac output, blood pressure, variability, and cognitive decline in geriatric cardiac patients. J Cardiopulm Rehabil Prev. 2011; 31: 290–297.

[16] Hansen AL, Johnsen BH, Sollers JJ, Stenvik K, Thayer JF: Heart rate variability and its relation to prefrontal cognitive function: the effects of training and detraining. Eur J Appl Physiol 2004; 93: 263–272.

[17] Colcombe S, Kramer AF: Fitness effects of the cognitive function of older adults: a meta-analytic study. Psychol Sci 2003; 14: 125–130.

[18] Smith PJ, Blumenthal JA, Babyak MA, Craighead L, Welsh-Bohmer KA, Browndyke JN, Strauman TA, Sherwood A: Effects of dietary approaches to stop hypertension diet, exercise, and caloric restriction on neurocognition in overweight adults with high blood pressure. Hypertension 2010; 55: 1331–1338.

[19] Cassilhas, R. C., Viana, V. A. R., Grassmann, V., Santos, R. T., Santos, R. F., Tufik, S., & Mello, M. T. (2007). The impact of resistance exercise on the cognitive function of the elderly. Medicine and Science in Sports and Exercise, 39(8), 1401-1407.

[20] Colcombe, S. J., Kramer, A. F., Erickson, K. I., Scalf, P., McAuley, E., Cohen, N. J., Elavsky, S. (2004). Cardiovascular fitness, cortical plasticity, and aging. Proceedings of the National Academy of Sciences of the United States of America, 101(9), 3316-3321.

[21] Tanaka, K., de Quadros, A. C., Santo, R. F., Stella, F., Gobbi, L. T. B., & Gobbi, S. (2009). Benefits of physical exercise on executive functions in older people with Parkinson's disease. Brain and Cognition, 69(2), 435-441.

[22] Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. Neuropsychologia, 44(11), 2037-2078.

[23] Diamond, A. (2002). Normal Development of Prefrontal Cortex from Birth to Young Adulthood: Cognitive Functions, Anatomy, and Biochemistry. In D. T. Stuss & R. T. Knight (Eds.), Principles of frontal lobe function (pp. 466-503). New York: Oxford University Press.

[24] Comité scientifique de Kino-Québec. (2011). L'activité physique, le sport et les jeunes -- Savoir et agir. Secrétariat au loisir et au sport, ministère de l'Éduction, du Loisir et du Sport.

[25] Audiffren M. Acute exercise and psychological functions: a cognitive energetic approach. In: T McMorris, P Tomporowski and M Audiffren editors. Exercise and cognitive function. Chichester: Wiley-Blackwell; 2009, pp. 3-39.

[26] Pesce C, Crova C, Cereatti L, Casella R, and Bellucci M. Physical activity and mental performance in preadolescents: Effects of acute exercise on free-recall memory. Mental Health and Physical Activity. 2009;2:16-22.

[27] Budde, H., Voelcker-Rehage, C., Pietrassyk-Kendziorra, S., Machado, S., Ribeiro, P., & Arafat, A. M. (2010). Steroid hormones in the saliva of adolescents after different exercise intensities and their influence on

working memory in a school setting. Psychoneuroendocrinology, 35(3), 382-391.

[28] Kubesch S, Walk L, Spitzer M, et al. A 30-minute physical education program improves students' executive attention. Mind Brain Educ 2009;3:235—42.

[29] Hill L, Williams JHG, Aucott L, et al. Exercising attention within the classroom. Dev Med Child Neurol 2010;52:929—34.

[30] Hill LJB, Williams JHG, Aucott L, Thomson J, Mon-Williams M. How does exercise benefit performance on cognitive tests in primary-school pupils? Dev Med Child Neurol 2011;53:630—5.

[31] Caterino MC, Polak ED. Effects of two types of activity on the performance of second-, third-, and fourth-grade students on a test of concentration. Percept Mot Skills 1999;89:245—8.

[32] Budde H, Voelcker-Rehage C, Pietrassyk-Kendziorra S, Ribeiro P, Tidow G. Acute coordinative exercise improves attentional performance in adolescents. Neurosci Lett 2008;441:219—23.

[33] Gabbard C, Barton J. Effects of physical-activity on mathematical computation among young-children. J Psychol 1979;103:287—8.

[34] McNaughten D, Gabbard C. Physical exertion and immediate mental performance of 6th-grade children. Percept Mot Skills 1993;77:1155—9.

[35] World Health Organisation, 1995. The use and interpretation of anthropometry. Geneva: WHO; World Health Org; 64: 929 41.

[36] Rolland-Cachera, 1982. Adiposity indices in children. American Journal of Clinical Nutrition.

[37] Rolland-Cachera MF, Cole TJ, Sempé M, Tichet J, Rossignol C, Charraud A, 1991. Body Mass Index variations: centiles from birth to 87 years. Eur J Clin Nutr, 45(1):13-21.

[38] Cole TJ, Bellizzi MC, Flegal KM, Dietz WH, 2000. Establishing a standard definition for child overweight and obesity worldwide: international survey. Br. Med. J; 320: 1–6.

[39] ImPACT_Clinical_Interpretation_Manual.pdf (last accessed April 8, 2013).

[40] Iverson GL, Franzen MD, Lovell MR, Collins MW: Construct validity of computerized neuropsychological screening in athletes with concussion. Arch Clin Neuropsychol 2004; 19: 961–962.

[41] Schatz P, Pardini JE, Lovell MR, Collins MW, Podell K: Sensitivity and specificity of the ImPACT test battery for concussion in athletes. Arch Clin Neuropsychol 2006; 21: 91–99.

[42] Colcome S, Kramer AF, Erickson KI, Scalf P, McAuley E, Cohen NJ, Webb W, Jerome GJ, Marquez DX, Elavsky S: Cardiovascular fitness, cortical plasticity, and aging. Proc Natl Acad Sci U S A 2004; 101: 3316–3321.

[43] Kakos LS, Szabo AJ, Gunstad J, Stanek KM, Waechter D, Hughes J, Luyster F, Josephson R, Rosneck J: Reduced executive functioning is associated with poorer outcome in cardiac rehabilitation. Prev Cardiol 2010; 13: 100–103.

[44] Stevenson JS, Topp R: Effects of moderate and low intensity long-term exercise by older adults. Res Nurs Health 1990; 13: 209–218.

[45] Cukierman-Yaffe T, Sulivan MD, Gerstein HC, Marcovina SM, Williamson JD, Launer LJ, Lazar RM, Lovato L, Miller MC, Coker LH, Murray A: Relationship between baseline glycemic control and cognitive function in individuals with type 2 diabetes and other cardiovascular risk factors. Diabetes Care 2009; 32: 221–226.

[46] Willeumier KC, Taylor DV, Amen DG: Elevated BMI is associated with decreased blood flow in the prefrontal cortex using SPECT imaging in health adults. Obesity (Silver Spring) 2011; 19: 1095–1097.

[47] Rothman KJ: BMI-related errors in the measurement of obesity. Int J Obes 2008; 32: 56–59.

[48] Sabia S, Kivimaki M, Shipley MJ, et al. Body mass index over the adult life course and cognition in late midlife: the Whitehall II cohort study. Am J Clin Nutr. 2009; 89:601–607.

[49] Elias MF, Elias PK, Sullivan LM, et al. Obesity, diabetes and cognitive deficit: The Framingham Heart Study. Neurobiol Aging. 2005; 26:11–16.

[50] Li Y, Dai Q, Jackson JC, Zhang J. Overweight is associated with decreased cognitive functioning among school-aged children and adolescents. Obesity. 2008; 16:1809–1915.

[51] Mond JM, Stich H, Hay PJ, et al. Associations between obesity and developmental functioning in pre-school children: a population-based study. Int J Obes. 2007; 31:1068–1073.

[52] Gustafson DR. Adiposity and cognitive decline: underlying mechanisms. J Alzheimers Dis. 2012; 30:S97–S112.

[53] Cournot M, Marquie JC, Ansiau D, et al. Relation between body mass index and cognitive function in healthy middle-aged men and women. Neurology. 2006;67:1208–14.

[54] Grosshans M, Loeber S, Kiefer F. Implications from addiction research towards the understanding and treatment of obesity. Addict Biol. 2011;16:189–98.

[55] Elias MF, Elias PK, Sullivan LM, Wolf PA, D'Agostino RB. Lower cognitive function in the presence of obesity and hypertension: the Framingham heart study. Int J Obes Relat Metab Disord. 2003;27:260–8.

[56] Laitala VS, Kaprio J, Koskenvuo M, Raiha I, Rinne JO, Silventoinen K. Association and causal relationship of midlife obesity and related metabolic disorders with old age cognition. Curr Alzheimer Res. 2011;8:699–706.

[57] Naderali EK, Ratcliffe SH, Dale MC. Obesity and Alzheimer's disease: a link between body weight and cognitive function in old age. Am J Alzheimer Dis Other Demen. 2009;24:445–9.

[58] Wilund KR. Is the anti-inflammatory effect of regular exercise responsible for reduced cardiovascular disease? Clin Sci. 2007; 112: 543–555.

[59] Steffen PR, Sherwood A, Gullette EC, Georgiades A, Hinderliter A, Blumenthal JA. Effects of exercise and weight loss on blood pressure during daily life. Med Sci Sports Exerc. 2001; 33: 1635–1640.

[60] Adamu B, Sani MU, Abdu A. Physical exercise and health: A review. Niger J Med. 2006; 15: 190–196.

AUTHORS

First Author – Mohamed Ali Baccouche, Research Unit, High Institute of Sport and Physical Education, University of Sfax, Tunisia.
Second Author – Ichraf Arous, Research Unit, High Institute of Sport and Physical Education, University of Sfax, Tunisia.
Third Author – Hanen Sellami, Department of Microbiology and Research Laboratory "Microorganismes et Pathologies Humaines", Habib Bourguiba University Hospital, Medical School of Sfax, University of Sfax, Tunisia.
Fourth Author – Ali Elloumi**,** Labortory SYFACTE , Faculty of Letters and Humanities, University of Sfax, Tunisia.