J. Phys. Ther. Sci. 31: 408–413, 2019

The Journal of Physical Therapy Science

Original Article

Effects of increased daily physical activity on mental health and depression biomarkers in postmenopausal women

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Abstract. [Purpose] Little is known about the effectiveness of daily physical activity on depression biomarkers in older adults. This study aimed to investigate the effects of increased daily physical activity for 8 weeks on depression biomarkers in postmenopausal women. [Participants and Methods] Thirty-eight postmenopausal females were randomly assigned into a control or an active group and were asked to wear a uniaxial accelerometer for 8 weeks. Blood samples were obtained at baseline and at the end of the intervention. During the intervention, the active group was asked to increase their physical activity level above their usual lifestyle whereas those in the control group maintained their daily lifestyle. [Results] After the 8-week intervention, the step counts of the participants in the active group increased. The serum concentration of the brain-derived neurotrophic factor and serotonin increased significantly in the active group, but not in the control group, as compared with baseline values. The serum concentration of derivatives of reactive oxygen metabolites and biological antioxidant potential did not change after the intervention in either group. [Conclusion] These findings may suggest that promotion of daily physical activity in postmenopausal women has a positive impact on depression without any change in oxidative stress.
Key words: Oxidative stress, Brain-derived neurotrophic factor, Ageing

(This article was submitted Dec. 7, 2018, and was accepted Jan. 22, 2019)

INTRODUCTION

The prevalence of depression and other mental disorders has been a major public health problem in every part of the world[1, 2)]. Mental health problems, mainly caused by stress, affect at least one out of every four people[2, 3)]. In addition, the deterioration of mental health has become a serious phenomenon, as various research evidence indicates that it leads to an increased risk for various diseases, including cardiovascular disease and diabetes[4)]. This can be seen especially in older adults, whereby their inability to adapt to the demands of the modern lifestyle has led to a decline in their physical and physiological functioning, thus resulting in depression[5)].

The guideline for promoting health is to exercise a minimum of 150 minutes at moderate intensity or 75 minutes at vigorous intensity over 3 to 5 days per week[6, 7)]. The relationship between physical activity and depression has been widely investigated, with the results indicating that increase in physical activity could be used as an alternative treatment in compari-

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son to medication to improve mental health[5, 8–10]. These studies show that overall physical activity level, in terms of intensity and duration of physical activity, may improve mental health and depressive symptoms.

Brain-derived neurotrophic factor (BDNF), which is the most abundant neurotrophic factor in the brain, is often seen to be lower in serum BDNF concentrations in older adults and patients with depression[11, 12]. Although decreased BDNF resulted in memory impairment, increased risk for depression, and hippocampus degeneration[13–15], a systematic review reported that physical activity could increase the brain blood flow, thus increasing the synthesis and release of BDNF[16]. These findings show that BDNF concentrations can be manipulated such that increasing them may reduce the risk of depression. In addition, a decrease in serotonin concentration has been associated with depression[17]. Previous research showed that the circulating concentrations of serotonin in postpartum depression patients were significantly lower compared to non-depressed persons[18]. Therefore, it is suggested that the circulating concentrations of BDNF and serotonin are considered as biomarkers for depression. Moreover, some studies have indicated that oxidative stress and antioxidant capacity can be new biological markers for depression[19–21]. Oxidative stress is caused by the imbalance between the reactive oxygen species (ROS) and antioxidant capacity, which leads to various diseases, including atherosclerosis, cardiovascular and neurodegenerative diseases[22–24]. Depression and aggravation of mental health are associated with the activation of innate immune responses and mild systemic inflammation[25, 26]. As activated inflammation responses increase the production of ROS, it is possible that depression may lead to increased oxidative stress by promoting inflammatory pathways.

Despite the fact that many studies have shown that a well-controlled exercise training has a positive effect on mental health and depression, studies on daily physical activity under free-living conditions are still lacking. In addition, research on the effect of daily physical activity on depression biomarkers and on oxidative stress markers as depression markers is scarce. Postmenopausal women in particular do not experience the protective antioxidant benefits and anti-inflammatory effects of estrogen, and are therefore likely to face an increased risk of disease related to oxidative stress such as cardiovascular disease, diabetes, and depression[27, 28]. From the perspective of prevention of depression, it is important to examine the effects of increased daily physical activity on mental health and depression biomarkers in postmenopausal women. Therefore, the purpose of this study was to investigate the effect of increased daily physical activity on depression biomarkers (i.e. BDNF and serotonin) as well as oxidative stress and antioxidant capacity in postmenopausal women.

PARTICIPANTS AND METHODS

Thirty-eight healthy postmenopausal females (age, 70.2 ± 3.9) were randomly assigned to either a control group (n=19) or an active group (n=19). The exclusion criteria included those who are on medication, have been diagnosed with depression, diabetes (hyperglycaemia), dyslipidaemia and disability through medical examination, and those who had already participated in another research intervention programme. One participant was excluded from the study and data analysis because she did not participate in the evaluation after the intervention. Prior to the study, informed consent from each participant was obtained after a detailed description of the study (i.e. purpose, methods, and risk) was delivered. The study was conducted according to the guidelines laid out in the Declaration of Helsinki and all procedures involving human participants were approved by the Research Ethics Committee for Human Research of Waseda University (approval number: 2014-271).

The participants in the active (PA) group were asked to increase their physical activities above their usual lifestyle under free-living condition, whereas the control group maintained their daily lifestyle. The anthropometric variables were measured 2 weeks before (Baseline) and after the study. Body height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (YS-OA, As One Co., Japan), and body mass was measured to the nearest 0.1 kg using a digital scale (Inner Scan 50, Tanita Co. Japan). Body mass index (BMI) was calculated using the weight in kilograms divided by height squared in metres. Waist circumference was measured to the nearest 0.1 cm using a flexible plastic tape at the level of the umbilicus. Arterial blood pressure was measured from the right arm of the participants while in a seated position by using an automatic blood pressure monitor (HEM-7322; OMRON Co. Japan). Participants were seated in a chair for 5 minutes before blood pressure was measured. At least two measurements were taken at each time point, and the mean of these values was recorded.

In order to determine daily physical levels, participants were asked to wear a uniaxial accelerometer (Active style Pro HJA-750C, Omron Healthcare Kyoto, Kyoto) each day at all times from rising in the morning until going to bed in the evening except during shower times. To ensure that seasonality was not an issue, accelerometers were collected simultaneously from all the participants. By measuring the magnitude and frequency of the acceleration, the device determines the level of intensity (metabolic equivalents: METs) generated by activity every 10 seconds from 0–9 METs (i.e. where 0 is the lowest and 9 is the highest). The data were only considered valid from the participants who wore the accelerometer for at least a total of 10 hours (600 minutes) daily for at least 4 weekdays and a weekend day. The duration of moderate to vigorous physical activity (MVPA) was calculated on a daily basis and used to estimate weekly activity by calculating a weighted average of daily weekday and weekend activity (i.e. weekly MVPA=[average daily weekday MVPA × 5] + [average daily weekend MVPA × 2]). All minutes recorded that were ≥3 METs were classified as MVPA.

As for mental health assessment, the measurement was conducted using a simplified version of the Geriatric Depression Scale (GDS). Blood samples were obtained at baseline and at the end of the study. The day prior to collecting the blood samples, the participants were required to refrain from any strenuous exercise and fast for at least 10 hours overnight. Fasting venous blood samples were collected at 8−9 a.m. the following day by a contracted public health nurse. After collection,

Table 1. The change of physical characteristics and physical activity at baseline and after 8 weeks

	Active (n=19)		Control (n=19)	
	Baseline	8 weeks	Baseline	8 weeks
Height (cm)	152.3 ± 4.4	-	152.5 ± 5.2	-
Weight (kg)	57.3 ± 8.7	57.2 ± 8.7	51.9 ± 7.0	51.6 ± 7.0
BMI (kg/m^2)	24.7 ± 3.5	24.7 ± 3.5	22.1 ± 2.6	22.8 ± 3.9
Systolic blood pressure (mmHg)	140.2 ± 19.6	134.5 ± 20.9	146.7 ± 25.7	135.0 ± 19.5
Diastolic blood pressure (mmHg)	84.3 ± 10.4	82.5 ± 11.7	84.6 ± 13.9	81.3 ± 8.3
GDS	3.7 ± 2.6	2.9 ± 1.7	3.6 ± 3.0	2.9 ± 2.6
Step Count (steps/day)	6,043.0 ± 3,027.6	7,978.0 ± 3,784.5**	6,157.0 ± 2,997.2	5,527.0 ± 2,853.6
MVPA (min/day)	77.3 ± 24.4	85.1 ± 31.8*	77.4 ± 34.4	80.7 ± 36.5

Data are shown as mean ± standard deviation value.
BMI: body mass index; GDS: geriatric depression score; MVPA: moderate to vigorous physical activity.
*p<0.05, **p<0.001 significantly different from the baseline in the same group.

Table 2. Results of blood parameters at baseline and after 8 weeks

	Active (n=19)		Control (n=19)	
	Baseline	8 weeks	Baseline	8 weeks
BDNF (pg/ml)	2,0764.7 ± 8,637.8	2,4252.3 ± 6,530.7*	2,1962.3 ± 8,049.7	2,0351.8 ± 6,182.7
Serotonin (ng/ml)	13.9 ± 0.9	15.0 ± 1.3*	15.3 ± 1.3	14.8 ± 1.3
d-ROMs (U/CARR)	386.0 ± 63.9	373.3 ± 63.5	329.9 ± 64.8	374.9 ± 57.0
HEL (nmol/L)	174.2 ± 88.7	188.3 ± 94.4	202.1 ± 9.9	210.2 ± 68.3
BAP (μM)	2,047.7 ± 143.1	2,116.6 ± 209.7	2,039.9 ± 207.1	2,200.3 ± 189.7
TRX (ng/ml)	182.7 ± 19.1	428.9 ± 146.6	167.8 ± 48.3	500.6 ± 209.2

Data are shown as mean ± standard deviation value.
BDNF: brain-derived neurotrophic factor; d-ROMs: derivatives of reactive oxygen metabolites; HEL: hexanoyl lysine; BAP: biological antioxidant potential; TRX: thioredoxin.
*p<0.05, significantly different from the baseline in the same group.

blood samples were allowed to clot for at least 30 minutes at room temperature and centrifuged at 3,000 rpm for 10 minutes at 4 °C. Obtained (serum samples) were transferred into tubes and stored at −80 °C until the day of assay. Serum BDNF and serotonin were measured using assay kits from R&D Systems (Minneapolis, USA). Serum concentrations of derivatives of reactive metabolites (d-ROMs) and biological antioxidant potential (BAP) were measured using assay kits from Diacron (Grosseto, Italy). Serum hexanoyl lysine (HEL) was measured using a commercial enzyme-linked immunosorbent assay (ELISA) from Nikken Seil Co. Ltd. (Tokyo, Japan). Concentrations of plasma thioredoxin (TRX) were also evaluated using commercial ELISA kit from Immuno-Biological Laboratories Co., Ltd. (Gunma, Japan).

All statistical analyses were performed using Predictive Analytics Software (PASW) SPSS Statistic version 21.0 (SPSS Japan Inc., Tokyo, Japan). The normality of the data was analysed using the Kolmogorov-Smirnov test and a two-way analysis of variance (ANOVA) was used to determine the changes in values between the 2 groups at baseline and after 8 weeks; (group [control and PA groups] × time [Baseline and 8 weeks]). When there was a significant interaction observed, the Bonferroni test (multiple comparison test) was used for post-hoc comparisons. Statistical significance was set at $p<0.05$. All data are presented as mean ± standard deviation (SD) of the mean values.

RESULTS

Table 1 shows the changes of physical characteristics and physical activity before and after 8 weeks of intervention. In the two-way ANOVA test, significant differences were only found in step count and MVPA. The analysis also showed that there was a significant interaction effect for step count ($p<0.01$) and main effect of time ($p<0.05$) for both step count and MVPA. Table 2 shows the results of BDNF, serotonin, serum oxidative stress markers and antioxidant capacity levels before and after 8 weeks of intervention. The analysis showed that there was also a significant interaction effect for BDNF concentrations ($p<0.05$) and serotonin ($p<0.01$).

DISCUSSION

The present study examined the effect of 8 weeks of daily physical activity on mental health and depression biomarkers in postmenopausal women. The study showed that 8 weeks of daily physical activity increased the amounts of steps, MVPA, BDNF, and serotonin concentrations under free choosing of physical activity. These findings suggest that increased daily physical activity can be effective in preventing depression in older adults by improving depression biomarkers.

Increased physical activity through cumulative logging of step count has been a key factor in promotion and maintenance of mental health such as reduced depression and anxiety, better self-esteem and health-related quality of life and efficient stress management[29–31]. Our findings showed that daily physical activity intervention for 8 weeks significantly increased the step counts. As seen from the Table 2, the step count of the PA group increased after the 8 weeks and was more likely to reach the 10,000 step-per-day thresholds. The value of 10,000 step-per-day is gaining popularity especially in Japan, and is approximately equivalent to the energy expenditure of 300 to 400 kilocalories-per-day[32].

In addition, physical activity intervention for 8 weeks significantly increased the amount of time of MVPA. Many previous studies have shown the association between time spent in both short and long MVPA and cardiovascular health as well as mental health. A study on the Swedish population reported that both low physical activity (LPA) and MVPA had a positive effect on depression, however, only MVPA was significantly associated with lowering anxiety symptoms. This study also found that moderate-intensity activity was primarily related to emotional well-being in women, whereas in men vigorous intensity activity was more related to decreased anxiety[33]. In the present study, all the participants were postmenopausal women. In fact, the participants performed domestic housekeeping, including cleaning, cooking, and laundry, as well as daily physical activity, including walking and line dancing. Therefore, our finding of MVPA was consistent with the previous study.

Based on previous studies, a decreased risk of depression and improvement in mental health were greatly associated with periodic exercise training and an increase in physical activity[34]. In this study, there was no significant difference between groups on the depression score using the GDS. During the pre-intervention phase, 7 people from each group had a GDS score in the 5−9 range, which indicates the possible presence of a pre-depressive state. However, after the 8-week intervention, 6 people in the control group remained in the 5–9 range whereas only 3 people in the PA group still had scored in this range. Although there was no significant difference, these findings indicated that the participants with higher GDS scores could benefit from increasing their daily physical activity.

In the present study, increased daily physical activity significantly increased the serum BDNF concentrations in postmenopausal women. BDNF has been shown to be associated with memory impairment and depression especially in older adults[13]. Although a decrease in BDNF concentration with age is inevitable, many past studies have demonstrated that acute or chronic exercise could increase BDNF concentration and thereby reduce depression symptoms in older adults[35–39]. In a previous study that involved 106 older female adults, participants who performed aerobic exercise 50 minutes, 3 times per week for 3 months showed a significant increase in BDNF concentrations and improvement in depression symptoms compared to the group who made no changes in their lifestyle[40]. From the perspective of lowering physical function and decreasing high-intensity physical activity with ageing, it is important to increase the concentrations of BDNF by increasing physical activity aside from exercising in older adults.

Ageing has been associated with impairment in brain serotonin transmission, which could contribute to depression[41]. To combat depression, many researchers have turned to exercise as a therapeutic tool whereby it could reduce the sensitivity of serotonin receptors in certain brain areas that affect mood and social behaviour[42]. A study with 16 older adult men who performed acute aerobic exercise demonstrated an increase in plasma tryptophan, which is a precursor of serotonin, in a 16-week intervention[41]. In a study that examined the association of the intensity of physical activity and serum serotonin showed that there was a significant linear relationship between the intensity of exercise (i.e. low, moderate, and high) and serum serotonin[43]. Our results also showed that the daily physical activity intervention significantly increased the serum serotonin concentration. However, one study found that there was a decrease in serotonin and depression after the administration of anti-depressant medication[44]. Another study reported that those who were in an exercise group had a larger percentage of decrease in serotonin compared to a stretching group after a 7-week high-intensity stationary cycling intervention[45]. The researchers suggested that the decrease in serotonin concentration could be due to uptake by the platelets as a consequence of the action of selective serotonin reuptake inhibitors[44, 45]. Although our study showed there was a significant increase in serotonin concentration, this suggests that physical activity could indeed increase serotonin concentration, and in a longer duration, could combat depression and other mental health disorders once the platelets uptake the serotonin.

Some studies have shown that elevated oxidative stress was associated with the development of depression and indicated the potential of peripheral biomarkers of depression[20, 21, 25]. In fact, one study reported an association between oxidative stress and depressed mood in a large sample of community-dwelling older adults[46]. Although we evaluated the effects of daily physical activity on oxidative stress status including antioxidant capacity, there were no significant intervention effects for these parameters. One possible reason is that our intervention mainly focused on daily based physical activity such as walking and housekeeping. On the other hand, systematic exercise training improved the oxidative stress status by increasing antioxidant capacity, as well as improved mental health or depression[47–49]. A previous study showed that adding a 3-week exercise programme to the usual treatment of severely depressed inpatients decreased serum oxidative stress levels[36]. Thus,

the intensity of physical activity and exercise during the intervention period may be not enough for improving oxidative stress status.

There are several limitations in this study. First, the participants in this study were mostly mentally healthy, potentially causing the GDS score to be insignificant. Secondly, although the participants in both groups were asked to maintain their lifestyle, it is unclear whether their average diet, sleep time and sleep quality changed during the intervention period. In the near future, we need to conduct daily physical activity intervention considering these factors in older adults.

In conclusion, the findings from the present study suggest that increasing daily physical activity could be effective in improving depression biomarkers. This may be useful for the prevention of depression in older adults.

Presentation at a conference

Masaki Takahashi, Takashi Arao, Hyeon Ki Kim, Miku Tsubosaka, Masashi Miyashita, Shigenobu Shibata: 2016 Effects of increased daily physical activity on brain-derived neurotrophic factor, serotonin and oxidative stress markers in older adults. 21st European College of Sports Science Annual Congress, Vienna, Austria.

Funding

This work was supported by Japan Society for the Promotion of Science (KAKENHI 15K21434) and Meiji Yasuda Life Foundation of Health and Welfare.

Conflict of interest

The authors declare no conflict of interest.

REFERENCES

1) Tonsing KN: A review of mental health literacy in Singapore. Soc Work Health Care, 2018, 57: 27–47. [Medline] [CrossRef]
2) Choudhry FR, Mani V, Ming LC, et al.: Beliefs and perception about mental health issues: a meta-synthesis. Neuropsychiatr Dis Treat, 2016, 12: 2807–2818. [Medline] [CrossRef]
3) Shohani M, Badfar G, Nasirkandy MP, et al.: The effect of yoga on stress, anxiety, and depression in women. Int J Prev Med, 2018, 9: 21. [Medline] [CrossRef]
4) Pan A, Keum N, Okereke OI, et al.: Bidirectional association between depression and metabolic syndrome: a systematic review and meta-analysis of epidemiological studies. Diabetes Care, 2012, 35: 1171–1180. [Medline] [CrossRef]
5) Blumenthal JA, Babyak MA, Moore KA, et al.: Effects of exercise training on older patients with major depression. Arch Intern Med, 1999, 159: 2349–2356. [Medline] [CrossRef]
6) Nelson ME, Rejeski WJ, Blair SN, et al.: Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc, 2007, 39: 1435–1445. [Medline] [CrossRef]
7) Haskell WL, Lee IM, Pate RR, et al. American College of Sports Medicine American Heart Association: Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Circulation, 2007, 116: 1081–1093. [Medline] [CrossRef]
8) Toni G, Belvederi Murri M, Piepoli M, et al. SEEDS study group: Physical exercise for late-life depression: effects on heart rate variability. Am J Geriatr Psychiatry, 2016, 24: 989–997. [Medline] [CrossRef]
9) Knapen J, Vancampfort D, Moriën Y, et al.: Exercise therapy improves both mental and physical health in patients with major depression. Disabil Rehabil, 2015, 37: 1490–1495. [Medline] [CrossRef]
10) Pinquart M, Duberstein PR, Lyness JM: Effects of psychotherapy and other behavioral interventions on clinically depressed older adults: a meta-analysis. Aging Ment Health, 2007, 11: 645–657. [Medline] [CrossRef]
11) Zhou C, Zhong J, Zou B, et al.: Meta-analyses of comparative efficacy of antidepressant medications on peripheral BDNF concentration in patients with depression. PLoS One, 2017, 12: e0172270. [Medline] [CrossRef]
12) Molendijk ML, Spinhoven P, Polak M, et al.: Serum BDNF concentrations as peripheral manifestations of depression: evidence from a systematic review and meta-analyses on 179 associations (N=9484). Mol Psychiatry, 2014, 19: 791–800. [Medline] [CrossRef]
13) Erickson KI, Miller DL, Roecklein KA: The aging hippocampus: interactions between exercise, depression, and BDNF. Neuroscientist, 2012, 18: 82–97. [Medline] [CrossRef]
14) Erickson KI, Prakash RS, Voss MW, et al.: Brain-derived neurotrophic factor is associated with age-related decline in hippocampal volume. J Neurosci, 2010, 30: 5368–5375. [Medline] [CrossRef]
15) Voss MW, Erickson KI, Prakash RS, et al.: Neurobiological markers of exercise-related brain plasticity in older adults. Brain Behav Immun, 2013, 28: 90–99. [Medline] [CrossRef]
16) Coelho FG, Gobbi S, Andreatto CA, et al.: Physical exercise modulates peripheral levels of brain-derived neurotrophic factor (BDNF): a systematic review of experimental studies in the elderly. Arch Gerontol Geriatr, 2013, 56: 10–15. [Medline] [CrossRef]
17) Meeusen R, Watson P, Hasegawa H, et al.: Central fatigue: the serotonin hypothesis and beyond. Sports Med, 2006, 36: 881–909. [Medline] [CrossRef]
18) Xie R, Xie H, Krewski D, et al.: Plasma concentrations of neurotransmitters and postpartum depression. Zhong Nan Da Xue Xue Bao Yi Xue Ban, 2018, 43: 274–281. [Medline]
19) Palta P, Samuel LJ, Miller ER 3rd, et al.: Depression and oxidative stress: results from a meta-analysis of observational studies. Psychosom Med, 2014, 76: 12–19. [Medline] [CrossRef]
20) Black CN, Bot M, Scheffer PG, et al.: Is depression associated with increased oxidative stress? A systematic review and meta-analysis. Psychoneuroendocrinol-

ogy, 2015, 51: 164–175. [Medline] [CrossRef]
21) Liu T, Zhong S, Liao X, et al.: A meta-analysis of oxidative stress markers in depression. PLoS One, 2015, 10: e0138904. [Medline] [CrossRef]
22) Vassalle C, Bianchi S, Battaglia D, et al.: Elevated levels of oxidative stress as a prognostic predictor of major adverse cardiovascular events in patients with coronary artery disease. J Atheroscler Thromb, 2012, 19: 712–717. [Medline]
23) Kondo T, Hirose M, Kageyama K: Roles of oxidative stress and redox regulation in atherosclerosis. J Atheroscler Thromb, 2009, 16: 532–538. [Medline] [CrossRef]
24) Vaváková M, Ďuračková Z, Trebatická J: Markers of oxidative stress and neuroprogression in depression disorder. Oxid Med Cell Longev, 2015, 2015: 898393. [Medline] [CrossRef]
25) Rawdin BJ, Mellon SH, Dhabhar FS, et al.: Dysregulated relationship of inflammation and oxidative stress in major depression. Brain Behav Immun, 2013, 31: 143–152. [Medline] [CrossRef]
26) Raison CL, Capuron L, Miller AH: Cytokines sing the blues: inflammation and the pathogenesis of depression. Trends Immunol, 2006, 27: 24–31. [Medline] [CrossRef]
27) Krstevska M, Dzhekova-Stojkova S, Bosilkova G: Menopause, coronary artery disease and antioxidants. Clin Chem Lab Med, 2001, 39: 641–644. [Medline] [CrossRef]
28) Karolkiewicz J, Michalak E, Pospieszna B, et al.: Response of oxidative stress markers and antioxidant parameters to an 8-week aerobic physical activity program in healthy, postmenopausal women. Arch Gerontol Geriatr, 2009, 49: e67–e71. [Medline] [CrossRef]
29) Asztalos M, De Bourdeaudhuij I, Cardon G: The relationship between physical activity and mental health varies across activity intensity levels and dimensions of mental health among women and men. Public Health Nutr, 2010, 13: 1207–1214. [Medline] [CrossRef]
30) O'Connell S, ÓLaighin G, Quinlan LR: When a step is not a step! Specificity analysis of five physical activity monitors. PLoS One, 2017, 12: e0169616. [Medline] [CrossRef]
31) Smith-McLallen A, Heller D, Vernisi K, et al.: Comparative effectiveness of two walking interventions on participation, step counts, and health. Am J Health Promot, 2017, 31: 119–127. [Medline] [CrossRef]
32) Tudor-Locke C, Bassett DR Jr: How many steps/day are enough? Preliminary pedometer indices for public health. Sports Med, 2004, 34: 1–8. [Medline] [CrossRef]
33) Jonsdottir IH, Rödjer L, Hadzibajramovic E, et al.: A prospective study of leisure-time physical activity and mental health in Swedish health care workers and social insurance officers. Prev Med, 2010, 51: 373–377. [Medline] [CrossRef]
34) Cooney GM, Dwan K, Greig CA, et al.: Exercise for depression. Cochrane Database Syst Rev, 2013, 6: CD004366. [Medline]
35) Pereira DS, de Queiroz BZ, Miranda AS, et al.: Effects of physical exercise on plasma levels of brain-derived neurotrophic factor and depressive symptoms in elderly women--a randomized clinical trial. Arch Phys Med Rehabil, 2013, 94: 1443–1450. [Medline] [CrossRef]
36) Schuch FB, Vasconcelos-Moreno MP, Borowsky C, et al.: The effects of exercise on oxidative stress (TBARS) and BDNF in severely depressed inpatients. Eur Arch Psychiatry Clin Neurosci, 2014, 264: 605–613. [Medline] [CrossRef]
37) Meyer JD, Ellingson LD, Koltyn KF, et al.: Psychobiological responses to preferred and prescribed intensity exercise in major depressive disorder. Med Sci Sports Exerc, 2016, 48: 2207–2215. [Medline] [CrossRef]
38) Meyer JD, Koltyn KF, Stegner AJ, et al.: Relationships between serum BDNF and the antidepressant effect of acute exercise in depressed women. Psychoneuroendocrinology, 2016, 74: 286–294. [Medline] [CrossRef]
39) Kerling A, Kück M, Tegtbur U, et al.: Exercise increases serum brain-derived neurotrophic factor in patients with major depressive disorder. J Affect Disord, 2017, 215: 152–155. [Medline] [CrossRef]
40) Yeh SH, Lin LW, Chuang YK, et al.: Effects of music aerobic exercise on depression and brain-derived neurotrophic factor levels in community dwelling women. BioMed Res Int, 2015, 2015: 135893. [Medline] [CrossRef]
41) Melancon MO, Lorrain D, Dionne IJ: Changes in markers of brain serotonin activity in response to chronic exercise in senior men. Appl Physiol Nutr Metab, 2014, 39: 1250–1256. [Medline] [CrossRef]
42) Teixeira CM, Vasconcelos-Raposo J, Fernandes HM, et al.: Physical activity, depression and anxiety among the elderly. Soc Indic Res, 2013, 113: 307–318. [CrossRef]
43) Zimmer P, Stritt C, Bloch W, et al.: The effects of different aerobic exercise intensities on serum serotonin concentrations and their association with Stroop task performance: a randomized controlled trial. Eur J Appl Physiol, 2016, 116: 2025–2034. [Medline] [CrossRef]
44) Moreno J, Campos MG, Lara C, et al.: Tryptophan and serotonin in blood and platelets of depressed patients. Effect of an antidepressant treatment. Salud Ment, 2006, 29: 1–8.
45) Wipfli B, Landers D, Nagoshi C, et al.: An examination of serotonin and psychological variables in the relationship between exercise and mental health. Scand J Med Sci Sports, 2011, 21: 474–481. [Medline] [CrossRef]
46) Milaneschi Y, Cesari M, Simonsick EM, et al. Health ABC study: Lipid peroxidation and depressed mood in community-dwelling older men and women. PLoS One, 2013, 8: e65406. [Medline] [CrossRef]
47) Fatouros IG, Jamurtas AZ, Villiotou V, et al.: Oxidative stress responses in older men during endurance training and detraining. Med Sci Sports Exerc, 2004, 36: 2065–2072. [Medline] [CrossRef]
48) Takahashi M, Miyashita M, Park JH, et al.: Low-volume exercise training and vitamin E supplementation attenuates oxidative stress in postmenopausal women. J Nutr Sci Vitaminol (Tokyo), 2013, 59: 375–383. [Medline] [CrossRef]
49) Takahashi M, Miyashita M, Park JH, et al.: The association between physical activity and sex-specific oxidative stress in older adults. J Sports Sci Med, 2013, 12: 571–578. [Medline]