Age and Gender Differences in the Cognitive Reserve Index

INTRODUCTION

Given the global trends in population growth and an increase in average life expectancy, it is estimated that the total number of people with dementia will be more than tripled by the year 2050,[1] so extensive research is being conducted to discover potentially modifiable risk factors for dementia: Low education, social isolation, and lack of cognitive stimulation, as well as depression in middle age, bad habits, and the presence of risk factors for other noncommunicable diseases.[2] Research shows that regular physical activity (at least three times a week) is associated with beneficial effect on cognitive functions regardless of its intensity,[3] and that physical inactivity as a bad habit in later life adds about 2% to the total prevalence of dementia. Besides that, three new modifiable factors have recently been identified: Excessive alcohol consumption, traumatic brain injury and air pollution, and it is now thought that, by controlling all of these risk factors, prevention or delaying up to 40% of dementia cases is possible.[2]

Neuroplasticity is based on a wide range of neurophysiological processes that extend from the molecular level to the level of neural networks. The first stage is the processes of functional plasticity, which modify synaptic efficiency: Long-term potentiation and depression and homeostatic scaling. If these processes are maintained for a longer periods of time, it eventually leads to structural (synaptogenesis, dendritization, and neurogenesis) and finally to network plasticity.[4] The mechanisms of neural plasticity are of key importance especially in the preclinical phase of neurodegenerative diseases, representing a kind of “reserve.”[5] There are two distinct protective mechanisms: Brain reserve (which refers to neurobiological capital, i.e., the structural characteristics of the brain, which are innate features and difficult to influence on) and cognitive reserve (CR). Alzheimer’s Association defined CR as “adaptability (efficiency, capacity, flexibility) of cognitive processes that helps to explain differential susceptibility of cognitive abilities or day-to-day function to brain aging, pathology or insult” and thus set the framework for use and implementation of this concept in further research.[6] Its effect is most often shown in normal brain aging and neurodegenerative diseases, where most cross-sectional studies have found that higher reserve is associated with better cognition, but on the contrary, some longitudinal studies have indicated that it may even accelerate cognitive decline.[7] Many research point to various contributing factors to higher CR, but recently in review papers, three socio-behavioral proxies have been identified that have a beneficial effect on cognitive aging
and dementia: Education, occupational, and leisure activities.\[^9\] Highly cited and detailed instrument for the assessment of CR, which includes all mentioned proxies is the Cognitive Reserve Index questionnaire (CRIq).\[^9\] Recently conducted, large longitudinal study on the elderly has shown that persons with high CRIq (estimated using this questionnaire) have as much as a 40% lower risk of developing dementia compared to low CRIq.\[^10\]

In that manner, we used CRIq with an aim to determine the values of CR index and potential differences across sex and age groups and thus to target vulnerable groups with lower CR and bigger risk of neurodegenerative diseases.

**METHODS**

The study was planned as a cross-sectional study that ultimately included a total of 223 participants aged 18–85 (mean age 52.34 ± 18.46 years) randomly selected from the general population. The exclusion criterion was the presence of significant neurological and psychiatric diseases. The study was approved by the Ethics Committee and each respondent signed an informed consent. Highly statistically significant positive correlations (p < 0.001) were obtained between the main and all subdomains of CRIq, while internal consistency showed good reliability (Cronbach’s α = 0.820).

**RESULTS**

The highest percentage of the tested sample (167 respondents or 74.9%) had medium level of total CRI score, followed by the medium–high (24 or 10.8%), medium–low (20 or 9%), and high CRI score (7 or 3.1%). The smallest number of respondents had a low level of CRI (5 or 2.2%). Mean values with gender differences of individual questionnaire items are presented in Table 1. Gender differences in the domains of the questionnaire are shown in Table 2.

Middle-aged respondents in all domains had higher values than other age categories, followed by young respondents, while the elderly had the lowest scores. However, analysis

| Table 1: Mean values (M±SD) of the questionnaire items and t-test results |
|--------------------|-----------------|-----------------|------|----------|------|------|
|                    | Total n=223     | Males n=102     | Females n=121 | t     | df    | P     |
| Age                | 52.34±18.46     | 54.27±18.85     | 50.71±18.04   | 1.440 | 221   | 0.151 |
| Years of education | 14.05±3.45      | 14.63±2.95      | 13.56±3.76    | 2.334 | 0.020 |
| Vocational training| 0.48±0.96       | 0.46±0.96       | 0.50±0.96     | -0.341| 0.733 |
| Total working activity* | 23.96±17.32 | 28.20±18.03 | 20.38±15.90 | 3.441 | 0.001 |
| Reading newspapers | 19.41±19.38     | 22.59±20.21     | 16.72±18.30   | 2.278 | 0.024 |
| Domestic chores    | 23.34±19.07     | 14.17±15.99     | 31.07±18.05   | -7.334| 0.001 |
| Driving            | 17.22±18.06     | 26.52±17.53     | 9.37±14.45    | 8.009 | <0.001|
| Leisure activities | 9.19±15.14      | 12.88±18.14     | 6.08±11.19    | 3.424 | <0.001|
| Using new technologies | 9.83±8.96       | 9.94±9.12       | 9.74±8.85     | 0.170 | 0.865 |
| Social activities  | 22.88±19.19     | 25.99±19.25     | 20.26±18.83   | 2.243 | 0.026 |
| Cinema, theater    | 6.04±10.97      | 7.02±10.63      | 5.21±11.22    | 1.226 | 0.222 |
| Gardening          | 14.83±18.66     | 11.55±16.12     | 17.60±20.14   | -2.441| 0.015 |
| Care for others    | 6.96±9.89       | 6.95±11.44      | 6.96±8.42     | -0.006| 0.995 |
| Voluntary work     | 1.40±6.13       | 1.39±6.01       | 1.41±6.25     | -0.021| 0.983 |
| Artistic activities| 2.86±9.27       | 2.28±8.10       | 3.35±10.18    | -0.859| 0.391 |
| Exhibitions, concerts | 11.00±14.58    | 12.89±15.65     | 9.40±13.48    | 1.792 | 0.074 |
| Leisure travel     | 10.77±13.69     | 11.88±13.82     | 9.84±13.56    | 1.111 | 0.268 |
| Reading books      | 14.20±16.31     | 13.16±16.08     | 15.08±16.52   | -0.878| 0.381 |
| Pet care           | 7.13±11.59      | 7.29±11.14      | 6.98±12.00    | 0.199 | 0.842 |
| Managing account   | 17.88±15.17     | 19.40±16.06     | 16.60±14.31   | 1.380 | 0.169 |
| No. of children    | 1.57±1.23       | 1.46±1.11       | 1.66±1.33     | -1.208| 0.228 |

*The sum of all working activities (main and additional jobs). Note: All values are given in years, except the number of children

| Table 2: T-test results for gender differences in CRI domains |
|-----------------|---------------|---------------|-----|----------|------|------|
| Gender          | n              | M             | SD  | t        | df   | P    |
| CRI-Education   | Males n=102    | 102.62        | 13.58| 2.425    | 221  | 0.016|
|                 | Females n=121  | 97.79         | 15.76|          |      |      |
| CRI-WorkingActivity | Males n=102 | 102.91        | 15.23| 2.708    | 221  | 0.007|
|                 | Females n=121  | 97.54         | 14.35|          |      |      |
| CRI-LeisureTime | Males n=101    | 100.20        | 14.63| 0.182    | 221  | 0.856|
|                 | Females n=121  | 99.83         | 15.30|          |      |      |
| CRI-Total score | Males n=102    | 101.43        | 13.85| 1.313    | 221  | 0.191|
|                 | Females n=121  | 98.79         | 15.80|          |      |      |
of variance (ANOVA) showed significant age differences only on LeisureTime (F (2,220) = 3.697; P = 0.026) and total score (F (2,220) = 4.477; P = 0.012) [Table 3, Graph 1]. Testing ANOVA only within male subsample did not show significant differences between the three age groups on any subdomain (p > 0.05) as well as on the total score (p = 0.059). In contrast, using ANOVA across different age groups in females, statistically significant differences in Education (F (2,118) = 5.381; P = 0.006) and WorkingActivity (F (2,118) = 4.024; P = 0.020) emerged. Post hoc comparison showed that elderly women (born in the period 1935–1950), who achieved lowest scores on these domains, significantly differed from other two female groups (p < 0.05), while the middle-aged female participants achieved highest scores [Table 3]. Within individual age groups, t-test ruled out gender differences in young and middle-aged groups (p > 0.05). In the group of elderly, men achieved higher average scores on both subdomains than women: Education (t = 3.128; P = 0.003) and WorkingActivity (t = 2.145; P = 0.037).

**DISCUSSION**

Great research efforts are being made to find a reliable indicator that could determine the risk of dementia and other neurodegenerative diseases for an individual, and within this, a relatively new concept of CR stands out. We found the lowest values in the group of elderly women, which is probably a sign of gender inequality at the time when they were educated and should have been active. However, it is important to point out the obvious existence of codependence between CRI-Education and WorkingActivities, that is, those persons who had higher levels of education also had more responsible jobs and thus higher levels of WorkingActivities. We have shown that gender differences become more pronounced in the group of elderly, but if the whole sample is observed, the middle-aged group records the highest CR scores [Graph 1]. Most studies showed that men achieve higher scores on all domains of CR, but we found statistically significant gender differences only in the subdomains of Education and WorkingActivity. This is

| CRI | Age group | Males n | Females n | Total n |
|-----|-----------|---------|-----------|---------|
| Education | Young (18-44 years) | 100.74±11.60 | 98.31±11.8 | 99.51±11.70 |
| | Adults (45-69 years) | 99.37±4.58 | 98.49±5.12 | 99.07±4.90 |
| | Elderly (70-85 years) | 98.51±5.39 | 98.30±6.13 | 98.39±5.97 |
| WorkingActivity | Young (18-44 years) | 105.64±15.59 | 103.23±15.81 | 104.44±15.76 |
| | Adults (45-69 years) | 98.62±23.41 | 98.23±23.41 | 98.42±23.41 |
| | Elderly (70-85 years) | 98.60±4.40 | 98.09±5.18 | 98.34±4.73 |

**Graph 1:** Differences in the values of total CRI scores between age groups

| CR | Young (18-44 years) | Adults (45-69 years) | Elderly (70-85 years) |
|----|------------------|-------------------|-----------------|
| CRI-Education | 98.34±5.24 | 98.23±6.25 | 98.23±5.97 |
| CRI-WorkingActivity | 96.51±21.00 | 98.23±6.25 | 98.23±5.97 |
| CRI-LeisureTime | 97.63±21.00 | 98.23±6.25 | 98.23±5.97 |
| CRI-Total score | 96.32±21.00 | 98.23±6.25 | 98.23±5.97 |

**Table 3:** Mean values (M±SD) of CRI domains across gender and age
similar to some other studies,[13] in which LeisureTime did not show gender differences, which could be due to men reading more newspapers, driving motor vehicles, having hobbies and participating in social activities on one hand, and women did more housework and gardening on other hand, so that in the final calculation of this subdomain, that difference was annulled. Additional research is certainly needed to assess the actual impact of a low CR index on the development of dementia.[7] The limitations of our research are the size of the sample as well as the lack of an objective external indicator of the cognitive state of respondents.

**Conclusion**

Higher cognitive reserve may be one of the several important factors that have potential to protect from developing a neurodegenerative disease and to slow cognitive decline or even dementia by providing better compensatory mechanisms.[6,10] The existence of gender and age differences in CR scores indicates the future potential application of the questionnaire in various sociological and epidemiological studies as a possible indicator of gender (in) equality throughout different cultural backgrounds and between different age categories, which may be of clinical importance due to different susceptibility to neurodegenerative diseases of persons with different CR. Like many other neuropsychological and cognitive instruments, this questionnaire also requires specific validation and established norms in various countries and regions.

**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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**Conflicts of interest**

There are no conflicts of interest.

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**References**

1. International AD, Wimo A, Ali G-C, Guerchet M, Prince M, Prina M, et al. World Alzheimer report 2015: The global impact of dementia: An analysis of prevalence, incidence, cost and trends. 2015. Available from: https://www.alzint.org/resource/world-alzheimer-report-2015/.
2. Livingston G, Huntley J, Sommerlad A, Ames D, Ballard C, Banerjee S, et al. Dementia prevention, intervention, and care: 2020 report of the Lancet commission. Lancet Lond Engl 2020;396:413-46.
3. Reas ET, Laughlin GA, Bergstrom J, Kritz-Silverstein D, Richard EL, Barrett-Connor E, et al. Lifetime physical activity and late-life cognitive function: The Rancho Bernardo study. Age Ageing 2019;48:241-6.
4. Koller EJ, Chakraborty P. Tau-Mediated dysregulation of neuroplasticity and glial plasticity. Front Mol Neurosci 2020;13:151.
5. Mercereon-Martinez D, Ibaceta-González C, Salazar C, Almaguer-Melian W, Bergado-Rosado JA, Palacios AG. Alzheimer’s disease, neural plasticity, and functional recovery. J Alzheimers Dis 2021;82(s1):S37-50.
6. Stern Y, Arenaza-Urquijo EM, Bartrés-Faz D, Belleone S, Cantillon M, Chetelat G, et al. Whitepaper: Defining and investigating cognitive reserve, brain reserve, and brain maintenance. Alzheimers Dement J Alzheimers Assoc 2020;16:1305-11.
7. Jammula VR, Leger H, Gilbert MR, Cooper D, Armstrong TS. Effects of cognitive reserve on cognition in individuals with central nervous system disease. Cogn Behav Neurol 2021;34:245-58.
8. Alves Pereira G, Silva Nunes MV, Alzola P, Contador I. Cognitive reserve and brain maintenance in aging and dementia: An integrative review. Appl Neuropsychol Adult 2021;1-11. doi: 10.1080/23279095.2021.1872079. Online ahead of print.
9. Nucci M, Mapelli D, Mondini S. Cognitive reserve index questionnaire (CRIq): A new instrument for measuring cognitive reserve. Aging Clin Exp Res 2012;24:218-26.
10. Almeida-Meza P, Steptoe A, Cedar D. Markers of cognitive reserve and dementia incidence in the English longitudinal study of ageing. Br J Psychiatry 2021;218:243-51.
11. Maiovis P, Ioannidis P, Nucci M, Gotzamani-Psarrakou A, Karacostas D. Adaptation of the Cognitive reserve index questionnaire (CRIq) for the Greek population. Neurol Sci 2016;37:633-6.
12. Ozakbas S, Yigit P, Akyuz Z, Sagici O, Abasiyanik Z, Ozdogar AT, et al. Validity and reliability of “Cognitive reserve index questionnaire” for the Turkish population. Mult Scler Relat Disord 2021;50:102817.