Identification of essential anthropometric and health-related markers for effective weight loss program in middle-aged women

Identificación de marcadores clave para la pérdida de peso en mujeres de mediana edad

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Abstract

Introduction: Effective weight loss programs should consider more than just total body weight reduction, incorporating other critical anthropometric and health-related markers.
Objective: This study aimed to identify the key markers essential for a healthy and effective weight loss regimen in women.
Methodology: A total of 143 women (mean age 39.32±8.60 years; BMI 30.27±5.94) from Malaysia participated. Various anthropometric and health-related markers were measured using standard procedures. Principal Component Analysis (PCA) was employed to extract the crucial markers for an effective weight loss program, while Multiple Regression Analysis (MLR) validated these variables.
Results: A 3-factor solution proved effective, with Component 1 including arm, hip, bust, thigh, and waist circumferences; Component 2 comprising body fat, weight, and visceral fat; and Component 3 involving bone mass and basal metabolic rate. These components were renamed as anthropometric attributes, adiposity, and metabolic skeletal health, respectively. The MLR model, with these components as independent variables and weight as the dependent variable, yielded a significant regression ($F(2163, 1) = 73.3$, $p < 0.0001$, $R^2 = 0.979$), explaining 98% of the variability in weight. All variables significantly contributed to the model ($p < 0.001$).
Discussion: The results highlight that effective weight loss goes beyond just reducing body weight. Key factors such as body measurements, fat levels, and metabolic health play a crucial role. The strong predictive ability of these factors ($R^2 = 0.979$, $p < 0.001$) suggests that weight loss programs should focus on overall body composition and health rather than just weight reduction for better, long-term outcomes.
Conclusions: This study accentuates the need for a holistic approach to weight loss, considering a comprehensive evaluation beyond just physical symptoms.

Keywords

Anthropometric parameters; comprehensive fitness program; health markers; middle-aged women; women's health; weight loss.

Resumen

Introducción: Los programas efectivos de pérdida de peso deben considerar más que solo la reducción del peso corporal total, incorporando otros marcadores antropométricos y de salud relevantes.
Objetivo: Este estudio tuvo como objetivo identificar los marcadores clave esenciales para un régimen de pérdida de peso saludable y eficaz en mujeres.
Metodología: Un total de 143 mujeres de Malasia (edad media 39.32±8.60 años; IMC 30.27±5.94) participaron en el estudio. Se midieron diversos marcadores antropométricos y de salud mediante procedimientos estándar. Se aplicó el Análisis de Componentes Principales (ACP) para identificar los marcadores más relevantes en un programa efectivo de pérdida de peso, mientras que el Análisis de Regresión Múltiple (ARM) validó estas variables.
Discusión: Se identificó una solución de tres factores eficaz, en la que el Componente 1 incluyó las circunferencias del brazo, cadera, busto, muslo y cintura; el Componente 2 comprendió la grasa corporal, el peso y la grasa visceral; y el Componente 3 incluyó la masa ósea y la tasa metabólica basal. Estos componentes fueron renombrados como atributos antropométricos, adiposidad y salud metabólica-esquelética, respectivamente. El modelo de ARM, con estos componentes como variables independientes y el peso como variable dependiente, mostró una regresión significativa ($F(2163, 1) = 73.3$, $p < 0.0001$, $R^2 = 0.979$), explicando el 98% de la variabilidad en el peso. Todas las variables contribuyeron significativamente al modelo ($p < 0.001$).
Conclusiones: Este estudio resalta la necesidad de un enfoque holístico en la pérdida de peso, considerando una evaluación integral que vaya más allá de los síntomas físicos.

Palabras clave

Parámetros antropométricos; programa integral de acondicionamiento físico; marcadores de salud; mujeres de mediana edad; salud de la mujer; pérdida de peso.

Introduction

Obesity is rising globally, with more middle-aged and older women facing weight-related health issues. This trend makes the need for effective, targeted weight loss programs both a pressing social priority and a promising business opportunity (Elmaleh-Sachs et al., 2023). The obesity of middle-aged women does not only concern excess body weight but is also associated with numerous health conditions, such as cardiovascular diseases, diabetes and musculoskeletal disorders (Safaei et al., 2021). Conventional weight loss programs often focus exclusively on reducing overall body weight, neglecting other important health-related markers, which can undermine their long-term efficacy and compliance (Lopez-Jimenez et al., 2022). This highlights the need for a holistic approach that addresses multiple aspects of health, particularly in older adults, where age-related physiological changes play a significant role in weight management.

The focus on middle-aged women in this study stems from their unique physiological and hormonal profiles, which differ markedly from those of younger women and men. In middle age, women often experience transitions such as perimenopause and menopause, leading to significant hormonal fluctuations, declines in basal metabolic rate (BMR), and shifts in fat distribution, particularly visceral fat accumulation (Mauvais-Jarvis et al., 2020). These factors contribute to a higher risk of developing obesity-related complications and create unique challenges in designing effective weight loss interventions (Villareal et al., 2005). By contrast, men are less affected by these hormonal changes and often display different fat distribution patterns and metabolic responses to weight loss programs, making women a particularly vulnerable and underrepresented population for targeted interventions (Lovejoy et al., 2009).

Increasing numbers of obese middle-aged women throughout the world have highlighted substantial public health concerns over several decades, generating a demand for the development of appropriate treatments (Organization, 2020; Semlitsch et al., 2021). While weight loss remains a central focus, modern research also emphasizes holistic approaches that take into account various anthropometric and health variables to promote overall well-being and lasting outcomes (Villareal et al., 2017). Hitherto, the multifaceted nature of health and well-being introduces challenges for both healthcare professionals and patients. It extends beyond mere weight considerations, encompassing various factors such as fitness, nutrition, mental health, and overall quality of life. Striking a balance between these elements is crucial for achieving sustainable results (Contillo et al., 2023).

Anthropometric and health-related markers, such as body fat percentage, visceral fat, and basal metabolic rate (BMR), have been recognized as key indicators of overall health and metabolic function, especially in middle-aged women (Piqueras et al., 2021). However, the challenge lies in identifying which of these markers should be prioritized within a weight loss program to achieve the best outcomes. With the diversity of potential markers, it becomes essential to focus on those that are most predictive of successful weight loss and improved health (Gaskin et al., 2024). This is particularly pertinent in middle-aged women; whose metabolic and physiological characteristics differ significantly from those of younger populations.

This study aims to address this knowledge gap by investigating and identifying the essential anthropometric and health markers crucial for a healthy and effective weight loss regimen specifically designed for middle-aged women. By employing advanced statistical techniques such as Principal Component Analysis (PCA) and Multiple Regression Analysis (MLR), we seek to distil the myriad variables into a set of key markers that can guide the development of more targeted and efficient weight loss programs. This approach aligns with recent calls in the field for more personalized and comprehensive weight management strategies (Bray, 2021).

Method

Participants

A total of 143 middle-aged women (average age = 39.32 ± 8.60 years; mean BMI = 30.27 ± 5.94) participated in the study. These participants were drawn from a finite population of women enrolled in weight

loss programs across four gym branches in Malaysia. Using the formula for sample size calculation in finite populations as follows:

$$n = \frac{N}{1 + N(e^2)'}$$

where N is the population size, e is the margin of error (5%), and n is the required sample size, we determined that 143 participants exceed the minimum sample size needed for a 95% confidence level and a margin of error of ± 5%.

Participants were included if they were middle-aged women (30–50 years), voluntarily enrolled in the weight loss program, and without any pre-existing medical conditions or recent surgical interventions that could affect weight loss outcomes. Exclusion criteria included pregnancy, use of weight loss medication, or participation in other weight management programs concurrently. Informed consent was obtained prior to participation, and the study adhered to the ethical guidelines outlined by the Helsinki Declaration, with ethical approval from the University of Malaysia Terengganu Ethics Committee (UMT/PPP/2-2/25/Jld.10(132)).

Anthropometric and Health assessment

In this study, we conducted anthropometric assessments on women using standard procedures. The measurements included weight, arm circumference, bust circumference, and waist circumference. Additionally, we evaluated various health-related markers, such as body fat percentage, fat mass, water weight, visceral fat, basal metabolic rate, body mass index (BMI), and basal metabolic age. Weight was measured in kilograms (kg) using a standard weighing scale, while arm, waist, and bust circumferences were measured in centimetres using a measuring tape. The Tanita weighing scale (Japan, BC-541) was used for assessing the health-related parameters. It is worth highlighting that the Tanita weighing scale is a bioelectrical impedance analysis (BIA) device that provides an accurate, non-invasive method to assess multiple body composition parameters. It measures weight while also estimating body fat percentage, visceral fat, and other health-related metrics by sending a weak electrical signal through the body. The signal travels differently through lean tissue and fat, allowing the scale to calculate these parameters with high reliability. This method was particularly relevant to our study as it enabled the collection of comprehensive data on body composition, which is essential for understanding the participants' health profiles and tailoring effective weight loss strategies. The measurements were conducted by trained personnel, each with an average of 7 years of experience in health assessment and evaluation, ensuring the reliability of the data.

Data analysis

Principal Component Analysis

Principal Component Analysis (PCA) is a mathematical method used to identify the structure of a dataset from a group of observed variables (Eswaramoorthi et al., 2018; Razali et al., 2017). PCA highlights key variables by examining the spatial and temporal heterogeneity of the data. This process involves removing the least important components, thereby retaining the most useful information. Applying PCA helps streamline large datasets by focusing on the most relevant information, which saves effort, cost, and time while retaining the original data's integrity (Musa et al., 2016, 2018). In this study, PCA was used to pinpoint essential anthropometric and health markers crucial for an effective and healthy weight loss regimen for women by extracting the most relevant parameters following previous recommendations (Abdullah et al., 2017; Eswaramoorthi et al., 2018; Taha et al., 2009).

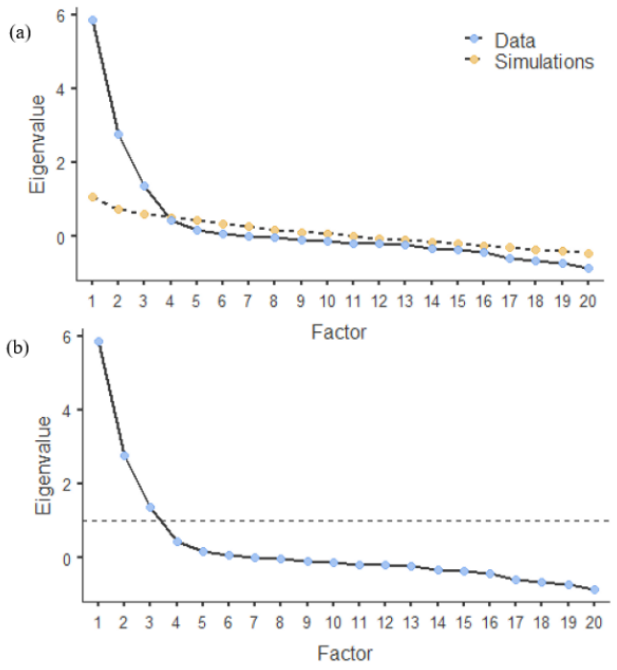
Development of Multiple Regression Model

In the current investigation, we employed multiple regression analysis (MLR) to create a model, using the new components as independent variables and the participants' weight as the dependent variable. The principal component analysis (PCA) scores were utilized to develop the MLR model and validate the extracted variables this is considered necessary to validate the variables extracted. Essentially, the PCA-derived components served as independent variables in an MLR model to predict participant weight i.e., the dependent variable. The statistical analysis was conducted using Jamovi version 2.4.14 for Windows, with all inferences evaluated at a significance level of $p \leq 0.05$.

Results

Figure 1 illustrates both the original dataset and the simulated predicted dataset generated by the PCA algorithm, showcasing a strong alignment between the predicted and observed data trends. This demonstrates the PCA model's ability to accurately represent the underlying structure of the dataset. Conversely, Figure 1b displays the scree plot of the PCA, highlighting the eigenvalues associated with each principal component. The plot indicates a steep decline in eigenvalues after the third component, a result confirmed using the elbow method. This technique identifies the optimal number of components by locating the "elbow" point, where adding additional components yields diminishing returns. Based on this analysis, a 3-factor solution was determined to effectively capture the key anthropometric and health-related parameters relevant to middle-aged women.

Figure 1. Scree plot and Eigenvalue Analysis of the Principal Component Analysis



¡Error! No se encuentra el origen de la referencia. presents the results of PCA analysis after applying varimax rotation. The table reveals three identified components, highlighting a distinct 3-factor solution. Component 1 includes variables consisting of arm circumference, hip circumference, bust circumference, thigh circumference, and waist circumference. Component 2 comprises body fat, weight, and visceral fat. Finally, component 3 involves bone mass and basal metabolic rate. We renamed the scores for each component as follows: 'anthropometric attributes,' 'adiposity,' and 'metabolic skeletal health.' These indicators were selected based on their factor loading values, which met or exceeded the preset threshold of 0.70. Notably, out of the 20 initially examined anthropometric and health-related parameters, 11 were identified as essential within these three components for weight loss programs in middle-aged women.

Table 1. Principal Component Analysis After Varimax Rotation

Variables	F1	F2	F3
Arm Circumference (CC) cm	0.952		
Hip CC (cm)	0.937		
Bust (cm)	0.921		
Thigh CC (cm)	0.921		
Abdominal CC (cm)	0.906		
Waist CC (cm)	0.741		
Body fat		0.806	
Weight (kg)		0.761	
Visceral fat		0.717	
Basal Metabolic Age			
Water Weight			
Skeletal Muscle			
Bone Mass			0.796

Basal Metabolic Rate			0.731
Muscle Mass			
Height			
Body Mass Index			
Age			
Ideal Weight			
Fat Mass			
% Variance	2.61	15.1	13.7
Cumulative %	26.1	41.2	54.9

¡Error! No se encuentra el origen de la referencia. presents the results of the multiple linear regression (MLR) analysis for the model developed. Notably, a highly significant regression equation with an R^2 value of 0.98 was found. This indicates that the model effectively accounts for approximately 98% of the variability in weight. Importantly, all the newly constructed independent variables (IVs) demonstrated strong predictive power for the participants' weight (dependent variable, DV) with a p-value < 0.001. These findings demonstrate that the health and fitness-related indicators specifically anthropometric attributes, adiposity, and metabolic skeletal health can reliably predict weight in middle-aged women.

Table 2. Multiple Linear Regression análisis for predicting the weight of the participants

Predictors	Estimate	SE	F	df	t	p
Intercept	73.3				421.7	
Anthropometric Attributes	1.77	0.174	101	1	10.1	0.0001
Adiposity	10.83	0.176	3503	1	59.2	0.0001
Metabolic Skeletal Health	8.64	0.183	2228	1	47.2	0.0001

Note: RMSE = 2.05; R = 0.989; R^2 = 0.979; F = 2163; p = 0.001

Discussion

The results of the PCA with varimax rotation, as presented in Table 1, reveal a compelling 3-factor solution that provides valuable insights into the essential markers for effective weight loss programs in middle-aged women. This finding aligns with contemporary research emphasizing the importance of multidimensional approaches in obesity management and weight loss interventions (Müller et al., 2018; Pranoto et al., 2024). Component 1, which we have termed 'anthropometric attributes,' encompasses key body circumference measurements including arm, hip, bust, thigh, and waist. This grouping is consistent with recent studies highlighting the significance of body shape and fat distribution in assessing obesity-related health risks (Neeland et al., 2019). For instance, Swainson et al. (Swainson et al., 2017) demonstrated that waist and hip circumferences are robust indicators of cardiometabolic risk, independent of BMI, reflecting the importance of these anthropometric measures in weight management programs.

Component 2, labelled 'adiposity,' comprises body fat, weight, and visceral fat. The inclusion of visceral fat in this component is particularly noteworthy, as it aligns with growing evidence of its critical role in metabolic health (Andarianto et al., 2024). It was emphasized by the preceding investigators that visceral adiposity is more strongly associated with cardiometabolic risk factors than subcutaneous fat, highlighting the importance of targeting this specific fat depot in weight loss interventions for middle-aged women (Shuster et al., 2012).

The third component, 'metabolic skeletal health,' includes bone mass and basal metabolic rate. This grouping reflects the complex interplay between body composition and energy metabolism in middle-aged adults. The inclusion of bone mass is particularly relevant for middle-aged women, given the increased risk of osteoporosis in this population. Villareal et al. (Villareal et al., 2017) demonstrated that combined aerobic and resistance exercise in diet-induced weight loss programs can help preserve bone mass and muscle strength in obese older adults, underscoring the importance of considering these factors in weight management strategies. The selection of these 11 essential markers from an initial pool of 20 parameters, based on factor loadings ≥0.70, provides a robust and focused set of indicators for weight loss programs. This refinement aligns with the principle of parsimony in clinical practice, offering a more manageable and targeted approach to assessment and intervention (Lean et al., 2018).

The results of the Multiple Linear Regression (MLR) analysis presented in Table 2 provide robust evidence for the predictive power of the identified health and fitness-related indicators in determining weight outcomes in middle-aged women (Putra et al., 2024). Our results suggest that the combination of anthropometric attributes, adiposity, and metabolic skeletal health provides a comprehensive and highly accurate predictor of weight in women. This further reinforces the validity and importance of our 3-factor solution. This finding aligns with recent research emphasizing the multifaceted nature of weight management and the need for comprehensive assessment approaches (Borer, 2021; Müller et al., 2018).

The significance of anthropometric attributes in weight loss programs may be attributed to their role in assessing body shape and fat distribution. This is consistent with findings by Neeland et al. who demonstrated that body fat distribution, particularly visceral and ectopic fat, plays a crucial role in cardiometabolic health, independent of total body weight (Neeland et al., 2024). On the other hand, adiposity revealed a strong predictive power of this factor, which includes body fat, weight, and visceral fat, corroborating previous findings which highlighted the critical role of visceral adiposity in metabolic health (Thamilovia & Mageshwari, 2024). The current finding suggests that assessing adiposity goes beyond simple weight measurement, providing a more holistic understanding of an individual's health status. The findings for the predictive power of metabolic skeletal health which encompasses bone mass and basal metabolic rate, align with research of the previous researchers who emphasized the importance of preserving bone and muscle mass in weight loss programs for older adults (Villareal et al., 2017). Our findings suggest that these often-overlooked aspects of health are crucial in predicting and managing weight effectively.

The strong predictive power of the MLR model has important implications for clinical practice and weight management programs. As highlighted by Lean et al. in their ground-breaking DiRECT trial analysis inferred that comprehensive approaches to weight management can lead to significant improvements in health outcomes, including remission of type 2 diabetes (Lean et al., 2018). Our model provides a framework for such comprehensive assessments, potentially enhancing the efficacy of weight loss interventions. Moreover, the high predictive power of the model supports the growing trend towards personalized medicine in weight management. As Lempesis et al. argue in their Endocrine Society Scientific Statement, effective obesity management requires tailored approaches that consider individual variations in body composition and metabolism. Our model, with its high explanatory power, could serve as a foundation for developing such personalized interventions (Lempesis & Georgakopoulou, 2023).

Conclusions

This study accentuates the importance of a comprehensive approach to weight loss in middle-aged women by identifying key markers specifically, anthropometric attributes, adiposity, and metabolic skeletal health that significantly predict weight outcomes. Through PCA and MLR analysis, these markers were shown to account for 98% of the variability in weight, emphasizing their critical role in effective weight management. By focusing on these specific indicators, weight loss programs can be more personalized and holistic, addressing not only weight reduction but also overall health and well-being, which is particularly crucial for middle-aged women.

This study provides a strong foundation for rethinking weight loss programs for middle-aged women. Integrating anthropometric, adiposity, and metabolic skeletal health markers into weight management strategies could provide a basis for moving beyond traditional approaches that focus solely on total body weight. This comprehensive approach offers more effective and sustainable interventions, enhancing overall health and quality of life for middle-aged women. Future research should build on these findings to refine and validate these markers across diverse populations, ensuring their applicability in various contexts and settings.

Limitations of the Study

While this study provides valuable insights, it is not without limitations. First, the finite population sample was limited to participants enrolled in four gym branches, which may restrict generalizability to other populations or geographic regions. Second, while the PCA and MLR models demonstrated strong

predictive validity, external validation of these findings in a more diverse cohort is necessary. Third, the study relied on self-reported adherence to dietary and exercise protocols, which may introduce bias. Future studies should aim to include larger, more diverse populations and integrate objective measures of adherence.

Conflict interest

The authors have no conflict of interest to declare.

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