

BENEFITS OF MOTOR AND/OR COGNITIVE EXERCISE: A REVIEW WITH RECOMMENDATIONS FOR THE THIRD AGE

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ABSTRACT

Physical activity in the form of aerobic and resistance exercise, leading to a high level of cardio-respiratory fitness, represents a strong non-pharmacological preventive tool against cognitive decline and thus the occurrence of neuro-degenerative diseases in the third age. However, the effects are even greater if such exercise is performed on regular basis in the form of simultaneous combination of a motor and additional cognitive task, dancing or interactive video dancing or as a body-mind meditative exercise like Tai Ji Quan.

The aim of this article is a review of benefits of motor / cognitive exercise with recommendations for older adults. In the first part, the benefits and effects of physical activity and exercise on cognitive functions are reviewed. Physical activity and exercise have an important role in mitigating age-related structural and behavioural changes within the brain, they increase BDNF levels in the hippocampus, enhance learning and neurogenesis in the hippocampal regions and optimize spatial abilities. The second part is expanded onto the benefits and effects of combined motor and / or cognitive exercise on cognitive functions with recommendations. This combination of motor and / or cognitive exercise could be achieved so that both activities are performed separately, one after another, named "motor and cognitive exercise" or simultaneously, named

“motor-cognitive exercise.” Based on this premise, we divided the second part into three sub-topics: i) the effects of physical exercise / training followed by computerized and other forms of cognitive training, ii) the effects of simultaneously performed motor and cognitive exercise / training and iii) the effects of dancing, interactive video dancing and ancient body-mind meditative techniques. Studies suggest that a combination of mental and physical training may result in greater cognitive gains, namely, in larger improvements in the executive control task and in the paired-associates task.

Keywords: ageing, neurogenesis, motor learning, computerized cognitive training, dancing, body-mind meditative techniques.

PREDNOSTI IN KORISTI GIBALNE IN/ALI KOGNITIVNE VADBE: PREGLED PODROČJA S PRIPOROČILI ZA TRETJE ŽIVLJENJSKO OBDOBJE

IZVLEČEK

Telesna aktivnost v obliki aerobne vadbe in vadbe proti uporabi, ki omogočata visoko stopnjo kardio-respiratorne pripravljenosti, predstavlja močno nefarmakološko preventivno orodje proti upadu kognitivnih funkcij in s tem pojavljanju nevrodegenerativnih bolezni v tretjem življenjskem obdobju. Učinki vadbe pa so lahko še večji, če se ta izvaja redno v obliki sočasne kombinacije gibalne in dodatne kognitivne naloge, plesa ali interaktivne plesne videoigre ali v obliki meditativne vadbe za telo in um, kot je npr. Tai Ji Quan.

Namen prispevka je pregled prednosti in koristi, ki jih ima gibalna/kognitivna vadba, s priporočili za starejše odrasle osebe. V prvem delu so predstavljene prednosti in koristi ter vplivi telesne aktivnosti in vadbe na kognitivne funkcije. Telesna aktivnost in vadba imata pomembno vlogo pri zmanjševanju s starostjo povezanih strukturnih in vedenjskih sprememb v možganih, hkrati pa vplivata na povečanje BDNF vrednosti v hipokampusu, spodbujata procesa učenja in nevrogeneze in izboljšujeta sposobnosti prostorske predstave. Drugi del prispevka je razširjen na prednosti in koristi ter učinke kombinirane gibalne in/ali kognitivne vadbe na kognitivne funkcije starejših oseb, s priporočili. Kombinacijo gibalne in/ali kognitivne vadbe je mogoče doseči tako, da obe dejavnosti opravljamo ločeno, eno za drugo, kar imenujemo "gibalna in kognitivna vadba/trening" ali pa sočasno, kar smo imenovali "gibalno-kognitivna vadba/trening". Na tej osnovi smo razdelili drugi del na tri podteme: i) učinki telesne vadbe/treninga, ki mu sledijo računalniško podprte in druge oblike kognitivne vadbe/treninga, ii) učinki sočasno opravljene gibalne in kognitivne vadbe/treninga in iii) učinki plesa, interaktivnih plesnih videoiger in meditativnih tehnik na telo in um. Študije poročajo,

da se kombinacija gibalne in kognitivne vadbe odraža v povečanih kognitivnih učinkih, posebno v večjem izboljšanju izvršilnih funkcij.

Ključne besede: *staranje, nevrogeneza, hipokampus, računalniško podprta kognitivna vadba, ples, meditativne tehnike za um in telo*

INTRODUCTION

Motor abilities, physical, functional and cognitive capacities decrease with ageing. However, with regular and adequate physical and cognitive exercise and training it is possible to reduce or even prevent such declines (Bherer, Erickson & Liu-Ambrose, 2013; Erickson, Gildengers & Butters, 2013; Erickson et al., 2014; Pišot et al., 2016). Health guidelines emphasize that all adults should avoid physical inactivity. According to the guidelines, one's lifestyle should include at least some physical activity in order to obtain health benefits. Physical activity for adults and seniors should include strength, balance and flexibility training, as well as aerobic exercise. The general aim of exercise in late adulthood should be improving the stability and responsiveness of the body, with reduction of the risk of falls as one of the first effects. An appropriate approach in the context of "risk of falls" prevention is the combination of different contents of exercise programs (strength, stability, responsiveness, flexibility etc.). Studies confirm that regular physical activity and high fitness level in the adulthood reduces the risk of negative effects of (primary) ageing as well as those, such as chronic diseases, related to the modern, sedentary lifestyle and environment pollution (secondary ageing) (Bherer, Erickson & Liu-Ambrose, 2013; Chodzko-Zajko et al., 2009; Erickson, Gildengers & Butters, 2013).

The risk of falls increases with age and the falls are the main cause of death associated with injury in the age over 65 years (Rubenstein, 2006). The falls are generally connected with serious consequences such as bone fractures and other injuries. The most common causes of falls are problems with walking and balance (Masud & Morris, 2001). These problems are often associated with neurological and skeletal muscle disorders, impaired ability of thinking, memory and vision as well as different risks in the environment (Richardson & Ashton-Miller, 1996). A sedentary lifestyle and / or lack of physical activity is a common cause, which provoke older people to lose muscle tone and bone mass, reduce their muscle strength and flexibility, which further contributes to increasing the risk of falling. The problem is complex, which can be combined by physiological, biological, behavioural, physical and socio-economic factors (Sattin, 1992).

With ageing, we are also facing difficulties in cognitive functioning, which increases the risk of falls. Of course, being active and exercising regularly cannot stop the biological aging process; however, with proper training we can mitigate or even prevent the age-related cognitive decline. Epidemiological studies suggest that a well-

-functioning cardiovascular system and a high level of physical activity reduce the risk of cognitive decline and dementia in the old age (Gregory, Parker & Thompson, 2012). Aerobic exercise and strength training, but mostly a combination of both, have been shown to improve some cognitive performance measures among previously sedentary older adults. The effects of such exercises on fitness status are largest for the tasks that require complex processing requiring executive control (Chodzko-Zajko et al., 2009).

Motor-cognitive exercise, which is characterized by an additional cognitive (mental) work during the execution of various motor exercises and tasks, can also represent the missing content, and perhaps even more effective upgrade of the usual forms of motor exercise. It has been shown that such exercise contributes to improving the mobility and may prevent falls in older adults (Shatil, 2013). However, the stability and focus of the movement is disrupted in the presence of additional cognitive demand.

The aim of this paper is to describe what are the benefits and effects of motor and / or cognitive exercises on the cognitive function in older adults. Physical activity has favourable effects across numerous physical and mental-health outcomes. It enhances cognitive functioning and it delays age-related cognitive decline which, therefore, results in a better quality of life and health outcomes. The fast developing area of brain-imaging techniques will continue revealing new insides into multiple neural mechanisms that occur at the corticospinal levels and beyond while being physically active per se. However, a growing body of literature in the recent years suggests that the combination of mental and physical training seems to have an additive effect on neurogenesis and it results in even greater increase in neurogenesis than either physical or mental activity alone.

BENEFITS OF PHYSICAL ACTIVITY AND EXERCISE ON COGNITIVE FUNCTION IN OLDER ADULTS

Extensive evidence suggests that physical activity can maintain functional abilities, well-being, and independence in the older person, and it is an essential component of everyday life, and therefore, it is beneficial also for healthy ageing (Netz, Wu, Becker & Tenenbaum, 2005; Penedo & Dahn, 2005; Rejeski & Mihalko, 2001; Gradari, Palles, McGreevy, Fontan-Lozano, & Trejo, 2016). Positive effects of physical activity on cognitive functioning are well reported as well, and are usually presented in two types of studies. The first are (longitudinal) randomized controlled trials that involve intervention and control group(s), and the second are cross-sectional studies that correlate physical activity and exercise levels with cognitive function outcomes and brain structures. The literature overview is summarized in the forthcoming paragraphs with the discussion of possible mechanisms that are most likely to occur.

Ageing process in humans is accompanied by stereotypical structural as well as neurophysiological changes that happen within the brain and variable rates of cognitive decline (Bishop, Lu, & Yankner, 2010). However, this degenerative process was shown to be operational in the older age (Dinse, 2006) and studies showed that physical ac-

tivity and exercise could be one of the lifestyle factors that can successfully moderate age-related cognitive and neurophysiological declines (Hillman, Erickson, & Kramer, 2008; Kramer & Erickson, 2007; Weuve et al., 2004). Kempermann et al. (2010) suggest that there is a need for a proper combination of physical activity and enriched environment for neurogenesis in adult brain. Physical activity and locomotion are believed to stimulate the proliferation of precursor cells in the hippocampus, while enriched environment and learning are needed to promote the survival of immature neurons (Kempermann et al., 2010).

In the animal studies it was shown that physical exercise enhances angiogenesis, synaptogenesis and neurogenesis, and that it regulates several neurotrophic factors (Carro, Nuñez, Busiguina, & Torres-Aleman, 2000; Cotman, Berchtold, & Christie, 2007; Van Praag, Shubert, Zhao, & Gage, 2005). Namely, it was shown that exercising increases BDNF (Brain Derived Neurotrophic Factor) levels in the hippocampus (Cotman & Berchtold, 2002), enhances learning and neurogenesis in the hippocampal regions (Van Praag et al., 2005) and optimizes spatial abilities (Creer, Romberg, Saksida, van Praag, & Bussey, 2010). The underlying protecting mechanism of physical activity and exercise on cognitive functioning in older age might be related to reduced inflammation and, therefore, not-impaired growth factor signalling in the brain and periphery (Cotman et al., 2007).

Studies in humans that have used brain-imaging techniques have revealed that physical activity and exercise have an important role in mitigating age-related structural and behavioural changes within the brain. In a study conducted by Colcombe et al. (2006) it was shown that a 6-month aerobic training resulted in significant increases of grey and white matter primarily located in prefrontal and temporal cortices. Furthermore, exercise was shown to increase hippocampal volumes, which were related to increased serum BDNF levels and improved memory as well (Erickson et al., 2011). Studies have also shown that aerobic exercise improves general cognitive functions (Weuve et al., 2004), and more specifically, aerobic exercise was shown to enhance visuospatial memory (Stroth, Hille, Spitzer, & Reinhardt, 2009) and executive control (Kramer et al., 1999). Further, some studies reported the effects and benefits of computerized cognitive training on executive functioning in older adults (Marusic et al., 2018), as well as its benefits on motor functions (Marusic et al., 2015), plasma level of the BDNF (Passaro et al., 2017) or even on vascular function (Goswami et al., 2015) after prolonged physical inactivity. Finally, the participants who exercised regularly had faster reaction times, better attention and cognitive flexibility (Masley, Roetzheim & Gualtieri, 2009; Smith et al., 2010).

Together with the above reported positive effects of physical activity on cognitive functioning in humans and animals, physical activity was shown also to have a protective effect against cognitive decline in the older age, as well as in some neurodegenerative diseases. A recent meta-analysis showed that greater amounts of physical activity earlier in life are associated with a 38% reduced risk of developing cognitive impairment later in life (Erickson et al., 2014). In a large-scale prospective cohort study that was carried out on Canadian older adult population, Laurin and colleagues (2001)

showed a positive relation between physical activity and lower risk of cognitive impairment, Alzheimer disease, and all types of dementia in the later life (Laurin, Verreault, Lindsay, MacPherson, & Rockwood, 2001). In a randomized controlled trial with 24-week physical activity intervention, older adults with memory problems (but without diagnosed dementia) showed a modest improvement in cognition (Lautenschlager et al., 2008). Positive effects of aerobic activity on medial temporal brain structures have been also registered in patients with Alzheimer's disease (Erickson et al., 2011; Yuede et al., 2009) and schizophrenia patients (Pajonk et al., 2010).

BENEFITS OF COMBINED MOTOR AND / OR COGNITIVE EXERCISE ON COGNITIVE FUNCTION IN OLDER ADULTS WITH RECOMMENDATIONS

Physical activity and high levels of cardiorespiratory / cardiovascular fitness, achieved with regular aerobic and resistance exercise / training as well as motor learning and coordinative exercise, have been shown to enhance cognitive function and decrease the risk of cognitive decline and dementia (Alzheimer's disease) in older population (Bherer, Erickson & Liu-Ambrose, 2013; Erickson, Gildengers & Butters, 2013; Erickson et al., 2014). New evidences emerge showing that the effects are even greater when physical activity and exercise are combined with (additional) cognitive tasks. This combination could be achieved so that both activities are performed separately, one after another (here we introduce the expression "*motor and cognitive exercise / training*") or simultaneously (for this we will use the expression "*motor-cognitive exercise / training*"). However, when there will be no emphasis on one of the above mentioned options, the term "*motor / cognitive exercise/training*" will be used.

Through the process of neurogenesis, many of new neuron cells are produced every day in the adult brain in the hippocampal formation, a brain structure necessary for many types of new learning, and one that is highly responsive to the effects of mental and physical training. These new neurons in the hippocampus are extremely responsive to the external environment, since physical activity and exercise have been shown to increase the number of cells that are produced, even after just one day of exercise (Curlik & Shors, 2011). Physical activity and exercise take advantage of neuroplasticity also in later life, which promotes neural, regional, and, possibly, total brain growth. The term neuroplasticity is usually used in reference to positive or adaptive (rather than maladaptive) changes to brain architecture that is above and beyond its current functioning limits (Erickson et al., 2014). As already described, the most well characterized physical activities for slowing the rate of cognitive decline and preventing dementia are the aerobic as well as resistance exercise / training, motor learning and coordinative exercise (Bherer, Erickson & Liu-Ambrose, 2013; Erickson et al., 2014). However, besides physical activity and exercise, Fratiglioni, Paillard-Borg and Winblad (2004) report that also a socially integrated network and cognitive leisure activities can play a significant role.

On the other hand, Curlik and Shors (2013) emphasize that physical training by itself is not enough to rescue new neurons from death, but learning must occur during the training process. Even more, learning has to be difficult to master in order to rescue these cells. This could be, for example, learning to associate two stimuli that overlap, but are separated by long temporal window or learning to associate two stimuli that do not occur together in time with sufficiently long temporal gap between them or learning to find the platform using only spatial cues outside the maze (Curlik & Shors, 2013). Since individual animals and humans tend to learn at different rate, it is also important how many trials are necessary to learn. Thus, it has been repeatedly shown that there are strong positive correlations between the number of trials necessary to learn the task or skill and the number of surviving cells in the animals' dentate gyrus (Curlik & Shors, 2013) – a part of the hippocampus thought to contribute to the formation of new episodic memories (Amaral, Scharfman, & Lavenex, 2007; Saab et al., 2009) – the spontaneous exploration of novel environments (Saab et al., 2009) and other functions (Scharfman, 2007), being one of a selected few brain structures currently known to have high rates of neurogenesis in adult rats (Cameron & McKay, 2001). This means that animals that need more trials of training in order to learn the skill tend to retain more cells than those that learn it with less effort. On the whole, these results show that learning has the greatest impact on neurogenesis when training task itself is challenging, and when many trials and / or days of training are required to master the skill (Curlik & Shors, 2011; Curlik & Shors, 2013). Therefore, the authors suggest that a combination of mental and physical training may result in greater cognitive gains and can have additive effects on the structure of the adult brain than either form alone, which may help to keep the brain fit for future learning. If we go a little further, greater cognitive gains could be achieved by using training regimens that combine physical and mental skill training, which in practice means motor learning. For example, learning to perform a new dance routine or when engaged in any new sports activities. These activities influence many learning processes, including working memory and require some significant degree of cognitive effort, suggesting that the mental effort intrinsic to many athletic and sporting endeavours can produce long-lasting effects in the structure of the adult brain (Curlik & Shors, 2013).

In the last 10–15 years, numerous studies (randomized exercise interventions, cross-sectional, prospective longitudinal and epidemiological studies) have been conducted to evaluate how physical activity and exercise (in the form of aerobic or resistance training, motor learning and coordinative exercise) in the adulthood and in the old age influences cognitive functions and brain structures in older adult population. However, only recently more emphasis has been given to motor / cognitive exercise strategies to maximize the effects on neural adaptations (neurogenesis) and cognitive function, in order to alleviate or prevent dementia and other neurodegenerative processes in the third age. All of them definitely require both mental and physical effort and are, thus, potentially useful to preserve or improve cognitive function in mid- and especially in late adulthood. Such strategies could include:

1. any kind of physical exercise / training followed by computerized and other forms of cognitive training,
2. simultaneously performed motor and cognitive exercise / training,
3. dancing and interactive video dancing or even
4. the ancient techniques such as Tai Ji Quan (Tai-Chi).

EFFECTS OF PHYSICAL EXERCISE / TRAINING FOLLOWED BY COMPUTERIZED AND OTHER FORMS OF COGNITIVE TRAINING

Shatil (2013) performed a four-condition randomized controlled trial among healthy older adults in order to evaluate if a 4-month mild aerobic and / or cognitive training enhance cognitive abilities more than either alone. One hundred twenty-two community dwelling and healthy older adults (65 – 93 year olds) were divided into four groups: the first group was engaged in cognitive training, the second in mild aerobic training, the third in the combination of both, and the fourth, as a control, in book-reading and discussion activities. The cognitive training intervention was performed in 48 forty-minute sessions three times per week for 16 consecutive weeks using a previously validated CogniFit® program. The mild aerobic training intervention consisted of 10 minutes of aerobic warm-up, 15 minutes of cardiovascular workout seated and standing, 5 minutes of aerobic cool-down, 10 minutes of strength training and 5 minutes of flexibility training, followed by brief relaxation; a total of 45 minutes, three times per week for 16 consecutive weeks. The combined intervention consisted of both the above mentioned interventions, receiving twice as many training sessions as the previous two groups. The control group needed to read the book “Active Living Everyday: Twenty Weeks to Lifelong Vitality” at home and held one 60-minute weekly meeting for discussion about it. The results indicate that, compared to older adults who did not engage in cognitive training (the mild aerobic and control groups), those who did (separate or combined training group) showed significant improvement in cognitive performance, especially in hand-eye coordination, global visual memory (working memory and long-term memory), speed of information processing, visual scanning, and naming words. These results and results of a similar study performed by Oswald, Gunzelmann, Ruprecht and Hagen (2006) suggest that it is the cognitive training (not mild aerobic training (Shatil, 2013) or physical training (Oswald et al., 2006)) which is driving the improvement in the combined condition (performed on separate sessions) and somehow contradict a research consensus that aerobic activity is a main mechanism in the enhancement of cognitive ability (Shatil, 2013). However, it is possible that the intensity and duration (four months only) of the interventions in the Shatil’s (2013) study were insufficiently high and long to induce cognitive gains or too broad-based (not sufficiently specific and intense) in the Oswald et al.’s (2006) study. On the other hand, positive effects of the combined interventions on cognitive function, independence of living, and some measures of health and emotional status (especially depression) could be observed up to five years after the intervention (Oswald et al., 2006). Future studies should aim to

investigate also the combination of different non-physical ways of training, such as action observation and motor imagery with physical exercise (Eaves, Riach, Holmes, & Wright, 2016).

EFFECTS OF SIMULTANEOUSLY PERFORMED MOTOR AND COGNITIVE EXERCISE / TRAINING

Further, if the effects of a simultaneously performed, motor-cognitive training intervention is compared to a single cognitive training intervention or to passive controls the motor-cognitive intervention results in larger cognitive and motor-cognitive (dual-task) improvements. In fact, Theill, Schumacher, Adelsberger, Martin and Jäncke (2013) looked at the effects of 10 weeks of simultaneously performed cognitive and physical training in 63 healthy older adults (65 – 84 year olds), who were divided in three groups. The first group simultaneously performed a verbal working memory and a cardiovascular training, while the second group performed only verbal working memory training, both for 20 training sessions two times weekly. The third group attended no training at all and served as a control. The cognitive training session contained 15 minutes of computer-based n-back training (continuous responses to a series of letters appearing all for three seconds, always comparing the subsequent letters with the letter in a given sequence n-times before) and 15 minutes of serial position training (learning a sequence of words in the correct order, presented for three seconds and followed by a distraction phase) – see Theill et al. (2013) for more details. On the other hand, the motor-cognitive training session consisted of 40-minute treadmill walking (including warm-up at a self-selected speed) at the intensity (walking speed) between 60 % and 80 % of the individual's age related maximum heart rate value ($HR_{\max} = 220 - \text{age}$), while simultaneously performing the same cognitive training as described earlier. The results indicate similar training progress and larger improvements in the executive control task for both experimental groups compared to the passive control group. However, the simultaneous, motor-cognitive training group showed larger improvements in the paired-associates task compared to the single cognitive training group and was able to reduce the step-to-step variability during the motor-cognitive dual-task condition compared to the single cognitive training group and passive controls. Thus, the authors (Theill et al., 2013) conclude that the simultaneous training of cognitive and physical abilities presents a promising concept to improve cognitive and motor-cognitive dual-task performance, offering greater potential on daily life functioning, which usually involves the recruitment of multiple abilities and resources rather than a single one.

EFFECTS OF DANCING, INTERACTIVE VIDEO DANCING AND ANCIENT BODY-MIND MEDITATIVE TECHNIQUES

Based on this premise it can be realized that even dancing and the ancient body-mind meditative exercise, such as Tai Ji Quan (Tai-Chi) is a form of motor-cognitive exercise, which requires substantial simultaneous mental and physical effort in order to be (adequately) performed. Their positive effects on physical and especially cognitive functions in older adults have recently been confirmed by several studies (Olsson, 2012). For example, Jovancevic, Rosano, Perera, Erickson and Studenski (2012) (a study protocol report) examined the effects of a 6-month interactive video dancing game intervention (using a commercially available Dance Dance Revolution system) in comparison to brisk walking (at least twice a week for 30 minutes, with a target of 150 minutes per week) and passive controls on physical and mental health, balance, attention and visual spatial skills in 168 overweight or obese, sedentary post-menopausal women (50 – 65 year olds). Similarly, Pichierri, Murer and de Bruin (2012) examined the effects of 12 weeks of additional dance video gaming to progressive strength and balance exercise on gait performance under single- and dual-task conditions (at normal and fast speed), foot placement accuracy (FPA), and falls efficacy (fear of falling questionnaire and gaze behaviour during FPA) in 31 community dwelling older adults (86.2 ± 4.6 years). Pilot findings of Jovancevic et al. (2012) suggest that interactive video dance is associated with increased fronto-parietal attention network activation and a trend towards improved reaction times, while the results of Pichierri et al. (2012) support previous findings that strength and balance exercise may lead to better walking performance in older untrained subjects. In addition, integrating a cognitive training (video dance gaming) to strength and balance exercise results in further improvements in walking performance under dual-task conditions (higher gait velocity and shorter single support time during fast dual-task walking), most likely due to functional or even structural changes in the brain (Pichierri et al., 2012). Furthermore, both interventions in the Pichierri's study reduced the concerns about falling and only the dance group improved foot placement accuracy (in the medio-lateral direction) without significant differences between the two groups after 12 weeks.

Why is this so? Interactive video dance games are a form of action video games that also require physical activity besides constant monitoring of the periphery for frequent unpredictable events that require quick and accurate responses, thus, influencing positively physical and cognitive skills, abilities and functions such as hand-eye coordination, processing in the periphery, mental rotation, divided attention and reaction times (Jovancevic et al., 2012). In fact, monitoring of the periphery places heavy demands on visual-attentional systems, as players need to keep track of many moving objects while ignoring distracters. These games also require precise visual-motor control in order to aim steps in space and time according to the sequence of moving targets (Jovancevic et al., 2012).

What about usual dancing exercise / training? Kattenstroth, Kalisch, Holt, Tegenhoff and Dinse, (2013) performed a study where 35 healthy older adults (60 – 94

year olds) were engaged in a 6-month dance intervention group one hour per week (Agilando™ dance program – it can be performed without a partner) or in a control group. Cognition, fluid intelligence, attention, reaction time, motor, tactile and postural performance, as well as subjective well-being and cardio-respiratory performance were assessed. Similarly, Hamacher, Hamacher, Rehfeld, Hökelmann and Schega (2015) examined the effects of a 6-month dancing program on motor-cognitive dual-task performance, where cognitive performance, stride-to-stride variability of minimum foot clearance, stride time and stride length while walking were measured in 35 older adults (years), who were assigned to a dancing group or a health-related exercise group. The results of Kattenstroth et al. (2013) indicate no changes or further degradation of performance after six months in the control group. On the other hand, beneficial effects were found in the dance group for dance related parameters such as posture and reaction times, cognitive, tactile and motor performance, and subjective well-being, without alterations in cardio-respiratory performance (Kattenstroth et al., 2013). Furthermore, dancing also lowers gait variability and improves cognitive performance in dual-task conditions in a greater extent than conventional health-related exercise (Hamacher et al., 2015). Thus, it could be concluded that the lack of changes of cardio-respiratory function found by Kattenstroth et al. (2013) indicate that even moderate levels of physical activity in combination with rich sensorimotor, cognitive, social, and emotional challenges can act to ameliorate a wide spectrum of age-related decline. This shows that dancing could be a powerful tool to improve motor / cognitive (dual-task) performance and it can play an important role in the maintenance of perceptual and cognitive abilities, contributing also to a reduced risk of falls in older adult population. In fact, learning new dance steps requires three-dimensional and geometric thinking, which has been associated with improved learning capabilities (Kattenstroth et al., 2013), thus, stimulating neurogenesis and preservation of new neurons as noted by Curlik and Shors (2013).

Similarly, even the ancient body-mind meditative techniques like Tai Ji Quan (Tai-Chi) represent an efficient exercise mode to preserve or improve motor / cognitive functions and performance. Recent studies demonstrate that it improves cognitive and physical function (Bherer, Erickson & Liu-Ambrose, 2013; Sun et al., 2015), coordination (Qiu & Zhu, 2003), visual span (Bherer, Erickson & Liu-Ambrose, 2013) and through improved balance (Qiu & Zhu, 2003) also the efficiency of postural control (Zhou et al., 2015). It relieves stress, reduces pain and muscle stiffness (Qiu & Zhu, 2003) and it is effective in reducing blood pressure and body mass index, maintaining normal renal function, and improving physical health of health-related quality of life (Sun & Buys, 2015). Furthermore, long-term Tai Ji Quan (Tai-Chi) exercising can also improve vagal modulations, it tends to reduce sympathetic modulations (Guo, 2015) and has shown to be the cost most effective strategy (compared to resistance training or stretching) for optimizing fall prevention in Parkinson disease patients (Li & Harmer, 2015). All of this is the scientific confirmation why our ancestors' knowledge should not be forgotten and why we should stand on their shoulders to further improve our knowledge, ourselves as human beings and to direct our actions into helping each other

as well as generations that still have to come to live a better, healthier and, thus, more contended and successful life.

CONCLUSION

Physical activity in the form of aerobic and resistance exercise leading to a high level of cardio-respiratory fitness represents a strong non-pharmacological preventive tool in the third age (Bherer, Erickson & Liu-Ambrose, 2013; Hökelmann et al., 2015). The effects are even greater if any type in this paper mentioned motor-cognitive exercise / training are performed on regular basis. It could be performed either as a simultaneous combination of a motor task (movements) with an additional cognitive task (Geržević & Dobnik, 2014; Geržević, Dobnik, & Pišot, 2014; Theill et al., 2013), as dancing or video dancing (Hamacher et al., 2015; Hökelmann et al., 2015; Jovancevic et al., 2012; Kattenstroth et al., 2013; Pichierri et al., 2012) or as a body-mind meditative exercise like Tai Ji Quan (Bherer, Erickson & Liu-Ambrose, 2013; Guo, 2015; Li & Harmer, 2015; Qiu & Zhu, 2003; Sun & Buys, 2015; Sun et al., 2015; Zhou et al., 2015).

Despite an increasing number of studies indicate a strong connection between physical activity and brain health and plasticity in late adulthood, many questions remain still open for future research. Although positive effects were found with moderate intensity exercise for several months, Bherer, Erickson and Liu-Ambrose (2013), Erickson, Gildengers & Butters (2013) and Erickson et al. (2014) noted, that the exact dose-response relationship between physical activity and mood, cognitive or brain health in older adults remains unknown. This means there is a very poor understanding of the types (aerobic exercise alone like walking, tennis, swimming or cycling; anaerobic alone like resistance exercise; combined motor and cognitive exercise, such as (simultaneous) motor-cognitive exercise, dancing or Tai Ji Quan etc.; competitive or non-competitive sports), intensity (low, moderate, high) and duration of exercise that might be most useful to promote a healthier brain. There is also a very poor understanding of what age is optimal to start exercising, as well as a poor understanding of the retention of the effects, since individuals stop exercising for a variety of different reasons including injuries, illnesses, and personal issues (e.g., mourning). It is still unknown whether the increased grey matter volume or improved white matter integrity persists after the completion of the exercise intervention or after some period of inactivity (follow-up assessments of the effects). And finally, the effects still need to be fully understood in cognitively impaired populations including persons with Alzheimer's disease, depression, and Parkinson's disease (de Dreu, Kwakkel, & van Wegen, 2015).

In the end, it could be concluded that physical activity and exercise hold great potential as inexpensive and effective methods of elevating cognitive function, improving brain health, and restoring brain function after atrophy or disease (Erickson et al., 2014).

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