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Original Research Article

IMPACT OF BODY COMPOSITION AND HYDRATION ON COGNITIVE PERFORMANCE IN ADULT HEALTHCARE STAFF

Jaya Khatri[1], Manish Kumar Verma [2], Rajani Bala Jasrotia 3, Vibha Gangwar [4]

[1]*PG Resident, Department of Physiology, Dr Ram Manohar Lohia Institute of Medical Sciences, Lucknow, Uttar Pradesh, India.*
[2]*Professor Junior Grade, Department of Physiology, Dr Ram Manohar Lohia Institute of Medical Sciences, Lucknow, Uttar Pradesh, India.*
[3]*Professor and Head, Department of Physiology, Dr Ram Manohar Lohia Institute of Medical Sciences, Lucknow, Uttar Pradesh, India.*
[4]*Professor Junior Grade, Department of Physiology, Dr Ram Manohar Lohia Institute of Medical Sciences, Lucknow, Uttar Pradesh, India.*

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Corresponding Author:
Dr. Jaya Khatri,
PG Resident, Department of Physiology, Dr Ram Manohar Lohia Institute of Medical Sciences, Lucknow, Uttar Pradesh, India.
Email: jayakhatri586@gmail.com

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ABSTRACT

Background: Water is a vital nutrient that keeps the body balanced and functioning properly. Even a slight dehydration, such as losing 1% to 2% of body's water content, can impair ability to function both intellectually and physically. Hydration levels and body composition can be checked with Bioelectrical Impedance Analysis (BIA). Cognition is defined as a process of knowing an individual's awareness. Cognitive function is assessed by cognitive evoked potential and reaction time.

Materials and Methods: Cross sectional observational study was done among 70 adult healthcare staff from age 26 years to 44 years. Hydration status and body composition parameters were assessed by Bioelectrical Impedance Analysis method and Cognitive Performance was assessed by measuring Reaction time both auditory and visual and Cognitive evoked potential. Multivariate regression analysis was performed to assess the effects of body composition parameters on cognitive performance.

Results: The regression analysis highlights gender and BMI as the determinants of body composition. Male gender was associated with higher hydration, lean mass, muscle mass, fat-free mass whereas BMI was the strongest predictor of fat-related parameters and influenced fat-free mass. Reaction time and P300 latencies are neurophysiological measures that are minimally influenced by body composition differences.

Conclusion: The findings demonstrate that body composition parameters did not independently predict either visual or auditory P300 latency or reaction time. This implies that P300 latency and reaction time are relatively stable neurophysiological markers in a healthy adult population that are largely insensitive to changes in body composition and hydration.

Keywords: Body Composition, Hydration, Cognitive Performance, Bioimpedance Analysis, Reaction time.

INTRODUCTION

Water is an important nutrient for life. Total body water makes up between 45–75% of body weight. A reduction in water consumption might impact physical performance and new research indicate that cognitive function may also be influenced. This study will examine hydration status and body composition and their relation with cognitive performance in adult healthcare staff.

Hydration is having enough fluid in different parts of the body. To evaluate body fluid volumes and hydration parameters in the general population and in patient bioelectrical impedance analysis (BIA) and bioelectrical impedance vector analysis (BIVA) are increasingly used in the last few years.[1,2] The body fluid volumes and hydration parameters, ratios were calculated for further analyses, namely TBW (Total body water) /Body mass, TBW/FFM (total body water to fat free mass), ECW/TBW (extracellular water to total body water), ICW/FFM (intracellular water to fat free mass), and ECW/ICW (extracellular water to intracellular water), Resistance (R) / Height (H) , and Reactance (Xc) / height (H).[3]

Cognition is the process of knowing what someone is aware of. Cognitive functions include memory, critical thinking, learning concepts, paying attention, and concentration. In cognitive performance assessment, the accuracy and/or speed of a response are evaluated. P300, also known as cognitive evoked potential, is an endogenous potential characterized by its latency in normal person. P300 is used to record reaction time. Reaction time tasks give baseline assessments of sensorimotor integration and processing speed that can be linked to neurophysiological indicators like P300.

Endogenous Event related potential (ERP) do not depend only on the individual's physical attributes, but also on brain reactions. The ERP are magnetic waves, where the third positive wave is known as P3 or P300, since it occurs around 300 milliseconds after the presentation of the stimulus. One of variables used to quantify the P300 is latency, which is related to information processing time, and amplitude. To evaluate the classic P300 (P3b), the oddball paradigm is usually used, by which subjects are instructed to discriminate the rare stimulus while irrelevant stimuli are also being presented. Tasks can be auditory, with stimuli at different sound frequencies or visual with presentation of figures.[4]

Cognitive performance diminishes when there is 2% or more than 2% body water loss. Hydration aids equilibrium and brain function. Since the brain is sensitive to fluid balance fluctuations, staying hydrated is crucial for cognitive performance. Mild dehydration can lead to cognitive performance issues such as diminished focus, prolonged reaction time, short-term memory deficits, emotional instability, and heightened anxiety. In adults, cognitive performance can be affected by water consumption, and sufficient daily hydration is essential for sustaining optimal cognitive function. Thus the aim of this study is to see the impact of body composition and hydration status on cognitive performance in adult healthcare staff. Further the objectives are to measure the association between total body water and cognitive performance by Reaction time in adult healthcare staff.

MATERIALS AND METHODS

This is cross sectional observational study conducted in Department of Physiology, Dr. Ram Manohar Lohia Institute of Medical Sciences, Lucknow, Uttar Pradesh after Ethical clearance obtained from the institutional ethics committee before the commencement of the study. (IEC No.-78/24). Study was done among Adult health care staff from age 26 years to 44 years. Given that average reaction time is (295.59±48.30) milliseconds. Sample size was 70.

Mean ($\bar{x}$)=295.59
Standard deviation(s) = 48.30
Margin of error(d) = 4% of mean
= 0.04*295.59 = 11.82
α is the level of significance i.e 5% @ $Z_{1-\alpha/2}$ =1.96
Z is normal standard variate
Sample size formula given below,

$$n=\frac{Z^2_{1-\frac{\alpha}{2}} \times S^2}{(d\ \bar{x})^2}$$

$$n = \frac{(1.96)^2 \times (48.30)^2}{(11.82)^2}$$

n = 64.10 ≅ 64

Adding 10% of loss of data then optimum sample size is

$$N = \frac{n}{1-0.1} = \frac{n}{0.9} = 71.22 \cong 70$$

Participants included were Adult healthcare staff with age >26 years and <44 years of good health. Both male and female gender are included. Subjects with age <26 years and > 44 years and who smoke or have consumption of habitual alcohol were excluded. Subjects who have habitual high caffeine (>250g/dl) and with intense physical activity were excluded. Also Subjects with history of fever, diarrhoea, allergy, or any chronic cardiovascular, liver, renal, neurological medical illness or endocrine disorder, or subjects on diuretics and steroid therapy and females with Pregnancy or lactation were excluded.

Written Informed consent was taken from all the subjects to participate in the study. Subjects were instructed not to undergo strenuous activities, they maintained normal diet, avoid alcohol consumption during 24 hours.

Hydration and Body Composition- It was measured through Bio-impedance analysis method using BIOPARHOM SAS Z METRIX (MADE IN FRANCE)

Cognitive evoked potential (P300) And Reaction time–It was measured in all subjects by using Neuro- MEPNET (Neuro-software version 4.4.9.0) in Neurophysiology lab of department of Physiology of Dr. R.M.L.I.M.S, Lucknow for the analysis of latency of P300 and Reaction time. Two types of stimulus meaningful and non-meaningful were given. Electrode placement for recording of P300 or P3 and reaction time (both auditory and visual) according to 10-20 montage system.

The study variables reported in continuous and categorical format. For the continuous variable test the normality. All continuous variables summarized as mean ± SD. Categorical variable presented as percentage and frequency was compared using Chi Square test. A p value <0.05 is considered statistical significance as per hypothesis. Adequate statistical test were applied as per objectives of the study. Statistical analysis was done using MS Excel and R statistical software.

RESULTS

The body composition analysis of participants demonstrated relatively symmetrical findings between the right and left sides of the body, with consistent average values across key parameters as shown in Table 1.

Table 1: Descriptive Summary of Body Composition of Study Subjects

Body Composition	Right		Left		Average	
	Mean	SD	Mean	SD	Mean	SD
Total Body Water	31.1	7.2	30.0	6.2	30.55	6.40
ECF and ICF Ratio (%)	76.39	11.94	71.1	7.7	73.76	8.72
Body Hydration	52.43	7.37	50.93	5.38	51.68	5.91
Total Body Protein	8.80	2.89	8.60	4.38	8.70	3.24
FAT MASS	15.01	5.79	14.68	10.46	14.84	7.77
Fat Mass (%)	24.83	7.27	22.68	9.24	23.76	8.08
Fat Mass Index	5.71	2.62	5.08	2.70	5.40	2.57
lean body mass	42.24	9.38	40.01	11.48	41.12	10.04
lean mass index	18.42	11.27	18.55	13.67	18.48	9.35
Lean mass (%)	69.34	14.85	65.84	13.97	67.59	11.79
FAT FREE MASS	45.2	8.2	45.6	8.8	45.41	8.24
FAT free mass (%)	75.24	7.18	74.60	12.88	74.92	8.83
Fat free mass index	16.98	1.76	16.97	2.23	16.97	1.87
Muscle mass	22.09	7.79	21.20	7.58	21.64	7.59
Muscle mass (%)	36.09	9.34	34.51	8.88	35.30	8.96
Muscle mass index	8.00	2.16	8.33	3.82	8.17	2.56

The average total body water was 30.55 ± 6.40, indicating an overall healthy hydration level. The ECF and ICF ratio averaged 73.76 ± 8.72%, while the body hydration level was 51.68 ± 5.91, showing adequate fluid distribution and balance within body compartments. In terms of body composition, the total body protein averaged 8.70 ± 3.24, and the fat mass was 14.84 ± 7.77, contributing to an average fat percentage of 23.76 ± 8.08%. The fat mass index was 5.40 ± 2.57, suggesting a moderate fat distribution relative to body size. The lean body mass averaged 41.12 ± 10.04, with a lean mass index of 18.48 ± 9.35 and lean mass percentage of 67.59 ± 11.79, indicating a predominance of lean tissue in the overall body composition. Similarly, the fat-free mass was 45.41 ± 8.24, with a fat-free mass percentage of 74.92 ± 8.83 and an index of 16.97 ± 1.87, further reflecting good muscle and bone tissue composition. The muscle mass component averaged 21.64 ± 7.59, contributing 35.30 ± 8.96% to total body weight, with a muscle mass index of 8.17 ± 2.56.

The assessment of cognitive performance parameters revealed that the participants demonstrated overall efficient cognitive and sensory-motor functioning as shown in table 2. The mean auditory reaction time was 271.21 ± 53.22 milliseconds, while the mean visual reaction time was slightly longer at 346.10 ± 38.59 milliseconds, indicating that participants responded more quickly to auditory than visual stimuli — a commonly observed trend due to faster auditory processing pathways.

Table 2: Descriptive Summary of Cognitive Performance of Study Subjects

Cognitive Performance	Mean	SD
Auditory reaction time	271.21	53.22
Visual reaction time	346.10	38.59
Latency p300 millisec Auditory	302.69	9.48
Latency p300 millisec Visual	317.71	19.41
MOCA score	28.81	1.30

The mean latency of P300 auditory potential was 302.69 ± 9.48 milliseconds, and the visual P300 latency was 317.71 ± 19.41 milliseconds, suggesting normal event-related potential responses and intact cognitive processing speed.

Overall, the findings indicate that the participants possessed good levels of attention, perception, and cognitive integrity, with only minimal inter-individual variation observed in reaction times and P300 latencies.

The correlation analysis between body composition parameters and cognitive performance was performed using Pearson's correlation coefficient to identify potential associations between physiological and neurocognitive indices as shown in table 3.

Table 3: Correlations of Body Compositions with Cognitive Performance

Pearson Correlation	Auditory reaction time		Visual reaction time		Latency p300 millisec Auditory		Latency p300millisec Visual	
	r-value	p-value	r-value	p-value	r-value	p-value	r-value	p-value
Total Body Water	-.102	.401	-.161	.183	-.261	.029	-.128	.290

ECF and ICF Ratio (%)	.080	.512	.085	.485	-.049	.690	.122	.313
Body Hydration	.084	.488	-.014	.907	.074	.542	.069	.571
FAT MASS	-.018	.884	-.093	.445	-.229	.056	-.137	.257
Fat Mass (%)	.020	.871	-.003	.982	-.045	.712	-.037	.761
Fat Mass Index	-.032	.794	-.093	.445	-.090	.457	-.081	.505
lean body mass	-.184	.127	-.140	.247	-.310	.009	-.198	.100
lean mass index	-.114	.346	-.089	.462	-.010	.937	-.022	.859
FAT FREE MASS	-.149	.220	-.213	.076	-.337	.004	-.222	.065
Fat free mass index	-.097	.424	-.170	.158	-.223	.063	-.193	.110
Muscle mass	-.160	.187	-.159	.189	-.229	.056	-.069	.571
Muscle mass index	-.183	.130	-.115	.344	-.243	.042	-.064	.598

Among the variables studied, latency of auditory P300 showed a significant negative correlation with several body composition measures, indicating that better body composition (i.e. higher lean or fat-free components) was associated with faster cognitive processing.

DISCUSSION

In the present study the participants were primarily aged 26 to 32 years (64.3%), with 21.4% aged 33 to 38 years and 14.3% aged 39 to 44 years, resulting in a mean age of 31.51 ± 5.25 years. The average total body protein (8.70 ± 3.24) indicates sufficient nutritional and functional status, as body protein content mostly reflects skeletal muscle and visceral protein reserves. The average fat mass of 14.84 ± 7.77 and fat percentage of 23.76 ± 8.08% suggest moderate obesity within physiologically tolerable parameters. Hydration affects cognitive performance through biochemical and physiological pathways. Dehydration alters blood flow, neurotransmitter activity, and electrolyte balance, affecting brain function. Dehydration reduces cerebral blood flow and increases stress hormone levels, which impairs cognitive function. Dehydration increases brain oxidative stress, which impairs cognition. ECW/ICW is a measure of fluid volume shift between the compartments and can be an indicator for systemic inflammation, pathologies or aging.[5]

Lean body mass made up a large part of total body weight, with a mean value of 41.12 ± 10.04 and a lean mass percentage of 67.59 ± 11.79. Fat-free mass also made up three-quarters of total body weight (74.92 ± 8.83%). These results indicate a prevalence of metabolically active tissue, typical of healthy young to middle-aged persons

Hydration is crucial for cognitive function, especially memory. The result supports earlier findings that hydration improves cognition. However, it highlights the need for more research on how hydration affects different cognitive domains and groups.

Bioelectrical impedance analysis (BIA) is widely used for estimating body composition including total body water (TBW), fat-free mass (FFM), and extracellular/intracellular water compartments. However, hydration changes can significantly influence BIA measurements, sometimes leading to misclassification of body composition components unless hydration status is standardized before measurement.[6]

In the present study, the mean auditory reaction time (ART) was 271.21 ± 53.22 ms, which was shorter than the visual reaction time (VRT) of 346.10 ± 38.59 ms. This finding aligns with established neurophysiological principles, as auditory stimuli are processed more fast than visual stimuli due to reduced synaptic delays and expedited conduction through the auditory pathways.

Faster reactions in the auditory when compared to the visual condition even with a signal transmission delay of 26 ms support the relevance of acoustic information processing faster and emphasize the auditory system promising target for training interventions.[7]

The relatively narrow standard deviation observed for auditory P300 latency (± 9.48 ms) compared with visual P300 (± 19.41 ms) may indicate greater consistency in auditory stimulus evaluation. This phenomenon has been noted in ERP study done by Kestens K et al. where auditory paradigms yield more temporally stable responses than visual paradigms, possibly due to reduced variability in perceptual encoding.[8]

This difference indicates faster brain processing and motor response start for auditory stimuli. Among the parameters examined, the latency of auditory P300 exhibited a strong negative connection with several body composition parameters, suggesting that body composition having more lean or fat-free components is linked to better cognitive processing. There were significant negative correlations between latency of auditory P300 and total body water ($r = –0.261$, $p = 0.029$), lean body mass ($r = –0.310$, $p = 0.009$), fat-free mass ($r = –0.337$, $p = 0.004$), muscle mass index ($r = –0.243$, $p = 0.042$), bone mineral content ($r = –0.272$, $p = 0.023$), and serum creatinine ($r = –0.238$, $p = 0.047$).

Body composition however measured (e.g., BMI, lean mass, fat distribution) also appears related to cognition, though research in healthy adult workers is less. For people with metabolic conditions, higher BMI and lean mass were associated with better cognitive scores, while visceral and abdominal obesity were linked with an increased risk of cognitive impairment. In healthcare staff, who often experience irregular shifts, stress, and variable physical activity, body composition may interact with hydration status to influence cognitive performance, potentially through inflammation, insulin sensitivity, or cerebrovascular mechanisms.[9]

Hydration status plays a key role in neurocognitive performance. Research in healthy adults generally supports that hypohydration impairments are seen in aspects of cognitive performance, attention, and reaction speed, although the strength of these effects varies. Hypohydration (body water loss >2% of body weight) has been associated with poorer performance on tasks requiring attention and executive function, while simple reaction time responses are less consistently affected in young, otherwise healthy participants.[10]

Fabea L et al in their study found that high body fat percentage, low muscle mass, and unfavourable body fat distribution (waist-to-hip ratio) are significantly associated with cognitive function. Increased muscle mass appeared to have a positive influence on cognitive function, whereas high body fat had a negative association.[11]

A Complementary pilot research using detailed body composition measures in older adults found that total body water percentage (%TBW) showed strong relationships with memory, learning, and psychomotor speed — suggesting that not just fluid intake, but how water is distributed within body compartments, may affect specific cognitive domains. These findings imply that body composition metrics such as TBW and extracellular water could act as intermediate variables linking hydration physiology with brain function.[12]

CONCLUSION

In the present study, univariate linear regression analysis was conducted to see if individual body composition factors independently forecasted auditory P300 latency, a recognized electrophysiological indicator of cognitive processing speed. Several body composition variables exhibited a negative regression coefficient, suggesting a correlation between improved body composition and reduced P300 delay, however none of these relationships achieved statistical significance. These results indicate that whereas body composition may correlate with neurophysiological processing speed, no single measure independently accounts for the diversity in auditory P300 latency within the study population. These results highlight the necessity of integrating comprehensive body composition studies instead of merely depending on anthropometric indices when investigating physiological factors influencing cognition. However the present study has few limitations, it was conducted with a relatively small sample size which may limit the statistically power of finding and restrict the generalizability of the result. The present study has not assessed the effect of nutritional intake on various body composition parameters and its association with cognitive performance in adult healthcare staff.This study offers an extensive assessment of hydration status, body composition, and their correlations with cognitive and neurophysiological performance among adult healthcare personnel aged 26 to 44 years. Neurophysiological metrics of cognitive processing, such as auditory and visual reaction times and P300 latencies, exhibited considerable independence from body composition metrics. The lack of significant associations indicates that fundamental psychomotor speed and cortical stimulus evaluation processes remain stable during early and mid-adulthood, exhibiting relative resilience to fluctuations in hydration status and body composition. The study also stresses how important it is for healthcare workers, who often work long hours, have high cognitive demands, and don't drink enough fluids. These circumstances may render them susceptible to chronic mild dehydration and detrimental alterations in body composition, potentially impacting cognitive health adversely over time. These findings underscore the significance of integrating body composition and hydration assessment into physiological and occupational health evaluations, and they validate the efficacy of electrophysiological measures, such as P300 latency, as sensitive instruments for elucidating cognitive processing. Additional longitudinal studies are necessary to investigate whether persistent changes in hydration status and body composition result in quantifiable cognitive decline in later adulthood.

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