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REVIEW / PRACA POGLĄDOWA

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COGNITIVE TESTS USED IN EXAMINING EFFECTS OF PHYSICAL TRAINING IN ELDERLY PEOPLE

TESTY POZNAWCZE STOSOWANE W BADANIU EFEKTÓW TRENINGU FIZYCZNEGO U OSÓB STARSZYCH

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Summary

Introduction. Cognitive tests are a valuable, sensitive and useful tool for examining the effectiveness of physical training.

Purpose. To show which studies are sensitive in examining cognitive changes induced by physical training. We explored meta-analysis with healthy participants and patients with MCI.

Materials and methods. Analysis of meta-analysis in the EBSCO database using keywords: meta-analysis, cognitive tests, physical training, elderly.

Results. 4 meta-analysis have 10 researches in common; however, diverse of inclusion and exclusion criteria led to inability in obtaining reliable results.

Discussion and conclusion. Some cognitive tests seems to be more sensitive in examining results of physical training. Diversity of research methodology induces much difficulties in comparing of studies.

Streszczenie

Wstęp. Testy poznawcze są wrażliwym i użytecznym narzędziem w badaniu skuteczności treningu fizycznego.

Cel. Sprawdzenie, które testy są wrażliwe na badania zmian poznawczych wywołanych przez trening fizyczny. Przeanalizowaliśmy metaanalizy ze zdrowymi uczestnikami i pacjentami z MCI.

Materiał i metody. Analiza metaanaliz w bazie danych EBSCO za pomocą słów kluczowych: metaanaliza, testy poznawcze, ćwiczenia fizyczne, osoby starsze.

Wyniki. 4 metaanalizy posiadają 10 wspólnych badań, jednakże zróżnicowanie kryteriów włączenia i wyłączenia doprowadziły do niemożności w uzyskaniu wiarygodnych wyników.

Dyskusja i wnioski. Niektóre testy poznawcze wydają się być bardziej czułe w badaniu wyników treningu fizycznego. Różnorodność metodologii wywołuje wiele trudności w porównywaniu badań.

Key words: meta-analysis, cognitive tests, physical training, elderly
Słowa kluczowe: metaanaliza, testy poznawcze, trening fizyczny, osoby starsze

INTRODUCTION

There are several factors which influence cognitive maintenance in the years of senile: subjects' sex, years of education, economic situation, overall state of health, years of physical exercising. Impact of physical training on cognitive functioning of the elderly has been reported multiple times for the past 3 decades [1, 2]. Moreover, meta-analysis from last decade confirmed positive effect of physical training on cognitive functioning [3-6].

However, underlying neurobiological mechanism is still unknown. Enhanced cardiovascular functioning is one of the hypothesis, widely described in other reviews [3, 7, 8].

Our aim is to present cognitive tests which were used in examining effects of intervention. First part of our review concerns interventions in Mild Cognitive Impairment (MCI) of the elderly, second one refers to healthy elderly participants.

MATERIALS AND METHODS

Cognitive tests used in meta-analyzes: effect of physical training on cognitive functioning in elderlies with MCI and dementia

Patricia Heyn et al. [4] meta-analysis is based on 30 researches containing MMSE (Mini–Mental State Examination). Researches included in meta-analysis examined effect of physical training in patients with MCI or dementia. Interestingly, MCI as a group of clinical syndromes has multiple diagnostic criteria [9]. Participants' MMSE average scores varied from 6 to 25 points [4]. It shows difference in pre-test overall health state of participants from interventions included in meta-analysis, what underlies problems in comparing size of effects in particular researches.

Gates et al. [3] meta-analysis included fourteen random control trials with MCI participants. Only 8 % of cognitive outcomes were statistically significant. Cognitive Participants' MMSE scores ranged from 24 to 28 points, age varied between 65 to 95 years. Interestingly, Gates et al. [3] shows no effects of aerobic training in memory improvement in the analyzed researches. Effects induced by aforementioned training modality were restricted to verbal fluency only [3]. However, two researches reported large significant effects of strength training on memory improvement [3].

Table I. *Noteworthy, a prior meta-analysis reported greatest improvement in researches with groups restricted to no more than 10 participants (modified version of Gates et al.* [3]*)*

Test	Total nr of intervention group	Total nr of control group	Mean Difference IV, Random, 95% CI
Stroop	240	204	2.97 [-1.19, 7.14]
TMTB	394	431	6.76 [-1.14, 14.67]
Fluency	461	484	1.32 [0.38, 2.26]
Digit Symbol Substitution Test	361	331	0.57 [-1.21, 2.34]
Digit Span	299	321	0.15 [-0.12, 0.42]
Learning/immediate memory & delayed memory	339	383	-0.01 [-0.16, 0.14]

Cognitive tests used in meta-analysis: effect of physical training on cognitive functioning in healthy elderly people

Colcombe and Kramer [5] included eighteen interventions in their meta-analysis. Exclusion criteria were: cross-sectional design, not random assignment, unsupervised intervention, aerobic exercises not included in intervention, age of participants under 55. Colcombe and Kramer analyzed one intervention with MCI participants and one with intervention group suffering from depression. Meta-analysis confirms that physical exercise is beneficial for all analyzed cognitive functions, especially for executive one [5].

Table II. *Noteworthy, summed results from 101 participants showed statistically significant difference of effect size between improvement of combined strength and aerobic training group and aerobic training only group (0.59 vs. 0.41, SE=0.043) (adapted from Colcombe and Kramer* [5]*)*

Cognitive tests	Effect size (exercise group)
executive (Erickson flanker task)	0.69
controlled (choice reaction time task)	0.47
spatial (Benton Visual Retention Task)	0.42
speed (simple reaction time, finger tapping speed)	0.28

Angevaren et al. [6] used criteria list for quality assessment of non-pharmaceutical trials (CLEAR NPT). Exclusion criteria refers to, inter alia, researches including depressed participants or in average age under 55, non-randomized trials, lack of fitness parameter or no quantitative data. 11 randomized studies were included into analysis. Cognitive tests used in the analyzed papers were categorized into sub-categories according to concept of Lezak [6, 10, 11].

Angevaren et al. [6] reported that eight of 11 analyzed studies showed that aerobic training influence positively on increment in VO_2 max (approx. 14 %). Increment coincided with better cognitive functioning, with largest effect on motor functioning (effect size 1.17), auditory attention (e.s. 0.50), cognitive speed and visual attention (both e. s. 0.26). Noteworthy, meta-analysis reported 33 cognitive tests only. Several tests were missed in analysis to avoid multiple representation of studies over the categories, and to facilitate the summing of particular results [6].

Comparison 1. Aerobic exercise vs. any intervention

Table III. *'Any intervention' could be consists of strength training, flexibility training or passive attendance in gym were applied. Comparison between aerobic training and no intervention could result in misleading results. In intervention group, factors other than aerobic training per se, can influence on cognitive functioning improvement (adapted from Angevaren et al.* [6]*)*

Outcome or subgroup title	No. of studies	No. of partici-pants	Effect size	Statistical method
1 Cognitive speed	6	312	0.24 [0.01, 0.46]	Std. Mean Difference (IV, Random, 95% CI)
1.1 Simple reaction time	1	37	-0.10 [-0.75, 0.54]	
1.2 Trailmaking part A 1	1	48	0.52 [-0.06, 1.10]	
1.3 Digit symbol substitution	4	227	0.23 [-0.03, 0.50]	
2 Verbal memory functions (immediate)	4	209	0.17 [-0.10, 0.44]	
2.2 Randt Memory test story recall	2	65	0.33 [-0.16, 0.82]	
2.3 Ross Information: Processing Assessment immediate memory	1	20	0.06 [-0.82, 0.93]	
2.4 Rey auditory verbal learning trial I-V	1	124	0.10 [-0.25, 0.45]	
3 Visual memory functions (immediate)	2	65	0.04 [-1.66, 1.75]	Mean Difference (IV, Fixed, 95% CI)
3.1 Benton visual retention	2	65	0.04 [-1.66, 1.75]	
4 Working memory	3	189	0.36 [-0.31, 1.03]	Mean Difference (IV, Random, 95% CI)
4.1 Digit span backward	3	189	0.36 [-0.31, 1.03]	
5 Memory functions (delayed)	1	124	0.06 [-0.44, 1.44]	Mean Difference (IV, Fixed, 95% CI)
5.1 Rey auditory verbal learning delayed recall trial	1	124	0.06 [-0.44, 1.44]	
6 Executive functions	7	326	0.16 [-0.20, 0.51]	Std. Mean Difference (IV, Random, 95% CI)
6.1 Trail making part B	2	65	0.35 [-0.14, 0.85]	
6.2 Ross Information: Processing Assessment problem solving	1	20	-0.88 [-1.81, 0.05]	
6.3 Wechsler Memory Scales mental control	1	16	-0.44 [-1.44, 0.55]	
6.4 Word comparison	1	53	0.24 [-0.30, 0.78]	
6.5 Task switching paradigm (accuracy)	1	124	0.03 [-0.32, 0.38]	
6.6 Verbal fluency	1	48	0.87 [0.28, 1.47]	
7 Perception	3	160	-0.10 [-0.63, 0.43]	
7.1 Face recognition (delayed recall)	1	124	0.17 [-0.18, 0.53]	
7.2 Ross Information: Processing Assessment auditory processing	1	20	-0.17 [-1.05, 0.71]	
7.3 Wechsler Adult: Intelligence Scales visual reproduction	1	16	-0.81 [-1.84, 0.22]	
8 Cognitive inhibition	3	189	-0.02 [-0.31, 0.26]	
8.1 Stroop color word (interference)	2	65	-0.07 [-0.56, 0.42]	
8.2 Stopping task (accuracy	1	124	0.01 [-0.35, 0.36]	
9 Visual attention	5	290	0.26 [0.02, 0.49]	
9.1 Digit vigilance	1	48	0.45 [-0.13, 1.02]	
9.2 2&7 test	2	65	0.30 [-0.19, 0.79]	
9.3 Letter search primary task RT	1	53	0.05 [-0.49, 0.59]	
9.4 Visual search (accuracy)	1	124	0.25 [-0.10, 0.60]	
10 Auditory attention	5	243	0.05 [-0.45, 0.54]	Mean Difference (IV, Random, 95% CI)
10.1 Digit span forward	5	243	0.05 [-0.45, 0.54]	
11 Motor function	4	237	0.52 [-0.25, 1.30]	Std. Mean Difference (IV, Random, 95% CI)
11.1 Finger tapping	3	113	0.72 [-0.35, 1.78]	
11.2 Pursuit rotor task (tracking error)	1	124	0.02 [-0.33, 0.38]	

Comparison 2. Aerobic training vs flexibility/balance training

Table IV. *Flexibility and balance are categorized into one group, nonetheless it resulted in a very few number of studies in each cognitive category (adapted from Angevaren et al.* [6]*)*

Outcome or subgroup title	No. of studies	No. of partici-pants	Effect size	Statistical method
1 **Cognitive speed**	3	189	1.29 [-0.41, 2.98]	Mean Difference (IV, Random, 95% CI)
1.1 Digit symbol substitution	3	189	1.29 [-0.41, 2.98]	
2 **Verbal memory functions (immediate)**	3	189	0.18 [-0.11, 0.47]	Std. Mean Difference (IV, Random, 95% CI)
2.1 Randt Memory test story recall	2	65	0.33 [-0.16, 0.82]	
2.2 Rey auditory verbal learning trial I-V	1	124	0.10 [-0.25, 0.45]	
3 **Visual memory functions (immediate)**	2	65	0.04 [-1.66, 1.75]	Mean Difference (IV, Fixed, 95% CI)
3.1 Benton visual retention	2	65	0.04 [-1.66, 1.75]	
4 Working memory	3	189	0.36 [-0.31, 1.03]	Mean Difference (IV, Random, 95% CI)
4.1 Digit span backward	3	189	0.36 [-0.31, 1.03]	
5 Memory functions (delayed)	1	124	0.06 [-0.44, 1.44]	Mean Difference (IV, Fixed, 95% CI)
5.1 Rey auditory verbal learning delayed recall trial	1	124	0.06 [-0.44, 1.44]	
6 Executive functions	4	242	0.16 [-0.09, 0.41]	Std. Mean Difference (IV, Random, 95% CI)
6.1 Trail making part B	2	65	0.35 [-0.14, 0.85]	
6.2 Word comparison	1	53	0.24 [-0.30, 0.78]	
6.3 Task switching paradigm (accuracy)	1	124	0.03 [-0.32, 0.38]	
7 Perception	1	124	3.70 [-3.68, 11.08]	Mean Difference (IV, Fixed, 95% CI)
7.1 Face recognition (delayed recall)	1	124	3.70 [-3.68, 11.08]	
8 Cognitive inhibition	3	189	-0.02 [-0.31, 0.26]	Std. Mean Difference (IV, Random, 95% CI)
8.1 Stroop color word (interference)	2	65	-0.07 [-0.56, 0.42]	
8.2 Stopping task (accuracy choice RT)	1	124	0.01 [-0.35, 0.36]	
9 Visual attention	4	242	0.22 [-0.03, 0.47]	
9.1 2&7 test	2	65	0.30 [-0.19, 0.79]	
9.2 Letter search primary task RT	1	53	0.05 [-0.49, 0.59]	
9.3 Visual search (accuracy)	1	124	0.25 [-0.10, 0.60]	
10 Auditory attention	3	189	-0.20 [-0.81, 0.40]	Mean Difference (IV, Random, 95% CI)
10.1 Digit span forward	3	189	-0.20 [-0.81, 0.40]	
11 **Motor function**	3	189	0.07 [-0.21, 0.36]	Std. Mean Difference (IV, Random, 95% CI)
11.1 Finger tapping	2	65	0.17 [-0.31, 0.66]	
11.2 Pursuit rotor task	1	124	0.02 [-0.33, 0.38]	

Comparison 4. Aerobic exercise vs. strength program

Table V. *The aim of meta-analysis were examining influence of aerobic training on cognitive functioning, however several analyzed studies contained strength intervention as well* [6]. *Interestingly, according to Gates et al.* [3], *strength training showed effect size in memory functioning as well (adapted from Angevaren et al.* [6]*)*

Outcome or subgroup title	No. of studies	No. of partii-cipants	Effect size	Statistical method
1 Verbal memory functions (immediate)	1	20	0.30 [-4.17, 4.77]	Mean Difference (IV, Fixed, 95% CI)
1.1 Ross Information Processing Assessment immediate memory	1	20	0.30 [-4.17, 4.77]	
2 Executive functions	1	20	-2.30 [-4.49, -0.11]	
2.1 Ross Information Processing Assessment problem solving and abstract reasoning	1	20	-2.30 [-4.49, -0.11]	
3 Perception	1	20	-0.06 [-2.93, 1.93]	
3.1 Ross Information Processing Assessment auditory processing	1	20	-0.06 [-2.93, 1.93]	

Common researches included in meta-analysis

Meta-analysis included in our paper [3-6] consist of 73 analyzed trials. Interestingly, several common interventions were included: 10 researches [1, 12-21] are analyzed in more than one meta-analysis.

Table VI. *Common researches causes inability in obtaining reliable results from overall results of analyzed meta-analysis* [3–6]

	Gates et al. [3]	Hayne et al. [4]	Angevaren [6]	Colcombe [5]
Gates et al. [3]		Molloy et al. [12]		
Hayne et al. [4]	Molloy et al. [12]			Dustman et al. [1], Hill et al. [13], Perri et al. [14], Hassmen et al. [21], Barry et al. [19], Powell et al. [20].
Angevaren [6]				Moul et al. [15], Madden et al. [16], Emery et al. [17], Emery et al. [18].
Colcombe [5]		Dustman et al. [1], Hill et al. [13], Perri et al. [14], Hassmen et al. [21], Barry et al. [19], Powell et al. [20].	Moul et al. [15], Madden et al. [16], Emery et al. [18], Emery et al. [17].	

RESULTS

Results from meta-analysis [3–6] showed tendency of some cognitive tests to be more sensitive in examining results of physical training. Gates [3] and Heyn [4] meta-analysis included participants with MCI and dementia. MCI as a group of clinical syndromes has multiple diagnostic criteria, therefore varied MMSE scores of participants included in meta-analyzes has been reported [3, 4]. Heterogeneity of results causes several difficulties in comparing of studies. Nevertheless, some tendencies of cognitive tests can be observed. Gates et al. [3] reported statistically significant positive influence of aerobic training on verbal fluency tests only. Moreover, strength training improved performance in memory tests, however data were based on 2 interventions only [3].

Colcombe and Kramer [5] analyzed researches containing multi-modal training, one research based on MCI participants' results, another study contained intervention group suffering from depression. Angevaren [6] included studies with aerobic training and healthy elderly participants only, therefore comparing results from Colcombe and Kramer [5] and Angevaren [6] could be misleading.

Additionally, analyzed meta-analyzes in our paper contain 10 common studies. Consequently, direct results of studies [3-6] cannot be compared. However, some conclusions could be obtained. Meta-analysis [5] reported largest effect of multi-modal training (strength and aerobic) on cognitive functioning. Additionally, physical exercise influence on every cognitive tests category; executive and control type of tests results in largest effect size.

Angevaren [6] et al. showed largest effects of aerobic exercise on motor function and auditory attention (effect sizes of 1.17 and 0.50, respectively), cognitive speed and visual attention resulted in less ES (both 0.26, all ES were obtained in comparison aerobic exercise with 'no intervention', not included in our paper). However, comparing with no exercise do not exclude effects other than aerobic training per se. Nevertheless, comparison of aerobic exercise with 'any intervention' (strength training, flexibility training) can give ambiguous results. Strength training can influence cognitive functioning, however, results can differ from effects of aerobic training. Interestingly, comparison between aerobic exercise and strength training showed large effect (ES = 2.30) of strength training on executive functions. However, results were based on one study only.

DISCUSSION AND CONCLUSION

Cognitive tests commonly used in examining of physical training effects and demonstrated largest effect size are MMSE, and auditory attention test: digit span, digit span backward, digit span forward.

Noteworthy, Voss et al. [22] proposed hypothesis in which physical activity improves cognitive accuracy, not cognitive speed. Moreover, taking part in intervention group can improve cognitive functioning unlike influence of physical activity per se. One of the possible factors could be increment in social activity and new environment of elderly participants in intervention group (attending to gym, meeting co-participants).

Colcombe et al. [5] reported that control group consisted of participants in age ranged from 55 to 65 (g = 0.108, SE = 0.053, n = 23, $p < .05$), and 66-70 (g = 0.258, SE = 0.045, n = 48, $p < .05$) noted larger performance improvement than 71-80 participants (g = 0.076, SE = 0.058, n = 25, n.s.).

Angevaren et al. [6] showed reduction of VO_2max in all but two examined control (no training) groups. VO_2max increase in controls were statistically non-significant.

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