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The Effect of Body Weight Variations on Specific Absorption Rate (SAR) Values and Body Temperature in MRI Examination: A Review

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Abstract: MRI examinations use a radiofrequency pulse (RF), which is absorbed by the body when the electromagnetic field is emitted. This is called the specific absorption rate (SAR) effect, which is defined as the heat absorbed per mass of tissue. The type of research uses a systematic literature review or Literature Review with a qualitative approach, with inclusion criteria for publication journals that discuss the effect of body weight on SAR values and changes in body temperature on MRI, as well as journals using retrospective data as clinical and quasi-experimental studies using patients or phantoms. Data processing is carried out by tabulating journals. Data is analysed descriptively and synthesizing research results, the results of which are reported narratively and are systematic, clear, comprehensive, by identifying, analysing, and evaluating through the collection of existing data with explicit search methods and involving a critical review process in selecting studies by aggregating data based on facts with a medical approach. The ten journals the author used have the same results. The results obtained from journals using variations in body weight that are classified as thin body weight (40-49 Kg) have lower SAR values than patients who are classified as normal weight (50-59 Kg) and patients with fat body weight (60-69 Kg) and patients with Obese weight (70-79 Kg) have SAR values far above the SAR value in patients with normal bodies. This proves that body weight will affect the amount of RF absorbed by the body, causing tissue heating, which causes an increase in SAR values. Weight gain can affect the increase in SAR values because the heavier the object, the greater the amplitude of the RF emitted, causing heating in the tissue, causing the SAR value to increase. An increase in body temperature can affect the increase in SAR values because RF absorption will interact with body water molecules to increase movement, equivalent to a rise in energy that will increase body temperature, due to tissue heating. There is an influence of body weight variation on the SAR value which shows that the amount of body weight determines the amount of RF emitted so that the body will absorb a lot, and there is an influence of body weight variation on the increase in body temperature which shows that if the body has a lot of fat, the fat in the subcutaneous tissue can maintain the temperature, both hot and cold and has an effect on RF radiofrequency exposure which adjusts to the surface of the object.

Keywords: MRI Examination; Specific Absorption Rate; Temperature; Weight.

Introduction

MRI is a medical imaging technique in radiological diagnostic examination, which produces a recording of cross-sectional images of the human body or organs using magnetic fields and vibrational resonance in the hydrogen atom nucleus [1][2]. This technology utilizes the properties of hydrogen atoms because, in most of the human body, there are hydrogen atoms [3]. The body absorbs the Radiofrequency signal when the electromagnetic field is emitted [4][5]. An MRI system not only requires a strong magnetic field but must also provide a Radiofrequency (RF) signal to obtain a response from the examined organ [6][7]. The generation of the RF field is carried out not based on ionizing radiation but on the generation of a RF field that can cause tissue heating [8]. The RF pulse absorbed by the body when the electromagnetic field is emitted is called the Specific Absorption Rate (SAR) effect. The SAR effect is the heat absorbed per tissue mass and has units of Watts per Kilogram (Watts/Kg) [9].

Weight gain can affect the increase in the SAR value, where the SAR value has been set with a maximum limit for the abdomen of 4 Watts/Kg, head 3.2 Watts/Kg, head and body 20 Watts/Kg, and for extremities 40 Watts/Kg. The SAR value can be seen in the SAR information on the MRI monitor, so that it can be seen to what extent the effect of body weight on body temperature and the increase in the SAR value [10][11]. In determining a person's weight, it is said that they are thin if their weight ranges from 40 kg to 49 kg, normal people if their weight ranges from 50 kg to 59 kg, obese people if their weight ranges from 60 kg to 69 kg, obese people 1 if their weight ranges from 70 kg to 79 kg, and obese people 2 if their weight ranges from 80 kg to 89 kg [12]. In addition to weight, SAR can cause changes in temperature and heating of body tissues.

Body heating during MRI is correlated with patient weight. Individuals with higher body mass tend to experience increased SAR and tissue temperature, thereby putting them at risk for local hyperthermia, especially in patients with sensitive conditions or medical implants. The increase in body temperature depends on the strength of the

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magnetic field, the SAR value, and the length of the examination [13]. The average body temperature is 37ºC, with a normal range of 36ºC to 37ºC. Changes in body temperature can occur due to the influence of magnetic fields, radiation, heat conduction from the skin to the surrounding air, and all levels of heat have a body temperature threshold [14].

The increase influences this increase in body temperature in the SAR value, and the SAR value can be influenced by the weight of the MRI examination patient, so it is necessary to weigh the patient first [15]. By weighing the body, it is expected to be able to find out the SAR value [9]. During imaging, most transmitted RF pulse electromagnetic fields turn into heat in the body's tissues, which can cause harm [16][17]. Heating or increasing body temperature due to RF pulses can make the patient feel uncomfortable and allow movement, which can cause motion artefacts that will impact the quality of radiography and anatomical information [18][19].

Meta-analysis of several research journals on SAR has obtained results. Body weight variation affects SAR values in MRI examinations, and an increase in body temperature is influenced by body weight [20]. Meanwhile, according to [21], there is no relationship between increased body temperature and body weight. However, body weight affects the increase in SAR values, and an increase in SAR values causes the temperature to increase. According to [22], it states that the length of time of RF exposure with increased SAR can increase the heating of organs, especially sensitive organs such as the eyes, ears, head, and internal organs, in contrast to the opinion of [23][24], stating that RF exposure increases heating of more sensitive organs such as the esophagus, then the back and chest, meanwhile, according to [25][26], which states that high RF exposure will increase heat in organs, especially in the extremities which can reach a temperature increase of up to 1ºC. According to [27][28], the highest temperature increase due to the increase in SAR value is due to the presence of a pacemaker or implant installation that triggers increased heating. As supported by [29], the heating of body tissue is due to having a complex geometry with weak conductive content that is sensitive to high resolution, especially RF absorption, which can also increase the SAR value. According to [30], to avoid high SAR values due to body weight that causes an increase in temperature, it is necessary to minimize it by reducing the Time Repetition (TR) parameter value to reduce the amount of RF absorbed. State by [31], that observing SAR values can be assisted by measuring the diffusion tensor so that the increase in SAR phase scanning values can be known. Another view, according to [32], observing SAR values can use a SAR Dosimeter with the benefit of being able to monitor SAR values. It can also measure the amount of RF.

Based on the study, it was obtained that body weight will determine the amount of RF in increasing the SAR value, but the increase will vary from each MRI modality used. In addition, based on the author's preliminary study at the National Hospital Surabaya, the National Brain Center Hospital, and the Premier Hospital Surabaya, they saw that there were patient complaints during MRI examinations, such as feeling hot and sweaty on their bodies, which caused the patient to move and cause motion artefacts. This can occur because the examination time is long in the MRI examination, generating many RF pulses, causing heating of the tissue so that the SAR value increases and is accompanied by a large magnetic field. Administratively, one of the things that must be fulfilled in the Hospital before conducting an MRI examination is weighing the patient. However, from the researcher's experience, there is still a lack of attention to body weight figures, as they are only estimated without weighing directly, affecting the patient and increasing the SAR value.

Based on the description above, the author is interested in studying further in the form of Meta-analysis with literature studies by adding insight into SAR, which was then raised into a thesis entitled "The Effect of Body Weight Variation on SAR Values and Body Temperature in MRI Examination."

Research Methods

The method used for the preparation of this review article is the literature review method. Using reference data searched through online databases such as Google Scholar, Researchgate, and PubMed. The flow chart of research in Figure 1 consists of identification (search journal), filtering (screening journal), credentials (assessed for eligibility), and including (analyzed with theproblem).

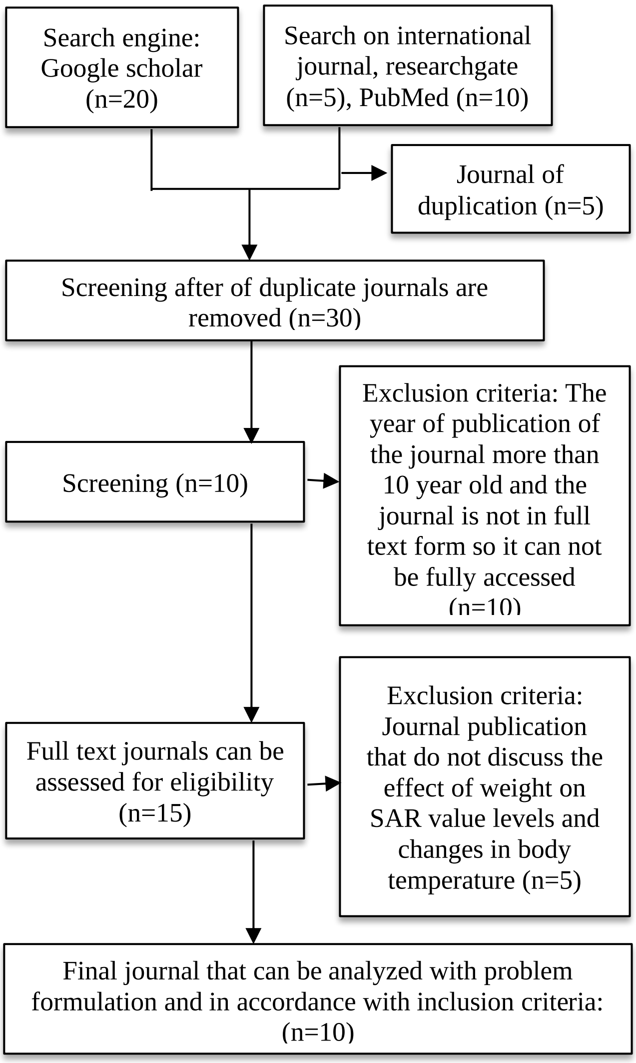

Figure 1. The flow chart of research

Inclusion criteria consist of journal publications with a Digital Object Identifier (DOI) and the year of publication within the last 10 years. Journal publications discuss the effect of body weight on the level of SAR and changes in body temperature in MRI examinations. Besides, publication journals operate operationally in patient populations, using retrospective data from clinical studies and quasi-experimental studies using patients or phantoms. Meanwhile, Exclusion Criteria consist of publications in journals that do not discuss the effects of body weight on the level of SAR and changes in body temperature in MRI examinations. The journal's publication year is more than 10 years. The journal is not in complete text form, so the journal cannot be fully accessed. Publication journals that are not operationally in the patient population use retrospective data as clinical studies and have no experiments using patients or phantoms.

The research methods used are SPSS statistical tests, diffusion tensor, thermographic, Finite Difference Time Domain (FDTD), fluoroptic thermometer, and SAR dosimeter measurements. The research flow used includes topic determination, Problem Formulation Identification, Data Search, Screening, Tabulation, Data Analysis, Writing Literature Study Results, and Research Conclusions. Data processing by reviewing, analyzing and reviewing theories from journals and textbooks regarding the effect of weight variation on SAR values and body temperature in MRI examinations. Meanwhile, data analysis is carried out by theoretically reviewing journals related to the effect of weight variation on SAR values and body temperature in MRI examinations and then drawing conclusions to answer the problem formulation and providing suggestions at the end of the review study and theoretical analysis

Results and Discussion

SAR values that are not based on actual body weight will have an effect on increasing the SAR value and increasing the patient's body temperature. This will have a significant impact, especially on patients who experience it and the resulting image. So it is essential to know the extent of the influence of body weight on the SAR value and body temperature so that it can be optimized or minimized for patient safety to provide good image quality. This literature study aims to determine the effect of body weight variations on the SAR value and body temperature in MRI examinations. The author conducted a comprehensive literature search through Google Scholar (Scholar), Researchgate, and PubMed. 10 Journals met the inclusion criteria (IC) with Y is Yes and N is No related to the topic of discussion in Table 1.

Table 1. Results of Literature Quality Assessment

Ref.	IC 1 (Y/N)	IC 2 (Y/N)	IC 3 (Y/N)	Hasil (√/x)
[20]	Y	Y	Y	√
[21]	Y	Y	Y	√
[22]	Y	Y	Y	√
[24]	Y	Y	Y	√
[25]	Y	Y	Y	√
[28]	Y	Y	Y	√
[29]	Y	Y	Y	√
[30]	Y	Y	Y	√
[31]	Y	Y	Y	√
[32]	Y	Y	Y	√

At this stage, researchers obtain data from literature conducted on scientific journal search engines using Google Scholar (Scholar) and electronic database sites, namely Researchgate and PubMed. From the literature study, 10 research journals have been obtained on SAR with different titles and numbers of journal pages, and the research methods of the journals analyzed vary. The research methods use SPSS statistical tests, diffusion tensor, thermographic, FDTD, fluoroptic thermometer, and SAR dosimeter measurements. The research locations from the journals were conducted in different places. The year of publication of each journal is different, where Journal One, Journal Three, Journal Nine, and Journal Ten are in 2017, while Journal Two and Journal Seven are in 2016, Journal Four and Journal Five in 2013, and Journal Seven in 2011, and for journal Eight in 2010. The sources for taking journals also come from three different sources, namely Google Scholar, Researchgate, and PubMed.

Table 2. The 1.5 Tesla MRI modality [20].

Weight (Kg)	T (ºC)	SAR (W/Kg)
45.6	0.9	0.4
48.9	1.1	0.4
51.4	1.2	0.4
52.1	1.9	0.4
54.5	1.8	0.4
55.2	1.7	0.4
55.7	1.7	0.5
57.1	2.1	0.5
60.7	2.1	0.5
66.4	2.3	0.5
73.5	2.4	0.5
74.3	2.4	0.5
74.5	2.5	0.5

Based on Table 2 shows a robust correlation between 88.7% of body temperature increases and body weight, while other factors influence 11.3%. There is a moderate correlation, with 59.6% of SAR values being influenced by body weight, while other factors influence 40.4% of SAR values. This shows that the analysis data obtained using linear regression statistical tests, with the test results of the influence of body weight variations on body temperature increases in MRI examinations, and the impact of body weight variations on SAR values in MRI.

Table 3. Body weight variations with MRI modalities [21]

Weight (Kg)	T (ºC)	SAR (W/Kg)	MRI (T)
44	0.8	1.17	1.5
66	1	1.6	1.5
77	1.2	1.21	1.5
44	1.3	2.1	3
66	2.1	2.3	3
77	2.4	2.5	3

Based on Table 3 shows a significant relationship between the increase in body temperature and the SAR value, with a value of $P = 0.049$. And there is a relationship between the rise in body temperature and the HR pattern marked with a significance value of $P = 0.01$. So it shows that the higher the RF absorption, the higher the body temperature, indicating a high SAR value. And the greater the decrease in HR and the increase in age, the higher the body temperature. Age, weight, and gender have no relationship with the rise in body temperature. However, suppose the reason for the relationship between body weight and an increase in SAR value is that body weight causes an increase in body temperature. In that case, body weight will affect the rise in body temperature. The recapitulation of journals can be seen in Table 4.

According to [20], his journal shows that the analysis data was obtained using linear regression statistical tests with test results showing the influence of body weight variations on the increase in body temperature in MRI examinations and the influence of body weight variations on SAR values in MRI examinations. The higher the RF absorption, the higher the body temperature, which indicates a high SAR value [21]. And the greater the decrease in HR and the increase in age, the higher the body temperature. While age, weight and gender have no relationship with increased body temperature. However, if the reason for the relationship between body weight and causing an increase in SAR value, then body weight will affect the increase in body temperature.

According to [22], it is stated that SAR is an important parameter to assess the RF Pulse absorbed by the body when the electromagnetic field is emitted. This survey focuses on investigating the impact of increasing SAR values in biomedical terms, with the results that all internal organs experience increased heat depending on the organ's sensitivity. According to [24], the increase in SAR value depends on the amount of RF exposure absorbed by the body and the length of RF exposure, causing the temperature of each organ to increase. Of the four organs studied, the one that showed the highest sensitivity due to exposure was the esophagus, which was experiencing an increase in temperature of 1.9ºC, and the organ with the lowest sensitivity was the chest, with an increase in temperature of 0.3ºC from the initial temperature of 35ºC and a SAR value of 4W/Kg.

According to [25], body temperature and SAR values were measured using an MRI 3 Tesla with an acquisition time of 28 minutes and 12 seconds. The results obtained were that implanting teeth could increase body temperature up to 1ºC. This causes a high heat sensation, especially in the extremities, where the effects are felt more.

According to [28], in his journal, the fluorotic probe method of installing a pacemaker, where the temperature increases with the highest RF of 128 MHz, increases the temperature of the whole body by 12.3ºC, with an increase in SAR value of up to 1.94 W/Kg from its normal limit. So, the overall results obtained are an increase in temperature and an increase in SAR value of up to 70%.

According to [29], research using the FDTD method to calculate RF on the human body found that human body tissue has a very complex geometry with weak conductive content that is very sensitive to high resolution, especially RF absorption, which is the cause of the increase in SAR values due to the large amount of RF emitted.

According to [30], the TR value affects body temperature and SAR value. The higher the TR value, the higher the increase in body temperature with TR 5000ms will increase to 0.14ºC. Likewise, the higher the TR value, the higher the increase in SAR value with TR 5000ms will increase to 10W/kg. According to [31], in measuring the SAR level during MRI scanning using a torso phantom, where the SAR value for a 1.5 Tesla magnetic MRI plane was 1.48, while for a 3Tesla magnetic MRI plane, the SAR value was 2.5 using the diffusion tensor coefficient measurement. According to [32], it shows that research using a dosimeter transducer, results were obtained for accurate SAR values based on RF exposure time, where at 8 minutes of exposure, the SAR value detected on the 2.0 W/Kg dosimeter transducer, at 14 minutes of exposure the SAR value detected on the 3.5 W/Kg dosimeter transducer, at 16 minutes of exposure the SAR value detected on the 4.0 W/Kg dosimeter transducer, and at 18 minutes of exposure the SAR value detected on the 4.5 W/Kg dosimeter transducer. These results prove accuracy.

Table 4. Recapitulation of journals

Source/Page and Subject	Journal Objectives	Journal Core	Research methods	Research result
Researchgate / 6 Pages / 13 patients [20]	The research in this journal aims to determine the effect of variations in body weight that have been determined on the increase in body temperature and SAR values in MRI Brain examinations.	Using 13 variations of body weight, Using the 1.5 Tesla MRI modality, namely: 1. Weight 45.6 Kg with a temperature increase of 0.9 ºC and a SAR value of 0.4 W / Kg. 2. Weight 48.9 Kg with a temperature increase of 1.1 ºC and a SAR value of 0.4 W / Kg. 3. Weight 51.4 Kg with a temperature increase of 1.2 ºC and a SAR value of 0.4 W / Kg. 4. Weight 52.1 Kg with a temperature increase of 1.9 ºC and a SAR value of 0.4 W / Kg. 5. Weight 54.5 Kg with a temperature increase of 1.8 ºC and a SAR value of 0.4 W / Kg. 6. Weight 55.2 Kg with a temperature increase of 1.7 ºC and a SAR value of 0.4 W/Kg.	The journal's research method is quantitative research with experimental research. Data analysis is done using statistical tests and the SPSS 17 application.	1. There is a strong correlation between 88.7% of body temperature increases and body weight, while other factors influence 11.3%. 2. There is a moderate correlation with 59.6% of SAR values influenced by body weight, while other factors influence 40.4% of SAR values

		7. Weight 55.7 Kg with a temperature increase of 1.7 ºC and a SAR value of 0.5 W/Kg. 8. Weight 57.1 Kg with a temperature increase of 2.1 ºC and a SAR value of 0.5 W/Kg. 9. Weight 60.7 Kg with a temperature increase of 2.1 ºC and a SAR value of 0.5 W/Kg. 10. Weight 66.4 Kg with a temperature increase of 2.3 ºC and a SAR value of 0.5 W/Kg. 11. Weight 73.5 Kg with a temperature increase of 2.4 ºC and a SAR value of 0.5 W/Kg. 12. Weight 74.3 Kg with a temperature increase of 2.4 ºC and a SAR value of 0.5 W/Kg. 13. Weight 74.5 Kg with a temperature increase of 2.5 ºC and a SAR value of 0.5 W/Kg.		
PubMed / 11 Pages / 3 patients [21]	The research in this journal aims to determine the relationship between increased body temperature and RF power on increased SAR values during routine MRI procedures and to determine the correlation between the effects caused and the body's physiological response.	Using three variations of body weight with MRI modalities of 1.5 Tesla and 3 Tesla, namely: 1. Weight 44 Kg with a temperature increase of 0.8 ºC and a SAR value of 1.17 W/Kg on MRI 1.5T 2. Weight 66 Kg with a temperature increase of 1 ºC and a SAR value of 1.6 W/Kg on MRI 1.5T 3. Weight 77 Kg with a temperature increase of 1.2 ºC and a SAR value of 1.21 W/Kg on MRI 1.5T 4. Weight 44 Kg with a temperature increase of 1.3 ºC and a SAR value of 2.1 W/Kg on MRI 3 T 5. Weight 66 Kg with a temperature increase of 2.1 ºC and a SAR value of 2.3 W/Kg on MRI 3T 6. Weight 77 Kg with a temperature increase of 2.4 ºC and a value SAR 2.5 W/Kg on 3T MRI	Linear and regression statistical analysis using experimental research types with SPSS statistical analysis.	1. There is a significant relationship between the increase in body temperature and the SAR value, with a value of P = 0.049. 2. There is a relationship between the increase in body temperature and the HR pattern marked by a significance value of P = 0.01.
Researchgate / 15 Pages / 3 patients [22]	The research in this journal aims to investigate and use methods to assess the impact of SAR levels in biomedical terms.	Using three variations of body temperature variations with MRI 1.5 Tesla modality, namely: 1. Increase in body temperature of 1.8 ºC and SAR value of 2.1 W/Kg on MRI 1.5T 2. Increase in temperature of 2 ºC and SAR value of 2.2 W/Kg on MRI 1.5T 3. Increase in temperature of 2.2 ºC and SAR value of 2.5 W/Kg on MRI 1.5T	The journal's research method is experimental, using observations of the increase in SAR values , calculations of the mass ratio, and evaluation of the increase in temperature.	The research results obtained by observing the biological effects and organ sensitivity when the SAR value increases showed that each organ experienced a temperature rise.
Researchgate / 10 Pages / 1 patient [24]	The purpose of the research in the journal is to find out the standard for RF absorption in the body so as not to increase the reduction in the SAR.	The initial temperature was 35ºC using the 1.5 Tesla modality. Then, the oesophagus experienced the highest increase, reaching a temperature of 36.9ºC, with the upper back reaching a temperature of 35.8ºC, the lower back reaching a temperature of 35.4ºC, and the chest reaching a temperature of 35.3ºC, with a SAR value of 4 W/Kg. The purpose of the research in the journal is to find out the standard for RF absorption in the body so as not to increase the reduction in the SAR.	The journal's research method is experimental; the research was conducted using the Finite Difference Time Domain (FDTD) method.	The study's results showed that exposure to RF for 45 minutes increased the temperature of organs previously at 35ºC, with a SAR value of 4 W/Kg.

Scholar / 6 Pages / 3 patients implanted [25]	The purpose of the study in this journal is to assess the effects of RF-induced heating and the highest SAR values for patients with implants in 3 Tesla MRI examinations.	Using the 3 Tesla modality, there was an increase in body temperature of up to 1ºC from the 1.5 Tesla modality	The journal's research method is experimental. Observations are made on the final SAR value, and thermometer measurements are taken.	The research results obtained by measuring body temperature and SAR values show that installing dental implants can increase body temperature by up to 1ºC.
Scholar / 4 Pages / Human-Shaped Phantom [28]	The research in this journal aims to present a methodological approach to measuring temperature and SAR values using a fluorometric probe.	1. With 0.5 T MRI modality, there can be an increase in body temperature of up to 0.8 ºC and a SAR value of 2.1 W/Kg 2. With 1.5 T MRI modality, there can be an increase in body temperature of up to 2.5 ºC and a SAR value of 2.8 W/Kg 3. With 3 T MRI modality, there can be an increase in body temperature of up to 3.2 ºC and a SAR value of 3.1 W/Kg	The research method in the journal was conducted using an experimental research design using a fluoroptic thermometer.	The research results obtained in the study using the fluorotic probe method showed that the increase in temperature with the highest radiofrequency of 128 MHz increased the whole body temperature by 12.3ºC.
Pubmed / 27 Pages / Patients in one area [29]	The research in this journal aims to determine the role of radiofrequency in the basic calculation of the SAR in MRI in terms of the scope of biological tissue.	SAR is the amount of energy absorbed by the entire body during a period divided by the body mass, where the electric field generated in the conductive tissue during transmission during excitation will drive the electric current in the tissue and cause tissue heating.	The journal research method uses the experimental research type, carried out using the Finite Difference Time Domain (FDTD) method.	The research results obtained in the study showed that human body tissue has a very complex geometry with weak conductive content that is very sensitive to high resolution, especially RF absorption, which is the cause of the increase in SAR values.
Pubmed / 15 Pages / 10 Patients [30]	The research in this journal aims to determine the average SAR energy absorption rate during the repetition time or Time Repetition (TR) for the heating level of the RF pulse.	With a modality of 1.5 Tesla, at a TR value of 1000ms, it will increase body temperature by 0.04ºC, while at TR 2000ms, it will increase the temperature by 0.06ºC. At TR 3000ms, the increase in body temperature is 0.08ºC. And at TR 4000ms, the rise in body temperature is 0.1ºC. At TR 5000ms, the temperature increases to 0.14ºC. The rise in TR value by 5000ms produces a high SAR value of 10W/kg	The research method in the journal is to use an experimental research type using Time Repetition (TR) values which vary from 1000-5000 ms	The research results in measuring body temperature at high TR variations produced a high SAR value, namely 10W/kg.
Pubmed / 6 Pages / Phantom torso [31]	The research in this journal aims to measure the SAR level during scanning using a human torso phantom with 1.5T and 3T MRI modalities.	The SAR value for the 1.5 Tesla magnetic MRI machine is 1.48 W/kg, while it is 2.5 W/kg for the 3 Tesla magnetic MRI machine.	The research method in this journal is experimental, using a body coil that transmits RF power. Imaging scanning is measured using diffusion tensor imaging.	The research results obtained were that the SAR value for the 1.5 Tesla magnetic MRI machine was 1.48 W/kg, while for the 3 Tesla magnetic MRI machine, using the diffusion tensor coefficient measurement, it was 2.5 W/kg.
Scholar / 7 Pages / Water Phantom [32]	The research in this journal aims to develop a scanner-independent dosimeter to measure RF power deposition and SAR during MRI exposure.	With the modality of 1.5 Tesla, the SAR value detected on the dosimeter transducer at 8 minutes of exposure is 2.0 W/Kg; at 14 minutes of exposure, it is 3.5 W/Kg; at 16 minutes of exposure, it is 4.0 W/Kg, and at 18 minutes of exposure, it is 4.5 W/Kg. These results prove the accuracy of.	The journal's research method is experimental; the research was conducted using a dosimeter transducer.	The research results obtained in the study using a dosimeter transducer provided accurate SAR values, which were obtained based on the time of RF exposure.

Body Weight Variation Against SAR Values in MRI Examination

Monitoring the SAR value is necessary for every MRI examination because the SAR value shows the energy measurement value absorbed per unit time in the tissue based on the body weight determined by the RF pulse applied in MRI. When the body is exposed to an external magnetic field, to receive signals in MRI, RF excitation pulses can provide energy differences. RF pulses will also interact with water molecules by accelerating the movement in rotation, which causes the heating of body tissue. Body weight numbers are essential in determining the amount of RF absorbed by the body.

The heavier the object, the greater the amplitude required to obtain an MRI image, where at a high SAR value, it will exceed the set limit if the body weight is significant. The heavier the body weight value, the greater the SAR value.

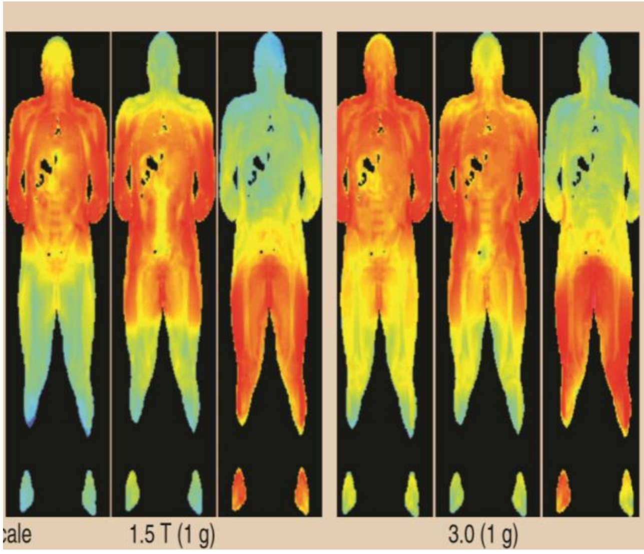

Figure 2. 1.5T and 3T SAR Heat Levels

High body weight will increase the SAR value because the weight determines the amount of RF emitted, so that the body will absorb a lot, causing an increase in the SAR value, where the SAR value is in the form of heat absorbed per mass of body tissue. The significant relationship between weight gain and the increase in SAR. At the average SAR value, the entire body has different tissue heat values that depend on body weight, where the SAR value can be automatically assessed on the monitor based on the patient's weight input.

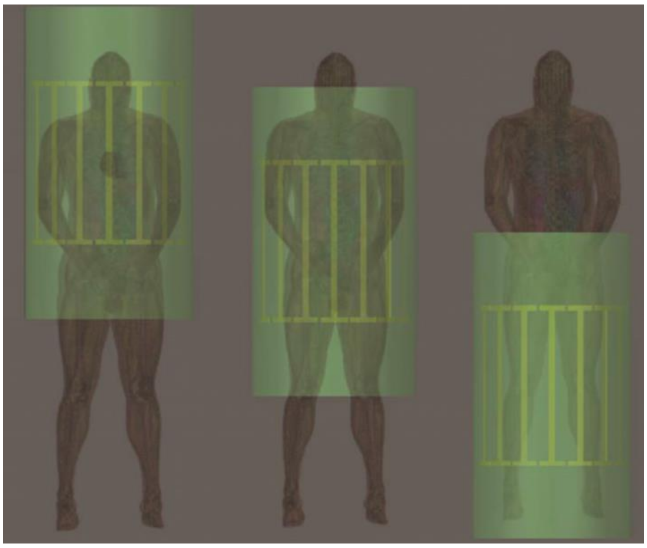

Figure 3. SAR Heat Area

The ten journals that the author uses have the same purpose. The results obtained from journals using variations in body weight that are classified as thin body weight (40-49 Kg) have lower SAR values than patients classified as normal body weight (50-59 Kg) and patients with fat body weight (60-69 Kg) and patients with Obese weight (70-79 Kg) have SAR values far above the SAR values in patients with normal bodies. This proves that body weight will affect the amount of RF absorbed by the body, causing tissue heating, which causes an increase in SAR values.

According to [22], the SAR is the power absorbed from the tissue mass, so that if the amount of RF absorbed by the body due to high body weight will cause an increase in the SAR value, this causes the heating level in the body to be susceptible to the effects that will be caused. With excess body weight conditions having a large body surface, the absorption of RF signals from the MRI plane is spread throughout the body, with the level of heat from the plane felt by body tissue. So, body weight significantly affects the SAR increase.

Therefore, it is expected that patients receive sufficient exposure to RF signals and do not exceed the specified safe limits that can cause RF effects and SAR values. Radiofrequency exposure can produce various physiological effects, including visual changes, hearing, endocrine, nervous, cardiovascular, immune, reproductive, and developmental functions.

Variation of Body Weight Against Body Temperature in MRI Examination

The weight figure for body temperature in MRI examination shows that excess body weight is associated with a lot of fat. Fat under the skin can maintain body temperature against temperature changes that occur in both hot and cold conditions. However, body temperature will have more influence on the SAR value because, overall, after an MRI examination, there can be an increase in body temperature caused by exposure to RF absorbed by the body during the acquisition. The heavier the weight value, the lower the body temperature will be. The relationship between body temperature and weight is not so strong. Still, the relationship is between body temperature and the SAR value because the amount of heat received by the body depends on the amount of RF energy absorbed, which will affect the increase in the SAR value. The RF signal emitted from the MRI machine causes energy transfer to the body and causes tissue heating.

The ten journals that the author uses have the same purpose. The results from the journal showed an increase in body temperature due to an increase in the SAR value, which the body weight and the MRI modality used can influence. In the MRI modality of 0.5 Tesla, if the SAR value increases, it will also increase the patient's body temperature, and the increase in body temperature will increase even more if the MRI modality used is 1.5 Tesla. The increase in temperature can reach 1ºC. The increase in body temperature will increase 2 times if using the MRI modality of 3 Tesla. This shows that magnetism provides heating to the body, which causes the SAR value to increase.

State by [21] also stated that RF interacting with water molecules in the body increases movement equivalent to an increase in energy that will increase body temperature due to tissue heating, thus causing an increase in the SAR value. This is directly proportional to [22], stating that the SAR is in the form of power absorbed from tissue mass, so if the amount of radiofrequency absorbed by the body increases, it causes the level of heating in the body to be susceptible to biological effects. The SAR absorption value measures the energy absorbed per unit time in the tissue determined by the RF pulse applied in MRI, so that the length of exposure to RF can cause heating of the tissue. When the electromagnetic field is emitted, the body absorbs the high RF pulse.

Body temperature will have more influence on the SAR value because of tissue heating caused by the absorption of RF in the body, so there is an increase in the SAR value, and tissue heating will trigger an increase in body temperature. A high SAR value is caused by an increase in the electrical conductivity of homogeneous body tissue, causing tissue heating, which will cause an increase in body temperature. To receive signals in MRI, RF excitation pulses can provide energy differences. Electrical conductivity of homogeneous body tissue RF pulses will also interact with water molecules by accelerating the movement in rotation. During MRI scanning, it can cause increased heating due to the deposition of RF power in the body, and this has an impact on increasing temperature. One of the main problems of the RF effect is that long scanning times can produce greater heating and can result in increased SAR values.

The SAR value will increase if the patient's weight is excessive because body weight causes a lot of RF to be emitted. Hence, the absorption of RF in the body also increases, with the absorption of a lot of RF, so that it can cause heating in the tissue. Tissue heating will trigger an increase in body temperature. Therefore, body temperature influences the SAR increase.

The increase in body temperature does not increase significantly based on body weight [24]. Still, the increase in body temperature depends on the SAR value due to the amount of RF absorbed. The average body temperature is 37ºC with a standard range of 36ºC to 37ºC. Changes in body temperature can occur due to the influence of magnetic fields, radiation, heat conduction from the skin to the surrounding air, and all levels of heat have a threshold at body temperature. The threshold for increasing body temperature due to the effect of the SAR, which is the maximum acceptable by tissue per kilogram, must be limited. RF causes the core temperature to rise to 0.7 °C or 1 °C for normal tissue. The USFDA recommends that RF exposure be limited so that the body temperature increases by less than 2 °C. This increase in body temperature is influenced by the increase in the SAR value, and the weight of the MRI patient can affect the SAR value, so it is necessary to weigh the patient first. By weighing the body, it is expected to know the SAR value. RF that interacts with water molecules increases movement equivalent to increased energy, which will increase temperature. And the use of high magnets can increase the SAR value. Especially at high magnetic field strengths such as 3 Tesla, due to the influence of SAR, this can cause changes in body temperature due to the RF signal absorbed by the tissue being too high.

The excess of RF power deposition can cause heating and burns, as evidenced by the report of the U.S. Regulatory Agency (FDA) on injuries received during MRI examinations related to the proximity of patients to metal, receiver coils, and magnetic bores that can pose additional risks, this is the main problem of the absorption effect of RF which produces greater heating not only increasing the value of the SAR and body temperature but can also result in the possibility of burns to the skin, one of which is caused by filling in the patient's weight figure that is not appropriate so that it will cause a difference in the amplitude of RF which results in an inappropriate value of the SAR that must be received and if there is an implant installation. The heating effect of tissue due to RF is called the SAR effect.

Conclusion

There is an influence of body weight variation on the SAR value, which shows that the amount of body weight determines the amount of RF emitted so that the body will absorb a lot, causing an increase in the SAR value, where the SAR value is in the form of heat absorbed per mass of body tissue. There is an influence of body weight variation on the increase in body temperature, which shows that if the body has a lot of fat, the fat in the subcutaneous tissue can maintain both hot and cold temperatures and affects RF exposure, which adjusts the surface of the object. There is an influence of body temperature on the SAR value, which shows the effect of tissue heating caused by the large amount of RF absorption in the body, so that there is an increase in the SAR value. The heating of the tissue will trigger an increase in body temperature. Therefore, it is expected that patients receive sufficient exposure to RF signals and do not exceed the specified safe limits that can cause RF effects and SAR values. Radiofrequency exposure can produce various physiological effects, including visual changes, hearing, endocrine, nervous, cardiovascular, immune, and reproductive and developmental functions.

Author’s Contributions

Nurul Auliyaa Hasbi: responsible for conceptualization of the study, data analysis, and writing the initial draft of the manuscript. Asmiati Amir: critical review of the structure and content of the manuscript. Muhammad Yunus: involved in data validation, interpretation of results, and preparation of the discussion and conclusion sections. All authors have read and approved the final version of the manuscript for publication.

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