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Nutritional status and anthropometric measurements: their impact on cognitive function in the elderly

Stan odżywienia i pomiary antropometryczne: wpływ na funkcje poznawcze u osób starszych

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Abstract

Introduction and objective: State of nutrition plays an important role in maintaining well-being, especially in the elderly. Evidence suggests an association between nutritional status, age, and cognitive efficiency in this age group. The aim of the study was to assess the relationship between anthropometric measurements, physiological factors, and cognitive function outcomes in individuals over the age of 65. **Materials and methods:** The study was conducted in 2014–2015 at the Clinic of Old Age Psychiatry and Psychotic Disorders, Central Clinical Hospital, Medical University of Lodz. Forty-one participants were qualified for the study. The research methods included interviews, physical examinations, a clinical-demographic questionnaire, and the Cambridge Neuropsychological Test Automated Battery (CANTAB). **Results:** Waist and arm circumferences demonstrated a significant correlation with cognitive processing speed and accuracy, while hip circumference measurements showed associations with cognitive performance in tasks involving lexical memory and object naming. Physiological factors, including pulse rate and basal metabolic rate, were also found to impact cognitive performance metrics. Higher pulse rates were associated with longer subsequent thinking times during tasks, while variations in basal metabolic rate influenced problem-solving abilities and response latency. **Conclusions:** Waist and abdominal circumferences were linked to cognitive processing speed and memory, highlighting the role of abdominal adiposity in cognitive function among older adults. Hip circumference affected memory and object identification. Physiological factors such as pulse rate and basal metabolic rate were found to impact cognitive performance.

Keywords: cognitive functions, nutritional status, anthropometric measurements, elderly, CANTAB

Streszczenie

Wprowadzenie i cel: Stan odżywienia odgrywa ważną rolę w utrzymaniu dobrego samopoczucia, zwłaszcza u osób starszych. Można wnioskować, że istnieje związek między stanem odżywienia osób w podeszłym wieku a sprawnością poznawczą w tej grupie wiekowej. Celem badania była ocena związku między pomiarami antropometrycznymi, czynnikami fizjologicznymi i wynikami funkcji poznawczych u osób powyżej 65. roku życia. **Materiał i metody:** Badanie przeprowadzono w latach 2014–2015 w Klinice Psychiatrii Wieku Podeszłego i Zaburzeń Psychotycznych Centralnego Szpitala Klinicznego Uniwersytetu Medycznego w Łodzi. Do badania zakwalifikowano 41 osób. Wśród zastosowanych metod badawczych znalazły się: wywiad, badanie przedmiotowe, kwestionariusz kliniczno-demograficzny oraz Automatyczna Bateria Testów Neuropsychologicznych Cambridge (Cambridge Neuropsychological Test Automated Battery, CANTAB). **Wyniki:** Obwody talii i ramion wykazały istotną korelację z szybkością i dokładnością przetwarzania poznawczego, podczas gdy pomiary obwodu bioder wykazały związek z wydajnością poznawczą w zadaniach związanych z pamięcią leksykalną i nazywaniem obiektów. Stwierdzono również, że czynniki fizjologiczne, takie jak tętno i zapotrzebowanie kaloryczne, mają wpływ na wskaźniki wydajności poznawczej. Wyższe tętno wiązało się z dłuższym czasem myślenia w trakcie wykonywania zadań, podczas gdy zmiany przemiany materii wpływały na zdolność rozwiązywania problemów i opóźnienie reakcji. **Wnioski:** Obwody talii i brzucha były powiązane z szybkością przetwarzania poznawczego i pamięcią, podkreślając rolę otyłości brzusznej w funkcjonowaniu poznawczym osób starszych. Obwód bioder wpływał na pamięć i identyfikację obiektów. Stwierdzono, że czynniki fizjologiczne, takie jak częstość tętna i podstawowa przemiana materii, wpływają na pomiary wydajności poznawczej.

Słowa kluczowe: funkcje poznawcze, stan odżywienia, pomiary antropometryczne, osoby starsze, CANTAB

INTRODUCTION

The quality of life in older adults is significantly influenced by their sense of independence, which includes mobility and well-functioning cognitive abilities. Diet and nutritional status play an important role in maintaining health and well-being, especially in the elderly. In this context, nutritional status refers to the overall health condition of an individual as influenced by the intake and utilisation of nutrients. It encompasses the balance between nutrients consumed through food and how effectively the body uses these nutrients for growth, maintenance, and overall health. It measures how well the body functions, including energy levels, immune response, and muscle strength.

Dietary intake may influence the risk of cognitive decline through multiple mechanisms, including adverse changes in the gut microbiota (Stolzer et al., 2023), deficiencies in dietary fibre (Shi et al., 2021), and other nutrient deficiencies (e.g. B vitamins, vitamin D, carotenoids, polyunsaturated fatty acids) (Flanagan et al., 2020). However, the exact details and associations between diet quality and cognitive impairment remain uncertain. It is believed that specific dietary patterns may have a preventive effect and may help mitigate age-related cognitive decline, even Parkinson's or Alzheimer's disease (AD) (Ozawa et al., 2021). One of the larger studies (Smyth et al., 2015), which included a cohort from 40 countries, demonstrated that higher diet quality was associated with a reduced risk of cognitive decline.

It has been suggested that there is a relationship between body mass index (BMI) and cognitive function among the elderly (Seo et al., 2021; Zhang et al., 2017). Analysis of data collected from the China Health and Nutrition Survey database reveals that better nutritional status in older individuals (e.g. BMI >24.5 kg/m^2 or a higher level of high-density lipoprotein cholesterol in women) is associated with superior memory and cognitive function performance (Li et al., 2020). According to a study including the non-clinical elderly population living in Northern Italy (Fostinelli et al., 2023), nutritional status was significantly linked to cognitive domain attention and executive functions, and better nutritional status was directly associated with a better performance in attention/executive function. Similarly, in a study among Brazilian geriatric patients, participants with malnutrition and an unfavourable waist-hip ratio showed cognitive decline (Assis et al., 2020). Also, research conducted on the aging population in Greece showed that the prevalence of malnutrition was directly associated with cognitive impairment but also with depression (Mantzorou et al., 2020). For these reasons, the need to detect malnourished individuals is essential (Antczak-Domagała et al., 2013).

There is reasonable evidence that dietary patterns influence anthropometric measures, physiological parameters, and cognitive functions (Magierski et al., 2014). The present study aimed to explore the relationships between anthropometric measurements, physiological factors, and cognitive function in individuals aged 65 and older, with a focus on identifying specific associations within this population.

PARTICIPANTS AND PROCEDURE

The study was conducted during the period of 2014–2015 at the Clinic of Old Age Psychiatry and Psychotic Disorders, Central Clinical Hospital, Medical University of Lodz. This research was undertaken as part of the DemNutr (Dementia and Nutrition) project implemented in the HARC consortium – Healthy Ageing Research Centre, HARC FP7 RegPot. A total of 41 participants were recruited based on specific inclusion criteria: individuals aged over 65, residing in the community, not hospitalised, not residing in care facilities, without declared cognitive impairment, and with either confirmed cognitive impairment without dementia or diagnosed dementia (in accordance with the International Statistical Classification of Diseases and Related Health Problems, 10th revision, ICD-10 diagnostic criteria resulting in the Mini–Mental State Examination, MMSE >18 points). Additionally, inclusion required the presence of a caregiver enabling precise evaluation of interview data.

Exclusion criteria encompassed individuals diagnosed with moderate and severe dementia syndrome, absence of a caregiver during the interview and examination, and the presence of somatic illnesses significantly influencing the assessed parameters (such as cancer), as well as undergoing chemo- and radiotherapy, connective tissue diseases, chronic or acute inflammation, and decompensated chronic conditions such as diabetes.

The study protocol involved an interview, physical examination, clinical-demographic survey questionnaire, and the Cambridge Neuropsychological Test Automated Battery (CANTAB). All patients provided written consent to participate in the study.

In the evaluation of specific cognitive parameters, five tests selected from the CANTAB tool (Cambridge Cognition, aCANTAB, adjusted for age and gender, and standardised, indicating the number of standard deviations from the standard zero. This standardisation corresponds to the intended range of standards, with negative scores signifying failure

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to attain the standardised value. In this study, results were expressed in arbitrary units [a.u.].

The Motor Screening test served as the initial component of the test battery, providing participants with an introduction to the touchscreen interface (Soares, 2015). Participants were presented with crosses in various locations on the screen and instructed to touch each cross using the forefinger of their dominant hand as swiftly and accurately as possible. The outcomes of the motor screening measured the participant's speed of response and pointing accuracy. Results were presented as mean latency and mean error.

The Paired Associates Learning (PAL) test evaluated episodic memory and associative learning of stimulus-location pairings (Barnett et al., 2016). In the presentation stage, six boxes opened sequentially, revealing different patterns inside. During the recall stage, the patterns reappeared individually in the middle of the screen, and participants responded by touching the corresponding box in the periphery where the pattern had previously appeared (Sahakian and Owen, 1992). Participants were required to match each pattern with its previously seen location. Test results were expressed as standard scores for total errors (adjusted) and total errors adjusted for six shapes. Failure to complete a stage correctly resulted in test termination after four unsuccessful attempts within one stage. The PAL primarily evaluates visual memory.

The Stockings of Cambridge test assessed executive functions in spatial planning (Dassanayake and Ariyasinghe, 2019). It is a modified version of the Tower of London task introduced by Shallice (1982), with analogous test problems. Participants were presented with two displays containing coloured balls stacked within stockings. The task was to replicate the pattern shown in the upper display using the balls in the lower display. Outcome measures included mean initial thinking time, mean subsequent thinking time, and problem-solving efficiency, all expressed as standard scores. Failure to complete a stage correctly resulted in test termination.

The Graded Naming Test evaluated semantic memory, akin to the original task by McKenna and Warrington (1980). Participants were shown a series of 30 black-and-white drawings, ranging from highly familiar to more challenging objects, and were asked to name each drawing. Results were expressed as standardised scores for the percentage of correct answers.

METHODS

To identify robust associations between nutritional status and clinical endpoints, a linear model approach was utilised. The dependent variable was defined as one of the components of nutritional status (in total, 22 different outcomes were tested) and the independent variables comprised the ensemble of clinical (cognitive) outcomes (in total, nine distinct variables were considered). Association tests were conducted between each of the 22 dependent variables separately and all nine independent variables together. This resulted in a series of 22 analyses, each including nine tests. This method avoids the strict FDR correction for 22 × 9 tests and this correction was only performed 22 times for the nine associations tested at a time. This approach was taken due to the relatively small sample size, as the power analysis did not allow for a fully agnostic approach in which all 22 dependent variables were considered as one experiment.

To regress out the effects of known predictors of cognitive outcomes, each of the 22 linear models included additional independent variables: age, sex, body mass, height, and waist-to-height ratio (WHR) into account (alongside the nine cognitive outcomes) in the definition of the design matrix.

The models were fitted by means of the limma package in R, and principal component analysis (PCA) as well as correlation analyses were performed with the aid of default functions in R.

RESULTS

Linear models for association testing

Using the approach based on linear models as described in the Methods section, several robust associations between the indicators of nutritional status and neurocognitive outcomes were discovered. Tab. 1 summarises these findings and contains only associations with adjusted *p*-values (false discovery rate, FDR) below the 0.05 significance threshold (here, again, the FDR correction was performed separately for each of the 22 dependent variables).

Due to a small number of positive findings, a power analysis was performed, revealing that a sample size approximately three times larger would be required to apply multiple-comparison correction across all tested hypotheses simultaneously (i.e. FDR correction across all 22 × 9 comparisons), assuming the simulated effect-size distribution estimated from the current data.

The proposed method utilises the empirical Bayes correction of coefficient estimates and therefore leads to more robust results by reducing the number of parameters (Tab. 1). The results reveal a positive association between mean latency and: (1) *hip circumference*; (2) *waist circumference* (WC) *at the umbilicus level*; (3) *abdominal circumference at the level of the iliac crests*, and a negative association between mean latency and fat. At the same time, positive associations were observed between: (1) *abdominal circumference at the level of the lower ribs* and *total errors adjusted*; (2) *arm circumference* and *total errors in the six shapes adjusted*.

Correlation between neurocognitive variables

According to our data, only three neurocognitive outcomes were found to be associated robustly with nutritional status. In fact, nutritional status was predominantly

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Waist circumference at the level of the umbilicus			
Variable	*logFC*	*P.Value*	*adj.P.Val*
Reaction time (mean latency)	**0.15**	**0.001**	**0.01**
Abdominal circumference at the level of the lower ribs			
Variable	*logFC*	*P.Value*	*adj.P.Val*
Visual memory (total errors, adjusted)	**–0.12**	**0.01**	**0.05**
Abdominal circumference at the level of the iliac crests			
Variable	*logFC*	*P.Value*	*adj.P.Val*
Reaction time (mean latency)	**0.14**	**0.004**	**0.03**
Hip circumference			
Variable	*logFC*	*P.Value*	*adj.P.Val*
Reaction time (mean latency)	**0.13**	**0.002**	**0.02**
Arm circumference			
Variable	*logFC*	*P.Value*	*adj.P.Val*
Visual memory (total errors, 6 shapes, adjusted)	**0.22**	**0.002**	**0.02**
Body fat			
Variable	*logFC*	*P.Value*	*adj.P.Val*
Reaction time (mean latency)	**–0.45**	**0.003**	**0.03**
logFC corresponds to the change in the target indicator of the nutritional status when the predictor associated with neurocognitive outcome changes by +1. *P*.Value is the nominal *p*-value for the test based on the likelihood ratio, and adj.*P*.Val stands for the FDR adjusted *p*-value.			

Tab. 1. Associations between indicators of nutritional status and neurocognitive variables

associated with mean latency. Hence, a correlation analysis was performed to test for associations between the cognitive variables. It can be concluded that the phenomenon whereby only a single cognitive outcome (mean latency) is robustly associated with nutritional status should not be seen as an artifact of the data. In other words, it cannot be interpreted by simply looking at the covariance matrix of the neurocognitive variables as one might expect – i.e. mean latency is not strongly correlated with the majority of variables (Fig. 1).

To further explore this issue, we performed PCA on the neurocognitive data. The first three components account for more than 10% of the total variance (0.3669, 0.2097 and 0.1599). Subsequently, correlation analyses were performed between the variables and components to conclude that mean latency was, in fact, the variable with the highest average correlation with these three leading components – all correlations had a negative value. Mean latency was only mildly negatively correlated (rho = –0.33) with mean error. Therefore, mean latency may be seen as the predominant source of variability in our data, making it more likely that it correlates with all variables describing nutritional status (Fig. 2).

Significant correlations were observed between specific anthropometric measurements and cognitive performance. Waist and arm circumferences were significantly associated with cognitive processing speed and accuracy. Additionally, hip circumference showed notable associations with performance in lexical memory and object naming tasks. Physiological factors also played a role in cognitive outcomes: higher pulse rates were linked to longer thinking times during cognitive tasks, while variation in basal metabolic rate (BMR) influenced problem-solving abilities and response latency. These results suggest that both body composition and physiological function may impact cognitive performance in older adults.

DISCUSSION

The findings of this study shed light on potential relationships between anthropometric measurements and cognitive function outcomes. The analysis revealed several statistically significant correlations between physical measurements and cognitive performance metrics across various domains. WC measured at the umbilicus level was found to be significantly correlated with cognitive processing speed and accuracy, indicating its potential influence on information-processing efficiency. Moreover, abdominal circumference measured at the level of the iliac crests showed significant associations with cognitive performance metrics, highlighting the relevance of abdominal adiposity in understanding cognitive function. Additionally, hip circumference was identified as a significant factor affecting cognitive performance in tasks related to lexical memory and object naming, suggesting its impact on recall and object identification abilities.

Previous research has reported nuanced results, suggesting that the association between WC and cognitive function varies across age groups and between men and women. Notably, larger WC was associated with better attention/working memory among younger old women (aged 65–74 years), while larger WC was linked to better learning/acquisition among younger old men in the same age group (Waki et al., 2020). In contrast, among older old men (aged 75–84 years), larger WC was associated with worse performance

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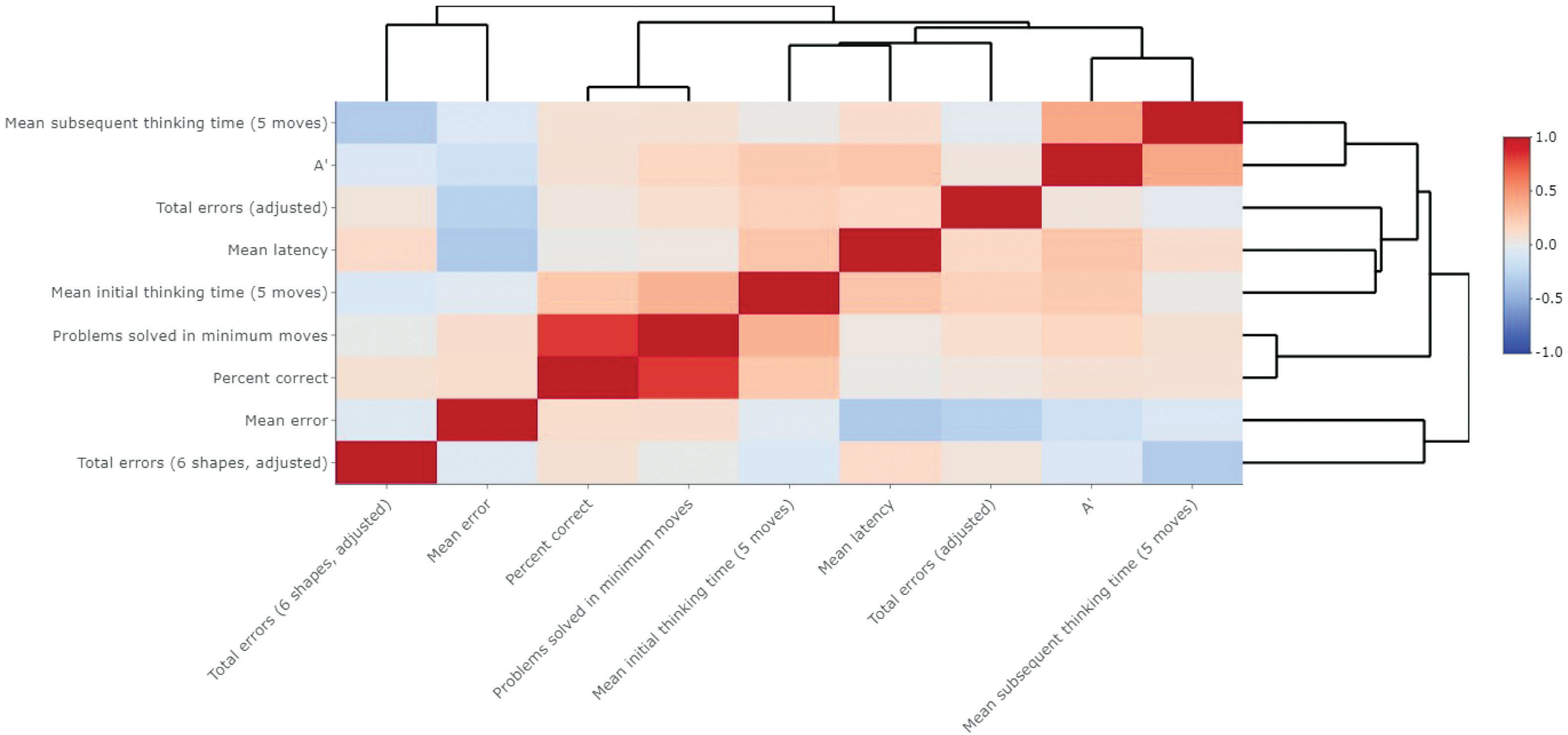
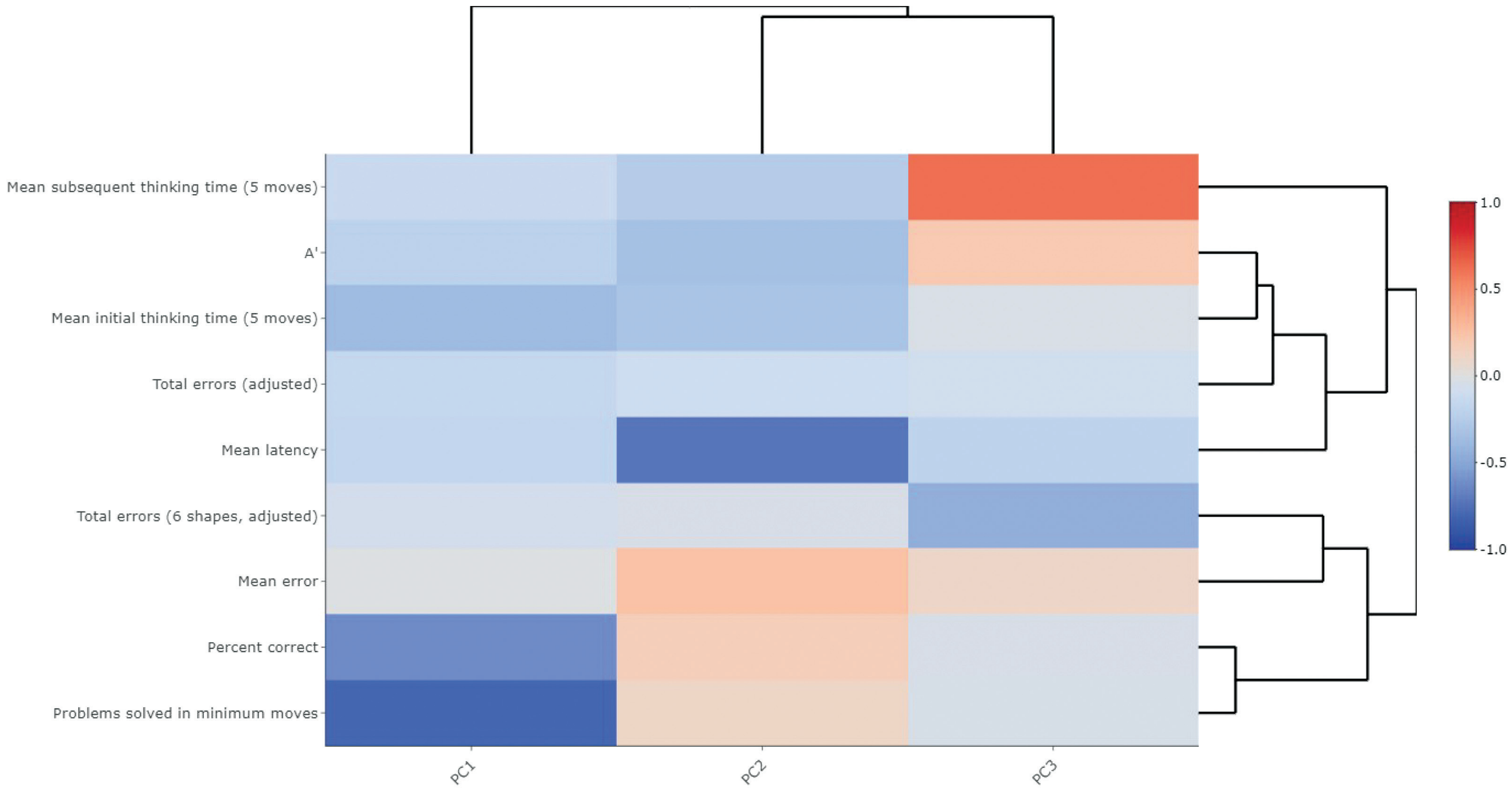


Mean error – accuracy in reaction (mean error); percent correct – lexical retrieval (percent correct); problems solved in minimum moves – planning ability (problems solved in minimum moves); total errors (6 shapes, adjusted) – associative learning and memory (6 shapes, adjusted); total errors (adjusted) – associative learning and memory (adjusted); mean latency – reaction time (mean latency); mean initial thinking time (5 moves) – planning and foresight (mean initial thinking time, 5 moves); A' – discriminatory attention (A'); mean subsequent thinking time (5 moves) – executive functioning (mean subsequent thinking time, 5 moves).

Fig 1. Strength and direction of correlations between neurocognitive variables (heatmap with Kendall's tau coefficient)



Mean error – accuracy in reaction (mean error); percent correct – lexical retrieval (percent correct); problems solved in minimum moves – planning ability (problems solved in minimum moves); total errors (6 shapes, adjusted) – associative learning and memory (6 shapes, adjusted); total errors (adjusted) – associative learning and memory (adjusted); mean latency – reaction time (mean latency); mean initial thinking time (5 moves) – planning and foresight (mean initial thinking time, 5 moves); A' – discriminatory attention (A'); mean subsequent thinking time (5 moves) – executive functioning (mean subsequent thinking time, 5 moves).

Fig 2. Strength and direction of correlations between the first three principal components and neurocognitive variables (heatmap with Kendall's tau coefficient)

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across multiple cognitive domains, including learning/acquisition, memory, attention/working memory, and language/fluency (Waki et al., 2020).

Arm circumference displayed significant associations with cognitive processing speed and accuracy, as well as with error rates and memory scores during task performance. This suggests that arm morphology may play a role in certain cognitive functions, potentially related to motor skills or spatial memory.

The findings of a study conducted using data from the China Health and Nutrition Survey revealed a significant positive association between higher mid-arm muscle circumference (MAMC) and better cognitive performance in older adults (Spangler et al., 2024). This suggests that arm morphology, as reflected by MAMC, may play a role in certain cognitive functions, potentially related to motor skills or spatial memory. The study's rigorous methodology, including standardised protocols for data collection and analysis, strengthens the validity of the findings, while the large and diverse sample size enhances their generalisability (Spangler et al., 2024).

Results indicated that higher MAMC was associated with better cognitive function across all ages. In minimally adjusted models, each 1-standard-deviation increase in MAMC was associated with a 13-point increase in global cognitive function (Spangler et al., 2024). This positive association remained consistent even after further adjustment for lifestyle behaviours, weight status category, and self-reported diagnoses of hypertension, diabetes, and myocardial infarction or stroke. Similar positive associations were observed between other measures of arm muscle mass, including mid-arm area, arm muscle area, and arm fat area – and cognitive function (Spangler et al., 2024).

Moreover, physiological factors such as pulse rate and BMR were found to be correlated with cognitive performance metrics. Higher pulse rates were positively associated with mean subsequent thinking time during 5-move tasks, while variations in BMR influenced problem-solving ability and response latency.

The study utilised Mendelian randomisation analysis to investigate the causal relationship between BMR and AD. Results indicated that higher BMR was associated with a reduced risk of AD (Zou et al., 2023). This finding suggests that elevated BMR, determined by innate genetic factors, may serve as a protective factor against the development of AD (Zou et al., 2023). Additionally, the study found evidence that height and weight, which influence BMR, may also affect the risk of AD (Zou et al., 2023). These results contribute to the understanding of the physiological factors underlying cognitive function and the risk of neurodegenerative diseases such as AD.

CONCLUSIONS

In conclusion, this study revealed significant correlations between anthropometric measurements, physiological factors, and cognitive function outcomes in aging individuals. Measures of waist and abdominal circumference were notably associated with cognitive processing speed and memory performance, emphasising the relevance of abdominal adiposity in understanding cognitive function among older adults. Additionally, hip circumference influenced cognitive performance in tasks related to memory and object identification. Physiological factors, such as pulse rate and BMR, were also found to impact cognitive performance metrics.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organisations which might negatively affect the content of this publication and/or claim authorship rights to this publication.

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Author contribution

Original concept of study: RM, TS. Collection, recording and/or compilation of data: KK, MS, RM, KAP. Analysis and interpretation of data: MS. Writing of manuscript: KK, MS, RBG, KAP. Critical review of manuscript: TS. Final approval of manuscript: TS, KAP.

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