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Relationship among the quality of cognitive abilities, depression symptoms, and various aspects of handgrip strength in the elderly

Odnos između kvaliteta kognitivnih sposobnosti, simptoma depresije i različitih aspekata snage stiska šake kod starijih osoba

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Abstract

Background/Aim. Both the cognitive and physical functioning changes occur within the normal aging, suggesting possible common biological processes. The aging process is often characterized by a reduction of adaptive responses, an increasing vulnerability and functional limitations. The aim of this study was to determine if there were correlations between particular cognitive abilities (verbal ability, spatial ability, processing speed, memory, verbal fluency, divergent thinking, memory, attention, executive functions, conceptualization, orientation, computation), depression symptoms and different dynamometric parameters of muscle contraction, during handgrip (HG) of both hands, in the elderly population. **Methods.** The sample consisted of 98 participants, 16 males and 82 females, aged from 65 to 85. Neuropsychological assessment included Montreal Cognitive Assessment (MoCA), Frontal Function Test (Go/No-Go), Categorical and Phonemic fluency tests and Geriatric Depression Scale Short Form (GDS-SF). Physical measures were assessed by Handgrip Dynamometry Tests (HG), and included: the maximum force (F_{max}), maximal rate of force development (RFD_{max}), static endurance HG time realized at 50% of maximal HG force ($tF_{max}50\%$) of dominant (Do) and non-dominant (NDo) hand. **Results.** Higher MoCA score was followed by higher values of muscle endurance of dominant hands. Higher values of F_{max} of dominant hand were associated with higher values of Alternating Trail Making that is by visuoconstructive abilities (MoCA). The variable Categorical fluency was in a small, positive correlation with F_{max}. No correlation of depressive symptoms with HG parameters was found except in the subgroup of female subjects. **Conclusion.** Better cognitive performance was associated with better HG muscle strength. Therefore, HG strength can be a useful tool in geriatric practice in monitoring not only physical, but also cognitive function status and decline. The link between lower cognitive functioning and lower values of HG variables, emphasize the need for increased awareness about it in clinical practice.

Key words:
aged; aging; cognition; depression; hand strength; risk assessment.

Apstrakt

Uvod/Cilj. Tokom procesa normalnog starenja javljaju se promene u kognitivnom i fizičkom funkcionisanju koje ukazuju na moguće zajedničke biološke osnove. Proces starenja često karakterišu smanjenje adaptivnih odgovora, sve veća ranjivost i funkcionalna ograničenja. Cilj rada bio je da se utvrdi povezanost određenih kognitivnih sposobnosti (verbalna sposobnost, prostorna sposobnost, brzina obrade, memorija, verbalna tečnost, divergentno razmišljanje, pamćenje, pažnja, izvršne funkcije, konceptualizacija, orijentacija, računanje), simptoma depresije i različitih dinamometrijskih parametara kontrakcije mišića tokom stiska obe šake – *handgrip* (HG) u starijoj populaciji. **Metode.** Ispitivanjem je obuhvaćeno 98 ispitanika, 16 muškog i 82 ženskog pola, starosti od 65 do 85 godina. Neuropsihološka procena uključila je Montrealsku skalu kognicije (MoCA), test frontalnih funkcija (Go/No-Go), testove kategorijalne i fonemske fluentnosti i kratku formu Gerijatrijske skale depresije (GDS-SF). Fizičke mere su procenjivane dinamometrijskim testovima HG i uključivale su: maksimalnu silu (F_{max}), maksimalnu brzinu razvijanja sile (RFD_{max}), vreme

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statičke izdržljivosti HG ostvareno na 50% maksimalne HG sile ($tF_{max}50\%$) dominantne (Do) i nedominantne (NDo) ruke. **Rezultati.** Bolji rezultat na MoCA skali bio je praćen višim vrednostima mišične izdržljivosti dominantne ruke. Veće vrednosti F_{max}-a dominantne ruke bile su povezane sa višim vrednostima alterniranog povezivanja brojeva i slova odnosno vizuelnokonstrukcionim sposobnostima (MoCA). Nije nađena korelacija simptoma depresije sa HG parametrima, osim u podgrupi ispitanica. **Zaključak.** Bolje kognitivne performanse bile su povezane sa većim stepenom mišićne snage HG. Stoga, snaga HG može biti korisno sredstvo u gerijatrijskoj praksi za praćenje stanja ne samo fizičke već i kognitivne funkcije i njihovog opadanja. Veza između nižeg kognitivnog funkcionisanja i nižih vrednosti HG varijabli, naglašava potrebu za povećanom svešću o tome u kliničkoj praksi.

Ključne reči:
stare osobe; starenje; saznanje; depresija; ruka, snaga; rizik, procena.

Introduction

Aging is a process of gradual deterioration of the physiological functioning that a human experiences over time. It is often characterized by a reduction of adaptive responses, increasing vulnerability, and functional limitations. Both the cognitive and physical functioning changes that occur within the normal aging process are often mentioned in the scientific literature. Some cognitive abilities, such as vocabulary, are resistant to brain aging and might even improve with age. Other capabilities, such as conceptual monitoring, memory, and processing speed, decline over time. A noticeable effect of the aging process is observed in the more complex tasks of attention, short-term working memory, and visual constructive skills, as well. Research has shown that concept formation, abstraction, and mental flexibility decrease, especially after the age of 70. Aging is also coupled with a deficit of inhibitory processes in cognitive functioning [1] and accompanied by a decline in physical functions. Changes occur both in muscle mass [2] and the functionality of the muscle and thus decrease explosive strength, muscular endurance, fine motor control, force steadiness, and the capacity for rapid muscle force production (RFD) [3]. Thus, age brings changes in the neuromuscular system that result in decreased muscle strength, balance, and proprioception, causing a slower motor response rate [4]. Among the elderly, cognitive impairment is known to occur frequently along with a decline in muscle strength, indicating a close relationship between these two phenomena [5, 6]. All this suggests that both cognitive and physical functioning are vitally important for successful functioning in old age and independent living. Therefore, the need to monitor, test, and correlate them is fully justified.

Numerous tests and batteries allow us to assess and monitor the cognitive and physical decline in the elderly. A wide range of tools has been developed to examine cognitive abilities in the elderly. These tools range from short screening tools to comprehensive neurophysiological assessments. On the other hand, physical functioning in the elderly population is usually examined through a muscle strength test, especially the muscular strength of the upper extremities (handgrip) [7]. Handgrip (HG) strength is a non-invasive measure widely used in research and clinical settings. Easily applicable, it is an indicator of muscle function, nutritional status, and physical health. HG is a reliable overall indicator of health in population-based studies [8]. Since it is also sensitive to changes related to aging processes, it is often used not only as a marker for muscle strength but also for biological vitality [9]. It is important to note that some researchers have found that the HG test is also associated with individual differences in cognitive functioning [5, 6, 10]. Thus, Buchman et al. [11] noticed that a decline in HG was associated with an increase in risk for Alzheimer's disease. Taekema et al. [12] concluded that weak HG predicted a decline in cognitive ability in the elderly, while Sternäng et al. [13] detected a longitudinal association between HG and cognition.

In previous studies, different cognitive abilities, such as fluid cognition, measures of crystallized cognition, and mental state examinations, were generally related to only one parameter of HG strength (HGS), *eg*, the maximum force F_{max} [14]. To our knowledge, few studies have considered other aspects of muscular contraction (rate of force development, duration of contraction, endurance, and the like). Therefore, our study aimed to determine if there were correlations between achievement in particular cognitive abilities (verbal ability, spatial ability, processing speed, and memory, verbal fluency, divergent thinking, memory, attention, executive functions, conceptualization, orientation, computation) and different parameters of muscle contraction concerning both hands in the elderly population.

Methods

The study was conducted as a prospective nonrandom clinical study of the cross-sectional study type. The sample consisted of 98 participants aged 65 to 85, 16 males aged [mean ± standard deviation (SD): 68.63 ± 5.15 years] [minimum (Min) – maximum (Max): 65.0–81.0 years], and 82 females (mean ± SD: 68.60 ± 4.35 years; Min–Max: 65.0–85 years). More detailed characteristics of the sample are shown in Table 1. Before taking part in the research, participants were introduced to the nature of the research and provided their informed consent.

Following inclusion criteria were used: absence of previous diseases and central nervous system (CNS) impairment including cerebrovascular injury (stroke), traumatic brain and spinal cord injury, trauma to the peripheral nerves; participant's ability to cooperate during examination and testing; the normal range of blood pressure, with or without therapy (controlled hypertension); the absence of severe diseases of the heart, lung, liver, kidney, and other organs; the absence of/or well-controlled diabetes mellitus. Exclusion criteria were: previous stroke or other severe neurological brain diseases; dementia (the presence of damage to at least two cognitive areas accompanied with everyday functional impairments); decompensated cardiomyopathy, unregulated arterial hypertension, presence of malignant disease, hepatic, or renal, or pulmonary insufficiency; uncontrolled diabetes mellitus with hypo- and hyperglycaemia, and quarterly glycosylated haemoglobin (Hb A1c) above 7%.

Procedures

The research was conducted in the Gerontology Centre of Belgrade in Daily centres and clubs located on the territory of Belgrade, as well as in the Department of Geriatrics of the Clinic for Internal Medicine of the Zvezdara University Clinical Centre, Belgrade. Testing procedures were implemented so that a respondent was tested and procedures completed in one day. The testing schedule included taking anamnestic data, followed by the cognitive and mental assessment. After completion of cognitive testing, physical testing was completed. The study was conducted in line with the Declaration of Helsinki and was approved by the Ethics Committee of the Zvezdara University Clinical Centre, Belgrade, Serbia.

Instruments and measures

Montreal Cognitive Assessment (MoCA) [15] is designed as a screening instrument for detecting mild cognitive dysfunction [16]. MoCA consists of a variety of tasks measuring different cognitive domains: executive functions, attention and concentration, memory, language, visuoconstructional skills, conceptual thinking, calculation, and orientation. The instrument contains following item clusters measuring aforementioned functions: Alternating Trail Making (ATM), Visuoconstructional Skills [(Cube), VCS_cube)], Visuoconstructional Skills [(Clock) VCS_clock)], Naming (M_N), Memory (M_M), Attention: Forward Digit Span (A_FDS), Attention: Backward Digit Span (A_BDS), Attention: Vigilance (A_V); Attention: Serial 7 subtraction (A_S7), Sentence repetition (SR), Verbal fluency (VF), Abstraction (M_A), Delayed recall (DR), Orientation (M_O).

Administration time is approximately 10 min. The total score is obtained by summing scores for individual items and by adding one point for the individuals who have 12 years of formal education or less, for a possible maximum of 30 points. A final total score of 26 and above is considered normal. The battery demonstrates good psychometric properties and a six-factor structure [17]. For the purposes of this research, we used the Serbian version of MoCA[18].

The Go/No-Go (GNG) test requires a subject to emit a simple motor response to one cue while inhibiting the response in the presence of another cue. The test was performed as a contrast program by asking the patient to hold one hand upright, and when the examiner raises one finger, the examinee should respond by raising two fingers. When the examiner raises two fingers, the examinee should not react at all. The answer should be as fast as possible, and always before the next time, the respondent should put his fingers down. Ten samples are given according to a pseudorandom schedule 1,1,1,2,1,2,2,1,1,2. The number of correct reactions from ten attempts is scored.

Testing Go/No-Go (GNG) is often used as a component of a behavioral neurological examination to assess inhibitory control. Performance in this test is associated with the preservation of the ventrolateral prefrontal cortex (lower frontal gyrus, fronto-insular region) and pre-supplementary motor area that is part of the response inhibition system [19].

It is one of the tests of verbal fluency and includes a listing of words that belong to a specific category (animals). Respondents are asked to name (enumerate) as many animals as possible for a limited time. The task is interrupted after 1.5 min (90 s). The respondent must state as many words in this category (the names of animals within the same species cannot be taken into account, *eg* chicken, rooster, hen, etc.). The number of correct, nonrepeated responses constituted the raw score. The limit value is 18 animal names [16].

This is a test of divergent thinking because there is more than one correct answer. Respondents need to formulate a specific word recall strategy. Categorical fluency reflects retrorolandic functions. Therefore, categorical fluency will be impaired in retrorolandic disorders, such as in the early phase of Alzheimer's disease [16].

The short form is the 15-item form. The score ranges from 0 to 15 and if it is six or more, then indicates signs of depression [16]. In a validation study comparing the long and short forms of this self-report scale for depression symptoms, it was found that both were successful in distinguishing depressed vs. non-depressed adults with a high degree of correlation, $r = 0.84$, $p < 0.001$[20].

Phonemic fluency tests require the respondent to indicate as many words as possible, beginning with a specific letter, for a specified time. The given initial letters of the words required by the respondents are selected according to the frequency in a particular language. In the Serbian version of the test that we applied, the letters (phonemes) s, k, l, are used because they are the most frequent in the Serbian language [16]. The authors state the limit values of 7 words for less educated and 9 words for educated respondents [16]. Respondents are asked to list as many nouns that begin with a certain letter in one minute. Personal names, geographical terms, and numbers are excluded.

Phonemic fluency predominantly reflects prerolandic functions. Impaired phonemic fluency indicates the onset of vascular dementia [16].

The evaluation of the contractile characteristics [21] of the hand muscles and finger flexors was conducted using a piece of standardized equipment – dynamometer [*ie*, a sliding device that measures isometric hand and finger flexor force with a tensiometric probe fixed inside the device (All4gym d.o.o., Serbia)]. During the test, subjects were sitting on a chair (without leaning their backs) while holding the device in the tested hand. Testing was performed first on one hand and then on the other one. The arm of the tested hand was stretched out alongside the body, without leaning on the trunk and a chair. The other hand was either leaning against the body or resting on the thigh. During the testing procedure, subjects were not allowed to move. Before the testing, the procedure was explained to the subjects, and they had the opportunity to try it several times. With verbal encouragement, subjects were asked to make the strongest and fastest pressure on the lever (probe). The test was conducted with a dominant and non-dominant hand twice with a break of one minute between attempts. The maximal force (F_{max}, expressed in N), maximal rate of force development (RFD_{max}, expressed in N/s), and static endurance HG time realized at 50% of maximal HG force ($tF_{max}50\%$, expressed in s) were obtained from this test for both hands – dominant (Do) and non-dominant (NDo). After a ten minutes rest period, the endurance test was performed, too. The test was operated by setting a value on the level of 50% of the maximal force. Subjects were asked to maintain a defined level of force (50%) with visual feedback on the computer for as long as possible (time was measured in s). Due to possible fatigue, only one attempt was carried out. The achieved force impulse ($I_{mp}F50\% = F_{max}50\% \cdot tF_{max}50\%$, expressed in Ns) was calculated as a measure of HG strength endurance.

Statistical analyses

Descriptive statistics were used to characterize the sample and the outcomes. In order to test the relationships between the selected variables, the Spearman's rank correlation was used (two-tailed). Coefficients (ρ) were interpreted as small (0.10–0.29), moderate (0.30–0.49), or strong (0.50–1.00) correlation. All analyses were performed using the SPSS for Windows software program, version 23, using a 0.05 level of significance.

Results

Sociodemographic characteristics of all participants are displayed in Tables 1, 2, and 3 showing motor and cognitive abilities of subjects. Tables 4 and 5 show the relationship

Table 1

Basic characteristics of subjects

Characteristics	Mean	SD	Median	Minimum	Maximum
Age (years)	68.60	4.46	66.50	65.00	85.00
BMI (kg/m^2)	27.14	4.06	26.55	17.93	38.58
G score	1.52	2.26	1.00	0.00	10.00

BMI – body mass index; G – Geriatric Depression Scale; SD – standard deviation.

Table 2

Motor characteristics of subjects

Characteristics	Mean	SD	Median	Minimum	Maximum
Fmax_NDo (N)	247.69	77.51	241.50	90.00	635.00
RFD_{max}_NDo (N/s)	1,129.50	491.89	1,078.00	349.00	3,601.00
tF_{max}50%_NDo (s)	61.36	36.73	60.29	4.53	173.48
I_{mp}F50%_NDo (Ns)	7,914.55	5,459.49	6,908.72	425.63	24,538.31
F_{max}_Do (N)	272.18	79.12	259.50	88.00	651.00
RFD_{max}_Do (N/s)	1,262.35	483.75	1,232.50	446.00	3,569.00
tF_{max}50%_Do (s)	66.62	37.18	64.00	8.91	248.10
I_{mp}F50%_Do (Ns)	8,920.45	5,037.93	8,456.49	1,147.99	25,912.08

F_{max}NDo – maximum force of non-dominant hand; RFD_{max}_NDo – maximal rate of force development of non-dominant hand; tF_{max}50%_NDo – static endurance handgrip (HG) time realized at 50% of maximal HG force of non-dominant hand; I_{mp}F50%_NDo – achieved force impulse of non-dominant hand; F_{max}Do – maximum force of dominant hand; RFD_{max}_Do – maximal rate of force development of dominant hand; tF_{max}50%_Do – static endurance handgrip time realized at 50% of maximal HG force of dominant hand; I_{mp}F50%_Do – achieved force impulse of dominant hand; SD – standard deviation.

Table 3

Cognitive abilities of subjects

Characteristics	Mean	SD	Median	Minimum	Maximum
MoCA score	23.96	3.20	24.00	15.00	31.00
Alternating Trail Making	0.51	0.50	1.00	0.00	1.00
Visuoconstructional Skills (Cube)	0.91	0.29	1.00	0.00	1.00
Visuoconstructional Skills (Clock, Contour)	0.98	0.14	1.00	0.00	1.00
Visuoconstructional Skills (Clock, Numbers)	0.74	0.44	1.00	0.00	1.00
Visuoconstructional Skills (Clock, Hand)	0.54	0.50	1.00	0.00	1.00
Naming	2.91	0.29	3.00	2.00	3.00
Attention: Forward Digit	0.92	0.28	1.00	0.00	1.00
Attention: Backward Digit Span	0.77	0.45	1.00	0.00	2.00
Attention: Vigilance	0.97	0.17	1.00	0.00	1.00
Attention: Serial 7 subtraction	2.69	0.58	3.00	1.00	3.00
Verbal fluency	0.70	0.46	1.00	0.00	1.00
Abstraction	1.33	0.73	1.00	0.00	2.00
Orientation	5.82	0.54	6.00	2.00	6.00
Go/No-Go	84.08	14.70	90.00	0.00	100.00
Categorical fluency	23.49	7.95	22.00	7.00	59.00
Phonemic fluency	25.60	8.80	24.50	2.00	55.00

MoCA – Montreal Cognitive Assessment; SD – standard deviation.

Table 4

Relationship between depression, cognitive ability, and various aspects of handgrip strength

Variable	G score	MoCA score	Go/noGo	Categorical fluency	Phonemic fluency
F_{max}_NDo, ρ/*p*	-0.041 / 0.689	0.051 / 0.615	-0.099/0.333	0.158/0.120	-0.095/0.350
RFD_{max}_NDo, ρ/*p*	-0.030 / 0.770	0.108 / 0.289	-0.060/0.558	0.111/0.277	-0.141/0.167
tF_{max}50%_NDo, ρ/*p*	-0.146 / 0.155	0.040 /0.694	0.024/0.813	-0.121/0.239	-0.045/0.664
I_{mp}F50%_NDo, ρ/*p*	-0.092 / 0.369	0.088/0.391	-0.003/0.979	-0.025/0.810	-0.083/0.417
F_{max}_Do, ρ/*p*	0.064 / 0.533	0.045/0.658	0.089/0.384	**0.290/0.004**	-0.097/0.342
RFD_{max}_Do, ρ/*p*	-0.054/ 0.598	0.035/0.735	0.070/0.492	0.171/0.092	-0.154/0.130
tF_{max}50%_Do, ρ/*p*	-0.196 / 0.054	**0.202/0.046**	0.010/0.922	-0.157/0.123	0.033/0.745
I_{mp}F50%_Do, ρ/*p*	-0.170 / 0.094	**0.247/0.014**	0.020/0.849	-0.012/0.910	-0.057/0.574

F_{max}NDo – maximum force of non-dominant hand; RFD_{max}_NDo – maximal rate of force development of non-dominant hand; tF_{max}50%_NDo – static endurance handgrip (HG) time realized at 50% of maximal HG force of non-dominant hand; I_{mp}F50%_NDo – achieved force impulse of non-dominant hand; F_{max}Do – maximum force of dominant hand; RFD_{max}_Do – maximal rate of force development of dominant hand; tF_{max}50%_Do – static endurance HG time realized at 50% of maximal HG force of dominant hand; I_{mp}F50%_Do – achieved force impulse of dominant hand; G – Geriatric Depression Scale Short Form; MoCA – Montreal Cognitive Assessment.
Bolded values are statistically significant.

Table 5

Relationship between MoCa and various aspects of handgrip strength

Variable	F_{max}_NDo (N)	RFD_{max}_NDo (N/s)	tF_{max}50%_NDo (s)	I_{mp}F50%_NDo (Ns)	F_{max}_Do (N)	RFD_{max}_Do (N/s)	tF_{max}50%_Do (s)	I_{mp}F50%_Do (Ns)
ATM								
ρ	**0.244**	**0.327**	0.138	**0.226**	**0.282**	**0.272**	0.078	**0.276**
p	**0.016**	**0.001**	0.178	**0.026**	**0.005**	**0.007**	0.443	**0.006**
VCS_cube								
ρ	-0.182	-0.158	-0.106	-0.121	-0.014	-0.073	0.038	0.040
p	0.072	0.120	0.302	0.237	0.891	0.473	0.714	0.693
VCS_clock C								
ρ	0.050	0.158	0.033	0.033	0.091	0.145	0.090	0.122
p	0.625	0.120	0.745	0.749	0.372	0.156	0.378	0.230
VCS_clockN								
ρ	-0.014	-0.043	0.088	0.063	-0.089	-0.085	-0.025	-0.040
p	0.894	0.677	0.389	0.539	0.382	0.408	0.810	0.696
VCS_clockH								
r	0.148	0.099	0.080	0.130	0.169	0.102	0.182	**0.251**
p	0.146	0.332	0.438	0.201	0.096	0.319	0.073	**0.013**
M_N								
ρ	-0.022	0.022	-0.094	-0.071	0.015	0.051	0.180	0.163
p	0.827	0.831	0.359	0.484	0.883	0.617	0.076	0.109
A_FDS								
ρ	-0.080	0.007	-0.129	-0.148	0.010	-0.032	0.090	0.067
p	0.434	0.944	0.208	0.146	0.925	0.753	0.379	0.513
A_BDS								
ρ	-0.082	0.113	-0.074	-0.075	-0.033	0.082	**0.264**	**0.216**
p	0.421	0.269	0.473	0.460	0.749	0.419	**0.009**	**0.032**
A_V								
ρ	0.043	0.017	-0.078	-0.031	0.135	0.047	-0.061	0.017
p	0.674	0.866	0.449	0.760	0.185	0.645	0.548	0.872
A_S7								
ρ	0.070	0.064	0.082	0.097	0.076	0.023	0.092	0.130
p	0.494	0.529	0.425	0.344	0.458	0.819	0.365	0.202
VF								
ρ	-0.038	-0.031	-0.170	-0.148	-0.092	-0.043	0.059	-0.007
p	0.708	0.763	0.096	0.147	0.367	0.678	0.562	0.944
M_A								
ρ	0.025	-0.018	0.136	0.114	0.017	-0.046	0.047	0.069
p	0.805	0.858	0.183	0.263	0.869	0.653	0.647	0.501
M_O								
ρ	0.067	0.064	-0.006	0.013	-0.019	-0.056	0.187	0.160
p	0.511	0.531	0.951	0.896	0.854	0.581	0.065	0.116

ATM – Alternating Trail Making; VCS_cube – Visuoconstructional Skills Cube; VCS_clockC – Visuoconstructional Skills Clock Contour; VCS_clockH – Visuoconstructional Skills, Clock Hands; VCS_clockN – Visuoconstructional Skills Clock Number; M_N – Naming; A_FDS – Attention: Forward Digit Span; A_BDS – Attention: Backward Digit Span; A_V – Attention: Vigilance; A_S7 – Attention: Serial 7 subtraction; VF – Verbal fluency; M_A – Abstraction; M_O – Orientation; F_{max}NDo – maximum force of non-dominant hand; RFD_{max}_NDo – maximal rate of force development of non-dominant hand; tF_{max}50%_NDo – static endurance handgrip time realized at 50% of maximal HG force of non-dominant hand; I_{mp}F50%_NDo – achieved force impulse of non-dominant hand; F_{max}Do – maximum force of dominant hand; RFD_{max}_Do – maximal rate of force development of dominant hand; tF_{max}50%_Do – static endurance handgrip time realized at 50% of maximal HG force of dominant hand; I_{mp}F50%_Do – achieved force impulse of dominant hand.
Bolded values are statistically significant.

between depression, cognitive ability, and various aspects of HG strength.

The variable Categorical fluency was in a small, positive correlation with F_{max}_Do (ρ = 0.290, $p < 0.01$), indicating that the higher values of the this variable are associated with higher values of the F_{max}_Do (Table 4). Similarly, the variable MoCA score was in small, positive correlations with both tF_{max}50%_Do (ρ = 0.202, $p < 0.05$) and I_{mp}F50%_Do (ρ = 0.247, $p < 0.05$), with higher MoCA score associated with higher values of tF_{max}50%_Do and I_{mp}F50%_Do.

Table 5 shows the relationship between different aspects of the HG and MoCA test.

The variable Alternating Trail Making was in a moderate, positive correlation with RFD_{max}_NDo (ρ = 0.327, $p < 0.01$), and small, positive correlations with F_{max}_NDo (ρ = 0.244, $p < 0.05$), I_{mp}F50%_NDo (ρ = 0.226, $p < 0.05$), F_{max}_Do (ρ = 0.282, $p < 0.01$), RFD_{max}_Do (ρ = 0.272, $p < 0.01$), and I_{mp}F50%_Do (ρ = 0.276, $p < .01$), with higher values of the Alternating Trail Making variable associated with higher values of the mentioned variables. Similarly, the variable Visuoconstructional Skills, Clock Hands was in a small, positive correlation with I_{mp}F50%_Do (ρ = 0.251, $p < 0.05$), with higher values of the Visuoconstructional Skills, Clock Hands variable associated with higher values of the ImpF50%_Do.

Finally, there were small, positive correlations between the Attention: Backward Digit Span and tF_{max}50%_Do (ρ = 0.264, $p < 0.01$) and I_{mp}F50%_Do (ρ = 0.216, $p < 0.05$), with high values of Attention: Backward Digit Span associated with higher values of both tF_{max}50%_Do and I_{mp}F50%_Do.

Discussion

The idea of this study was to examine the physical characteristics presented by HGS and the quality of cognitive ability in elderly persons. There were significantly more women than men among the participants in this study for several reasons: women were represented in greater numbers than men at the institutions where we conducted the research, more women agreed to participate in the research, and more women met the inclusion criteria.

Our results indicate that muscle function, including strength, explosiveness, and endurance, correlates with different qualities of cognitive ability. An important finding from this study shows that higher values of muscle force (F_{max}) correlate with better scores on the Categorical fluency test in the total sample of subjects. Second, these results indicate that there is a correlation between certain abilities achieved on the Moca test, such as Alternating Trail Making, Visuoconstructional Skills (Clock, Hand), and attention (Backward Digit Span) with maximum power (F_{max}) and force development rate (RFD). The next important finding of this study is that endurance (tF_{max}50% and I_{mp}F50%) was better in cognitively more competent (MoCA) subjects. We did not find a correlation between the results of the Go/ NoGo test and different aspects of HG.

It is well-known that a decline in muscle mass of 1%–2% per year and muscle strength begins in the fourth decade of life, accelerating beyond the fiftieth year of life [22]. In addition to the reduced muscle strength, changes in RFD capacity were observed in young people, especially the male. These changes are related to the early stage of contraction that the authors associate with the rate of muscle activation. The results indicate that muscle force F_{max} and RFD have common mechanisms that depend on neuromuscular changes associated with healthy aging. In this study, we explored a connection between HGS and categorical verbal fluency. Research on specific cognitive abilities has shown that attention maintenance, speed of information processing, verbal short-term and long-term memory, as well as the level of vocabulary development are the abilities that underlie verbal fluency [23]. Our findings indicate that a stronger HG (Fmax) was associated with better performance on the Categorical fluency test in our subjects. We find similar results in a recent study examining HGS and cognitive ability in elderly cancer survivors [24]. Studies examining brain activity while performing semantic categorical fluency tests have revealed activity in the left dorsolateral prefrontal gyrus and left parahippocampal gyrus [25]. In addition, activity was detected in the left ventrolateral, dorsolateral and medial regions of the frontal lobes as well as in the left inferior temporal lobe [26]. Activity in bilateral frontal and temporal regions of the brain has also been reported [26, 27]. Besides, it was found that HG activates the primary motor area, supplementary motor areas, and premotor cortex [28], which are part of the frontal lobe.

Since it is known that executive functions have been seen as regulated by the prefrontal regions of the frontal lobes and that Alternating Trail Making has been considered an indicator of multiple aspects of executive functions, this may explain the positive correlation between handgrip parameters and Alternating Trail Making in our subjects. According to some authors, the rate of force development (the ability to rapidly develop the muscle force) is a suitable parameter for assessing the explosive power of the elderly [29]. Thus, the RFD parameter is correlated with many activities performed daily [30]. Then, it is sensitive to detect acute and chronic changes in neuromuscular function [31]. Similarly, RFD can be a sign of changes in nervous system functioning, since RFD is principally dependent on the discharge rate of the motor units that are currently recruited, as well as on changes in the recruitment order characteristics [32]. These changes in the functioning of the nervous system can also be associated with the onset of depressive symptoms. We hypothesized that subjects with depression signs would have changes in some motor characteristics, particularly in Fmax and RFD. Our expectations were based on the following facts: atrophy of the hippocampus and other brain regions associated with depression [33]; aging process is known to be associated with oxidative stress and inflammation [34], which may affect neuromuscular function as well as the onset of depressive symptoms; neurodegenerative and functional changes in dopamine striatal system associated with aging [35], that are connected with the onset of depressive symptoms [36] and with changes in motor function [37]. However, a correlation between depression and muscle strength characteristics measured by the HG test in the total group of our subjects was not found. We only noted that higher values of the Geriatric Depression Scale score (G score) were associated with lower values of RFD max in the subgroup of our female subjects.

The association of muscular endurance with cognitive performance in the elderly has been examined both through the impact of training and through cardiorespiratory fitness levels ($VO2_{max}$). Thus, Ozkaya et al. [38] conclude that strength training and endurance training may have facilitating effects on early information processing and cognition. Hayes et al. [39] found a positive relationship between cardiorespiratory (CRF) ability and executive functions. Wendell et al. [40] extend these findings to other cognitive functions. This association is probably supported by the positive influence of $VO2_{max}$ on functional and structural changes of the frontoparietal region in the elderly [41]. It is noteworthy that more and more evidence points to the relationship between cognition and muscle strength and endurance. Based on this growing evidence, resistance exercises that contribute to the preservation and augmentation of muscle strength and endurance can initiate beneficial neurobiological processes and may be crucial for healthy aging involving brain and cognition preservation. Similar to the above-mentioned findings, our results indicate that endurance is associated with cognitive ability. However, in our study, we examined the connection in two different ways. First, we tested endurance through the HGS test and measured endurance at 50% of the max force of subjects, and then calculated the force impulse. Secondly, many studies have connected global mental status (e.g., Mini-Mental State Exam), but we included multiple aspects of cognitive ability using MoCA, Go/No-Go, categorical and verbal fluency.

Limitations

Our study has demonstrated that HGS is associated with some aspects of cognitive functioning. In addition to some strong points of this study, there are also several limitations. First, there was a gender ratio discrepancy in the composition of the study sample. Second, data on certain factors known to influence strength was not collected. Anthropometric data, as a precise indicator of type and level of physical activity, are one example. The collection of such data was beyond the scope and resources of our exploratory study. Additionally, prospective studies are needed to make the causal inference reliable.

Conclusion

We found that better cognitive performance was associated with better muscle strength and a slower decline in muscle strength. It seems possible that impaired cognitive control of movement affects muscle function and strength in elderly subjects. Therefore, we also confirm, that HGS can be a useful tool in geriatric practice in monitoring not only physical, but also cognitive function status and decline. These findings emphasize the need for increased awareness about it in clinical practice.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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