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Study protocol

Cognitive SuperAging in Physically Active Women (COSACTIW): Study Protocol and data from the NANOK

Hana Georgi, Melisa Schneiderová, Josef Mana, Zuzana Tichá, Klára Daďová, Radek Trnka, Iveta Vojtěchová, Jiří Lukavský

Abstract

Exceptional cognitive aging, or superaging is a recent area of research. SuperAgers are defined as persons aged at least 80 years who have youthful episodic memory. Studies are scarce and very little is known about their lifestyle and leisure activities including their engagement in physical activity, which is otherwise known to be associated with better health. The project aims to identify associations between a lifelong physically active lifestyle, objective fitness and cognitive superaging in old-old women.

COSACTIW is a cross-sectional ex-post-facto study. Herewith, we present its protocol. There were 225 women aged 80-96 years tested who reported that their engagement in physical activity between the ages of 30 to 60 years was at least on the level recommended for adults by the World Health Organization, i.e. at least 150 minutes of moderate-intensity aerobic physical activity per week. Episodic memory was tested with Rey Auditory Verbal Learning Test, non-memory tests were Trail Making Test, Verbal fluency – animals, and Boston Naming Test – 30 item version. Several questionnaires were used to map previous and current leisure activities. Objective data were obtained with the Senior Fitness Test. We also present benchmark data from a previous Czech study of cognitively normal older persons, NANOK, to whom we will compare our sample. Specifically, we are going to use a subsample of 70 women, aged 80-94 years, who were selected from the NANOK sample using the same inclusion criteria as in COSACTIW. There were 23 (32.9%) SuperAgers among them.

Our findings may offer insights into preventive strategies for successful aging and cognitive resilience.

Keywords: SuperAging; cognition; physical activity; lifestyle

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With the new millennium, an area of research within healthy/successful aging emerged, and that of superior, elite, youthful cognitive aging or "superaging" (SA). It brought the old- and oldest-old people whose cognition is and remains excellent or youthful, and whose brains show resemblance to younger persons in several areas to light (Gefen et al., 2014; Harrison et al., 2012; Rogalski et al., 2013). Definitions of superior cognition in old age vary, but each has clear criteria (Mana & Bezdicek, 2020; Nyberg & Pudas, 2019).

There are two different approaches to the definition of the reference group in studies of superiorly cognitively performing older adults: 1) younger adults (=usually 50-60 years old) (Harrison et al., 2012); or 2) age-appropriate norms (Yu et al., 2019). While using age-appropriate norms may reduce cohort effects, there is a growing body of studies adopting the Northwestern University SuperAging Program (NUSA) approach using the young-old adults' normative values and the terms „SuperAging" and „SuperAgers". That should ensure comparability with other studies (Borelli et al., 2018). SuperAgers are individuals over the age of 80 with episodic delayed memory performance at least as good as normative values for 50 to 65-year-olds and normal non-memory cognitive functions (Gefen et al., 2014; Harrison et al., 2012; Rogalski et al., 2013).

Several studies found from about 12% (Červenková et al., 2020), through 17% (Harrison et al., 2018) up to 37 % of healthy aging old- and oldest-old to be SA, cognitive elite or successful agers in samples of general cognitively-healthy population (Meng & D'Arcy, 2014; Saint Martin et al., 2017). So far, studies suggest a higher prevalence of SA in women than men (Červenková et al., 2020; Maccora et al., 2021).

Lifestyle and SA

Aging is regulated by both nature (genes) and the environment and lifestyle (nurture) (Priya Singh et al., 2019). While one is not able to change inherited physiological characteristics, it is common human strife to overcome "fate", improve living conditions and prevent negative events and life course through an exercise of free will. Various lifestyle adaptations are tried to that end (Wainwright et al., 2007; WHO, 2019).

Lifestyle is considered one of the key components of cognitive reserve, which is the capability of the brain to cope with the consequences of changes or damage to the brain, including aging-related ones, through pre-existing cognitive processes (Alvares Pereira et al., 2021; Stern, 2002; Stern et al., 2020). By definition, SA shows signs of high cognitive reserve. So far, little is known about the predominant **lifestyle** of SA. Our previous study showed differences in the number of cognitive leisure activities between SA and non-SuperAgers (nonSA) (Heissler et al., 2021). We also found non-significant differences in the number of physical activities (PA) between SA and nonSA, although SA considered PA less tiresome. However, the study did not render data to distinguish sedentary or physically active lifestyle. While the sample was not random, it was stratified and it is considered representative of the general Czech population of the age-band (Heissler et al., 2021; Štěpánková, Nikolai, et al., 2015). Lifestyle is now commonly understood as the everyday behaviour and activities of individuals in terms of work, activities, entertainment and eating. An integral part of lifestyle is our physical activity or the lack of it.

Physical activity

Physical activity belongs to the factors that are proven to have a health-promoting effect including a pro-cognitive one across the life span (Nyberg & Pudas, 2019) and shows strong effects on cognitive function in older persons (Liu et al., 2020). On the other hand, physical inactivity is the major cause of poor health in older age (I.-M. Lee et al., 2012). PA has a brain neuroprotective effect and

attenuates cognitive decline via mitigation of cerebrovascular risk (Ahlskog et al., 2011; Livingston et al., 2020), and is connected with successful (disease-free) aging, and being functionally independent (Gopinath et al., 2018). Besides self-reported physical activity, objective fitness is also researched with cognition, and the associations show the same tendencies as physical activity (Yang et al., 2018).

People differ in levels of PA in their lifestyle, from extremely sedentary to master athletes. Masters athletes are even considered examples of successful aging in some studies (Geard et al., 2017). Certain types of sports activity (especially aerobic) are often associated with superior cognitive performance (Zhao et al., 2016). While there are people who do sports on a master's level in each country, more people enjoy PA as their recreational hobby and live a physically active lifestyle.

There is an over one-hundred-year-old tradition of Sokol, a nationwide gymnastic movement, in the Czech Republic. Sokol embraces everyone regardless of gender or age. The organization has about 160 thousand members and is active in 1000 settlements (Sokol, 2021). Another organization promoting PA (walking, cycling and skiing tourism), with a long tradition and over 30 thousand members is the Czech Tourist Club (*Czech Tourist Club*, 2021). Both organizations support regular PA in their members of all age groups. A physically active lifestyle is not a dominion of younger generations only; many people go for sports and remain physically active until a very late age.

Gender

There are undoubtedly individual family-specific gendered practices and lifestyles, but predominantly, lifestyle variation is related to gender in a given social setting and culture (Choo & Ferree, 2010). It encompasses different socioeconomic living conditions, political situations and technological advances in different eras (Parker & Agahi, 2013). In older persons, some **gender-specific** features in cognition (Sundermann et al., 2016) and brain aging (Goyal et al., 2019) are observed. There are also gendered differences in factors related to physical activity in older age (Kaplan et al., 2001; Y.-S. Lee, 2005). For example, Barha et al. (2017) showed in their meta-analysis that women's executive processes may benefit from exercise (aerobic training) more than men‘s. Yaffe et al. (2001) illustrated that women with higher levels of baseline PA (walking) were less likely to develop a cognitive decline in their prospective study with a large sample of community-dwelling older women, and thus added to the body of evidence of the positive effect of PA in aging. To find relevant answers, it is important to study aging-related issues with special focus on gendered differences and similarities. This is reflected by studies of men or women only.

Project aims

Our project, Cognitive SuperAging in Physically Active Women (COSACTIW), aims to elucidate some aspects of successful cognitive aging and its relations to a physically active lifestyle, sociodemographic, and health factors in older women. We choose to focus on the associations of a lifestyle of PA/sports in adulthood and old age based on self-reports of old-old women. Restricting the focus on women will allow us to obtain a homogenous sample from the view of gender.

Also, we aim to lay down a platform for a follow-up study, so that we can study the stability of the found phenomena over time. A longitudinal stretch could render more relevant data on further analyses such as genetic or neuroimaging ones that are not in the scope of the currently proposed project.

Our study would thus add to the research focused on women such as Women’s Health and Aging Study (Fried, 1999), Nurses’ Health Study (Bartali et al., 2014), Women’s Health Initiative Study (Woods et al., 2016), etc. COSACTIW is an indirect continuation of the previous projects related to

cognitive aging and superaging (National Normative Study of Cognitive Determinants of Healthy Aging, NANOK - NT13145 and Cognitive SuperAging - GA18-06199S). The project was approved by the Institutional Research Ethics Board (Nr. 3/2021).

Research goals

The primary goal is to identify associations between a lifelong physically active lifestyle and cognitive superaging in old-old women. We expect a higher prevalence of SA in our sample than in NANOK.

Secondary goals

- To find associations between:
  - objective fitness and cognitive performance.
  - objective fitness and self-reported levels of physical activity.
- Our study also aims to describe other lifestyle factors most associated with the cognitive superaging of physically active women. Therefore, the factors of health, socio-demographic parameters etc. will be examined.

The secondary goals translate to several hypotheses, the main ones are:

- Higher objective fitness will be positively correlated with better overall cognitive performance.
- Higher objective fitness will be positively correlated with the current higher physical activity (IPAQ-E) and with higher physical activity in recent years (COBRA-B).
- We also hypothesise that SA will report higher engagement in cognitive / mental activities.
- SA and nonSA will not differ in the basic sociodemographic parameters (education type, family status, living arrangements, type of profession – mental or manual).
- SA and nonSA will not differ in subjective health, symptoms of depression, symptoms of anxiety.
- SA will report higher psychological well-being than nonSA.

METHODS

Design of the study: cross-sectional ex-post-facto.

Timeline

Year 1 - 2: Preparations of the methods lasted from the beginning of the project, i.e. April 1st until August 2022. The project's website www.superaging.cz was published. Data collection started, after the summer, which is in our experience the slowest period of the year for the recruitment of older persons in a similar type of research. Between September 6th, 2022, and December 13, 2023, we collected data from 225 women who fulfilled the inclusion criteria.

Year 3: The year 2024 is reserved for analyses, presentation of the results, manuscripts preparations and submissions. Psychological data were thoroughly re-checked and the sample was controlled for inclusion and exclusion criteria. SuperAgers will be defined based on the set cognitive criteria detailed above.

Sample

Inclusion criteria: age ≥ 80 years; functional independence; without serious mental or physical disease or impairment (i.e. dementia, currently treated cancer, haemodialysis), without abuse of alcohol or drugs, head trauma with unconsciousness in the medical history, and/or uncorrected visual or hearing disorder; speaking Czech at the level of a native speaker; the lifestyle of PA at least since they were 30 years old until at least 60 years of age (cf. above) on the levels recommended by the World Health Organisation (WHO) for adults, which is to engage in "at least 150–300 minutes of moderate-intensity aerobic physical activity; or at least 75–150 minutes of vigorous-intensity aerobic physical activity; or an equivalent combination of moderate- and vigorous-intensity activity throughout the week, for substantial health benefits" (WHO, 2020a, p. 32).

Exclusion criteria: subnormal cognitive performance (MMSE below 1 SD below the education- and age-appropriate norm) and daily functioning (FAQ). Each participant will receive a status of SA or nonSA based on her cognitive performance (the definition is below).

The original plan was to recruit two subsamples of women (total N = 222). Subsample 1: PAW (*n* = 111): Physically Active Women, i.e. women with a life-long history of physical activity (as above) who are still going for some kind of sports/targeted PA. Subsample 2: exPAW (*n* = 111): women who used to have sports as their predominant type of hobby since the age of 30 but for any reason discontinued the PA before the age of 75, but not before the age of 60. This was planned so that we may distinguish between association of continued and discontinued engagement in recommended levels of physical activity and the current cognitive and objective fitness status. Whether we managed to recruit exPAW will be found after detailed analyses of the obtained data. The preliminary check showed a scarcity of exPAW.

Recruitment: via the website, Facebook, senior clubs, Czech Sokol Society, Czech Tourist Club, and snow-ball. We omitted using universities of the third age (U3A) as a recruitment venue. Students at U3A can be considered a special population who are easily recruited. They also share the active participation in learning activities which is a specific characteristic by itself that can be associated with cognition in older age, which we did not wish for.

The sample size was estimated using power analysis. The primary goal/hypothesis will be tested via a Chi-Squared test of independence with SA aging (SA vs. nonSA) and predominant type of lifelong activity (general population vs COSACTIW sample) as grouping variables. We expect about 1/3 of the sample to be SA implying a small to moderate effect size (Cramer's V = 0.2). Consequently, we will need 102 participants in each group, physically and ex-physically active, to be able to detect significant differences with sufficient power (alpha = .05, 1-beta = .90). Based on our previous studies, we expect an 8% exclusion rate leading to the estimated sample size of 111 participants in each subsample.

Procedure

Data collection

1) Cognitive and psychological part – included Informed Consent signature, cognitive testing, and all relevant questionnaires and reports of socioeconomic status, health, and selected lifestyle parameters. Estimated duration: max 1.5 hours. After a short break:
2) the Senior Fitness Test was performed as a voluntary part of the assessment. Average estimated duration: 15 minutes.

Participants received 1.000 CZK (about 55 €) as remuneration for participation in the study. A financial incentive is common for participation in scientific studies in the Czech Republic (usually not in online surveys).

Participants were recruited and assessed with the help of psychometrists, whom we trained to secure a shared adherence to the procedure. The psychometrists' names are listed in the Acknowledgment section.

Pilot testing

The original method to obtain retrospective report of engagement in mental and physical activities over the life course, RETROS, was piloted on team members and their adult family members, N=30 (Schneiderová et al., 2022). Before implementing the full study, a pilot testing phase was conducted on a group of independent and cognitively healthy older adults who were not a part of the study sample to ensure clarity and comprehension of the test battery items.

Another pilot study aimed to examine the test-retest reliability of self-report instruments (including RETROS) for measuring leisure activities that we included in the study and to pre-prepare procedures for the analyses of the study data. The pilot study (N=86) was realized and is currently under review in a scientific journal.

METHODS

Inclusion/exclusion criteria

General Cognitive Status was assessed with the Mini Mental-State Examination (MMSE) (Štěpánková, Nikolai, et al., 2015). Besides the cognitive assessment, we assessed activities of daily living with the Functional Activities Questionnaire (FAQ) (Pérès et al., 2008; Pfeffer et al., 1982). The attitude/relationship to and participation in physical activity over the life course was reported with an Attitude to Physical Activity scale (A2PA), a single-question screening scale.

Sociodemographics

Data on age, family status, living arrangements (living alone, with a partner, with family, with strangers or other), housing (house, one's apartment, rented apartment, senior facility), work history (prevalent type of job position; job before retirement; ongoing paid work; physical demands of performed jobs throughout life; manual/mental type of profession); need of a formal social care assistance.

Cognitive tests in SuperAging definition

The definition (according to NUSA): 1) superior episodic memory = delayed recall of word list episodic memory test *at or above* average normative values for 60 years old; 2) normal non-memory cognitive performance = non-memory tests scores (Trail Making Test – Part B, Boston Naming Test-30 and Category verbal fluency – Animals) within one standard deviation of the average range for their age and education level or better (Cook Maher et al., 2017, 2022; Harrison et al., 2012; Rogalski et al., 2019).

Previous Czech studies used the Philadelphia Verbal Learning Test as a measure of episodic memory delayed recall and previous estimates of normative values for BNT-30 (Červenková et al., 2020; Heissler et al., 2021; Kopeček et al., 2023; Ticha et al., 2023). The BNT-30 norms published in 2022 showed a significant effect of age, education, and gender. Therefore, the recent norms by Bezdicek et al. (2022) will be used in COSACTIW studies. We used the Rey Auditory Verbal

Learning Test as it is more common in other SuperAging studies than PVLT. Table 1 shows the overview of the measures, normative studies and cut-off scores. The cut-off scores listed with the NUSA articles are estimates as the norms reflect race and education in more detail.

Table 1.

Neuropsychological measures used for defining SuperAgers

	Previous Czech studies		COSACTIW		NUSA	
Domain	Method (norms)	Cut-off score	Method (norms)	Cut-off score	Method (norms)	Cut-off score (estimates)
Episodic memory	PVLT (Bezdicek et al., 2014)	8/9 Age category: 60-64	RAVLT (Frydrychová et al., 2018)	Lower: 7/8; Higher: 8/9 Age category: 62-74	RAVLT (Schmidt, 2004) based on (Ivnik et al., 1992) or CVLT	8/9
Non-memory domains	TMT-B (Nikolai et al., 2018)	Lower: 249/250; Higher: 223/224 Age category: 80+	TMT-B (Nikolai et al., 2018) Age category: 80+	Lower: 249/250; Higher: 223/224	TMT-B (Heaton et al., 2004)	Lower: 265/264; Higher: 214/215
	VF – Animals (Nikolai et al., 2018)	Lower: 11/12; Higher: 12/13 Age category: 80+	VF – Animals (Nikolai et al., 2018)	Lower: 11/12; Higher: 12/13 Age category: 80+	VF Animals (Heaton et al., 2004)	Lower: 11/12; Higher: 12/13
	BNT-30 (Nikolai et al., 2018)	Lower: 24/25; Higher: 26/27 Age category: 80+	BNT-30 (Bezdicek et al., 2022)	Lower: 18/19; Higher: 22/23 Age category: 75-96	BNT-30 (Saxton et al., 2000) or (Jefferson et al., 2007)	Lower: 23/24; Higher: 25/26

Note. COSACTIW – "Cognitive SuperAging in Physically Active Women"; NUSA – Northwestern University SuperAging Program; PVLT - Philadelphia Verbal Learning Test; RAVLT - Rey Auditory-Verbal Learning Test; CVLT – California Verbal Learning Test; TMT-B - Trail Making Test – Part B; VF Animals – Verbal Fluency – Animals; BNT-30 - Boston Naming Test – 30 items. Lower: in Czech studies - basic a trade school, usually 9-12 years of schooling; NUSA studies 8-11 years of schooling. Higher: in Czech studies – secondary school graduation „maturita" or any tertiary education degree, usually 12 or more years of schooling; NUSA 13-15 years of schooling.

Physical activity and fitness

Subjective reports about physical activity were obtained with the International Physical Activity Questionnaire for the Elderly (IPAQ-E) (Chlumsky et al., 2018; Hurtig-Wennlöf et al., 2010). Detailed information on long-term physical activities was obtained with an adjusted COBRA questionnaire and a newly developed RETROS questionnaire (Nevalainen et al., 2015; Schneiderová & Mana, 2023). COBRA-B was adapted to open questions regarding the intensity of performed physical activity as in the WHO recommendations (Livingston et al., 2020; WHO, 2020b).

Objective physical fitness data were obtained with the Senior Fitness Test, which is a functional test evaluating the capacity to perform daily activities safely (Dadova & Beranova, 2016; Rikli & Jones, 2001). Our protocol included chair stands in 30 s, biceps curls in 30 s with 2,27 kg weight, 2-min. step test, and 2,45-m up-and-go test. Chair-sit-and-reach test and back-scratch test were omitted. With

that, we asked about height, weight, and waist circumference, which are common physical measures to calculate e.g. Body Mass Index and are health-related (Ross et al., 2020).

Time perspective: All the main subjectively reported lifestyle features will be subjects of reports related to present times (IPAQ-E, COBRA-B), and retrospectively to the life course since the age of 30 (RETROS). IPAQ-E focuses on the period of last week, COBRA-B on a typical summer week over the last 6 years. In RETROS, the participants marked trajectories of levels of individually relevant parameters on visual scales using the "now" as the mid-point of a 5-point Likert-like scale for 5-year periods with a possibility to mark a turning point (e.g., injury). This will serve as a check of whether / when the activities were discontinued and are still performed.

PAW identification: We identify PAW women based on activities listed in RETROS; at least one activity performed at least once a week or at least two performed several times a month until age 75. We also collected information on the level of professionalism in sports engagement (professional, amateur, recreational; trainer), and membership in sports clubs, and formal sports organizations.

Other Lifestyle Factors

Mental leisure activities of various types were assessed with an adapted version of the COBRA leisure activity questionnaire (Nevalainen et al., 2015), the adaptation is based on previous experience with it and contains only the most relevant types of activities (Heissler et al., 2021), and with RETROS (see above) over the life-course.

Social activity: For social activities engagement, we used two subscales of an extended version of the Victoria Longitudinal Study – Activity Lifestyle Questionnaire by Jopp & Hertzog (2010): Social – Private (6 items) and Social – Public (5 items), and a single item of the Religious subscale *("Attend church service"*). Altogether, it included 12 items in the form of brief activity descriptions (e.g. Going out with friends). The participants were asked about frequency of performing each activity over the past two years on a 9-point Likert-type scale with the response options ranging from 0 (never), 1 (less than once a year), 2 (about once a year), 3 (2 or 3 times a year), 4 (about once a month), 5 (2 or 3 times a month), 6 (about once a week), 7 (2 or 3 times a week), to 8 (daily). The variables for the two subscales, Social-Private and Social-Public, were the average responses on items within each subscale (de Frias & Dixon, 2014).

The protocol included questions: on satisfaction with the frequency of social contact; on the frequency of talking to other people (every day – almost every day – at least once a week – a few times a month – almost never); on keeping social contacts with people of their age; and the age of their friends (My friends are mostly from my age category. – My friends are usually younger than me. - My friends are usually older than me. - My friends are from all age categories, younger, same, or older. - I do not have friends.); whether they walk a dog.

Well-being factors

Depressive symptoms, anxiety: The levels of symptomatology were assessed with the abbreviated Geriatric Depression Scale, GDS-15 (Heissler et al., 2020; Sheikh & Yesavage, 1986), and Geriatric Anxiety Inventory (Byrne & Pachana, 2011; Heissler et al., 2018).

Health: The first item of SF12 was used as a proxy of overall subjective health rating it on a five-point scale (excellent – very good – good – fair – poor) (Ware et al., 1996). Questions on smoking, history of smoking, and alcohol consumption per week were asked.

Psychological well-being: Positive Relations with Others subscale of the Carol Ryff's (Morozink et al., 2010; Ryff, 1989; Ryff et al., 2007) 42-item Psychological Well-Being questionnaire (PWB) was included in the research protocol to confirm the findings of Cook Maher et al. (2017), whose sample of SuperAgers showed statistically higher scores in this 7-item PWB subscale than non-SuperAgers. PWB is a self-report measure using a 6-point Likert scale ranging from "1 –strongly disagree" to "6 –strongly agree" (scoring according to Ryff & Keyes (1995). To obtain the total score, at first, the subscores in negatively worded items (2, 3, and 6) are reversed, and then the 7 subscores are summed. A higher total score indicates a higher level of psychological well-being, namely positive relations with others.

It is also possible to derive the subscale Positive Relations with Others of the shorter PWB-18 version (Ryff & Keyes, 1995) from our data (items 2, 5, and 6).

Medication: We obtained self-reports of medication used presently – antidepressants, hypnotics, anxiolytics, antihypertensive, antidiabetics, nootropics, endocrinological or other medicines.

Method of analysis

To meet the primary goal, the frequency of SuperAgers among the general population will be compared via the Chi-Squared test of independence. For that, we need to prepare the dataset from the National Normative Study of Cognitive Determinants of Healthy Aging, NANOK (see below).

The secondary goal, to describe the lifestyle factors most associated with cognitive superaging of women, will be investigated via the Bayesian multilevel generalized linear model. Multilevel modelling allows for explicit inclusion of the dataset's hierarchical structure and is robust to outliers as well as multiple comparisons because of its partial pooling property (Gelman et al., 2012). Using generalized linear modelling will allow us to investigate potentially non-linear relationships with potentially non-normal response functions. Finally, unlike the frequentist approach, the Bayesian approach can describe model parameters (i.e., effects) in a continuous manner via posterior probability distributions, can quantify evidence of null hypothesis and is more easily integrated into the multilevel modelling framework (Kruschke & Liddell, 2018). The results will be interpreted according to current Bayesian reporting guidelines and all modelling steps will be recorded using a Bayesian workflow (Gelman et al., 2020; Makowski et al., 2019).

Dissemination of results

Besides research articles analysing the data and dissertation thesis focusing on leisure activities we also employ other means to promote the topic of superior cognitive aging and our findings through the project's Facebook profile, project website, Osel.cz popularization article (Vojtěchová, 2022) and at conferences. So far, we presented the project and its preliminary results at the Psychological Days 2022 [Psychologické dny] (Olomouc), Scientia Movens Conference 2023 (Prague), Ageing 2023 (Prague), Sports Medicine [Tělovýchovné lékařství] 2023 (Mariánské Lázně), Contexts of Contemporary Psychology [Kontexty současné psychologie] (Ostrava). In 2024, we plan to present the results at the Psychological Days [Psychologické dny] (Olomouc), Sports Medicine [Tělovýchovné lékařství] (Ostrava), the 33rd International Congress of Psychology (Prague), and Global Conference on Psychology (Liverpool, UK), and the 17th European Congress of Adapted

Physical Activity (Seville, Spain). After our research articles are accepted for publishing, we plan to summarize the findings in a Czech popularization article.

SUPERAGING WOMEN IN NANOK

The inclusion criteria for the NANOK sample were: age 60 years or older, functional independence, absence of serious neurological (e.g. no stroke, no trauma resulting in loss of consciousness in medical history), psychiatric (e.g. psychosis, major depressive disorder, or cognitive impairment in medical history), or somatic disease affecting cognition (e.g. no current chemotherapeutic or radiologic treatment). Štěpánková et al. (2015) provided a detailed overview of the criteria and the project realization.

The SuperAging (SA) sub-studies included only persons who were at least 80 years of age (Červenková et al., 2020; Ticha et al., 2023). The analyses showed there were 12% of SuperAgers in the sample of men and women (N=208) in the year 2012. Among the sample's 114 women (61 with lower education; 54%), 16 (14%) fulfilled the criteria for SA. The SA criteria are presented above in Table 1.

Episodic memory was assessed with the Czech version of the 12-word Philadelphia Verbal Learning Test (PVLT) (Bezdicek et al., 2014), which consists of five trials of a 12-word list presentation followed by free recalls, an intrusion word list presentation and its free recall, and then free and cued short delayed and long delayed recalls. The stimulus words belong to three semantic categories. The PVLT norms do not reflect gender or education. For non-memory tests, the norms by Nikolai et al. (2018) were used, which provide normative data for the age category 80+ and lower and higher education. All normative articles used in this study for the norms are based on the NANOK sample.

Besides the tests, the participants were asked whether they performed several types of leisure activities regularly, at least once a week. The nominal answers were yes/no. They were also asked whether they perceived any difficulties in the domains of memory (the opening question in MMSE), attention, judgment – logical thinking, mood, and functional independence. The nominal answers were yes/no.

Preparation of benchmark dataset from NANOK

To be able to compare the COSACTIW sample with the NANOK sample, we first applied the COSACTIW inclusion criteria of cognitive global function (Mini-Mental State Examination, MMSE, cut score 23/24 for lower, or 24/25 for higher education) and functional independence (Functional Activity Questionnaire, FAQ, cut score 5/6) (Bezdicek, 2021; Folstein et al., 1975; Pfeffer et al., 1982; Štěpánková, Nikolai, et al., 2015).

44 out of 114 did not meet the above inclusion criteria for COSACTIW. Table 2 shows the number of participants who were excluded from the original NANOK sample and the criterial tests for exclusion in sub-groups of women with lower (with basic or secondary education such as trade school without state graduation exam „maturita“) and higher education (graduating from secondary/high school with state leaving exam „maturita“ or with education from a tertiary school).

Table 2.

Numbers of excluded participants from NANOK sample based on the COSACTIW criteria

Education	MMSE < cut score	FAQ < cut score	MMSE and FAQ < cut scores	Total
Lower education	7	20	2	25
Higher education	7	14	2	19

Note. MMSE – Mini-Mental State Examination; FAQ – Functional Activity Questionnaire.

Sample

The final NANOK sample included 70 women aged 80 - 94 years. The sociodemographic characteristics are in Table 3. The sample's performance in the neuropsychological tests that are part of the SA definition is in Table 4.

Results

Based on the above-mentioned definition of SA, we found 14 SA (20%) using the same norms used in the previous studies by the NANOK team (Červenková et al., 2018; Heissler et al., 2021, 2023; Kopeček et al., 2023; Ticha et al., 2023). After we applied the now available gender-controlled norms for the Boston Naming Test (Bezdicek et al., 2022) that will be applied in our further analyses of COSACTIW data, we identified 23 SA (32.9%).

To analyse the differences between nonSA and SA groups, we used the Mann-Whitney U test for continuous variables and χ^2 for the categorical variables. The analyses did not show any statistical differences between SA and nonSA groups in the sociodemographic characteristics (Table 3), performance in the tests that were part of the inclusion criteria - MMSE, FAQ (Table 4), levels of depressive and anxiety symptoms - GDS-15, GAI (Table 4), perceived difficulties in the psychological functioning domains (Table 6) or engagement in several types of leisure activities (Table 5).

Table 3.

Sociodemographic characteristics

Characteristic	Total		nonSA	SA	Statistics		
	M (SD) [min-max]		N=47	N=23		p	Effect size
Age	83.6 (3.38) [80-94]		83.8 (3.47) [80-94]	83.3 (3.24) [80-92]	U=495.0	0.570	0.084
Education (years)	12 (2.84), [8-22]		11.6 (2.56) [8-18]	13.0 (3.20) [8-22]	U=402.5	0.082	0.255
	Type	Counts (% of total)					
Education	Lower	36 (51.3%)	26	10	X^2=0.87	0.352	
	Higher	34 (48.7%)	21	13			
Education (types)	Primary	17 (24.3%)	14	3	X^2=0.70	0.072	
	Trade school	19 (27.1%)	12	7			
	Secondary	29 (41.4%)	20	9			
	Tertiary	5 (7.1%)	14	3			
Family status	Single	0	0	0	X^2=2.17	0.538	
	Married	15 (21.4%)	11	4			
	Widowed	48 (68.6%)	30	18			
	Divorced	7 (10%)	6	1			
Living arrangements	Alone	33 (47.1%)	20	13	X^2=2.94	0.400	
	With a partner	11 (15.7%)	9	2			
	With family	7 (10%)	6	1			
	Other	19 (27.1%)	12	7			

Note. Effect size – rank biserial correlation.

Table 4 shows there were statistically significant differences in performance between SA and nonSA groups in all the criterial cognitive tests (number of correctly recalled items in PVLT delayed free recall trial; time to complete TMT-B; the sum of correctly named items in spontaneous naming and semantic cue trials of BNT-30; number of animals named in 60 seconds in Category fluency tests-Animals).

Table 4.

Performance in tests

	Total N=70		nonSA N=47	SA N=23	Statistics		
Test	M (SD)	Min-Max	M (SD)	M (SD)	U	p	Effect size
MMSE	27.03 (1.63)	24-30	27.2(1.81)	27.3(1.20)	489.5	0.521	0.094
FAQ	0.96 (1.49)	0-5	1.0 (1.52)	0.87 (1.46)	512.5	0.694	0.052
GDS-15	3.01 (2.90)	0-14	3.26 (3.23)	2.52 (2.02)	490.5	0.531	0.093
GAI	4.01 (4.26)	0-14	4.04 (4.43)	3.96 (3.99)	531.0	0.910	0.018
PVLT delayed free recall	7.64 (2.83)	1-12	6.19 (2.19)	10.6 (1.16)	26.5	**< .001**	0.951
TMT-A	58.7 (23.6)	11-132	60.6 (25.9)	54.8 (18.1)	469.5	0.378	0.131
TMT-B	161 (74.2)	67-448	176 (82.3)	133 (43.9)	356.0	**0.037**	0.312
BNT-30	24.1 (4.05)	11-30	23 (4.11)	26.3 (2.95)	279.0	**0.001**	0.484
Animals	19.5 (6.21)	7-36	17.7 (5.75)	23.1 (5.59)	263.5	**< .001**	0.513

Note. Effect size – rank biserial correlation. MMSE – Mini-mental State Examination; FAQ – Functional Activity Questionnaire; GDS-15 = Geriatric Depression Scale 15-item version; GAI – Geriatric Anxiety Inventory; PVLT – Philadelphia Verbal Learning Test (score is the number of correctly spontaneously recalled words after a delay of ca 20 min); TMT – Trail Making Test (score – seconds to complete); BNT-30 – Boston Naming Test, 30-item version (the total score is sum of items correctly named spontaneously and those named correctly after a semantic cue); Animals – Category fluency score is the number of unique animals named in 60 s.

Table 5.

Activities performed regularly and the number of persons in each group who engaged in them

Activity type	Counts	Specifications	nonSA Yes/No	SA Yes/No	X^2	p
Further education	13 (18.6%)	Any educational courses (language, U3V, memory training etc.)?	8/39	5/18	2.94	0.634
Physical exercise	49 (70.0%)	Physical exercise (swimming, tai-chi, cycling, hiking, rehabilitation etc.)?	34/13	15/8	0.37	0.541
Crossword, riddles	54 (77.1%)	Crosswords, sudoku etc.?	35/12	19/4	0.58	0.446
Social contacts	69 (98.6%)	Contact with colleagues, friends or family?	46/1	23/0	0.50	0.481
Culture	29 (41.4%)	Attending cultural events, theatre, cinema, exhibitions etc.?	17/30	12/11	1.63	0.202
Reading books	61 (87.1%)		40/7	21/2	0.53	0.467
Another hobby	58 (82.9%)		40/7	18/5	0.51	0.475

Table 6.

Self-reported difficulties in cognitive and emotional domains and the number of participants who report the difficulties or complaints

Domain	Counts	nonSA Yes/No	SA Yes/No	X^2	p
Memory	38 (54.3%)	29/18	9/14	3.17	0.075
Concentration	16 (22.9%)	10/37	6/17	0.20	0.653
Judgment, thinking	3 (4.3%)	3/44	0/23	1.53	0.216
Mood	15 (21.4%)	10/37	5/18	0.002	0.965
Functional independence	9 (12.9%)	6/41	3/20	0.001	0.974

Discussion

Our ex-post-facto study may help to set the priorities in prevention strategies and may guide persons who purposefully seek a healthy lifestyle to promote their mental fitness until old age. The results of our study will help to focus further studies on factors related to cognitive SuperAging, and cognitive resilience. A higher **prevalence** of SA in the physically active sample in this study would suggest that PA helps to reach a superior cognitive status compared to more sedentary persons, i.e. „common population“, and not only helps to have a lower probability of developing dementia. Negative results would indicate other underlying factors that need further exploration (e.g. focused on biological factors). When these factors and their roles are investigated in-depth, relevant intervention studies may follow.

Recent reviews show that the associations between regular PA and cognition across the lifespan (Ciria et al., 2023) and in older age are weaker than expected (Iso-Markku et al., 2024). “However, even a weak association is important from a population health perspective“ (Iso-Markku et al., 2024). Analyses of life-course data with the current lifestyle, cognition, and fitness will allow us to make suggestions as to their probable associations in older age. Additionally, comparisons with the NANOK, that we consider benchmark data, will allow for suggestions about the role of lifelong engagement in PA. The analyses of the NANOK sample in this paper and those already published resulted in formulation of our above listed hypotheses about SuperAgers. We anticipate observing higher levels of engagement in mental activities within the SA group, mirroring the findings reported in the NANOK study (Heissler et al., 2021), Conversely, we expect minimal sociodemographic discrepancies, functional independence differences, or health variations (including anxiety and depression symptoms) between SAs and the non-SA population.

In-depth discussions of the specific results will be presented in future research papers leveraging the COSACTIW data.

Using different methods and norms

In the studies by the Northwestern University SuperAging Programme team and other studies based on the same definition, we can see slight differences in the approaches. Their studies, and similar ones, differ in the specific word list tests of episodic memory. Some used the California Verbal Learning Test (Harrison et al., 2018; Sun et al., 2016), which is a predecessor of PVLT, and most used RAVLT (Cook Maher et al., 2017, 2022; Harrison et al., 2012; Rogalski et al., 2019). As for the non-memory domains, there are minimum requirements of performance within the normal range, i.e. at least -1 standard deviation below the age-appropriate norm (Cook Maher et al., 2022; Gefen et al., 2014; Harrison et al., 2012; Rogalski et al., 2019). These requirements are in some studies set as

inclusion criteria for the whole sample, including the non-SuperAgers (Cook Maher et al., 2022). In other studies, the minimum non-memory performance is required only for SuperAgers, and the inclusion criteria are based for example on MMSE, preserved activities of daily living, and absence of certain medical issues (Cook Maher et al., 2017; Harrison et al., 2012, 2018). In COSACTIW, we opted for the prevailing conditions: we use RAVLT as a measure of episodic memory, and we set the inclusion criteria for the whole sample as most studies – normal cognition and functional independence, no serious medical issues that are known to impact cognition.

The previous analyses of the NANOK sample did not use the same inclusion criteria (MMSE, FAQ) as we intend to use in COSACTIW analyses, which resulted in a larger sample, N=114 versus N=70 (Červenková et al., 2020; Ticha et al., 2023). Another difference is using PVLT in NANOK and RAVLT in COSACTIW. The cut-off scores are very similar, mostly 8/9 in delayed free recall, but norms for RAVLT distinguish between persons with lower and higher education (the cut-off score for lower education is 7/8). The main difference between the prevalences of SA that were reported originally and that we report now is caused not only by reducing the original NANOK sample of older women following COSACTIW cognitive inclusion criteria but also by using the now available norms for BNT-30 (Bezdicek et al., 2022), which offer adjustments not only for education but also for gender. They showed that older women have slightly lower performance than men and therefore they are not as strict as the norms used before (Nikolai et al., 2018).

The originally reported SA prevalence was 12% in the whole sample or 14% of women only. After the above-described adjustment of the dataset and analyses (i.e. with the COSACTIW criteria and the same norms), the prevalence is 32.9% of SA women in NANOK.

Limitations

The main limitation of our study is the absence of lifestyle data of the identical type from the general population. The NANOK sample was realized in 2012 when the concept of SuperAging was new, and the project had a different aim. Thus, the prevalences of SA in both samples will be compared with the reservation of not knowing what the self-reported levels of PA of NANOK participants would reveal. We believe if there are statistically significant associations, we can suggest a trend at least.

It is to be expected that individual participants differ in their health-related functional fitness due to various factors, including their membership in sports organizations and their level of participation in sport (from purely amateur without any professional supervision or training to semi- or professional sportswomen). Health-related fitness is defined as a multidimensional construct containing three to five components: cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition (Britton et al., 2020). In our study, we measure only a narrow selection of facets through SFT and BMI to estimate health-related fitness. NANOK data are lacking such data and thus will not allow for comparisons of these parameters.

Self-reports suffer from lower reliability (e.g. in contrast to objective measurements). For example, a Polish study showed that while the objective PA declined with age in women over 60 years old, the self-reports did not match the decline. The study also documented that sedentary behaviour is underestimated, and moderate and vigorous PA is overestimated (Ogonowska-Slodownik et al., 2022). Our study relies only on self-reports and objective measurement of present fitness, Senior Fitness Test. We did not employ any wearable devices to directly monitor engagement in PA or sedentary behaviour, activity, mobility, and sleep. The reason for this was to increase the likelihood of involving older people in the 80+ age group in our research, as we considered wearables to be a

compliance risk. There are reports of quite high wearable adherence in research on older people, especially in women, but not in persons of such high age (Paolillo et al., 2022). Employing wearables would also mean a high cost that would make the project very expensive. Wearables could be part of a follow-up project if the predicted trends are confirmed.

There is a possibility that we may have not collected sufficient exPAW participants. In such a scenario, the PAW and exPAW groups will be combined for analyses. While existing literature does not specify the most optimal life stage for engaging in physical activity to preserve cognitive function in old age, it acknowledges the well-established benefits of physical activity across all life stages (Frank et al., 2023).

Lifestyle encompasses many aspects, and reporting lifestyle over many decades is a challenging task methodologically and also time-wise. To ensure successful recruitment and compliance with the study protocol we reduced the methods, questions asked, and tests administered to about an 1.5 hour long session in average. This duration was based on our previous experience with research on populations of this age category. Thus, we are missing interesting data such as regarding their socioeconomic status, trajectory of their work career and their satisfaction with it, number of raised children, and duration of maternity leave (it was quite common to place children in "jesle", i.e. public day care facility for infants, and on the other hand there were many stay-at-home moms with more children). Life course of each participant was undoubtedly unique in many ways, which would be extremely difficult to describe in statistically approachable manner, would require extended sessions to collect the data, and due to expected limited reliability of self-reports, it may not be efficient. Our compromise on the range and volume of data collected is based on cited studies and also on the team's experience with previous research.

These limitations will be emphasized in our publications.

Conclusion

Our project aims to explore successful cognitive aging in older women, particularly its connections with physical activity engagement, sociodemographic characteristics, and general health. While acknowledging potential limitations, we anticipate the findings to offer practical insights into preventive strategies for successful aging and cognitive resilience. Additionally, our results may pave the way for future research investigating the phenomenon of cognitive SuperAging.

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CRediT author statement

HG: drafted the study (28%); MS: corresponding author, co-drafted and revised the manuscript (60%); JM, ZT, KD, RT, IV, and JL revised the manuscript (each 2%).

About authors

All authors work at the Prague College of Psychosocial Studies, where they are researchers of the COSACTIW study. Their other employments are not listed here.

PhDr. Hana Georgi, Ph.D. is a researcher in geropsychology. She is the COSACTIW`s principal investigator.
E-mail: hana.georgi@pvsps.cz

Mgr. Melisa Schneiderová is a doctoral student of clinical psychology at the Faculty of Arts, Charles University.
Pražská vysoká škola psychosociálních studií, Hekrova 805, 149 00 Praha 11-Háje.
E-mail: melissaschneiderova@seznam.cz
Corresponding author.

Mgr. Josef Mana is a doctoral student of neurosciences at the First Faculty of Medicine, Charles University, a psychologist and a statistician.
E-mail: ironmana@email.cz

Mgr. Zuzana Tichá, Ph.D. is a candidate for board certification in clinical psychology, and a researcher in psychology.
E-mail: frydrychova.zuzka@gmail.com

PhDr. Klára Daďová, Ph.D. is an expert in human movement science.
E-mail: klara.dadova@ftvs.cuni.cz

doc. Ing. Radek Trnka, Ph.D. is an anthropologist and an associate professor of psychology.
E-mail: trnkar@volny.cz

RNDr. Iveta Vojtěchová, Ph.D. is a behavioural neurobiologist.
E-mail: iveta.vojtechova@nudz.cz

doc. Mgr. Jiří Lukavský, Ph.D. is a cognitive psychologist and computational scientist.
E-mail: lukavsky@praha.psu.cas.cz

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