NORDIC WALKING COMBINED WITH SIMPLE COGNITIVE EXERCISES IMPROVES OLDER WOMEN ABILITY TO SELECT VISUAL STIMULI PROPORTIONALLY TO THE INCREASE IN PHYSICAL FITNESS

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Abstract

Results of experimental studies suggest that regular physical exercise improves general cognitive function such as attention, memory or speed of information processing in elderly. Despite relatively numerous studies that have demonstrated the benefits of the cognitive area the researchers emphasize the need for further research. The aim of the study was to determine the effect of regular Nordic walking (NW) exercises on the selection of visual stimuli in older women and to establish correlations between perceptual and physical fitness benefits. The study examined 60 women aged 64 to 93 years in three groups. Twenty people participated in a 3-month programme combining NW and CT (group NW+CT), 20 people participated only in NW classes (group NW), and 20 people were a control group (group C). The Attention and Perceptivity Test, the Fullerton Functional Fitness Test, and the Romberg balance tests were conducted. The improvements in abilities to select visual stimuli were found in both experimental groups. Almost all indices of improved physical fitness were positively correlated with indices of improved visual perception. NW training connected with simple cognitive exercises is effective in improving ability to select visual stimuli. Physical training should involve both aerobic and strength exercises combined with cognitive exercises.

Keywords: *Elderly, Nordic Walking, cognitive training, physical activity, physical fitness*

Introduction

Associated with aging changes in the brain structure and functions may lead to a decline in cognitive function (Eckert, 2011; Levin et al., 2014). These changes can be delayed and even reversed with active lifestyles and involvement in physical activity (Barha et al., 2017; Erickson et al., 2014; Kelly et al., 2014; Voelcker-Rehage & Niemann, 2014). Both cross-sectional and prospective studies have indicated the correlations between regular physical activity and reduced risk of dementia and deterioration of cognitive function (Chodzko-Zajko et al., 2009). Results of experimental studies suggest that regular physical exercise improves general cognitive function such as attention, memory or speed of information processing (Kelly et al., 2014; Voelcker-Rehage & Niemann, 2014; Chodzk-Zajko et al., 2009; Chapman et al., 2013; Eggenberger et al., 2016; Gonzalez-Palau et al., 2014; Szmul et al., 2018). Despite relatively numerous studies that have demonstrated the benefits of the cognitive area the researchers emphasize the need for further research (Brown et al., 2017; Young et al., 2015; Theocharidou et al., 2018).

However, the attention should be also paid to the fact that changes induced by physical activity are varied depending on the type of exercise. Positive changes in the speed of information processing and attention have been observed in older people who participated in aerobic exercises. The studies concerned memory and inhibition abilities less frequently (Brown et al., 2017; Young et al., 2015). Benefits of strength exercises and balance training seem to be lower and have concerned improved speed of information processing and attention (Fragala et al., 2014; Granacher et al., 2010; Iulian et al., 2015). The benefits of cognitive nature were greater when the intervention involved physical exercise with mixed character (Levin et al., 2014; Chodzko-Zajko et al., 2009). For example, information processing, memory and attention have been found to improve following training protocols that combined aerobic and flexibility exercises (Kamegaya et al., 2014). Improved information processing and attention has been documented in people who participated in strength and balance training (van het Reve & de Bruin, 2014). Intervention that combined aerobic, strength and balance exercises (Vaughan et al., 2014) led to improvements in information processing, attention and inhibition. Enhanced memory, inhibition abilities and attention have been observed following the aerobic and strength training (Berryman et al., 2014).

One of the forms of training that combines exercises of various types is Nordic walking, used successfully for comprehensive rehabilitation of people who suffer from various somatic disorders (Collins et al., 2012; Fritz et al., 2011; Reuter et al., 2011) and for activation of older adults (Ossowski et al., 2014). Another benefit of Nordic walking is that exercises that engage cognitive functions can be performed during walking. Interventions that combine physical and cognitive training yield even better benefits to the cognitive area. Their positive effects on information processing, memory, attention and reaction inhibition ability have been observed (Falbo et al., 2016; Leon et al., 2015; Maki et al., 2012). Integration of cognitive tasks into physical exercise programs has mostly concerned attention, memory, psychomotor functions and problem solving.

Therefore, multicomponent physical exercise programs and those that combine physical exercise with cognitive training seem to be the most efficient means of improvement in cognitive function of older adults compared to interventions limited to exercises of one type. In light of the data presented in the previous reviews and meta-analyses the best strategy to prevent deterioration of cognitive abilities with age and even improvements in such indicators as processing speed, psychomotor speed or attention, is to combine cognitive and physical exercises (Cadore et al., 2013; Hortobagyi et al., 2015).

Despite a vast array of studies devoted to the effects of physical exercises on cognitive processes of older adults, many problems remain unsolved. Little is known about the impacts of cognitive training on perception, including ability to select stimuli. As the person ages, a decline in susceptibility and sensitivity of senses is observed. The information received from the surroundings has a limited range, is less detailed and its transfer to the brain takes longer. Sensory integration of information from various modalities deteriorates, which leads to worse reception of complex stimuli, especially if several simple processes have to be performed simultaneously. The process of stimuli selection also becomes less efficient (Craik & Salthouse, 2008). Ability to discriminate between stimuli that differ in specific characteristics is an important factor that determines the effectiveness of the person's activities. It determines the possibilities of avoiding harmful and dangerous situations and finding changes that occur in the environment. This ability shows interindividual variation in terms of the size of the area subjected to the search and the number of mistakes. In the process of stimuli selection, perception is closely related to attention that determines what people notice. Sensory memory is also important (iconic memory in the case of visual stimuli), which maintains a sensory stimuli trace for a short time (Reuter et al., 2011). The decline in effectiveness of stimuli selection has significant consequences for behaviour. Therefore, activities oriented at reduction in the speed of these negative modifications become critical.

The above described beneficial changes in the processes of memory, attention and speed of information processing following regular physical exercise combined with cognitive training create expectations of the improved process of stimuli selection in older adults participating in physical exercise training. The effects are likely to be especially substantial in people participating in physical exercise training combined with additional cognitive exercises.

Obviously, physical activity leads not only to improved cognition of older adults but it also contributes to maintaining or even improving physical fitness, including the ability to maintain balance, precision of movements and coordination (Hortobagyi et al., 2015; Baker et al, 2007; Ji et al., 2017; Kattenstroth et al., 2013; Bednarczuk 2020). These effects are also different depending on the type of physical exercises. The review published by Levin et al. (2017) revealed that physical training that includes various components (aerobic training, strength, balance and flexibility exercises etc.) yields greater benefits in the area of motor activity compared to uniform exercises.

The researchers who have monitored the effects of programs of regular physical exercises have devoted much attention to analyses of changes of cognitive and motor character, but the analyses have been performed separately. Since motor and cognitive functions engage similar brain systems, it can be expected that they are exposed to the effect of analogous neurodegenerative processes. Therefore, it can be expected that correlations occur between the benefits in the motor and cognitive areas. This is supported by the findings of a systematic review by Levin et al. (2017). The relationships concerned mainly improved psychomotor speed, gait speed, improved ability to maintain balance in the physical area, and improved concentration of attention, increased processing speed and decline in dual-task costs in the cognitive area. They were mostly observed in participants of programs that combined physical training with cognitive exercises. However, these correlations have been rarely the focus of direct interest of researchers (Levin et al., 2017). This justifies continuation of the research on correlations between changes that occur in physical fitness and cognition of seniors caused by regular physical exercise.

The aim of the present study was: 1. to determine the effects of regular Nordic walking exercises with cognitive training to improve selection of visual stimuli in older women; 2. to establish the correlations between changes in physical fitness and visual perception. The study also attempted to find the answer to the question whether cognitive benefits can be predicted based on changes in physical fitness.

Materials & Methods

Participants

The examinations were performed using the field experiment method. Three groups were formed: two experimental groups that participated in Nordic walking sessions (group NW) and in Nordic walking sessions and cognitive training (group NW+CT) and a control group without interventions (Group C).

Each group included volunteers - residents of three day care centres in the big city of over a million inhabitants in Poland. Inclusion criteria were age over 60 years, health status and physical fitness level that allowed for participation in the physical exercise program (qualification by the general practitioner and assessment of a Nordic walking coach), normal mental health status (evaluated from observation and interviews with psychologists and carers). Exclusion criteria were motor and cognitive function impairments, poor health status that precluded them from physical activity. Purposive sampling with "threes" was employed to ensure evenness of the groups, after adopting the criterion of: general health status evaluated by a general practitioner; physical fitness evaluated by observation of a Nordic walking coach; cognitive ability assessed by a psychologist from a day care centre.

Overall, 81 residents (27 people in each group) met inclusion criteria. Due to an insignificant number of men (n = 9; 3 in each group) willing to participate in the study and meeting the inclusion criteria, it was decided to exclude them from the study.

In the case of losing one subject of the “three”, the results of the remaining subjects were excluded from the analyses. Final analyses involved 60 women who participated in all measurements of physical fitness and perception. An additional criterion of inclusion into analyses in the case of NW+CT and NW group was participation in at least 85% of sessions. Each group consisted of 20 women.

Age of participants ranged from 64 to 93 years (M = 80.25; SD = 5.755). They were mostly widows (n = 54) and were living alone (n = 51). Most of the women had secondary education level (n = 47) and vocational education level (n = 9). All the participants had been employed in the past and had performed physical work (n = 40) more often than mental (n = 10) or mixed (n = 10). The study participants evaluated their financial status mostly as average (n = 41) and, less often, as good (n = 12) and poor (n = 7). The majority of the women assessed their former lifestyles as medium active (n = 35), less often as active (n = 17) and very active (n = 8). Thirty two participants were very rarely involved in physical activity, and 22 of them did this at any opportunity.

The groups did not differ significantly in terms of age (F (2, 57) = 0.528; p = .592), education level (χ^2 = 4.723; p = .580), marital status (χ^2 = 7.036; p = .318), living alone or with family (χ^2 = 2.766; p = .598) and material situation (χ^2 = 9.669; p = .139).

Methods

The Attention and Perceptivity Test, version 3/8 (Ciechanowicz & Stańczak, 2006) was used to evaluate the ability to select visual stimuli. The task of the examined person is to delete the indicated digits (3 and 8) printed on an A4 sheet of paper as quickly and as accurately as possible in 3 minutes. It provides three indices of perception: speed of perception work (number of analysed digits), perception fallibility (number of errors - erratic crossing) and attention fallibility (number of skipping digits). Standard conditions of performing the test were used (3 minutes). The examinations were conducted in small groups of a few people. Before the test began, it had been examined whether a person understood the instructions.

The Fullerton Functional Fitness Test (Rikli & Jones, 2011) was performed to evaluate physical fitness. The test is composed of 6 consecutive trials that evaluate:

1. Arm Curl Test: upper body strength.
2. Back Scratch Test: upper body mobility.
3. Chair Sit and Reach Test: lower body flexibility.
4. 30-second Chair Stand Test: lower body strength.
5. 8-Foot Up and Go Test: agility (dynamic balance).
6. 6-Minute Walk: long-distance aerobic endurance.

The task was performed with the right and left hand in the first and second test, and with the right and left leg in the third, and better results were recorded. In the post-test, the trials were performed with the same leg as in the pre-test.

Furthermore, we performed the Romberg tests and determined the ability to maintain balance on the left and right foot with eyes open and closed.

All the tests were conducted twice: in the beginning of the program (pre-test) and after its completion (post-test).

Procedure

The exercises in Nordic walking were aimed to improve functional fitness: aerobic capacity, joint stabilization, flexibility, muscle strength, static and dynamic balance and motor coordination. This training was enhanced with cognitive exercises performed during walking. The program took 3 months, with training repeated twice a week for 60 minutes. A warm-up protocol in the initial part (10 minutes) was followed by strength exercises (15 minutes) and respiratory and flexibility exercises (5 minutes). Strength training was performed individually using the person's own body weight and in pairs using Nordic walking poles. Six exercises (1 set with 15 repetitions) were performed for 4 first weeks, followed by 4 weeks with five exercises (2 sets with 12 repetitions) and 4 weeks with the same exercises (3 sets with 10 repetitions). Next, the older adults walked for 30 minutes. For the first 10 minutes of wal king, participants followed a mental Nordic walking program that consisted in solving various mathematical tasks and memorizing a string of characters or digits. The route was measured using dedicated equipment with an in-built GPS POLAR m400 module operated by a coach who supervised training.

The participants from the NW+CT group participated in the same physical exercise sessions as in the NW group and were subjected to additional cognitive training performed during separate sessions. The cognitive training sessions were designed according to the author's program including:

1. Short-term memory exercises using mnemonic devices (chain method and symbol method);
2. Exercises that require alertness and extended focus of attention;
3. Exercises of intercultural integration that consist in creation of image associations;
4. Exercises of working memory that require simultaneous storing and processing of information;
5. Exercises of creative thinking. The program took 3 months, with training repeated twice a week for 60 minutes.

The control group without interventions participated in typical classes offered to residents of day care centres.

The study was approved by the Research Ethics Committee of the Józef Piłsudski University of Physical Education in Warsaw (No. SKE 01-46/2016). The Committee in accordance with their recommendations concerning research with humans. The study were reviewed and approved by a board of experts in many fields (including ethical standards). Before the study began the board took into account the observance of ethical standards in this human research. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All persons were orally informed about the aims of the projects and all testing procedures and all gave their informed written consent prior to their inclusion in the study.

Results

The effects of regular Nordic walking to improve selection of visual stimuli

Repeated measures analysis of variance (group x measurement) was used to determine intergroup differences and changes in time in the ability to select visual stimuli. The respective data are presented in Tables 1 and 2. The main effect of the group was significant in the case of perception fallibility and attention fallibility. The number of errors was the lowest, whereas the number of skipping digits was the highest in the C group. The NW and NW+CT groups did not differ significantly in terms of these indicators. The main effect of the measurement was significant in all cases. In the second measurement, better ability to select visual stimuli was found compared to the first measurement: the number of reviewed characters increased whereas the number of mistakes and skipping digits declined. Interaction between the group and measurement turned out to be significant in all cases (Table 1).

Table 1. Comparison of the ability to select visual stimuli (ANOVA measurement x group)

	Measurement		Group			ANOVA		
	I (*M±SD*)	II (*M±SD*)	C (*M**)	NW (*M**)	NW+CT (*M**)	Measurement (*F*, *p*, η²)	Group (*F*,*p*,η²)	Interaction (*F*, p, η²)
speed of perception (number of analysed digits)	454.41±142.090	506.97±143.987	440.90	467.35	535.80	54.247; <0.001; 0.483	2.759; *ns*	35.722; <0.001; 0.552
perception fallibility (number of erratic crossing)	2.08±1.900	1.34±1.365	0.88	2.55	1.75	38.968; <0.001; 0.402	7.044; 0.002; 0.195	11.708; <0.001; 0.288
attention fallibility (number of skipping digits)	7.95±11.429	7.20±11.818	13.45	4.75	4.22	5.486; 0.023; 0.086	4.706; 0.012; 0.140	16.737; <0.001; 0.366

M* - weighted mean

Analysis of the data contained in Table 2 reveals more details of manifestations of this interaction. Changes that reflect the improved ability to select visual stimuli occurred only in the NW and NW+CT groups. The perception speed index increased significantly in the NW+CT and NW groups, and it did not change in the C group. The groups did not differ significantly in terms of the number of reviewed digits in the first measurement. In the second measurement, participants from the NW+CT groups reviewed significantly more digits compared to those from the C group.

A significant decline in the index of perception fallibility occurred only in both experimental groups. In the first measurement, it was significantly lower in the C group compared to both remaining groups. In the second measurement, the groups did not differ significantly in these terms.

Table 2. Comparison of the results of both measurements in subgroups (Tukey's post-hoc test)

	Measur.	Group C (1) (*M±SD*)	comparison of measur. *p**	Group NW (2) (*M±SD*)	comparison of measure. *p**	Group NW + CT (3) (*M±SD*)	comparison of measure. *p**	comparison of groups 1-2 *p**	1-3 *p**	2-3 *p**
speed of perception	I	450.00±159.984	*ns*	443.65±128.875	0.006	469.80±140.759	<0.001	*ns*	*ns*	*ns*
	II	431.81±170.061		491.05±94.605		601.80±100.501		*ns*	0.002	*ns*
perception fallibility	I	0.86±1.459	*ns*	3.20±1.795	<0.001	2.25±1.713	<0.001	<0.001	0.045	*ns*
	II	0.90±1.513		1.90±1.410		1.25±0.967		*ns*	*ns*	*ns*
attention fallibility	I	12.48±18.198	.017	5.70±4.219	0.027	5.45±3.395	0.002	*ns*	*ns*	*ns*
	II	14.43±18.076		3.80±2.262		3.00±1.864		0.033	0.017	*ns*

The attention fallibility index changed significantly in all groups. However, it increased in the C group, but declined in NW and NW+CT groups. No significant intergroup differences were found in the first measurement. Significantly greater number of skipping digits was recorded in the second measurement in the C group compared to other groups, which did not differ from each other. The results of this part of the analyses suggest the improvement in the ability to select stimuli in both experimental groups, slightly greater in the NW+CT group.

Indices of improvement in perception ability were also computed. In the case of perception speed index, the result of the first measurement was deducted from the second, thus obtaining the index of increase in the number of reviewed characters. By deducting the result of the second measurement from the first, the index of decline in perception fallibility and attention fallibility was obtained (decline in the number of errors and number of skipping instances). One-way analysis of variance ANOVA and Tukey's post-hoc tests was used to determine the differences between groups (see Table 3).

Table 3. Comparison of improvement indices (ANOVA)

	Group			ANOVA (F, p, η^2)	Tukey's post-hoc test		
	C (1) (*M±SD*)	NW (2) (*M±SD*)	NW+CT (3) (*M±SD*)		1-2	1-3	2-3
perception speed increase	-18.19±24.961	47.40±53.275	132.00±80.080	35.722; <0.001; 0.552	<0.001	<0.001	<0.001
decline in perception fallibility	-0.05±0.218	1.30±1.129	1.00±1.170	121.708; <0.001; 0.288	<0.001	0.002	*ns*
decline in attention fallibility	-1.95±3.170	1.90±2.511	2.45±2.188	16.737; <0.001; 0.366	<0.001	<0.001	*ns*

The groups differed significantly in terms of the value of indexes of changes, with the highest effect size found for the index of perception speed increase. In the C group, the number of reviewed characters declined, whereas an increase in this number was observed in the experimental groups, significantly higher in the NW+CT groups compared to NW. Mean index of decline in perception fallibility in the C group was close to 0 and significantly lower than in both experimental groups. These groups did not differ significantly in this respect. The index of decline in perception fallibility adopted a negative value in the C group (which suggests deterioration), significantly lower than in NW and NW+CT groups. The decline in the speed of perception was greater in the NW+CT group compared to NW. These groups did not differ significantly in terms of both remaining indices of change.

The correlations between changes in the ability to select visual stimuli and changes in physical fitness

Before determination of the correlations between indices of changes in the ability to select visual stimuli and physical fitness, Pearson product-moment correlation coefficients were computed for linear correlations between indices of selection of visual stimuli and physical fitness in the first measurement (before the beginning of the program) and second measurement (after its completion). During the first measurement, perception speed was positively correlated with aerobic endurance (r = 0.323; p = 0.011) and agility (r = 0.336; p = 0.040). Perception fallibility was negatively correlated with mobility of the upper body (r = -0.265; p = 0.039). In the second measurement, perception speed was positively and stronger correlated than in the first with aerobic endurance (r = 0.465; p < 0.001) and agility (r = 0.413; p = 0.001). Perception fallibility was negatively and stronger (than in the first measurement) correlated with mobility of the upper body (r = -0.346; p = 0.006) and aerobic endurance (r = -0.293; p = 0.022). No significant correlations were found between attention fallibility and results of tests of physical fitness in both measurements.

Next, the correlation coefficients were computed between the indices of improvement in physical fitness and improvement in the ability to select visual stimuli (see Table 4). In most cases, they concerned all three indices of changes (increase in the perception speed, decline in perception fallibility and attention fallibility). The bigger the increase in physical fitness, the greater improvements in the ability to select visual stimuli. The most of significant relationships were found for the index of the decline of attention fallibility. The strongest correlation for this index was found with the increase in strength of lower body and agility. The strongest correlations for the increase in the perception speed were observed for the increase in upper body strength and agility. For the decline in perception fallibility was mostly linked to the increase in lower body.

The next step was to determine whether the improvement in physical fitness allows for predicting changes in the ability to select visual stimuli. The stepwise regression analysis was used for the purpose. The factors were indices of changes in physical fitness. The results of the analyses are shown in Table 5.

Table 4. Correlations between the improvement in the ability to select visual stimuli and improvement in physical fitness (Pearson's r coefficients)

Variable	Increase in perception speed	Decline in perception fallibility	Decline in attention fallibility
Improved balance (eyes open, left leg)	0.406**	0.392**	0.348**
Improved balance (eyes open, right leg)	0.407**	0.300*	0.486**
Improved balance (eyes closed, left leg)	0.234	0.211	0.193
Improved balance (eyes closed, right leg)	0.100	0.085	0.197
Increased aerobic endurance	0.615**	0.395**	0.341**

Improved flexibility	0.326*	0.307*	0.340**
Improved upper body mobility	0.234	0.167	0.380**
Increased lower body strength	0.467**	0.498**	0.542**
Increased agility	0.588**	0.324*	0.529**
Increased upper body strength	0.644**	0.378**	0.442**

* p< 0.05 ** p< 0.01

Table 5. Predictors of improvement in ability to select visual stimuli (stepwise regression analysis)

Dependent variable	Step	Predictor	β	Model (R^2; F; p)
Increase in perception speed	1.	Increased upper body strength	0.644	0.404; 41.714; < 0.001
	2.	Increased upper body strength	0.428	0.476; 28.270; < 0.001
		Increased aerobic endurance	0.355	
Decline in perception fallibility	1.	Increased lower body strength	0.498	0.236; 19.499; < 0.001
Decline in attention fallibility	1.	Increased lower body strength	0.542	0.282; 24.560; <0.001
	2.	Increased lower body strength	0.406	0.345; 16.811; < 0.001
		Improved balance (eyes open, right leg)	0.303	

The improvement in perception speed could be predicted at 47% based on the increase in the right upper limb strength and aerobic endurance. A positive predictor of the decline in perception fallibility was the increase in lower body strength, which allowed for prediction of changes at nearly 50%. A decline in attention fallibility could be predicted at nearly 35% based on the increase in lower body strength and improved balance on the right leg with eyes open. With introduction of an additional factor - the group, this was the only predictor that eliminated previously revealed predictors in the case of the increase in perception speed (β = 0.741; R2 = 0.541; F = 71.833; p < 0.001). Greater improvements in perception could be expected in the groups with interventions, especially in the group NW+CT. In the case of the decline in attention fallibility, the group factor was the strongest predictor (in the first step: β = 0.556; R2 = 0.298; F = 26.446; p < 0.001; in the second step: β = 0.347) and eliminated the factor of balance improvement from the equation. The second step of the analysis revealed the increase in lower body strength as a predictor (β = 0.301). Both predictors allow for prediction of a decline in the number of skipping instances at over 33% (F = 16.041; p < 0.001). The result of the regression analysis for the index of decline in perception fallibility (number of errors) remained unchanged, whereas the increase in lower body strength was its predictor.

Discussion

Our results are consistent with previous findings that physical training, especially extended with cognitive exercises, is likely to improve cognitive function in older adults. In our examinations, the ability to select visual stimuli was improved in both experimental groups: an increase in perception speed and a decline in perception fallibility and attention fallibility were documented. To date, little research has been done to evaluate the effect of physical activity on perception. However, tasks that require selection of visual stimuli engage not only visual perception but also attention and working memory. Consequently, it can be expected that effectiveness of these functions also increased. This is consistent with the findings of the previous comparative, prospective and experimental studies (Levin et al., 2017; Bherer et al., 2013).

In an attempt to explore the mechanisms behind cognitive effects of physical exercise training, researchers tend to emphasize the fact that physical exercise are likely to lead to changes in cerebral structure (Erickson et al., 2014; Chapman et al., 2013; Muller et al., 2017; Rehfeld et al., 2017). Cognitive benefits can be also connected with increased brain plasticity. One of the substances which actively promote the process of creation of new neural connections in the brain is brain-derived neurotrophic factor (BDNF). In people with higher BDNF levels, loss of memory and cognitive function with age is slower compared to people with low level of this protein. An increase in BDNF has been observed in older adults participating in physical exercise training, dancing classes and physical-cognitive training (Erickson et al., 2014; Muller et al., 2017). It was higher in people who improved their physical fitness to greater extent (Heisz et al., 2017).

The older adults from both experimental groups examined in our study participated in Nordic walking training sessions. However, the session design was not limited to aerobic exercise typical of Nordic walking training. It was interspersed with resistance exercises performed with poles aimed to develop strength of upper and lower limbs, and balance and flexibility exercises. The results obtained in our study confirm the beneficial influence of the combined training on cognitive function of older adults. Previous studies of its effect have found, among other things, the improvements in information processing, inhibition, memory and attention (Kamegaya et al, 2014; van het Reve & de Bruin, 2014; Vaughan et al., 2014; Berryman et al., 2014). To date, examinations of training effects of Nordic walking have focused on the physical area. It was found that practising the sport helps improve aerobic capacity and oxygen uptake (Reuter-Lorenz & Park, 2010), develop strength of lower limbs, flexibility (Ossowski et al., 2014) and balance (Reuter et al., 2011). Fewer studies have explored cognitive effects. Gmiąt et al. (2018) found improvements of perceptive function in older adults participating in Nordic walking training, including focus of attention during performance of the tasks that involved visual perception. It was accompanied by increased concentration of BDNF. A study of multiple sclerosis patients who participated in a physical exercise program that also included Nordic walking found improvements in memory and acceleration of information processing. However, changes in executive function and memory were not observed (Chenet et al., 2016).

During walking, the study participants performed cognitive exercises. Therefore, physical exercises were enhanced with the components of cognitive training. A systematic review of studies published by Levin et al. (2017) revealed that a multicomponent physical training yields more benefits than homogeneous exercises (aerobic or strength training), whereas the combined physical and cognitive training is the most efficient intervention. The results obtained in our study confirmed the effectiveness of this procedure. A significant improvement in various cognitive functions have been observed in previous studies of older adults participating in strength and balance exercises connected with attention selectiveness (de Bruin et al., 2013), aerobic and strength exercises combined with tasks that stimulated memory and psychomotor function (Leon et al., 2015), and balance and resistance training exercises combined with cognitive training (van het Reve & de Bruin, 2014).

Beneficial changes were slightly greater in the NW+CT group that participated additionally in specific cognitive training. Therefore, additional cognitive stimulation intensified (although to an insignificant degree), beneficial changes in the ability to select visual stimuli. The effectiveness of specifically cognitive interventions has been demonstrated in multiple studies of both healthy older adults and people with mild impairments of cognitive function (Martin et al., 2011; Reijnders et al., 2013). However, they require adequate training of personnel and special equipment and, therefore, are cost-intensive. Integration of exercises that activate cognitive functions into the conventional physical training seems to be an interesting alternative. Such exercises can be conducted by physical activity or physical recreation coaches while the duration of the session is not significantly extended.

A statistically significant increase in the number of skipped instances was found in the control group, which suggested deteriorated attention. These changes seem to reflect the deterioration of perception observed with age. Similar changes have been also observed in other control groups without interventions (McAdams-DeMarco et al., 2017). As the person ages, performance of many tasks that require cognitive processes starts to decline. Information processing time extends, working memory deteriorates, while inhibition and updating processes become less efficient, especially at a substantial load to memory (Bherer et al., 2013). A decline in ability to select visual stimuli observed in the control group in our study suggests that typical activities of residents of day care centres are insufficient to prevent regressive changes resulting from the ageing process.

The results of the present study suggest that changes in perception in terms of the ability to select visual stimuli in older adults are correlated with changes in physical fitness, especially strength (of both upper and lower body). The improved perception speed and a decline in perception fallibility and attention fallibility increased for higher increases in strength and aerobic endurance, agility and flexibility and ability to maintain balance with eyes open. Furthermore, these relationships were confirmed by the regression analysis: the value of indices of improvement in the ability to select visual stimuli can be predicted based on the increase in upper limb strength and lower body strength, increase in aerobic endurance and improvement in ability to maintain balance.

It should be emphasized that numerous statistical correlations, mostly with moderate strength, were found for all indices of changes in the ability to select visual stimuli and most of indices of changes in physical fitness. Only the indices of improved balance with eyes closed were not significantly correlated with any of the indices of improvement in perception ability in terms of selecting visual stimuli. It is worth emphasizing that mean values of these indices did not vary depending on the group and were close to 0.

The data obtained in our study seem to confirm the conclusion from the qualitative analysis of the results obtained in previous studies that have examined changes in physical and cognitive fitness of older adults following cognitive and physical training. Simultaneous improvements in performance of cognitive and motor tasks were observed mainly in participants of programs that combine physical and cognitive exercises or mixed physical training. For example, studies have found improved mobility and ability to maintain balance, information processing speed and attention (van het Reve & de Bruin, 2014; Vaughan et al., 2014), and psychomotor speed and information processing speed and attention (van het Reve & de Bruin, 2014; Leon et al., 2015). Based on the results of a review of studies, Levin et al. (2017) found that the improvements in the cognitive area (mainly attention and information processing) were mostly accompanied by improved gait, mobility, balance and psychomotor speed.

The correlations between indices of changes in the areas of cognition and physical fitness have been rarely examined. Falbo et al. (2016) found a positive strong correlation between the increase in effectiveness of inhibition and decline in gait variability in people participating in training programs that consisted in simultaneous performance of physical and cognitive exercises and substantially poorer correlation in the group that participated only in a physical exercise program. Williamson et al. (2009) documented correlations between the improvement in attention effectiveness and improved results from the Short Physical Performance Battery test, including the test of five-time standing up from a chair without support of hands and in certain tests of maintaining balance. Furthermore, the improvement in gait speed and standing up from the chair was correlated with better results from the short-term test. These findings are consistent with the results of our previous studies.

We found particularly strong correlations for strength increase indices. Strength increase indices for upper body allowed for prediction of changes in ability to select visual stimuli and were its positive predictor. The question remains what this relationship results from? The easiest way is to assume that greater strength of the upper limb is likely to help perform the task of crossing the symbols more efficiently, regardless of the selection speed. The sources of correlations between the improved ability to select visual stimuli and strength of lower body in the chair stand test are not that obvious and difficult to be reduced to merely motor activity. They have been also documented in previous studies (Williamson et al., 2009), which suggest that this is a general tendency. It can be expected that physical exercise combined with cognitive training have a beneficial effect on these functions and structures which determine both physical fitness and cognition.

As mentioned earlier, benefits of cognitive character can be linked to the increase in brain neuroplasticity, as indicated by an increase in the BDNF factor. However, it does not provide information about which brain areas are exposed to this effect. The results of examinations that have used neuroimaging method suggested that physical exercise leads to increased volume of grey and white substance in the prefrontal brain regions (Erickson et al., 2014; Voelcker-Rehage & Niemann, 2013; Muller et al., 2017; Liu-Ambrose et al., 2012; Niemann et al., 2014). The changes in the prefrontal structures resulting from ageing result in many cognitive deficits such as deteriorated attention and processing speed and allow for prediction of multiple motor defects and deterioration of performance of the tasks that require complex coordination, loss of balance, deterioration of mobility, longer time of performance of complex motor tasks (Reijnders et al., 2013). Therefore, positive changes that occur in these brain regions may condition both improvement in the results of both physical fitness tests and cognition.

Substantially fewer statistically significant correlations than between indices of change were found between the results of physical fitness and ability to select visual stimuli in pre-test and post-test. It seems that they illustrate which components of physical fitness determine efficient performance of the symbol crossing test. Perception speed (number of symbols reviewed in 3 minutes) was correlated with aerobic endurance, whose indicator was the distance covered over 6 minutes. The participants performed tasks that required endurance in both cases. Time to stand up from the chair and start walking represented the agility index. It partially depends on the motor component of reaction time, which (in addition to perception speed) determines the number of crossed symbols. Strength of upper body allows for better performance of the crossing task. Number of errors was the fallibility index. At least part of errors may have resulted not just from improper perception of symbols but from poor fitness of the upper body (flexibility). This may explain the correlation between perception fallibility and flexibility.

The results of the study allow for formulation of practical recommendations for organizers of care for older adults. Inclusion of physical activity into daily routines provides benefits for both physical fitness and cognitive function. American College of Sports Medicine (2009) recommends moderate intensity training for older adults, compose d of aerobic exercises, muscle strength and flexibility training, and, if a person experiences frequent falls or difficulties with moving, also balance exercises. Integrating cognitive training into physical activity sessions may enhance positive cognitive effects. Further research is needed to compare the effects of homogeneous and complex physical exercises and physical training combined with cognitive exercises of various kind. This allows for formulation of more detailed indications for the type, content, intensity and frequency of not only physical but also cognitive exercises performed during a single session for older adults.

Our study has some limitations. The scope of generalization of the results is limited for several reasons. Firstly, the study examined only women. It is often difficult to find sufficient number of men (similar to the number of women) during examinations of older adults. This results from the fact that women live longer and participate in organized forms of daily care more often. They are also more willing to participate in scientific research. Secondly, the examinations were performed in the capital of Poland, where access to various forms of activation of older adults is much better than in rural areas. It can be expected that the women we examined had more opportunities to be involved in activities improving physical fitness and cognitive function compared to their peers from other areas, which is likely to have had an effect on their psychophysical fitness. Thirdly, the relatively small size of the groups was insufficient for the comparison of the correlations between changes in physical fitness indices and ability to select visual stimuli in people who participated only in Nordic walking training and those who followed a combined cognitive and physical exercise training program. Such a comparison would provide additional information about the effect of cognitive and physical exercises on fitness of older adults.

Conclusions

The study indicated that Nordic walking training connected with simple cognitive exercises is effective in improving ability to select visual stimuli. Physical training should involve both aerobic and strength exercises combined with cognitive exercises.

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