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Comparative Adiposity Study of a Body Shape Index and Body Adiposity Index with BMI using DEXA as Gold Standard

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Abstract: Introduction: In today's world, rising obesity epidemic is one of the biggest healthcare challenges which subsequently contributes towards other significant health issues like diabetes, musculoskeletal diseases certain cancers and cardiovascular diseases. Various anthropometric measures like BMI, body adiposity index(BAI), ABSI has been devised for estimating the body fat. Objective: This current study was conducted to assess the agreement of a body shape index (ABSI) and body adiposity index (BAI) measurement methods with body mass index (BMI) using DEXA as gold standard for estimating the adiposity of the body. Methodology: A cohort study was conducted on a total of 40 subjects belonging to the age group of 25-45 years. The subjects underwent a 24-hour dietary recall. Data pertaining to frequency of food intake, general health, social habits and lifestyle were collected through a questionnaire. Routine demographic details were collected and measurements of height, weight, waist circumference and hip circumference were performed using the SECA scale. Biochemical parameters evaluated includes: lipid profile and blood sugar levels. The subjects were screened for the risk of cardiovascular disease and diabetes. Body adiposity measures like BMI, BAI, ABSI and DEXA were calculated to estimate the body's adiposity. The statistical analysis of the data was performed with Medcalc software. Results: Correlation studies revealed gender (r -0.727, P <0.001, CI -0.847 to -0.537), BMI (r 0.76, P <0.001, CI 0.592 to 0.868), BAI (r 0.69, P <0.001, CI 0.482 to 0.824), ABSI (r -0.37, P 0.019, CI -0.611 to -0.066) and region fat percentile (r 0.99, P <0.001, CI 0.99 to 0.99) as significantly correlated with DEXA tissue fat percentile. A strong positive correlation was also observed between DEXA tissue percentile and measurements like BMI, BAI and region fat percentile, whereas the correlation with ABSI was moderate inverse. Insignificant correlation was attained with variables like age and bone mineral content. However, the inter-rater agreement statistics performed on classified variables showed that BMI possessed significant moderate agreement (K = 0.54) and BAI had poor agreement (K = 0.14) with DEXA tissue fat percentile. Additionally, mountain plot analysis revealed a positive bias of 9.35 between BMI and DEXA tissue fat (%) (limits of agreement -5.89 to 25.72), and a bias of 4.44 for BAI, with more variability (limits of agreement between -13.58 and 22.48) compared to BMI.

Conclusion: From the current study we can conclude that, BMI, BAI and ABSI underestimate the body adiposity when compared to DEXA tissue fat %. Additionally, BAI also exhibited a poor agreement with reference when assessed as a classified measure, compared to BMI.

Key words: A Body Shape Index (ABSI), Body Adiposity Index (BAI), Body Mass Index (BMI), Dual-Energy X-ray Absorptiometry (DEXA), adipocytes, anthropometry, obesity.

I. INTRODUCTION

Rising obesity epidemic is often regarded as one of the biggest challenge faced by the healthcare industry. According to WHO's fact sheet of obesity and overweight published in 2016, it was apparent that the worldwide prevalence of obesity has doubled since 1980.[1] As per 2014's record, approximately 1.9 billion adults are reported to be overweight, among which over 600 million were considered as obese.[1] Overweight and obesity contributes to around 3.4 million adult death annually.[2]

Overweight and obesity is often found to be responsible for generation of non-communicable diseases like diabetes, musculoskeletal disorder certain cancers and cardiovascular diseases.[2]

Studies have delineated that, fat distribution renders a better estimate of the metabolic risk, than the magnitude.[3] Various anthropometric measures have been developed for estimating the body fat. Body mass index (BMI) is one of the most widely used index for assessing body fat, since its discovery in 1832, by Adolphe Quetelet. This index of weight-for-height has been used irrespective of age and gender, to characterize individuals based on obesity.[2] One of the major drawback of this technique is the lack to denote the fat distribution in the body.[4, 5] This measure has been inferred as an invalid tool for determining body composition, as it fails to differentiate lean body mass from fat mass.[6] Moreover, studies have concluded BMI as an inappropriate tool for the direct measurement of body fat content in athletes.[7]

Recent studies have reported Body Adiposity Index (BAI) as a superior tool for estimating body adiposity compared to BMI.[10] However, both BMI and BAI have been outlined to possess equivalent role in predicting body fat percentage.[11] The observation have been accounted to the stronger correlation of BAI with body fat percentage, than BMI.[11, 12] The index was validated among the American population by a study conducted by Chang et al, in 2014 which concluded that, BAI imparts a valid estimation of fat percentage in elderly women.[13] The study further suggested BMI as a better estimation tool for adiposity in aged men. However, the validation of BAI on American population by other investigations manifested a negative feedback and hence, BAI was regarded as an inappropriate measure of fat percentage, depicting poor accuracy and precision.[14] Likewise, studies on the Chinese population have raised BAI as a questionable overall index of adiposity compared to BMI.[15] Furthermore, studies based on Asian population have suggested BMI as the most reliable predictor of aortic stiffness, in type 2 diabetes mellitus multi-ethnic Asian patients.[16] Studies also indicated waist circumference (WC) measurement as a good indicator of obesity risk over BMI.[8] According to Seidell, WC measurement provides better indication of all causes of mortality compared to BMI.[9]

Research comparing other latest proposed anthropometric measures have reported that A Body Shape Index (ABSI) is not a better predictor of adiposity and associated cardiovascular risk, compared to WC measurement in Indian population.[17] However, the study by Malara et al, have concluded ABSI as more accurate, in measuring the variation in circulating insulin level and the lipoprotein than BMI, in healthy young male subjects.[19]

The most accurate method to measure the body fat is the Dual-energy X-ray absorptiometry (DEXA or DXA) scan and is considered as the gold standard.[20] This measure is regarded as a precise index in quantifying body fat within short-scanning time and low exposure to X-ray.[21] Study conducted by Salamone et al, have proposed DEXA as an accurate method to measure elderly fat mass. This technique is currently utilized as a tool for the assessment of regional and gross body composition.[22]

This current study was conducted to compare the agreement of different adiposity studies like A Body Shape Index (ABSI) and Body Adiposity Index (BAI) with BMI while using DEXA as gold standard.

II. METHODOLOGY

A cohort study was conducted in a diagnostic center in southern India after attaining approved by the institutional ethics committee and informed consent was obtained from all the participants.

1) *Objective:* To compare the agreement of adiposity studies like A Body Shape Index (ABSI) and Body Adiposity Index (BAI) with BMI while using DEXA as gold standard.
2) *Participants:* A total of 40 patients (24 men and 16 women) belonging to the age group of 25-45 years were selected for the study, based on random convenience sampling method which was conducted in between 2014-2015.
3) *Inclusion criteria:* Both male and female patients belonging to the age group of 25-45 years were included in the study.
4) *Exclusion criteria:* Pregnant women, lactating mothers and patients above 45 years and below 25 years were excluded from the study.
5) *Evaluation of base line, dietary and lifestyle parameters***:** Routine demographic details such as age, gender, educational qualification, occupation and socio-economic status were obtained from the participants. The subjects underwent a 24-hour dietary recall. Data pertaining to frequency of food intake, general health, social habits and lifestyle were collected through a questionnaire. Biochemical parameters like lipid profile and blood sugar levels were evaluated. The subjects were screened for the risk of cardiovascular disease and diabetes. The cardiovascular risk was evaluated using the Framingham risk score. Body adiposity measures like BMI, BAI, ABSI and DEXA were calculated for all the subjects. Measurements of height, weight, waist circumference and hip circumference were performed with SECA scale. The height and weight of the subjects were measured using the SECA stadiometer and SECA electronic weighing scale respectively. The values were further used to calculate ABSI, BAI and BMI. Tissue fat (%), region fat (%) and bone mineral content was extracted/estimated from the DEXA reports.

The ABSI was calculated using the Krakauer and Krakauer formula, as follows: [8]

$$ABSI = WC / (BMI^{2/3} \times height^{1/2})$$

BAI was calculated using the following formulae:[23]

$$BAI = (HC\ in\ cm / (height\ in\ m)^{1.5}) - 18,\ and$$

BMI was calculated using the below mentioned formula:[24]

$$BMI = weight\ in\ kg / (height\ in\ m)^2$$

6) *Applied statistical interpretation:* Descriptive data are presented as Mean (SD) or median (range), and frequency data are presented as counts. Relationship of variables like age, gender, BMI, BAI, ABSI, region fat percentage and bone mineral content with DEXA tissue fat percentage was assessed by Pearson's or Spearman's correlation.[25] The inter-rater agreement between body adiposity measures and gold standard DEXA tissue fat percentage was verified by kappa method (quadratic weighted). Further mountain plots were used to examine the agreement of different body adiposity measures with DEXA tissue fat percentage. A P value of <0.05 was considered statistically significant for all the analysis.

Tissue fat (%) and BMI were classified into underweight, normal and obese groups as follows: tissue fat percentile: <25 – underweight, 25 - ≤50 – normal, and >50 – obese; BMI: <18.5 – underweight, 18.5 - ≤25 – normal, and >25 – obese. The classification of men based on age group were into various BAI group were: 20 – 39 years - <8%, 8-26% and >26%; 40-59 years - <11%, 11-29% and >29%; and 60-79 years - <13%, 13-31% and >31%. Similarly, women were classified as: 20-39 years - <21%, 21-39% and 39%; 40-59 years - <23%, 23-41% and >41%; and 60-79 years - <25%, 25-43% and >43%. All the statistical analysis was performed using the Medcalc software.

III. RESULTS

The median age of the subjects was 34.15, ranging from 22.9 – 55.9, with a male to female ratio of 1:0.66. The descriptive data of various evaluated adiposity measures are provided in table 1. Correlation studies revealed that gender (r -0.727, P <0.001, CI -0.847 to -0.537), BMI (r 0.76, P <0.001, CI 0.592 to 0.868), BAI (r 0.69, P <0.001, CI 0.482 to 0.824), ABSI (r -0.37, P 0.019, CI -0.611 to -0.066) and region fat percentile (r 0.99, P <0.001, CI 0.99 to 0.99) are significantly correlated with DEXA tissue fat percentile (table 2). A strong positive correlation was observed between DEXA tissue percentile and measurements like BMI, BAI and region fat percentile, whereas the correlation with ABSI was moderate inverse. Gender showed a strong negative correlation indicating that male subjects (coded 1) had lesser tissue fat percentile compared to the female subjects (coded 0). An insignificant correlation was noted with variables like age (r 0.147, P 0.364, CI -0.172 to 0.439) and bone mineral content (r -0.144, P 0.376, CI -0.436 to 0.176). However, the inter-rater agreement statistics performed on classified variables showed that BMI had significant moderate agreement (K = 0.54) and BAI had poor agreement (K = 0.14) with DEXA tissue fat percentile (table 3).

Body adiposity measurements	Values*
BMI	26.07 (4.89)
BAI	29.78 (19.08-50.42)
ABSI	0.08 (0.06-0.1)
Tissue fat (%) estimated by DEXA	36.32 (12.16)
Region fat (%) estimated by DEXA	34.97 (11.86)
Bone mineral content (g) estimated by DEXA	2585.35 (382.32)

* Mean (SD) or Median (range)

Table 1: Descriptive data of various body adiposity measurements

Variables	Correlation co-efficient#	P value	95% confidence interval
Age	0.147	0.364	-0.172 to 0.439
Gender	-0.727	<0.001	-0.847 to -0.537
BMI	0.76	<0.001	0.592 to 0.868
BAI	0.69	<0.001	0.482 to 0.824
ABSI	-0.37	0.019	-0.611 to -0.066
Region fat (%)	0.99	<0.001	0.99 to 0.99
Bone mineral content (g)	-0.144	0.376	-0.436 to 0.176

\# Pearson's co-efficient for normal data and Spearman's co-efficient for abnormal data

Table 2: Correlation co-efficient of variables with DEXA tissue fat

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Body adiposity measurements	Kappa	95% confidence interval
BMI	0.54*	0.32 to 0.759
BAI	0.14	-0.08 to 0.36

* P value <0.05

Table 3: Agreement of DEXA tissue fat (%) with other measurement methods

The mountain plot analysis of the body adiposity measurements showed that the region fat % had the least bias of 1.35 with DEXA tissue fat % (limits of agreement 0.5 to 2). The measurement had only a slight overlap with BMI values. A positive bias of 9.35 was observed between BMI and DEXA tissue fat (%) (limits of agreement -5.89 to 25.72), and a bias of 4.44 for BAI, with more variability (limits of agreement between -13.58 and 22.48) compared to BMI. Both the plots overlapped with each other. ABSI had a wide rightward shift of curve with median of 35.17 (11.91 lower limit and 57.63 upper limit), and the tail of the ABSI plot overlapped slightly with that of BMI (figure 1).

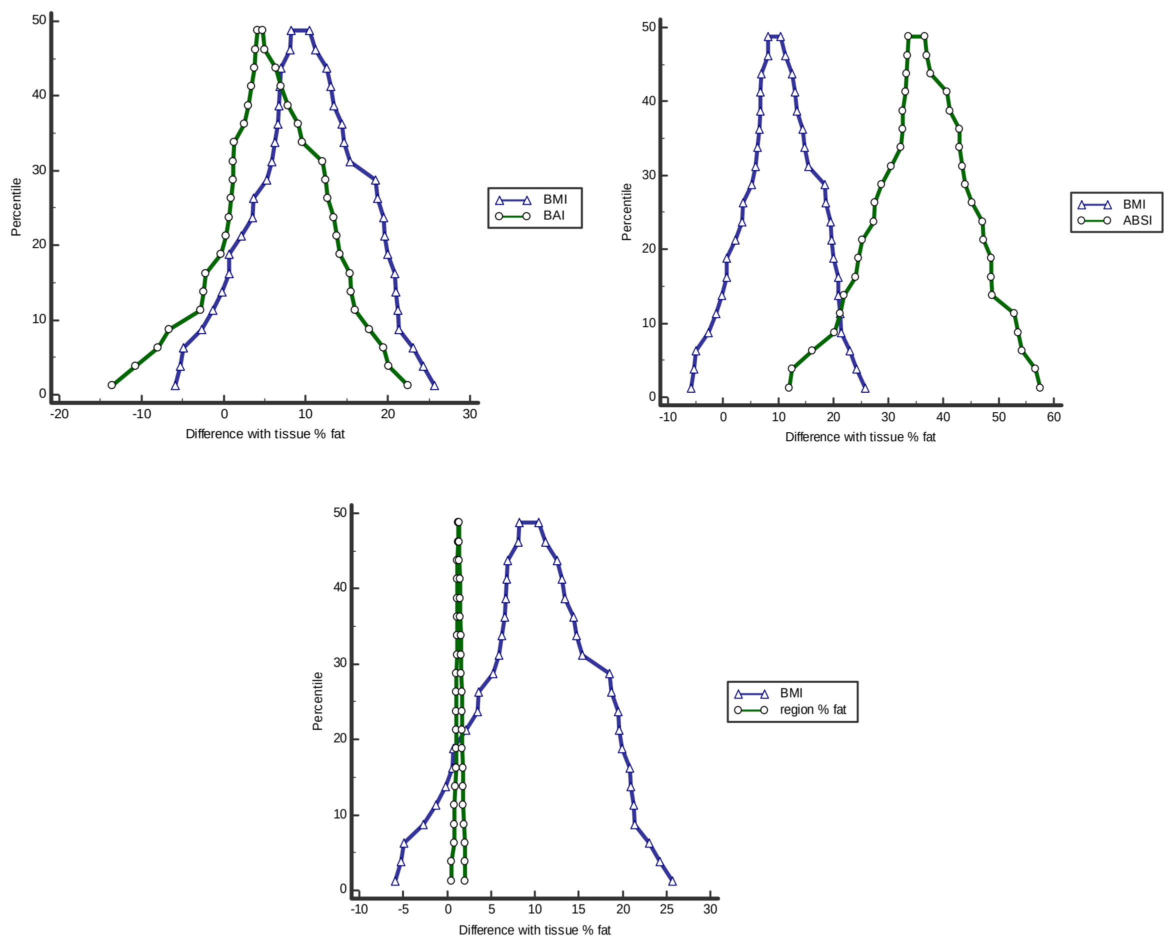

Figure 1: Mountain plot of percentile differences for BMI, BAI, ABSI and region fat % vs. DEXA

IV. DISCUSSION

It was apparent from the present study that, a strong positive correlation prevails in between body adiposity measures like BMI, BAI and region fat percentile with DEXA-derived tissue fat percentage. A moderate negative correlation was observed with ABSI, and a strong negative correlation with gender. While, the inter-rater agreement showed only a moderate significant agreement of BMI with DEXA tissue fat percentile, and poor agreement of BAI with DEXA-derived tissue fat percentage. The study by Lam et al, on 105 Chinese subjects, reported that BMI showed a better correlation to DEXA derived percentage adiposity, than BAI, and concluded that BAI underestimated DEXA derived percentage adiposity. The study exhibited the presence of positive correlation of hip circumference with height. The poor performance of BAI can be attributed by the positive correlation between the variables, which were considered as non-correlated with each other.[15] The observations were found to be in agreement with the results of our present study. However, contradictory studies have noted a higher correlation between BAI and percentage body fat, compared to that between BMI and percentage body fat, calculated by DEXA.[26, 27] Since the variables involved in the calculation such as hip circumference and height are dependent on the bone structure.[26]

The mountain plot to estimate the percentile difference with DEXA tissue fat percentage revealed an overlap in the BMI and BAI plot. However, the tail of the ABSI plot only overlapped slightly with that of BMI. Furthermore, the plot on region fat percentile (estimated by DEXA) depicted the least bias with DEXA tissue fat percentage. These observations are substantiated by a similar study conducted by Regi et al., where a strong positive correlation of BAI with BMI and no correlation of ABSI with BMI was reported. Moreover, the study demonstrated a significant correlation of BMI and BAI with DEXA fat percentage in female population, which corroborates the present observation, where a strong positive correlation was noted between anthropometric measures like BMI and BAI with DEXA tissue fat percentage, in both the sexes. The study concluded that ABSI was negatively correlated with DEXA fat percentage and BMI.[17] Furthermore, a New York based study by Geliebter in 2013 concluded that, BMI significantly correlates with percentage of fat from DEXA, and not BAI, in clinically severe obese women.[28] Additionally, studies conducted on Indian population have claimed ABSI as an unreliable tool for the determination of body fat percentage; even though waist circumference possessed positive correlation with DEXA-derived tissue fat percentage. [17]

According to study conducted by Sun et al., majority of the population studies had reported a higher BMI and hip circumference and a lower height, weight and weight circumference in women.[26] In 2012, Bergman et al delineated that, the body adiposity was lesser in males (46.2 ± 4.3) compared to females (54.7 ± 7.1).[29] Additionally Sun et al., in 2013 reported an elevation of 12.8% in the body fat percentage in women compared to men, when determined by DEXA.[26] Likewise, the current study also have recorded a lesser tissue fat percentage in males compared to females.

The mean BMI, BAI and ABSI noted in the present population was reported to be 26.07 (4.89), 29.78 (19.08-50.42) and 0.08 (0.06-0.1) respectively. A recent study conducted by Verma et al., on rural population of Haryana, has reported a mean BAI and BMI of 27.88±6.16 and 23.45±4.68 respectively, comparable to the present study, where a slightly higher average BAI and BMI of 29.78 and 26.07 respectively, in the urban Indian population were reported.[30] Study conducted by Bergman et al. has recommended BAI as a strong predictor of body fat percentage in Mexican American and African American population.[29] However, study conducted by Regi et al. had demonstrated BAI as an inappropriate tool for adiposity measurement in Indian population.[17] Since height is a constant parameter in adults therefore, the hip circumference may presumably induce error in the estimation of body fat percentage , while using the tool.[29]

The major limitations of the present study include a small sample size and the utilization of a convenient sample, which makes the generalization of the results inappropriate. Furthermore, a full scale DEXA scan should have been performed to correlate the bone mass with the fat mass to attain better outcome for the study. The power of the present study could be low due to small sample size, therefore in future, further studies with large sample size could be conducted to explore sub-group level agreement.

V. CONCLUSION

It was apparent from the current study that, BMI, BAI and ABSI underestimated the body adiposity compared to DEXA tissue fat percentage. DEXA region fat percentage was found to perform better as expected. Additionally, BAI also had exhibited a poor agreement with reference when assessed as a classified measure, compared to BMI.

A. Conflicts of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

VI. ACKNOWLEDGEMENT

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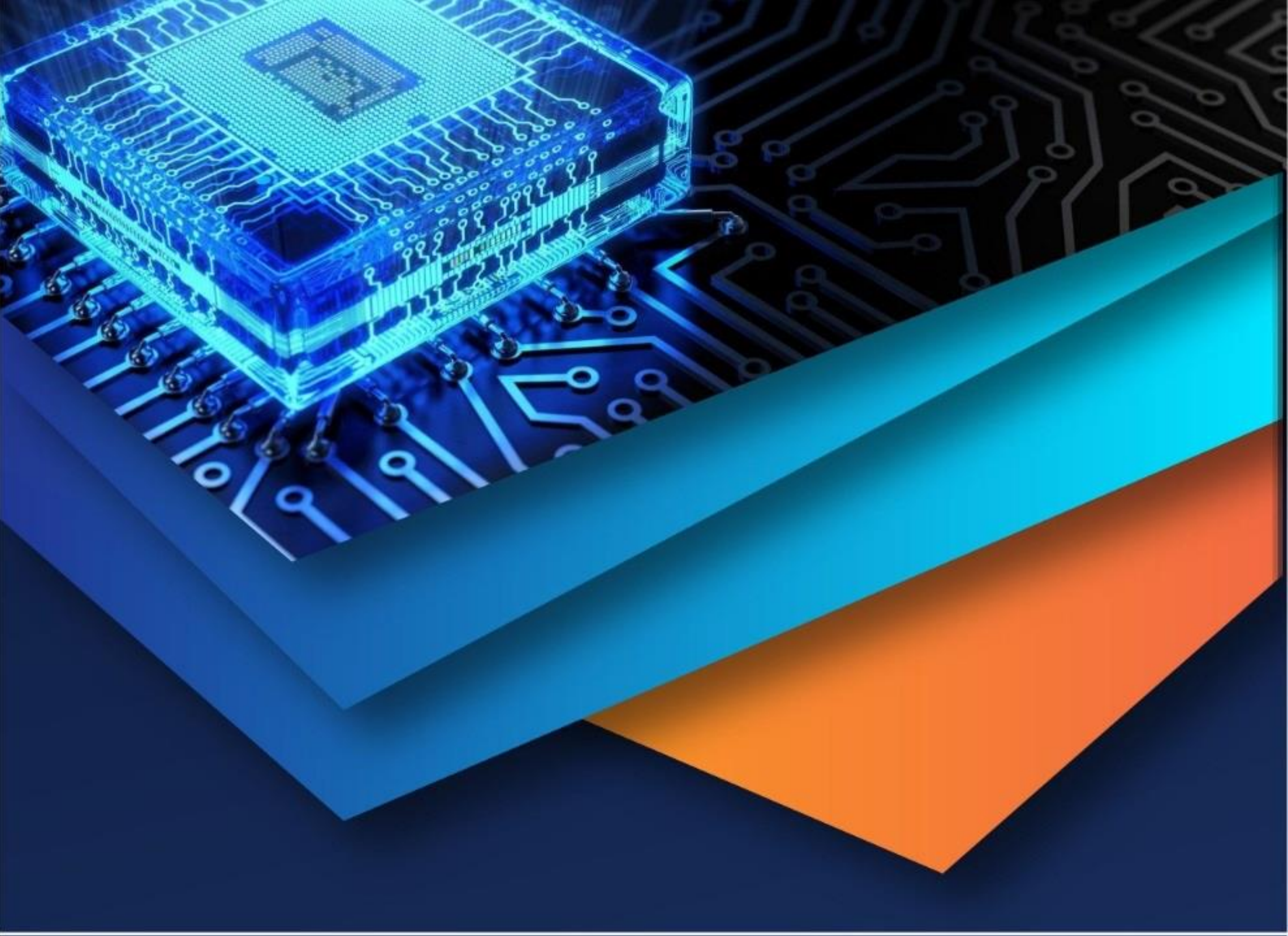

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