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ORIGINAL ARTICLE

Neuromuscular Electrical Stimulation as A Diagnostic Tool in Obesity- A Cross-Sectional Study

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ABSTRACT

Background: Obesity is a growing public health concern, particularly in urban areas of India, where it is more prevalent than in rural regions. This study aims to assess the effectiveness of neuromuscular electrical stimulation (NMES) markers in diagnosing Class I and Class II obesity in women.

Methods: This cross-sectional study was conducted at the Physiotherapy outpatient department, Madha Hospital, Kovur, Chennai, over 12 weeks. One hundred women aged 20-45 years were included, with 50 in each of the Class I and II obesity groups. Women with Class III obesity or associated co-morbidities were excluded. Anthropometric measurements, such as BMI and skin fold thickness in the abdomen and thigh, along with NMES markers (Surge Faradic Current [SFC] and Interrupted Galvanic Current [IGC]) in the abdomen and thigh, were collected. Data analysis was performed using SPSS version 20. An unpaired t-test was used to compare the NMES markers between the two groups. Correlation analysis between BMI and NMES markers was also conducted. ROC analysis was used to determine the Area under the Curve (AUC) for diagnostic accuracy.

Results: There was a significant difference in the NMES markers between Class I and II obese women at $P \leq 0.005$. SFC demonstrated a superior diagnostic ability with a higher AUC than IGC at a significance level of $P<0.000$. The significant correlation between BMI and NMES markers at the $p<0.05$ level further supports the utility of NMES in obesity assessment.

Conclusion: NMES markers can effectively analyze obesity in women, with SFC showing better diagnostic accuracy than IGC.

Keywords: Body mass index (BMI), Obesity, Neuromuscular electrical stimulation markers (NMES), Skin folds thickness (SFT).

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INTRODUCTION

Obesity is a primary global health concern that affects people of all ages, from children to older people. A study by the Indian Council of Medical Research (ICMR)2015 found that increased urbanization, sedentary lifestyles, and higher consumption of processed and fast foods have increased obesity. These changes have resulted in a higher prevalence of both abdominal and general obesity in urban populations compared to rural areas [1].

An uneven distribution of body fat characterizes obesity. Obese women often accumulate more subcutaneous fat in the lower abdomen and gluteal-femoral areas, a pattern known as peripheral or gynoid obesity, commonly referred to as "pear-shaped" obesity [2]. Various measurements such as height, weight, body mass index (BMI), waist-to-hip ratio, and skinfold thickness are used to assess different aspects of adiposity. These methods are popular due to their simplicity, ease of use, and minimal equipment requirements [3].

More advanced methods for measuring body fat include densitometry, plethysmography, underwater weighing, nuclear magnetic resonance imaging, dual-energy X-ray absorptiometry (DXA), and bioelectrical impedance analysis. However, these techniques are often complex, expensive, and less practical for widespread clinical or epidemiological use [4].

The World Health Organization (WHO) defines obesity based on BMI, with a BMI of over 30 kg/m^2 indicating obesity. People with a BMI between 25 and 30 kg/m^2 are considered overweight, while those with a BMI over 30 kg/m^2 are classified into three obesity classes: Class I (30-35 kg/m^2), Class II (35-40 kg/m^2), and Class III (over 40 kg/m^2) [5]. The distribution of body fat, particularly visceral fat accumulation, is a significant health risk factor linked to cardiometabolic diseases such as diabetes, hypertension, dyslipidemia, and coronary artery disease [6].

Neuromuscular electrical stimulation (NMES), also known as electrical muscle stimulation (EMS), is a technique that uses electrical impulses to induce muscle contractions [7]. These impulses are delivered to the muscle's motor points via active electrodes [8], arranged in monopolar or bipolar configurations. NMES is widely used in physical therapy and rehabilitation because it can stimulate muscle contraction and potentially aid muscle re-education and strengthening.

NMES delivers a waveform of electrical current with parameters such as stimulus frequency, amplitude, and pulse width. The strength of the muscle contraction can be adjusted by altering these parameters [9].

The motor point is the location in the muscle that exhibits a brisk contraction at the lowest stimulation level. Transcutaneous electrodes use external leads that connect to a stimulator. Two electrodes in either a monopole or bipolar configuration must produce an electrical current flow. The active electrode is placed directly over the peripheral nerve or motor point, and the inactive electrode is placed either on the fascia or tendinous insertion (monopolar technique) or near the active electrode (bipolar technique). NMES preferentially recruits superficial motor units, with deeper motor units progressively recruited as stimulation intensity increases, thus increasing contraction strength. Applying NMES over a nerve trunk or motor point is better than applying it on the muscle belly. Delivering NMES over a nerve trunk can stimulate reflex pathways through the spinal cord, leading to evoked contraction [10].

The NMES stimulus supplies electrons to depolarize the nerve. The number of electrons supplied per stimulus equals the current. The muscle repolarization to the stimulus is called a twitch. The most commonly used waveforms in electrotherapy are faradic current (SF), surged faradic current (SFC), Galvanic current (GC), and Interrupted galvanic current (IGC). This study uses the surged faradic (SFC) and interrupted galvanic current (IGC).

Faradic current has a pulse duration of 0.1 – 1 ms and a 50-100 Hz frequency. Suppose the peak current applied to the subject increases and decreases rhythmically. In that case, the peak amplitude's rate of increase and decrease is slow, and the resulting shape of the current waveform is called a surged faradic current. For interrupted galvanic current, pulses are square with an adjustable duration and frequency. A duration of 100 ms with a frequency of 30 per minute is commonly used. The rise and fall of intensity may be sudden (square) or gradual (trapezoidal), triangular, and sawtooth impulses. An optimal NMES utilizes the minimal stimulus frequency that produces a fused response. The frequency range for NMES is 10 – 50 Hz [11]. The objective of the study was to explore the role of NMES as a diagnostic tool in class I and class II obese women.

NMES has the potential to offer insights into muscle function and body composition, which could be relevant for understanding obesity and its associated health risks. However, the relevance of NMES as a primary tool for diagnosing or managing obesity remains to be fully established,

METHODOLOGY

This study was a cross-sectional study conducted in the Department of Physiotherapy at Madha Hospital in Kovur, Chennai, over 4 months. Ethical approval for the study involving human subjects was obtained from the Research and Ethical Committee at SIMATS (Saveetha Institute of Medical and Technical Sciences). Before their inclusion in the study, all subjects provided written informed consent after being briefed about the research's benefits, outcomes, and scope. The study included 100 subjects based on specific inclusion and exclusion criteria. The subjects were divided into two groups: class I obese women (50 individuals) and class II obese women (50 individuals) using a stratified random sampling method.

The inclusion criteria for this study are as follows: female subjects aged between 18 and 50 years, with a Body Mass

Index (BMI) falling within the range of obesity class I (BMI 30–34.9) and class II (BMI 35–39.9). Only participants meeting these criteria will be considered for inclusion in the study to ensure a homogeneous sample representative of the target population.

The exclusion criteria for this study are as follows: male subjects, subjects with a BMI falling within obesity class III (BMI ≥ 40), subjects with any associated co-morbidities (such as hypertension or diabetes mellitus), and subjects with chronic systemic disorders (including, but not limited to renal failure). These criteria are established to minimize confounding factors and ensure a more uniform study population.

Anthropometric Markers:

Measurements of anthropometric markers were performed on subjects wearing appropriate attire without shoes. BMI was calculated by dividing weight (in kg) by the square of height (in m2) and categorized into Class I Obesity (BMI > 30) and Class II obesity (BMI > 35) [12].

The skin fold thickness of the abdominal and thigh muscles (SFT) was measured using a skin fold caliper to estimate obesity. The measurements were taken on the right side for consistency. The tester pinched the skin at the appropriate site to lift the underlying skin and adipose tissue, but not muscle. The caliper was then applied 1 cm below at a right angle to the pinch, and the measurement in millimeters (mm) was recorded. The mean of two measurements was taken, and if the two measures differed significantly, a third measurement was taken, and the same examiner recorded the median values.

Abdomen: The measurement was taken with the subject standing, with the site being 5 cm lateral to and at the level of the midpoint of the umbilicus [13,14].

Thigh: The measurement was taken with the subject seated, with the site being the front of the thigh, halfway between the inguinal crease and the anterior patella along the long axis of the femur [14].

Neuromuscular electrical stimulator (NMES) Markers:

Electrical stimulation parameters include frequency, pulse width/duration, and intensity/amplitude. The muscle motor point identification was done before applying the active electrodes at the motor point for stimulation. The muscle motor point was identified by scanning the skin surface with a pen electrode (active or negative electrode) and with a second electrode called the reference or inactive electrode (positive electrode), which is larger than the active electrode and is placed over the antagonist muscle using the monopolar configuration method of application. The therapist slightly presses the pen electrode on a specific skin area overlying the targeted muscle for 3-5 seconds. Then, the pen electrode is moved to adjacent locations to check for the mechanical response until an evident contraction of the muscle is obtained. After that, the stimulation current intensity is decreased to elicit minimal muscle contraction. Gobbo et al. stated that NMES delivered at the identified motor point is vital to elicit muscle contraction while minimizing current intensity and discomfort [15].

Subjects are positioned supine with the hip and knee flexed to relax the abdominal muscles. Measurements are performed on the right-hand side of the body. The active electrode is placed above the motor point of the abdominal muscles - external oblique (EO), rectus abdominis (RA), and thigh muscles – vastus medialis (VM) and vastus lateralis (VL) [16].

External oblique (EO) – The electrode is positioned horizontally, inferior to the costal margin. A stimulus at a frequency of 0.5 Hz and pulse width (100 ms) is applied, and the electrode is moved laterally until minimal muscle contraction is obtained.

Rectus abdominis (RA) – The electrode is positioned vertically, approximately 3 cm lateral to the umbilicus, and moved laterally and superiorly until minimal muscle contraction is obtained.

Vastus medialis (VM) – The electrode is applied to the outer three fingerbreadths superior medial to the base of the patella.

Vastus lateralis (VL) – The electrode is applied to the outer superior lateral aspect of the base of the patella.

DATA ANALYSIS

The collected data were tabulated and analyzed using both descriptive and inferential statistics. All parameters were evaluated using the Statistical Package for the Social Sciences (SPSS) version 20. An unpaired t-test was used to find a statistical difference between the groups of obese women of class I and II. Correlation analysis was used to measure the strength of the association between BMI and NMES markers and SFT.ROC analysis was used to measure the Area under curve (AUC) value of the NMES markers of the abdominal and thigh muscles.

RESULTS

Table 1 compares demographic and anthropometric parameters between Class I and II obesity in women.BMI was significantly higher in Class II obese women(36.78±1.58) as compared to class I obese women(31.02± 1.25) ($p<0.05$) in Table 1.

Table 1: Comparison of demographic and Anthropometric parameters between Class I and Class II obese women

Parameters	Class I		Class II		P value
	Mean	SD	Mean	SD	
Age	32.88	8.51	2.88	8.45	1.00
Height	158.24	6.83	158.00	5.99	0.85
Weight	77.64	7.00	91.76	6.56	0.000
BMI	31.02	1.25	36.78	1.58	0.000

($p<0.05$)

In comparison, the Mean values of NMES marker-surged faradic current (SFC) and Interrupted galvanic current

(IGC) between class I and Class II obese women.

The abdominal muscle external oblique (EO) and rectus abdominus (RA) show statistically significant differences between both groups in Table 2.

Table 2: Comparison Of NMES Marker In Abdominal Muscle Between Class I And II Obese Women

NMES Marker-Abdominal	Class	N	Mean±Standard Deviation	P Value
Abdominal (EO) – SFC (mA)	I	50	36.10±5.22	0.000
	II	50	40.02±4.46	
Abdominal (EO) – IGC (mA)	I	50	39.18±5.52	0.000
	II	50	43.34±4.42	
Abdominal (RA) – SFC (mA)	I	50	35.04±4.29	0.005
	II	50	37.42±4.01	
Abdominal (RA) – IGC (mA)	I	50	38.18±4.42	0.002
	II	50	40.84±3.95	

($p<0.05$)

In comparison, the mean values of NMES marker-surged faradic current (SFC) and Interrupted galvanic current (IGC) between class I and Class II obese women.

On the thigh muscle, the vastus medialis (VM) and vastus lateralis (VL) show a statistically significant difference between both groups in Table 3.

Table 3: Comparison Of NMES Marker In Thigh Muscle Between Class I And Class II Obese Women

NMES Marker-Thigh	Class	N	Mean±Standard deviation	p- Value
Thigh(VM) – SFC (mA)	I	50	38.36±4.62	0.000
	II	50	41.52±3.73	
Thigh(VM) – IGC (mA)	I	50	42.24±4.33	0.003
	II	50	44.68±3.73	
Thigh(VL) – SFC (mA)	I	50	37.60±3.43	0.000
	II	50	40.40±2.87	
Thigh(VL) – IGC (mA)	I	50	41.58±3.33	0.003
	II	50	43.54±2.97	

($p<0.05$)

In comparison, the mean values of skin fold thickness (SFT) between class I and Class II obese women on abdominal and thigh muscles show a statistically significant difference between both groups in Table 4.

Table 4: Comparison Of SFT Marker In Abdominal And Thigh muscles between Class I And II Obese Women

SFT Marker	Class	N	Mean±Standard deviation	p- Value
Abdominal – SFT	I	50	30.56±2.03	0.000
	II	50	33.34±2.47	
Thigh – SFT	I	50	40.88±1.92	0.000
	II	50	43.30±3.12	

($p<0.05$)

In comparison, r values of BMI and NMES Markers of the abdomen-surged faradic current (SFC) and Interrupted galvanic current (IGC) between class I and Class II obese women, r value of NMES Markers – SFC and IGC of EO and RA Class II is positively correlated with BMI when compared with Class I which is negatively correlated with BMI in Table 5.

Table 5: Correlation Of BMI with NMES Marker In Abdominal Muscle Between Class I and II Obese Women

BMI				
NMES Marker-Abdominal	**Class**	**N**	**r-value**	**p- Value**
Abdominal (EO) – SFC (mA)	I	50	- 0.072	0.619
	II	50	0.675**	0.000**
Abdominal (EO) – IGC (mA)	I	50	-0.124	0.390
	II	50	0.652**	0.000**
Abdominal (RA) – SFC (mA)	I	50	- 0.197	0.169
	II	50	0.551**	0.000**
Abdominal (RA) – IGC (mA)	I	50	-0.177	0.291
	II	50	0.520**	0.000**

** Correlation is significant at the 0.05 level.

In comparison, the r-values of BMI and NMES Markers of Thigh - surged faradic current (SFC) and Interrupted galvanic current (IGC) between class I and Class II obese women, r value of NMES Markers – SFC and IGC of VM and VL Class II are positively correlated with BMI when compared with Class I which is negatively correlated with BMI in Table 6.

Table 6: Correlation of BMI with NMES Marker In Thigh Muscle Between Class I and II Obese Women

BMI				
NMES Marker-Thigh	**Class**	**N**	**r-value**	**p- Value**
Thigh (VM) – SFC (mA)	I	50	0.118	0.413
	II	50	0.496**	0.000**
Thigh (VM) – IGC (mA)	I	50	0.164	0.254
	II	50	0.406**	0.003**
Thigh (VL) – SFC (mA)	I	50	0.035	0.809
	II	50	0.505**	0.000**
Thigh (VL) – IGC (mA)	I	50	0.026	0.857
	II	50	0.507**	0.000**

** Correlation is significant at the 0.05 level.

On Receiver operating curve (ROC) analysis, on comparison of the Area under curve (AUC) value of NMES markers between SFC and IGC in abdomen and Thigh muscle, it showed the highest Area under curve (AUC) value for predicting obesity with SFC marker in abdomen and Thigh muscle.

Table 7: ROC Analysis of NMES Marker In Abdomen and Thigh Muscle Obese Women

NMES Marker -Thigh	AUC Value	Cut Off Value	p-Value	Sensitivity	Specificity
Abdominal(EO) – SFC (ma)	0.740	38.5	0.000	0.490	0.200
Abdominal(EO) – IGC (ma)	0.680	41.5	0.000	0.520	0.290

Abdominal(RA)– SFC (ma)	0.716	36.5	0.000	0.530	0.220
Abdominal(RA) – IGC (ma)	0.664	39.5	0.000	0.520	0.310
Thigh (VM) – SFC (mA)	0.665	39.5	0.000	0.610	0.330
Thigh (VM) – IGC (mA)	0.630	43.5	0.001	0.510	0.270
Thigh (VL) – SFC (mA)	0.717	39.5	0.000	0.480	0.220
Thigh (VL) – IGC (mA)	0.678	42.5	0.000	0.520	0.260

(p<0.000)

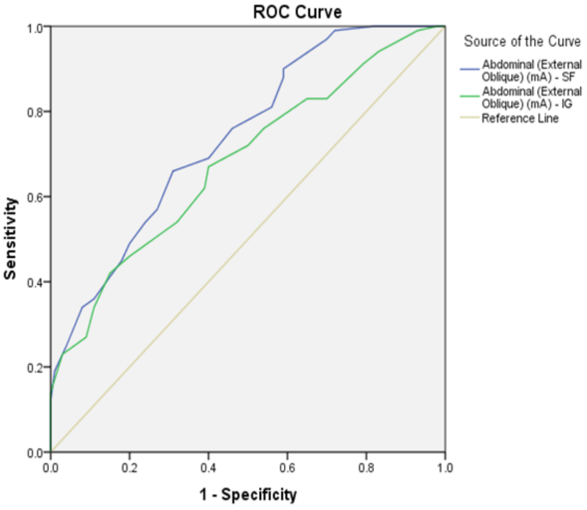

FIGURE 1: AUC Value of SFC and IGC Markerin Abdominal (External Oblique)

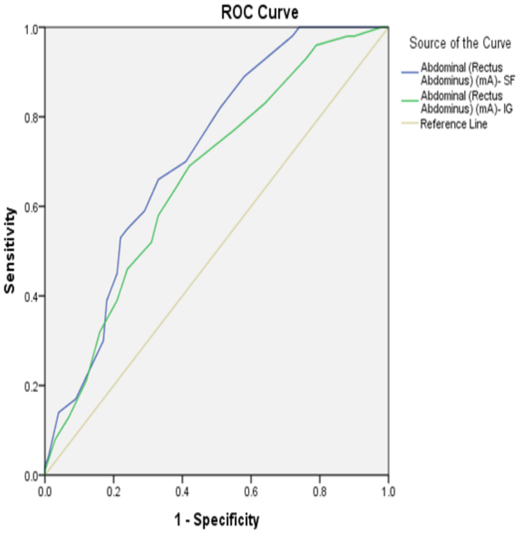

FIGURE 2: AUC Value of SFC and IGC Marker in Abdominal (Rectus Abdominus)

In the Receiver Operating Characteristic (ROC) curve analysis for NMES markers between SFC and IGC in abdomen muscle EO and RA from Fig 1 and Fig 2, we found the highest Area Under the Curve (AUC) value for predicting obesity with SFC marker value of 0.740, compared to IGC marker value of 0.680 in EO, and SFC marker value of 0.716 with IGC 0.664 in RA muscle of the abdomen, at a significance level of P<0.000.

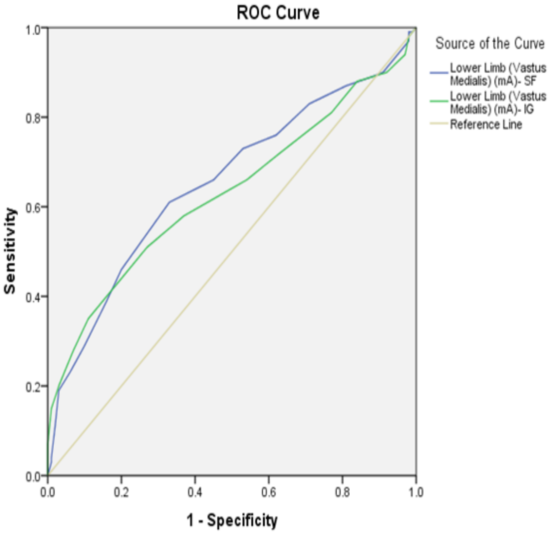

FIGURE 3: AUC Value of SFC and IGC Markerin Thigh (Vastus Medialis)

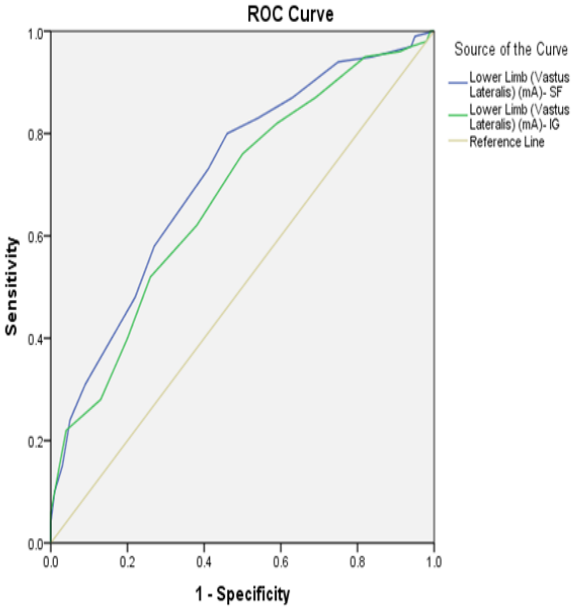

FIGURE 4: AUC Value of SFC and IGC Marker in Thigh (Vastus Lateralis)

In the Receiver Operating Characteristic (ROC) curve analysis for NMES markers between SFC and IGC in thigh muscles VM and VL from Fig 3 and Fig 4, found that the AUC value was higher with SFC marker value of 0.655 compared to IGC 0.630 in VM, and SFC value of 0.717 with IGC value of 0.678 in VL muscles of the thigh at P<0.000.

DISCUSSION

In this study, we aimed to evaluate the effectiveness of neuromuscular electrical stimulation (NMES) markers in predicting obesity in women with class I and II obesity. Specifically, we sought to explore the relationship between subcutaneous fat thickness and two NMES markers—Surge Faradic Current (SFC) and Interrupted Galvanic Current (IGC)—in diagnosing obesity in these women and to compare these findings with standard diagnostic techniques. Additionally, we investigated the correlation between NMES markers and traditional Body Mass

Index (BMI) markers. According to the World Health Organization (WHO), obesity is defined as a BMI greater than 30 kg/m², with class I obesity ranging from 30–34.9 kg/m² and class II obesity from 35–39.9 kg/m². Our findings suggest that NMES markers, particularly SFC and IGC, may provide valuable supplementary information in assessing obesity, potentially offering a more precise method for diagnosing individuals with class I and II obesity. These markers could enhance the predictive accuracy of BMI measurements and contribute to a more nuanced understanding of body composition in obese women, providing a useful tool for both clinical and research applications. For Asian populations, the WHO proposes a BMI cutoff of 27.5 kg/m2 for obesity [17]. While BMI can be used as a screening tool for obesity, clinical interpretation, and physical examination are necessary to confirm the presence of excess adiposity. Our results indicated that the mean BMI value was significantly higher in class II obese women (36.78) compared to class I obese women (31.02) at a significance level of $p<0.05$.

Previous research studies examined using NMES (neuromuscular electrical stimulation) for therapeutic purposes, such as treating obesity rather than diagnosing obesity. NMES is a non-invasive, cost-effective, and readily available tool commonly used in electrotherapy departments. However, no studies have utilized NMES as a diagnostic tool for evaluating obesity. This study aims to explore the feasibility of using NMES markers (specifically surge faradic current SFC and interrupted galvanic current IGC) to diagnose obesity in class I and class II obese women. The rheobase, the minimum current required to stimulate a muscle, typically falls within the 2 to 18 mA range. It is influenced by electrode geometry, subject anatomy, shape, and the type of electrical pulse used.

Bioelectrical impedance analysis (BIA) is a method that measures the body's electrical impedance to the flow of alternating current using one or more frequencies applied to the skin surface through electrodes [18]. The movement of the current is measured on the skin and muscles using surface electrodes. The body's conductivity varies, and impedance can be used to estimate body composition. The study of neuromuscular electrical stimulation (NMES) is similar to BIA and is directly related to body composition. Higher current intensities are needed in individuals with excessive subcutaneous adipose tissue to produce visible muscle contractions. The thickness of the subcutaneous fat layer is directly related to signal loss from the skin. People with greater subcutaneous body fat require more current to stimulate skeletal muscle contraction.

Maffiuletti et al. (2008) state that a larger amount of subcutaneous fat thickness limits current diffusion and impedes current flow in the targeted muscle in obese women [19].

In the unpaired T-test analysis of NMES markers in class I and II obese women, the mean values of SFC and IGC markers for the abdominals EO and RA were statistically significant at the $P<0.05$ level.

Similarly, in the unpaired T-test analysis of NMES markers in class I and II obese women, the mean values of SFC and IGC markers for thigh VM and VL were also statistically significant at the $P<0.05$ level. These findings are consistent with previous studies. According to Do Henry et al. (2008), the amplitude required to evoke muscle contraction increased due to the increased impedance of subcutaneous fat thickness [20]. Jerold Petrosky et al. (2008) also stated that the thickness of the subcutaneous fat layer is directly proportional to impedance, which affects the passage of electrical impulses into the muscle [21].

In the unpaired T-test analysis of skin fold thickness (SFT) markers in the abdomen and thigh muscles of class I and class II obese women, it was observed that the mean values of class I and class II were statistically significant at $P<0.05$ level.

When comparing the mean values of SFC and IGC NMES markers between class I and class II obese women, it was found that the mean value of class I is less compared to class II obese women, indicating less impedance or resistance to electrical stimulation to evoke minimal muscle contraction in this study. This may be due to less subcutaneous fat than in class II obese women, which correlates with the findings of Miller MG et al. (2008) [22]. His studies found that a greater amplitude of current is required for those with thicker subcutaneous tissue to achieve the desired muscle contraction.

Our correlation studies showed a similar correlation in class II obese women when comparing the BMI and NMES markers of abdominal and thigh muscles. This suggests that NMES markers can help analyze obesity in women. These findings align with Ransing et al. (2013), who found a strong positive correlation between BMI and subcutaneous fat [23].

In the Receiver Operating Characteristic (ROC) curve analysis for NMES markers in the abdomen and Thigh muscles, the present study estimated cutoff values for NMES markers as follows:

Abdominal muscle: SFC (EO) 38.5, IGC (EO) 41.5, SFC (RA) 36.5, IGC (RA) 39.5.

Thigh muscle: SFC (VM) 39.5, IGC (VM) 43.5, SFC (VL) 39.5, IGC (VL) 42.5.

Based on the above cutoff value of 38.5 for the SFC NMES marker and 41.5 for the IGC NMES marker, the SFC and IGC NMES marker scores for detecting obesity in women were 74 % and 68%, respectively, with a sensitivity specificity of 0.490 and 0.200 for the SFC and 0.520 and 0.290 for the IGC NMES marker at the $p<0.000$ level.

The SFC and IGC NMES marker scores in identifying female obesity were 71% and 66%, respectively, with sensitivity and specificity of 0.530 and 0.220 for SFC and 0.520 and 0.310 for IGC NMES Marker at $p<0.000$ level, based on the cutoff value in abdominals RA 36.5 for SFC NMES marker and 39.5 for IGC NMES marker.

According to the Thigh VM cutoff values of 39.5 for the SFC NMES marker and 43.5 for the IGC NMES marker, the respective scores for the SFC and IGC NMES markers in identifying female obesity were 66% and 63%, with sensitivity and specificity of 0.610 and 0.330 for the SFC and 0.510 and 0.270 for the IGC NMES marker at the p<0.000 level.

The SFC and IGC NMES marker scores in identifying female obesity were 71% and 67%, respectively, with sensitivity and specificity of 0.480 and 0.220 for SFC and 0.520 and 0.260 for IGC NMES marker at p<0.000 level, based on the cutoff values in Thigh VL of 39.5 for SFC NMES marker and 42.5 for IGC NMES marker.

Figures 1 and 2's AUC values for the SFC and IGC markers in the external oblique and Rectus abdominus demonstrate the markers' discriminative ability to identify muscle activation levels and the significance of abdominal muscle assessment.

The AUC values for the SFC and IGC markers for the thigh muscle, vastus medialis, and vastus lateralis in Figures 3 and 4 highlight the significance of accurate thigh muscle assessments in rehabilitation.

A relatively high AUC suggests their effectiveness in differentiating between states, supporting their utility in obesity diagnostics and rehabilitation protocols targeting this muscle group.

After comparing the results as mentioned above, we found that the Surge Faradic Current (SFC) marker, as opposed to the Interrupted Galvanic Current (IGC) marker, is more accurate in assessing obesity in the abdominal and thigh muscles of obese women (class I and class II) in this study.

The SFC marker is a valuable tool for identifying excess adiposity because it demonstrated a stronger correlation with subcutaneous fat thickness. Clinically, the SFC marker provides a simple way to confirm the existence of excess body fat in women through patient inspection or physical examination.

This practical approach enhances the diagnostic process, providing healthcare providers with a reliable, non-invasive means to assess obesity in this population. These findings are consistent with previous studies. Gandeviaet(2001)also stated that the NMES marker could be a reliable research tool for understanding intact muscle contraction in obesity using electrotherapy techniques [24].

However, the study has several limitations that should be considered. First, the findings may not be generalizable to populations with associated co-morbidities, class III obese women, or male subjects, as these groups were excluded from the study. Additionally, the research focused specifically on two NMES markers, and further studies are needed to explore the utility of other NMES parameters for a more comprehensive evaluation of obesity. Incorporating additional outcome measures, such as invasive biomarkers and gold-standard measurement techniques like dual-energy X-ray absorptiometry (DXA) or MRI, would validate the NMES markers more robustly and strengthen the findings. Future research should address these gaps and further refine the use of NMES in obesity diagnosis and management.

CONCLUSION

The study aimed to analyze the use of NMES as a diagnostic tool in obese women. It found that BMI was significantly higher in class II obese women compared to class I obese women. When comparing abdominal and thigh NMES markers, the study found that mean SFC and IGC were lower in class I obese women than in class II obese women, suggesting lower impedance or electrical current resistance in class I obese women. Additionally, the mean SFT of the abdominal and thigh muscles was higher in class II obese women than in class I obese women. Correlation analysis of BMI and NMES markers showed a positive correlation in class II obese women when compared to class I obese women. AUC values infer that SFC NMES markers are more helpful in analyzing obesity than IGC NMES markers. This study concludes that NMES can be used as a diagnostic tool in the analysis of obesity in class I and II women population, along with a physical examination to confirm the presence of excess subcutaneous fat.

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AUTHORS CONTRIBUTION STATEMENT

All the authors approved the final version of the research paper to be published and agreed to be accountable for all aspects of the work related to its accuracy or integrity.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCE

[1] Omorede E, Osayande G, Azekhumen N, Emmanuel O, Obuzor A. A comparative study of different body fat measuring instruments. *Niger J Physiol Sci*. 2018;33(4):125-128.

[2] Pradeepa R, Anjana RM, Joshi SR, et al. Epidemiology of type 2 diabetes and its complications in India. *Indian J Med Res*. 2015;142(2):139-150.

[3] Arner P. Obesity and human fat cell metabolism. *J Endocrinol*. 1997;155(2):191-192.

[4] Taghizadeh S, Abbasalizad Ferhangi M. Neck circumference as a potent anthropometric predictor of cardiovascular diseases and metabolic syndrome. *J Nutr Tasty Health*. 2019;7(2):70-75.

[5] Silver HJ, Wesch ED, Avison MJ, Niswender KD. Diabetes, metabolic syndrome and obesity: targets and therapy. *Diabetes Metab Syndr Obes*. 2010;3:337-347.

[6] Lucas RE, Fonseca AL, Dantal RO. Neck circumference can differentiate obese from non-obese individuals. *Med Express*. 2016;3(4):M160403.

[7] Satardekar MB, Deepak V, Bhoir V. Analysis and enhancement in the performance of electrical muscle

stimulator. *Int J Eng Sci Res Technol*. 2017;6(1):1-5.
[8] Lokhande M. Muscle stimulation. *Int J Core Eng Manage*. 2014;1(9):52-56.
[9] Pavlovic R, Tokulja D, Petokovic S, Dragutinovic S. Electro-muscle stimulation: the application in practice. *Acta Kinesiologia*. 2016;10(Suppl):49-55.
[10] Sheffler LR, Chae J. Neuromuscular electrical stimulation in neurorehabilitation. *Muscle Nerve*. 2007;35(5):562-590.
[11] Dlazevich AJ, Collins DF, Millet GY, et al. Enhancing adaptation to neuromuscular electrical stimulation training intervention. *Exerc Sport Sci Rev*. 2021;49(4):244-252.
[12] Carnier R, Rovis M, et al. Anthropometric clinical indicators in the assessment of visceral obesity: an update. *Nutr Clin Diet Hosp*. 2016;36(2):168-179.
[13] Doucet BM, Lam A, Griffin L. Neuromuscular electrical stimulation for skeletal muscle function. *Yale J Biol Med*. 2012;85(2):201-215.
[14] Garie AL, et al. Improved predictions of body fat by measuring skinfold thickness, circumference, and bone health. *Obes Res*. 2005;13(3):52-56.
[15] McCaughey EJ, McLean AN, Allan DB, Gollee H. Detection of motor points of the abdominal muscle. *Eur J Appl Physiol*. 2014;114(12):2483-2489.
[16] Gobbo M, Maffiuletti NA, Orizio C, et al. Muscle motor point identification is essential for optimizing neuromuscular electrical stimulation use. *J Neuroeng Rehabil*. 2014;11:17.
[17] Weir CB, Jan A. BMI classification percentile and cutoff points. *Star Pearl Internet*. 2024 Jan.
[18] Thajer A, et al. Comparison of bioelectrical impedance-based methods on body composition in young patients with obesity. *Children (Basel)*. 2021;8(4):295.
[19] Maffiuletti NA, et al. Differences in electrical stimulation thresholds between men and women. *Ann Neurol*. 2008;63(5):507-512.
[20] Dohenry S, et al. Effect of subcutaneous fat thickness and surface electrode configuration during neuromuscular electrical stimulation. *Med Eng Phys*. 2010;32(5):468-474.
[21] Petrofsky J. The effect of the subcutaneous fat and the transfer of current through skin into muscle. *Med Eng Phys*. 2008;30(9):1168-1176.
[22] Miller MG, et al. Subcutaneous tissue thickness alters the effect of NMES. *J Sport Rehabil*. 2008;17(1):68-75.
[23] Ransingh S, et al. Body mass index and body fat percentage estimated by bioelectrical impedance in a group of Sri Lankan adults: a cross-sectional study. *BMC Public Health*. 2013;13:797.
[24] Gandevia SC. Spinal and supraspinal factors in human muscle fatigue. *Physiol Rev*. 2001;81(4):1725-1789.