Body fat and cognitive performance in elderly women: role of physical activity.

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Published online: July 31, 2021

(Accepted for publication July 15, 2021)

DOI:10.7752/jpes.2021.s3272

Abstract

Purpose: Recent studies have demonstrated that age-related cognitive dysfunction is more extensive in the overweight and obese individuals as compared to individuals with normal Body Mass Index. Systematic physical activity reduces the risk of obesity and promotes postnatal hippocampal neurogenesis. It would be of interest, therefore, to determine which factor is of greater importance for cognitive improvement in elderly: decreased body fat mass or increased level of physical activity. **Materials/methods:** We investigated the relationship between reduction of body mass index and/or increase in physical activity on cognitive performance in elderly women (26 women; age 63.03 ± 4.19). The volunteers took part in 3-month physical training. To evaluate the cognitive performance in our subjects we used face/name association test. The content of adipose tissue was determined by measuring the skin folds. **Results:** After 3-month physical training we observed statistically significant differences in the content of body fat tissue before and after physical training ($43.66\% \pm 3.47$ and $37.51\% \pm 3.57$, respectively) and in the mean result in the face/name association test ($71.69\% \pm 7.73$ and $79.84\% \pm 7.35$, respectively). We did not observe statistically significant relationship between percentage change in fat content and percent change in the face/name association test result after the three-months physical training. **Conclusion:** Three-month period of moderate physical training improved cognitive function and caused a reduction of body fat percentage in elderly women. No direct relation between increase in cognitive efficiency and decrease in body fat content. The cognitive improvement in elderly women might be directly and independently impacted by increased level of physical activity itself.

Key words: obesity, physical training, cognitive function, memory, neurogenesis, elderly

Introduction

Aging is one of the main factors in reducing the level of cognitive abilities (Bherer, Erickson & Liu-Ambrose, 2013; Raz, 2000). Cognitive decline in elderly people has a variety of possible causes associated prominently with structural and functional changes in the central nervous system. Even in the physiological aging process of the brain loss of the number of nerve cells, loss or regression of dendrites and dendritic spines, loss of synapses, changes in receptors for neurotransmitters and changes in electrophysiological properties of cells are observed (Barnes, 1994; Kuhn, Dickinson-Anson & Gage, 1996). At the same time the rate of neurogenesis decreases which adversely affects on the level of cognitive functions (Heine, Maslam, Joels & Lucassen, 2004). Recent studies have demonstrated that age-related cognitive dysfunction is more extensive in the overweight and obese individuals as compared to individuals with normal Body Mass Index (BMI) (Boeka & Lokken, 2008; Gunstad, Paul, Cohen, Tate, Spitznagel & Gordon, 2007; Cournot, Marquie, Ansiau, Martinaud, Fonds, Ferrières & Ruidavets, 2006). Higher BMI in elderly is associated with poorer performance on tests for memory, language, verbal fluency and motor skills (Delgado-Rico, Rio-Vall, Gonzalez-Jimenez, Compoy & Verdejo-Garcia, 2012; Dwojaczny, Zegarski, Sikorski, Złomańczuk & Tafil-Klawe, 2016; Benito-Leon, Mitchell, Hernandez-Gallego & Bermejo-Pareja, 2013).

The biological mechanism by which cognition is weakened by excess body mass is not fully understood. We know that obesity is associated with cardiovascular diseases, diabetes and insulin resistance, all of which can have negative effects on cognitive performance (Barnes, Yaffe, Satariano & Tager, 2003; Greenwood & Winocur, 2005). Furthermore, adipose tissue may be a source of adipokines, chemokines and inflammatory cytokines all of which can exert negative influence on the brain function (Gorelick, 2010; Pickering & O'Connor, 2007). Very interesting seems to be research which shown that obesity has a negative effect on the condition of the vascular endothelium, which in turn contributes to the impairment of the blood-brain barrier and consequently, to the impairment of cognitive functions (Toth, Tarantini, Csiszar & Ungvari, 2017). The latest scientific research also shows a significant differences in the composition of the gut microbiota in obese and non-obese people which also may affect on the level of cognitive functions (Agustí, García-Pardo, López-Almela, Campillo, Maes, Romani-Pérez & Sanz 2018). Several hypotheses are currently proposed to represent the potential mechanisms underlying the effects of gut microbiota on cognitive function. Among other

things, it was described the influence of gut microbiota on the brain-blood barrier permeability (Braniste, Al-Asmakh, Kowal, Anuar, Abbaspour, Tóth, Korecka, Bakocevic, Kundu, Gulyás, Halldin, Hultenby, Nilsson, Hebert & Volpe, 2014), on the release of neurotransmitters such as serotonin, ghrelin and cholecystokinin (Desbonnet, Garrett, Clarke, Bienenstock & Dinan, 2008) as well as the effect of gut microbiota composition on neurotrophic factors for example: brain-derived neurotrophic factor (BDNF) and cAMP-response element-binding protein (CREB) (Bercik, Denou, Collins, Jackson, Lu, Jury, Deng, Blennerhassett, Macri, McCoy, Verdu & Collins, 2011). Several lines of evidence indicate that increased body mass is also associated with atrophy in many areas of human brain especially temporal and frontal lobes, parietal cortex, hippocampus, cerebellum and also midbrain (Taki, Kinomura, Sato, Inoue, Goto, Okada, Uchida, Kawashima & Fukuda, 2008; Ward, Carlsson, Trivedi, Sager & Johnson, 2005; Gustafson, Lissner, Bengtsson, Björkelund & Skoog, 2004). With aging, adipose tissue undergoes significant change. In particular, the change is observed in the distribution (from subcutaneous to intraabdominal visceral depots), cellular composition and levels of endocrine signaling. These changes may also be related to cognitive dysfunction (Chan, Rimm, Colditz, Stampfer & Willett, 1994; Goodman-Gruen & Barrett-Connor, 1996).

Physical activity is an important factor influencing both the body mass and cognitive performance (Złomańczuk, Milczarek, Dmitruk, Sikorski, Adamczyk, Zegarski, Tafil-Klawe, Cheszy, Klawe & Rakowski, 2006; Zegarski, Cheszy, Złomańczuk, Milczarek, Tafil-Klawe & Sikorski, 2008). It is well known that systematic physical activity can reduce the risk of obesity but also increases cerebral blood volume, perfusion of the hippocampus and promotes postnatal hippocampal neurogenesis (Colcombe, Erickson, Scalf, Kim, Prakash, McAuley, Elavsky, Marquez, Hu & Kramer, 2006; Pereira, Huddleston, Brickman, Sosunov, Hen, McKhann, Sloan, Gage, Brown & Small, 2007; van Praag, Shubert, Zhao & Gage, 2005; Lucas, Ainslie, Murrell, Thomas, Franz & Cotter, 2012).

Studies conducted on animals have shown that systematic physical activity leads to an increase in the proliferation rate of neuronal stem cells (van Praag, Kempermann & Gage 1999), increases the growth of neurites and increases the chances of survival of progenitor cells (Wu, Chang, Yu, Chen, Jen, Wu, Lo & Kuo, 2008). Furthermore, it has been shown positive effect of physical activity on the survival of newly formed neurons (Nilsson, Perfilieva, Johansson, Orwar & Eriksson, 1999), synaptic plasticity (Farmer, Zhao, van Praag, Wodtke, Gage & Christie, 2004) and gene expression of some neurotransmitters and growth factors acting within the central nervous system (Cotman & Berchtold, 2002).

So far, majority of research focused on the negative effect of excess body fat mass on level of cognitive function in elderly. Relatively limited number of studies addresses the problem of cognitive changes resulting from the reduction of body fat mass and/or increase in physical activity. Previously reported data suggested that reduction in body mass was the source of beneficial effect on cognitive function (Veronese, Facchini, Stubbs, Lunchini, Solmi, Manzato, Sergi, Maggi, Cosco & Fontana, 2017; Colantuoni, 2012; Boraxbekk, Stomby, Ryberg, Lindahl, Larsson, Nyberg & Olsson, 2015).

It would be of interest, therefore, to determine which factor is of greater importance for cognitive improvement in elderly: decreased body fat mass or increased level of physical activity.

Material and Methods

The study was conducted in accordance with the Declaration of Helsinki for Human Studies. The study protocol was approved by a local Ethics Committee.

Volunteers (26 women, age 63.03 ± 4.19) were recruited from the local The Third Age University in Bydgoszcz. Only healthy, post-menopausal, and not using hormone replacement therapy women were qualified to participate in the study. The volunteers took part in a closely supervised training program incorporating both strength and endurance components. The program was continued for three months. The exercise sessions took place three times a week. Each session lasted 45 minutes (Zegarski, Tafil-Klawe, Cheszy, Sikorski, Złomańczuk, Milczarek, Dmitruk, Hagner-Derengowska, Sielski & Rakowski, 2008).

The level of cognitive ability was measured using face/name association test. The face /name association test consists of two stages. In the first stage - acquisition phase volunteers were exposed to 50 faces associated with a single name each on a computer screen. Then there was a 10 minute break followed by a second phase - retrieval phase. During retrieval phase volunteers were presented with the same faces but each face had two names associated with it. One of those names was the same name as presented during first stage. The percent of correctly answered names and duration of the retrieval phase were saved for each volunteers (Złomańczuk, Milczarek, Dmitruk, Sikorski, Adamczyk, Zegarski, Tafil-Klawe, Cheszy, Klawe & Rakowski, 2006).

The content of adipose tissue was determined by measuring the skin folds. The measurement of the thickness of skin fold were conducted before and just after the three-month physical training period. The thickness of the skin fold was measured by Harpenden skinfold calliper with the range at 0-80mm and the pressure of 10g/mm². For each volunteer skin fold were measured in three areas: triceps, abdomen and subscapular region. Two measurements were performed in each area. The results of these measurement were then averaged. The percentage of fat in body was calculated based on formula (Durnin & Womersley, 1974; Piechaczek H, 1975):

Body density (D) = $1,127900 - 0,000210 \log(\text{skinfold abdomen}) - 0,000164 \log(\text{skinfold subscapula}) - 0,000064 \log(\text{skinfold triceps})$ $F\% = 100\% \times (4,201/D - 3,813)$.

Statistical significance of the differences scores between before and after physical training was assessed using two-tailed paired t-test. $P < 0,005$ was considered statistically significant. The results are presented as means with standard deviation.

Results

We observed statistically significant differences ($p < 0,005$) in the content of body fat tissue before and after physical training ($43,66 \pm 3,47$ and $37,51\% \pm 3,57$ respectively). Reduction in fat content was noted in all volunteers (by $1,2 - 22,94\%$) (Fig.1). Before the beginning of the exercise program the mean result in the face/name association test was $71,69\% \pm 7,73$. After the three-month exercise program result averaged $79,84\% \pm 7,35$. This score was significantly different ($p < 0,005$). 21 women improved their score (by $2,63 - 32,35\%$). The score remained unchanged in 2 and decreased in 3 women (by $3,22 - 9,52\%$) (Fig.2). Statistically no significant differences were observed in the duration of the test retrieval phase. The mean retrieval duration equalled $222,53 \pm 79,69$ seconds and $196,73 \pm 76,97$ seconds before and after three-months physical training, respectively. We did not observe statistically significant relationship between percentage change in fat content and percent change in the face/name association test result after the three-months physical training (Fig.3).

Fig. 1. Individual relative values of percentage body fat. Each subject's results from before (1) and after (2) exercise program are connected by a line.

Fig 2. Individual scores in the face/name association test. Each subject's results from before (1) and after (2) exercise program are connected by a line. Solid line depicts subjects who fared better on the post-training test, dashed lines those who fared worse, dotted lines represents individuals with score unchanged after 3 month training.

Fig. 3. Correlation between changes (after and before the three-month training program) in body fat content and in face/name association test results .

Discussion

The results obtained from our research and presented in this report indicate that three-month period of moderate physical training improved cognitive function measured by face/name association test ($p < 0,005$) (Fig.2) and at the same time resulted in decrease body fat percentage ($p < 0,005$) (Fig.1). However, we failed to see proportional relationship between decrease in body fat percentage and increase in cognitive test scores.

(Fig.3) While both parameters were influenced by three-month training program, the high drop in body fat percentage did not necessarily correlated with high level of improvement in the cognitive test and *vice versa*.

Furthermore Our findings are concordant with the results from other studies which also demonstrated that overall weight loss is associated with cognitive function improvement in obese subjects. Research conducted by Boraxbekk. et al. (Boraxbekk, Stomby, Ryberg, Lindahl, Larsson, Nyberg & Olsson, 2015) showed that weight loss induced by dietary calorie restriction had a beneficial effect on attention and memory. Other studies demonstrated that cognitive function such as memory and attention was improved after bariatric surgery (Marques, Halpern, Correa, de Melo, Horie, Buchpiguel, Martins Novaes Coutinho, Ono, Prando, Santo, Cunha-Neto, Fuentes & Cercato, 2014).

Several lines of evidence indicate that increase in body mass negatively impacts cognitive performance (Delgado-Rico, Rio-Vall, Gonzalez-Jimenez, Compoy & Verdejo-Garcia, 2012; Dwojaczny, Zegarski, Sikorski, Złomańczuk & Tafil-Klawe, 2016; Benito-Leon, Mitchell, Hernandez-Gallego & Bermejo-Pareja, 2013; Nilsson & Nilsson, 2009). Our previous study revealed that people with correct body weight scored higher in the face/name test compared with the overweight or obese subject ($p < 0.005$) (Dwojaczny, Zegarski, Sikorski, Złomańczuk & Tafil-Klawe, 2016). However, the relationship between body fat mass and cognitive performance is not a simple one. Currently, it is accepted that increased body mass index is associated with many pathophysiological changes with the potential to negatively impact on central nervous system, including cognitive functioning. In obese subjects vascular changes, impaired insulin regulation, chronic systemic inflammation are observed (Convit, Wolf, Tarshish & de Leon, 2003; den Heijer, Vermeer, Van Dijk, Prins, Koudstal, Hofman & Breteler, 2003; Bellinger, Madamba & Siggins, 1993; Kaplanova, Pridalova & Zborilova, 2018; Marynowski, Wojciechowska, Trojanowska & Cudnoch-Jędrzejewska, 2021). While weight loss is usually associated with improvement in glucose tolerance, insulin sensitivity, blood pressure, and inflammation. Improving each of these parameters can improve the function of the central nervous system (Stephan & Siervo, 2010; Lofgren, Herron, West, Zern, Brownbill, Ilich, Koo & Fernandez 2005; Dattilo & Kris-Etherton, 1992). In our data we observed lack of proportionality between increase in cognitive performance and the decrease in level of body fat content. This observation indicates that while both parameters are influenced by physical exercise, the mechanisms of this influence are independent or partially independent for each of these parameters. Our non-proportionality data also suggest that the cognitive change is influenced by training program not solely because the training results in decrease in body fat content.

The brain structure that is significantly activated when subject performs name/face association test is the hippocampus (Sperling, Bates, Cocchiarella, Schacter, Rosen & Albert MS, 2001). The main functions of hippocampus are related to processes controlling learning and memory. The positive impact of physical activity on cognitive performance may be associated with stimulation of neurogenesis in the hippocampus (van Praag, Shubert, Zhao & Gage, 2005; van Praag, Kempermann & Gage, 1996). Several lines of evidence indicated that hippocampus is strongly influenced both by the level of adiposity and the level of physical activity. Brain scanning techniques showed that a greater BMI is related to reduced hippocampal volume (Taki, Kinomura, Sato, Inoue, Goto, Okada, Uchida, Kawashima & Fukuda, 2008). Furthermore, hippocampus is sensitive to fat tissue-derived inflammatory cytokines impairing synaptic plasticity in the dentate gyrus and CA regions of hippocampus (Bellinger, Madamba & Siggins, 1993; Pickering & O'Connor, 2007). Physical exercise - on the other hand - increases grey and white matter volumes in the prefrontal cortex, increases cerebral blood volume and perfusion of the hippocampus (Taki, Kinomura, Sato, Inoue, Goto, Okada, Uchida, Kawashima & Fukuda, 2008; Erickson, Raji, Lopez, Becker, Rosano, Newman, Gach, Thompson, Ho & Kuller, 2010). It was demonstrated that exercise-induced changes in levels of molecular growth factors (e.g. brain -derived neurotrophic factor, insulin-like growth factor) have positive impact on the neurogenesis in adult mammalian brain. The proliferation and incorporation of local hippocampal precursor cells was demonstrated to relate to hippocamp-dependent cognitive functions (van Praag, Shubert, Zhao & Gage, 2005).

Conclusion

The current study demonstrated that in elderly women decrease in body fat percentage and increased cognitive efficiency are associated with the increased level of physical activity induced by three-month training program. While both body fat content decrease and cognitive performance improvement were observed, there was no direct relation between increase in cognitive efficiency and decrease in body fat content. It can be concluded that the cognitive improvement was not only associated with change in body mass but might also be directly and independently impacted by increased level of physical activity itself.

Conflict of interest: None declared.

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