RESEARCH ARTICLE

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Acute Effect of Resistance Training on Cognitive Function of Costa Rican Older Adults

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Abstract: Different types of exercise interventions have shown to improve cognitive performance; however, there is scarce evidence on the acute effect of resistance training (RT) on cognitions in older adults. The purpose of this study is to determine the acute effect of RT on cognitive performance in healthy older adults. 45 adults (Mean age = 65.3 ± 3.7 yr.) were randomly allocated to one of three groups: high-intensity RT (G1), low-intensity RT (G2), or inactive control (G3). Participants completed cognitive tests assessing processing speed, visuospatial processing, executive function, and cognitive control, working memory and immediate memory. The RT protocol for G1 and G2 consisted of six exercises. A 3x2 ANCOVA was performed with education as a covariate. Significant improvements were found on visuospatial processing in G1 (Pre = 61.6 ± 2.1 vs. Post = 69.7 ± 2.4; 95%CI = 4.8, 11.4; $p \leq 0.001$) and G2 (Pre = 62.4 ± 2.2 vs. Post = 67.0 ± 2.5; 95%CI = 1.2, 8.1; $p = 0.009$). Other tested cognitive abilities were unchanged by acute exercise or rest. Acute RT enhanced or maintained cognitive performance in older adults. It was possible to successfully perform 1RM tests with older adults. Additional evidence is needed to determine effective protocols to improve cognition in older adulthood.

Keywords: Resistance Training, Cognition, Older Adults, Aging, Acute Effect

About the Authors

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1. Introduction

The World Health Organization (WHO) estimates that the number of older adults will grow from 524 million in 2010 to 1.5 billion in 2050 [1]. This global demographic change demands that immediate attention be paid to the prevention and intervention of neurodegenerative processes, as well as to the expected changes related to increasing age. Starting in the third decade of life and during ageing there is a gradual deterioration of brain function, which is associated with changes in cognitive abilities [2]. Even in older adults without pathologies, cognitive impairments that hinder daily activities and limit independence and security are common [3, 4]. However, this does not mean that ageing necessarily implies a significant deterioration, since lifestyle (e.g., healthy eating, physical activity, social interaction) also influences cognitive health as one ages.

Physical activity, especially aerobic exercise, is known to improve some cognitive domains [1, 5-8]. Chronic resistance exercise has also shown to increase performance on various cognitive variables. A meta-analysis reported that resistance training (RT) positively affected cognitive scores including global cognition (SMD 0.71, 95%CI 0.30–1.12, $p < 0.001$), measures of cognitive impairment (SMD 1.28, 95%CI 0.39–2.18, $p = 0.005$), and executive function (SMD 0.39, 95%CI 0.04–0.74, $p = 0.029$), although working memory was not influenced [9].

Regarding the acute effect of RT on cognition, Chang and Etnier [10] reported a significant improvement in processing speed and executive function in young adults after a bout of resistance exercise. Tzuk et al. [11] found that an acute session of resistance exercise increased test scores on attention and executive functioning in young adults as well. Likewise, resistance exercise has been found to exert an acute positive effect on some cognitive functions in adolescents [5]. Meanwhile, the acute effect of RT has been less studied in older population [12]. A meta-analysis on the acute effect of RT on cognition including young, middle aged and older adults found a significant effect size of RT compared to non-exercise groups, favoring improvements on inhibitory control and cognitive flexibility [13].

Chang et al. [14] evaluated the effect of acute resistance exercise on a sample of adults aged 55-70 years and reported improvements in performance of the Stroop test. It has been suggested that intensity of RT has an impact on improvements observed following a single bout of exercise. However, there is conflicting evidence regarding which intensity provides better outcomes. Findings by Chang and Etnier [10] suggested that moderately intense RT (70% 10RM) leads to greater improvements than low (40% 10RM) or high (100% 10RM) RT. Soga et al. [12] also reported stronger effects for moderate intensities, while Wilke et al. [13] found a larger effect size for low and high intensity RT. However, there is insufficient evidence about which types of RT interventions could have a positive effect on the cognitive performance of older adults [4].

Most studies of exercise and cognition during ageing have focused on the effect of aerobic exercise, even though RT has several benefits for the elderly population such as improving body composition, coordination, strength and quality of life [5]. Therefore, the purpose of this study was to determine if there is an acute effect of RT on the cognitive performance of healthy older adults.

2. Materials and Methods

2.1 Participants

45 adults (37 women and 8 men) aged over 60 years (average age = 65.3 ± 3.7 years), were randomly assigned to one of three possible groups: a) high intensity RT (G1), b) low intensity RT (G2), or c) inactive control (G3). Participants were recruited through the Institutional Program for Adults and the Elderly (PIAM) of the University of Costa Rica. As a requirement for their voluntary participation, subjects had no contraindications to exercise and were cognitively intact (Mini Mental State Examination score ≥25).

2.2 Measures

Personal and demographic information. Data on age, sex, education (years of formal education), and weekly physical activity was collected. In addition, they reported medical conditions and medications of regular use.

Cognitive evaluations. Participants completed four cognitive tests, which were applied by the psychologist. The Mini Mental State Examination (MMSE) [15], a brief assessment of basic cognitive awareness, episodic memory, and visuospatial construction, was used as a first screening. This test allows to discriminate persons with possible cognitive impairment. The test is scored from 0 to 30; scores below 25 indicate possible cognitive decline [15, 16].

As an inclusion criterion, participants had to obtain a minimum score of 25. The three forms of the Stroop Test were also applied [17]: a) color naming, b) word reading and c) interference. Each form assesses different cognitive functions such as processing speed (word reading), visuospatial processing (color naming), executive function, and cognitive control (interference). The Trail Making Test (TMT) was also employed [18]. Forms A and B of this test were applied as measures of visuospatial processing (A), executive function (B) and cognitive control (B). Finally, the Digit Span (DS) was applied [19]. Both the forward and backward versions of the test were used to evaluate working memory (backward) and immediate memory (forward).

2.3 Procedures

Session 1. Each participant signed an Informed Consent form, in which the objective and methodology of the study were detailed. Next, demographic and personal information was recorded, and the cognitive screening test (MMSE) was completed to determine if the person could participate. Then the pretest cognitive tests (Stroop Test, TMT and DS) were completed.

Sessions 2-4 (exercise groups). Participants completed a familiarization phase with the exercises to be performed in the intervention, in which they learned to use each machine with the correct posture and breathing patterns. In each session the degree of perceived exertion was increased (from 1 to 9), using the OMNI effort scale [20]. Subjects in the control group did not attend these sessions.

Session 5. Participants in G1 and G2 performed a one repetition maximum test (1RM), which identified the maximum amount of weight that the person could lift in each exercise to perform one repetition. A maximum of five attempts was used for each exercise, with at least three minutes of rest between attempts, and alternating upper and lower body exercises.

Session 6. In the intervention session, subjects in groups G1 and G2 performed a five-minute warm-up on a stationary bicycle. Next, they carried out the training protocol. Immediately after finishing exercise, the cognitive tests of the posttest were applied. The control group had to remain sitting on a chair for 30 min and then perform the cognitive tests. All groups were asked not to exercise that day before attending the session.

Session 7. All participants underwent a bone mineral density test by means of dual energy X-rayabsorptiometry (DEXA) and their anthropometric information was collected.

Experimental protocol. The intervention consisted of a RT program with biomechanical equipment. Cybex machines (Cybex International, Medway, MA, USA) were used to perform the following exercises: a) knee extension, b) chest press, c) knee flexion, d) seated row, e) leg press, and f) biceps curl. Participants in G1 performed three sets of eight repetitions at 70% of 1RM, while participants in G2 completed four sets of 14 repetitions at 30% of 1RM. Each set consisted of two exercises; one lower body combined with one upper body movement. At the end of each series, there was a two-minute break. Verbal cues were used to guide the speed of execution. Participants in the control group remained seated for 30 minutes.

2.4 Statistical Analysis

Given that educational level is known to influence performance on the cognitive tests used in this study [21-23], the analysis was performed adjusting according to participants' years of formal education. Thus, a two-way (3x2) analysis of covariance (ANCOVA) was performed using education as a covariate. All analyses were performed with the Statistical Package for the Social Sciences, version 24 (IBM Corporation, Armonk, New York, USA). Descriptive statistics are presented as mean and standard deviation (M ± SD).

3. Results and Discussion

Table 1 shows the participants' characteristics. All participants were physically active. Nine participants exercised for one hour a week, 11 exercised two hours a week, 10 exercised three hours a week, seven exercised four hours a week, and eight exercised five hours a week. 36 of the 45 older adults were found to have chronic non-transmittable diseases such as diabetes, high blood pressure, and dyslipidemia. Six had osteoporosis or osteopenia and were undergoing treatment for this condition. All participants had medical permission to perform RT, and there were no injuries or adverse events as a result of their participation in the study. One G2 participant did not attend the intervention session for reasons unrelated to the study.

Table 1. Descriptive characteristics of the sample (n = 45)

Variable	G1 (n = 15)	G2 (n = 15)	G3 (n = 15)
Age (years)	65.1 ± 3.9	65.6 ± 4.3	65.5 ± 3.4
Education* (yr.)	12.7 ± 3.8	12.9 ± 4.8	13.2 ± 3.4
MMSE (score)	29 ± 1.2	28.9 ± 1.5	28.3 ± 1.8

*Years of formal education; G1 = High intensity RT; G2 = Low intensity RT; G3 = Inactive control group

Table 2. ANCOVA results for cognitive measures

Test	Source of Variance		
	A: Groups	B: Measurement	A x B: Group x measurement
Stroop Color Naming	.350	.112	.009*
Stroop Word Reading	.412	.846	.307
Stroop Interference	.584	.878	.318
Stroop Interference – Color Naming	.278	.361	.321
TMT-A time	.503	.148	.153
TMT-A errors	.908	.249	.756
TMT-B time	.454	.057	.841
TMT-B errors	.107	.539	.865
Digit Span Forward	.102	.698	.866
Digit Span Backward	.297	.584	.178
Forward - Backward	.274	.534	.503

P values for each dependent variable.

Significant improvements were found on visuospatial processing in G1 (Pre = 61.6 ± 2.1 vs. Post = 69.7 ± 2.4 pts.; 95%CI = 4.8, 11.4; $p \leq 0.001$) and G2 (Pre = 62.4 ± 2.2 vs. Post = 67.0 ± 2.5 pts.; 95%CI = 1.2, 8.1; p = 0.009, Table 2). Processing speed, executive function, cognitive control, working memory and immediate memory were unchanged by acute exercise or rest.

4. Discussion

The purpose of this study was to determine if a RT session influenced cognitive performance of healthy older adults. Visuospatial processing was improved in both exercise groups, while no changes were found on executive functioning, cognitive control, working memory or immediate memory. These results are consistent with previous reports. For example, a study by Pontifex et al. [24] compared the acute effect of RT and aerobic exercise on the working memory of young adults. While aerobic exercise improved reaction time and working memory, RT did not produce such effects. Dunsky et al. [2] studied the acute effect of aerobic and resistance training on cognitive functions and only found a significant improvement due to aerobic training.

It is noteworthy that other studies have reported improvements on executive functioning and cognitive control following an acute bout of RT [5, 10, 11]. Regarding the chronic effect of RT, cognitive control has also been particularly susceptible to change [12]. However, in the present study, cognitive control performance was not altered. Visuospatial processing was evaluated with the Stroop Test, specifically the color naming task. Scores on this test have been reported to improve immediately after a session of RT [10, 14]. Performance in the color naming condition has also shown to improve linearly with increasing exercise intensity of an acute RT protocol [25]. In this sample, while Stroop Color Naming scores improved after RT, there were no differences between intensities.

The WHO recommends that older people engage in RT at least twice a week, in combination with aerobic and flexibility training. This form of training is known to prevent deterioration in the ability to perform daily tasks and decrease the risk of falling [26]. A meta-analytic study found that resistance training is effective at increasing muscle strength in the older adult population [27]. Based on their study, these authors also propose that this type of exercise can prevent disability during ageing. Likewise, evidence has been found that RT significantly increases the well-being of older adults [26].

In this project, it was possible to recruit and maintain a group of 45 older people interested in doing an exercise modality less common for this age group. There was an exceptionally high adherence, with only one participant not participating in the last session for reasons unrelated to the study. Furthermore, unlike that reported by other authors, it was possible to successfully perform the maximum 1RM tests with older adults. Dunsky et al. [2], used a different strategy, allowing the participants to choose a weight with which they felt comfortable to execute between five and 15 repetitions of each exercise, and from this they estimated the value of 1RM. The researchers used this procedure because they considered it dangerous to perform a maximal test in this population. In the present study, the maximum tests were carried out without any injuries, pain or discomfort. However, it is important to note that, although the participants did not have recent experience in resistance exercise, they were physically active. For this reason, it is recommended that, when working with older adults, training plans and physical tests are chosen with caution and according to the physical capacity of the participants.

It should also be noted that there was low male participation in the study, with only eight men. Due to this, the random allocation of participants resulted in a group without men and statistical analysis by gender was not possible.

5. Conclusion

In conclusion, the acute high intensity and low intensity resistance training protocols used in the present study improved visuospatial processing and did not generate positive or negative changes on other cognitive variables of healthy older people. However, other authors have found contrasting evidence. Given that there is still no consistent evidence on the acute effect of resistance exercise on cognitive function in older adults, more experimental and meta-analytical studies are needed on this topic. In addition, it is important that these investigations clearly report the training protocols executed, indicating the exercises, number of sets and repetitions, rest time and intensity, so that different protocols can be tested and eventually an effective protocol can be found to improve cognitive performance.

References

[1] S.F. Tsai, P.C. Chen, M.J. Calkins, S.Y. Wu, Y.M. Kuo, Exercise Counteracts Aging-Related Memory Impairment: A Potential Role for the Astrocytic Metabolic Shuttle, Frontiers in Aging Neuroscience, (2016) 57. [DOI] [PubMed]

[2] A. Dunsky, M. Abu-Rukun, S. Tsuk, T. Dwolatzky, R. Carasso, Y. Netz, The effects of a resistance vs. an aerobic single session on attention and executive functioning in adults, PloS one, 12(4) (2017) e0176092. [DOI] [PubMed]

[3] S.B. Chapman, S. Aslan, J.S. Spence, L.F. Defina, M.W. Keebler, N. Didehbani, H. Lu, Shorter term aerobic exercise improves brain, cognition, and cardiovascular fitness in aging, Frontiers in Aging Neuroscience, 5 (2013) 75. [DOI] [PubMed]

[4] H.L. Schimidt, The role of regular physical exercise for enhancement of long-term memory in the elderly: a review of recent evidences, PAJAR - Pan American Journal of Aging Research, 3(2) (2015) 60-68. [DOI]

[5] A.T. Harveson, J.C. Hannon, T.A. Brusseau, L. Podlog, C. Papadopoulos, L.H. Durrant, M.S. Hall, K.D. Kang, Acute Effects of 30 Minutes Resistance and Aerobic Exercise on Cognition in a High School Sample, Research quarterly

for exercise and sport, 87(2) (2016) 214-220. [DOI] [PubMed]

[6] K.A. Intlekofer, C.W. Cotman, Exercise counteracts declining hippocampal function in aging and Alzheimer's disease, Neurobiology of disease, 57 (2013) 47-55. [DOI] [PubMed]

[7] S. Snigdha, C. de Rivera, N.W. Milgram, C.W. Cotman, Exercise enhances memory consolidation in the aging brain, Frontiers in Aging Neuroscience, 6 (2014) 3. [DOI] [PubMed]

[8] F. Yu, K. Bil, Correlating heart rate and perceived exertion during aerobic exercise in Alzheimer's disease, Nursing & health sciences, 12(3) (2010) 375-380. [DOI] [PubMed]

[9] J.-F. Landrigan, T. Bell, M. Crowe, O.J. Clay, D. Mirman, Lifting cognition: a meta-analysis of effects of resistance exercise on cognition, Psychological research, 84(5) (2019) 1167-1183. [DOI] [PubMed]

[10] Y.-K. Chang, J.L. Etnier, Effects of an acute bout of localized resistance exercise on cognitive performance in middle-aged adults: A randomized controlled trial study, Psychology of sport and exercise, 10(1) (2009) 19-24. [DOI]

[11] S. Tsuk, Y. Netz, A. Dunsky, A. Zeev, R. Carasso, T. Dwolatzky, Riki Salem, Shai Behar, Arie Rotstein, The Acute Effect of Exercise on Executive Function and Attention: Resistance Versus Aerobic Exercise, Advances in cognitive psychology, 15(3) (2019) 208-215. [DOI] [PubMed]

[12] K. Soga, H. Masaki, M. Gerber, S. Ludyga, Acute and Long-term Effects of Resistance Training on Executive Function, Journal of cognitive enhancement, 2(2) (2018) 200-207. [DOI]

[13] J. Wilke, F. Giesche, K. Klier, L. Vogt, E. Herrmann, W. Banzer, Acute Effects of Resistance Exercise on Cognitive Function in Healthy Adults: A Systematic Review with Multilevel Meta-Analysis, Sports medicine (Auckland), 49(6) (2019) 905-916. [DOI] [PubMed]

[14] Y.-K. Chang, C.-L. Tsai, C.-C. Huang, C.-C. Wang, I.H. Chu, Effects of acute resistance exercise on cognition in late middle-aged adults: General or specific cognitive improvement?, Journal of science and medicine in sport, 17(1) (2014) 51-55. [DOI] [PubMed]

[15] M.F. Folstein, S.E. Folstein, P.R. McHugh, "Mini-mental state": A practical method for grading the cognitive state of patients for the clinician, Journal of psychiatric research, 12(3) (1975) 189-198. [DOI]

[16] N. Berryman, L. Bherer, S. Nadeau, S. Lauzière, L. Lehr, F. Bobeuf, et al., Multiple roads lead to Rome: combined high-intensity aerobic and strength training vs. gross motor activities leads to equivalent improvement in executive functions in a cohort of healthy older adults, AGE, 36(5) (2014) 1-19. [DOI] [PubMed]

[17] J.R. Stroop, Studies of interference in serial verbal reactions, Journal of experimental psychology General, 121(1) (1992) 15-23. [DOI]

[18] S.G. Armitage, An analysis of certain psychological tests used for the evaluation of brain injury, Psychological monographs, 60(1) (1946) i-48. [DOI]

[19] D. Wechsler, (1981) WAIS-R: manual: Wechsler adult intelligence scale--revised, Harcourt Brace Jovanovich [for] Psychological Corp, New York.

[20] R.J. Robertson, (2004) Perceived exertion for practitioners: rating effort with the OMNI picture system, Human Kinetics.

[21] F. Ostrosky Solís, A. Lozano, Digit Span: Effect of education and culture, International journal of psychology, 41(5) (2006) 333-341. [DOI]

[22] T.N. Tombaugh, Trail Making Test A and B: Normative data stratified by age and education, Archives of clinical neuropsychology, 19(2) (2004) 203-214. [DOI]

[23] W. Van der Elst, M.P.J. Van Boxtel, G.J.P. Van Breukelen, J. Jolles, The Stroop Color-Word Test: Influence of Age, Sex, and Education; and Normative Data for a Large Sample Across the Adult Age Range, Assessment (Odessa, Fla), 13(1) (2006) 62-79. [DOI] [PubMed]

[24] M.B. Pontifex, C.H. Hillman, B. Fernhall, K.M. Thompson, T.A. Valentini, The Effect of Acute Aerobic and Resistance Exercise on Working

Memory, Medicine and science in sports and exercise, 41(4) (2009) 927-934. [DOI] [PubMed]

[25] Y.-K. Chang, J.L. Etnier, Exploring the dose-response relationship between resistance exercise intensity and cognitive function, Journal of sport & exercise psychology, 31(5) (2009) 640-656. [DOI] [PubMed]

[26] J. Steele, K. Raubold, W. Kemmler, J. Fisher, P. Gentil, J. Giessing, The Effects of 6 Months of Progressive High Effort Resistance Training Methods upon Strength, Body Composition, Function, and Wellbeing of Elderly Adults, BioMed research international, 2017 (2017) 2541090. [DOI] [PubMed]

[27] M.D. Peterson, M.R. Rhea, A. Sen, P.M. Gordon, Resistance exercise for muscular strength in older adults: A meta-analysis, Ageing research reviews, 9(3) (2010) 226-237. [DOI] [PubMed]

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Ethics approval

This study did not require Institutional Review Board approval. Universal ethical principles were followed by the researchers

Author contribution statement

Study design and conceptualization- R.H-G and J. M-J; Data collection, statistical analysis and draft preparation- R.H-G ; Interpretation of results and draft preparation- J. M-J. Both authors read and approved the final version of the draft.

Informed Consent

Written consent was obtained from participants

Availability of data and material

No additional data are available.

Conflict of interest

The Authors have no conflicts of interest to declare that they are relevant to the content of this article.

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