EFFECT OF COMBINATION OF BEHAVIOURAL INTERVENTION AND NUTRITION EDUCATION WITH BROWN RICE (COMBINE-BROWN) WEIGHT LOSS PROGRAM ON BODY COMPOSITION AND OXIDATIVE STRESS AMONG OVERWEIGHT AND OBESE ADULTS

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by

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LIST OF SYMBOLS

1- β	Power of the study
α	Type 1 error
α	Alfa
A	Average ash weight
β	Type 2 error
B	Blank
c	Centi
ε	Epsilon correction
γ	Gamma
g	Gram
k	Kilo
∫	Light pathlength which is determined from the Calibrator
L	Litre
µ	Micro
m	Mili
M	Molar
n	Nano
n	Number
P	Average protein weight
R	Average residue weight
SW	Average sample weight
T	Titration value
T	Reaction time

v	Volume
w	Weight
W	Weight of the sample
%	Percent
<	Less than
>	More than
≥	Greater than or equal to
^{o} C	Celcius

LIST OF ABBREVIATIONS

1,5 AG	Serum 1,5-anhydroglucitol
$^1O_2$	Singlet oxygen
ADP	Air-displacement plethysmography
Ag	Aleurone grain
Ag	Silver
AGE	Advanced glycation end products
AIDS	Acquired immunodeficiency syndrome
Al	Aluminium
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
APHA	American Public Health Association
As	Arsenic
ATP	Adenosine triphosphate
B1	Thiamine
B2	Riboflavin
B3	Niacin
B6	Pyridoxine
B9	Folic acid
Ba	Barium
BAZ	BMI-for age z score
Be	Beryllium
BERNAS	Padi Beras Nasional
BIA	Body impedance analyser

BIA	Bioelectrical impedance analyser
BLBR	Black rice and brown rice
BMI	Body mass index
BMR	Basal metabolic rate
BP	Blood pressure
BR	Brown rice
BR1	Brown rice variety 1
BR1-RC	Brown rice variety 1 (rice cooker method)
BR1-S	Brown rice variety 1 (steaming method)
BR2	Brown rice variety 2
BR2-RC	Brown rice variety 2 (rice cooker method)
BR2-S	Brown rice variety 2 (steaming method)
BRAVO	Brown Rice and Visceral Fat Obesity in Okinawa
C	Carbon
Ca	Calcium
CAT	Catalase
Cd	Cadmium
CDC	Centres for Disease Control
CHO	Carbohydrate
Cl	Confidence interval
cm	Centimetres
Co	Cobalt
COMBINE	Combination behavioural intervention of nutrition education and exercise

COMBINE-BROWN	Combination of behavioural intervention and nutrition education with Brown rice
CONSORT	Consolidated Standards of Reporting Trials
Cr	Chromium
CRP	C-reactive protein
CT	Computed tomography
Cu	Copper
Cu/Zn SOD	Copper/Zinc Superoxide dismutase
CVD	Cardiovascular diseases
Cw	Cell wall
DASH	Dietary Approaches to Stop Hypertension
DEXA	Dual-energy x-ray absorptiometry
df	Degree of freedom
dH2O	Distilled water
DM	Diabetes mellitus
DNA	Deoxyribonucleic acid
DNL	de novo lipogenesis
DTNB	Ellman's Reagent or [5,5-dithio-bis- (2-nitrobenzoic acid)]
EAR	Estimated average requirement
ECG	Electrocardiogram
EDTA	Ethylenediaminetetraacetic acid
En	Endosperms
EPOC	Post-exercise oxygen consumption
εTNB	molar absorption coefficient of TNB

ETC	Electron transport chain
FAD	Flavin adenine dinucleotide
FAO	Food and Agriculture Organization
FDA	Federal Drug Association
Fe	Iron
FFQs	Food frequency questionnaires
FITT	Frequency, intensity, time and type of activity
FMN	Flavin adenine mononucleotide
F-stat	F-statistic
GABA	Gamma-aminobutyric acids
γ-oryzanol	Gamma-oryzanol
GBD	Global Burden of Disease
GBR	Germinated brown rice
GDH	Glutamate dehydrogenase
GENKI	Genmai (brown rice) Evidence of Nutrition for Kenko (health) Innovation
GI	Glycaemic index
GL	Glycaemic load
GLM	General linear model
GLUT-4	Glucose transporter type-4
GNET	Global Nutrition and Epidemiologic Transition Initiative
GPX	Glutathione peroxidases
GR	Glycaemic response
GR	Glutathione reductase
GSH	Glutathione, Reduced Form

GSIS	Glucose-stimulated insulin secretion
GSSG	Glutathione, Oxidised Form
H_2O_2	Hydrogen peroxide
HbA1c	Haemoglobin A1c
HCl	Hydrochloric acid
HD	High dose
HDI	Human Development Index
HDL-C	High density lipoprotein cholesterol
HNO_3	Acid nitric
HOCl	Hypochlorous acid
HRP	Horseradish Peroxidase
HRQOL	Health-related quality of life
hs-CRP	Highly sensitive C-reactive protein
HUSM	Hospital Universiti Sains Malaysia
iAUC	Incremental area under curve
ICP-MS	Inductively coupled plasma mass spectrometry
ICP-OES	Inductively coupled plasma-optical emission spectrometry
IL-6	Interleukin-6
IPAQ-BM	Malay version of the International Physical Activity Questionnaire
IPH	Institute of Public Health
IQR	Inter quartile range
IWQOL-LITE	Impact of weight on quality of Life-LITE
K	Potassium

KDA	Korean Diabetes Association
kg	Kilogram
kHz	Kilohertz
KoGES	Korean Genome and Epidemiology Study
LAGB	Laparoscopic adjustable gastric banding
LD	Low dose
LDL-C	Low density lipoprotein cholesterol
LF	Long-form
LGS1	Long grain specialty 1
LGS2	Long grain specialty 2
Li	Lithium
MANS	Malaysian Adult Nutritional Survey
MD	Medium dose
MDA	Malondialdehyde
METs	Metabolic equivalents
Mg	Magnesium
$mg^{-1}kg^{-1}$	Milligram per kilogram
µA	Microamperes
µg /L	Microgram per Litre
µL	Microlitre
µM	Micromolar
MIR	Manganese/ferum ratio
mL	Millilitre
mm	Millimetre
mM	Millimolar

Mn	Manganese
Mo	Molybdenum
MOH	Ministry of Health
MRI	Magnetic resonance imaging
MVPA	Moderate-to-vigorous physical activity
N	Nitrogen
Na	Sodium
Na^+-K^+-ATPase	Sodium-potassium-ATPase
NADP	Nicotinamide Adenine Dinucleotide Phosphate, Oxidized Form
NADPH	Nicotinamide Adenine Dinucleotide Phosphate, Reduced Form
NAOH	Sodium hydrochloride
NCD	Non-communicable diseases
NCEP ATP III	National Cholesterol Education Program Adult Treatment Panel III
ND	Non-detected
NF-kB	Nuclear factor kappa B
ng/l	Nanogram per Litre
NGOs	Non-govermental organisations
NHANES	National Health and Nutrition Examination Survey
NHMS	National Health and Morbidity Survey
Ni	Nickel
NIH	National Institute for Health Research
NO	Nitric oxide

NPANM III	National Plan of Action for Nutrition Malaysia III
O	Oxygen
O_2^-	Superoxide radical
O_3	Ozone
OD	Optical density
ODB	Optical density blank
ODS	Optical density sample
OH^-	Hydroxyl radical
P	Parenchymal cell layers
Pb	Lead
PERSUADE	Peer Support Program for Adults with Metabolic Syndrome
PGBR	Pre-germinated brown rice
PLP	pyridoxal phosphate
ppb	Part per billion
pps	Points per second
ppt	Part per trillion
PS	Power and Sample Size
PTFE	Polytetrafluoroethylene
PUFA	polyunsaturated fatty acids
PURE	Prospective Urban and Rural Epidemiology
QOL	Quality Of life
RC	Rice cooker
RF	Reference food
RG	Refined grain

RNI	Recommended nutrient intake
RNS	Reactive nitrogen species
R-OH	Alcohol
R-OOH	Organic peroxides
ROS	Reactive oxygen species
RSD	Relative standard deviation
RYGB	Roux-en-Y gastric bypass
S	Steaming
Sb	Antimony
SD	Standard deviations
Se	Selenium
SEM	Standard error of the mean
SEM-EDX	Scanning electron microscope-energy dispersive X-ray Spectroscopy
SF	Short-form
SF-36	Short form-36
Si	Silicon
SLiM	Specialist Lifestyle Management
SOD	Superoxide dismutase
Sr	Strontium
T2D	Type 2 diabetes
TBA	Thiobarbituric acid
TBARS	Thiobarbituric acid reactive substances
TC	Total cholesterol
TCA	Trichloroacetic acid

TEI	Total Energy Intake
TGs	Tryglyceride
Th	Thorium
Ti	Titanium
TNB	5-thio-2-nitrobenzoic acid
TNB^{2-}	2-nitro-5-thiobenzoate anion
TNF-α	tumour necrosis factor-alpha
TPP	Thiamine pyrophosphate
TSC	Technical Sub-Committee
TTM	Transtheoretical Model of Behaviour Change
U	Uranium
UL	Tolerable upper intake level
USM	Universiti Sains Malaysia
V	Vanadium
VSG	Vertical sleeve gastrectomy
w/v	Weight by volume
WC	Waist circumference
WG	Whole grain
WHO	World Health Organisation
WHR	Waist-to-hip ratio
WR	White rice variety
WR	working reagent
WR-RC	White rice variety (rice cooker method)
WR-S	White rice variety (steaming method)
Zn	Zinc

LIST OF APPENDICES

KESAN KOMBINASI INTERVENSI TINGKAHLAKU DAN PENDIDIKAN PEMAKANAN BERSERTA BERAS PERANG DALAM PROGRAM PENURUNAN BERAT BADAN (COMBINE-BROWN) KE ATAS KOMPOSISI BADAN DAN STRES OKSIDATIF DALAM KALANGAN DEWASA YANG BERLEBIHAN BERAT BADAN DAN OBES

ABSTRAK

Walaupun beras perang terkenal dengan nilai yang berkhasiat tetapi keberkesanan program kombinasi intervensi beras perang, tingkahlaku, pendidikan makanan dan senaman (COMBINE-BROWN) agak terhad. Kajian ini terbahagi kepada tiga fasa. Objektif Fasa I dan II bagi kajian ini adalah untuk menentukan komposisi makanan, perbezaan tekstur beras, perbezaan elemen dan ultrastruktur beras, dan tindak balas glisemik untuk varieti beras perang 1 dan 2 (BR1 dan BR2) dan varieti beras putih (WR). Selain itu, tujuan utama Fasa III adalah untuk menentukan perbezaan antropometri, komposisi badan dan penanda stress oksidatif antara kumpulan kontrol (kumpulan COMBINE) dan kumpulan intervensi (kumpulan COMBINE-BR) dalam 12 minggu intervensi dan 12 minggu kajian susulan. Sebanyak 66 peserta yang berlebihan berat badan dan obes dibahagikan kepada dua kumpulan (kumpulan COMBINE dan kumpulan COMBINE-BR) dengan menggunakan reka bentuk kuasi eksperimen. Pada fasa intervensi, sejumlah 22 peserta (33.33%) dalam kumpulan COMBINE dan 7 orang (10.61%) peserta dalam kumpulan COMBINE-BR menarik diri daripada kajian ini. Selain itu, seramai 37 peserta dalam kumpulan COMBINE dan 38 peserta dalam kumpulan COMBINE-BR menamatkan kajian susulan pada minggu ke-24. Perbezaan antropometri, komposisi badan, jumlah skor Impak Berat Kualiti Hidup-LITE (IWQOL-LITE), jumlah skor aktiviti fizikal (IPAQ-

Long) diukur pada minggu 0, minggu ke-12 dan minggu ke-24. Di samping itu, profil biokimia, termasuklah profil glukosa, profil lipid, profil fungsi ginjal, dan penanda stres oksidatif diukur pada minggu 0 dan minggu ke-12 sahaja. Hasil akhir analisa diukur dengan menggunakan analisis ANOVA berulang, mengikut kaedah per-protokol (PP) dan analysis tujuan merawat (ITT) seperti yang disarankan oleh garis panduan CONSORT (Consolidated Standards of Reporting Trials). Fasa I menunjukkan bahawa beras perang mengandungi komposisi dan elemen makanan yang lebih banyak berbanding dengan beras putih. Di samping itu, di Fasa II, ketiga-tiga beras yang dikaji mempunyai indeks glisemik pada tahap yang sederhana. Di Fasa III, kedua-dua kumpulan menunjukkan peningkatan yang signifikan ($p<0.05$) terhadap penurunan berat badan, jumlah peratusan lemak badan, profil lipid, tahap antioksidan (GPX dan GR), jumlah fizikal aktiviti dan skor IWQOL-LITE dalam tempoh 12 minggu intervensi. Kumpulan COMBINE-BR menunjukkan penurunan tekanan oksidatif yang signifikan berbanding dengan kumpulan COMBINE, dengan peningkatan yang signifikan dalam penurunan penanda stress oksidatif TBARS. Selari dengan analisa PP, analisa ITT menunjukkan bahawa pembolehubah berat, jumlah peratusan lemak badan, dan penanda stress oksidatif mempunyai perbezaan yang signifikan ($p<0.001$) bagi kedua-dua kumpulan berdasarkan kesan waktu. Selain itu, variabel berat dan penanda stress oksidatif (TBARS) menunjukkan interaksi rawatan yang signifikan ($p<0.05$) dengan waktu. Berdasarkan hasil pendapatan yang terakhir dari analisa ITT, kumpulan COMBINE menunjukkan penurunan berat badan yang lebih tinggi (-6.88kg) berbanding dengan kumpulan COMBINE-BR (-4.34 kg) pada fasa intervensi. Walau bagaimanapun, kumpulan COMBINE-BR menunjukkan kecenderungan keberlanjutan berat yang lebih berkesan (-0.37 kg) berbanding dengan kumpulan COMBINE (meningkat sebanyak 1.75 kg) semasa kajian susulan pada minggu ke-24. Kesimpulannya, pengambilan beras putih yang bersederhana, perlaksanaan aktiviti fizikal berserta modifikasi tingkahlaku secara konsisten dapat membantu menurunkan berat badan. Di samping itu, pengambilan beras perang dapat membantu meningkatkan kandungan mineral, serat makanan dan antioksidan. Justeru, paket intervensi beras perang berpotensi sebagai alternatif untuk memelihara berat badan selepas penurunan berat badan, meningkatkan sistem imun dan mencegah penyakit yang terlibat dengan obesiti.

EFFECT OF COMBINATION OF BEHAVIOURAL INTERVENTION AND NUTRITION EDUCATION WTH BROWN RICE (COMBINE-BROWN) WEIGHT LOSS PROGRAM ON BODY COMPOSITION AND OXIDATIVE STRESS AND AMONG OVERWEIGHT AND OBESE ADULTS

ABSTRACT

Brown rice is well known for its nutritious value. However, little is known regarding the effectiveness of a combination of behavioural intervention and nutrition education with brown rice (COMBINE-BROWN) weight loss program. The present study was divided into three phases. Phase I and II of the study's objectives were to determine the nutrition composition, textural, elemental and ultrastructure difference, and glycaemic response for the brown rice variety 1 and 2 (BR1 and BR2) and white rice variety (WR). Meanwhile, Phase III of the study mainly aimed to evaluate the difference in body composition, oxidative stress biomarkers among the control group (COMBINE Group) and intervention group (COMBINE-BR Group) in a 12 week intverention and subsequent 12 week follow-up. A total of 66 overweight and obese participants were allocated into two arms (COMBINE Group and COMBINE-BR Group) in a quasi-experimental design. In the intervention phase, 22 participants (33.33%) in the COMBINE Group and 7 (10.61%) participants in the COMBINE-BR Group dropped out from the study. Meanwhile, 37 participants in the COMBINE Group and 38 participants in the COMBINE-BR Group completed the follow-up at week-24. The body composition, body anthropometric, total scores of the impact of weight on quality of life-LITE, and total scores of physical activities using International Physical Activity Questionnaires were measured at 0-week, 12-week and 24-week. Meanwhile, the biochemical profiles, including glucose, lipid, and

antioxidants, were determined at 0-week and 12-week. The final outcomes were measured using repeated measure ANOVA for time effect and time-treatment effect using both per-protocol (PP) and intention-to-treat (ITT) analyses as suggested by Consolidated Standards of Reporting Trials reporting guidelines. The finding from Phase I reported a greater nutritional composition and elements content in brown rice than in white rice. Meanwhile, in Phase II, an intermediate glycaemic index was reported for the rice varieties. In Phase III, both groups showed significant improvement ($p<0.05$) in weight loss, total body fat percentage, lipid profile, antioxidants level (GPX and GR), total physical activity and the scores of IWQOL-LITE in the 12-week intervention period. The COMBINE-BR Group significantly reduced oxidative stress compared to the COMBINE Group, as shown by a significant reduction of TBARS biomarkers. In parallel with PP analysis, the results showed a significant difference ($p<0.001$) in mean weight, body fat percentage, and oxidative stress biomarkers for both groups using ITT analysis based on time. Meanwhile, significant time-treatment interaction ($p<0.05$) was observed for weight and oxidative stress biomarkers (TBARS). Based on the final outcomes of intention-to-treat analyses, although the COMBINE Group showed more significant weight loss (-6.88kg) than the COMBINE-BR Group (-4.34 kg) in the intervention phase, the COMBINE-BR Group showed a weight maintenance trend (-0.37 kg) as compared with the COMBINE Group (increased by 1.75 kg) during follow-up evaluation at week-24. In conclusion, adequate intake of white rice, physical activity and behavioural modification in a consistent mode might aid weight loss. Meanwhile, brown rice could be beneficial in adding extra minerals, dietary fibre and antioxidant properties, which might act as an alternative therapeutic regimen for weight maintenance, improve the immune system and thus prevent obesity-related diseases.

CHAPTER 1

INTRODUCTION

1.1 Background

Overweight and obesity are public health issues, defined as excessive fat deposition in the body that may harm health (WHO, 2022b). The World Health Organisation (WHO) classified overweight as body mass index (BMI) ≥ 25 kgm^{-2} and obese as BMI ≥30 kgm^{-2} (WHO, 2022b). A systematic analysis of the Global Burden of Disease GBD) showed that the increasing pandemic of overweight and obesity is affecting the lives of millions of children and adults (GBD, 2017). The prevalence of obesity and its comorbidities has continued to increase over the past decades (Malik *et al.*, 2020). According to a global, regional, and time-trend prevalence of central obesity in a systematic review of 13.2 million subjects, the overall prevalence of central obesity was 41.5%, almost reaching half of the world (Wong *et al.*, 2020). A rapid increase in BMI was observed in Southern America, East Asia, the Middle East, North Africa, South Asia, and South-East Asia in a population-based study (Bentham *et al.*, 2017).

A new world bank report showed that over 70 per cent of low- and middle-income countries face double-burden diseases, with a high prevalence of malnutrition and obesity. Malaysia is categorised as a middle-income, developing country in the South-East Asian region, which faces the problem of double-burden diseases (Shekar and Popkin, 2020). Currently, Malaysia is ranked as the fattest country in this region. Almost half of the Malaysian adult population, which comprises 9.9 million citizens, are categorised as overweight or obese, which moves towards alarming overweight and obesity trends (IPH, 2019; WHO, 2022b).

The energy imbalance might be the main reason for overweight and obesity, particularly physical inactivity and high dietary energy consumption (Hall *et al.*, 2022). The sedentary lifestyle and unhealthy habits have led to non-communicable diseases (NCD), which lead to 71% of mortality rates globally. The most NCD mortality rate was cardiovascular diseases (CVD), followed by cancer, respiratory diseases, and diabetes mellitus (DM) (WHO, 2022a). The NCD placed a severe health burden on countries, resulting from disability and loss of healthy life years, known as the burden of disease costs. The intangible cost of NCD in Malaysia is estimated to be approximately RM 100.79 billion annually (WHO, 2022a). Besides, obesity was associated with a decrease in health-related quality of life (Stephenson *et al.*, 2021), lower work productivity, activity impairment, and an increase in healthcare issues (Rozjabek *et al.*, 2020). The increased refined grain intake and low whole grain intake were among the primary risk factors contributing to non-communicable diseases (Bhavadharini *et al.*, 2020; Melaku *et al.*, 2019).

The meta-analysis review revealed that whole grain consumption is advantageous in preventing non-communicable diseases, particularly diabetes mellitus, cardiovascular diseases, and colorectal, pancreatic, and gastric cancers (McRae, 2017). Whole grain consumers' mortality rate decreased by 18% (Ma *et al.*, 2016). Meanwhile, refined grain consumption was associated with increased obesity and a higher risk for NCDs (Gaesser, 2019). The 2015 Dietary Guidelines Advisory Committee suggested that the American population substitute half or most refined grains with whole grains (USDA, 2020). Meanwhile, the Malaysian Dietary Guidelines suggest that Malaysians consume adequate amounts of rice and cereals, preferably whole grain (MOH, 2021). The dietary intervention of weight loss using cereals has been reported to be beneficial in weight loss in a few randomised control trials (Anunciação *et al.*, 2019; Rahmani *et al.*, 2019; Rosi *et al.*, 2020). Besides, brown rice also revealed weight loss properties in a few animal studies (Chua *et al.*, 2018). Rice bran feeding also alleviates dyslipidaemia and weight loss in high-fat diet-induced obese mice (Zou *et al.*, 2020). A pilot study in Indonesia reported that replacing white rice with brown rice significantly decreased body weight, body fat percentage, and fasting blood glucose in diabetic participants (Handayani *et al.*, 2021). Meanwhile, in Malaysia, brown rice administration in hypercholesterolemia rats has been shown to reduce body weight (Imam *et al.*, 2014).

The general structure of whole grain and refined grain (Heart Foundation, 2022) and rice (Cozzano *et al.*, 2018) are shown in Figure 1.1 and Figure 1.2, respectively. The whole grain has three main layers: the outer germ and bran layers and the inner endosperm layer. The whole grain has undergone a milling and polishing process to obtain refined grain to remove the outer germ and bran layer. Similarly, the whole brown rice is refined into polished rice after the de-husking process (Phongthai *et al.*, 2017) (Figure 1.3). Meanwhile, the structure of rice plants and rice seeds consists of rice husk, rice grain, rice bran, and rice grain (Peanparkdee and Iwamoto, 2019). Brown rice has three main layers, similar to the general whole grain structure. Precisely, brown rice has brownish appearance. The outer bran layer consisting of a pericarp, seed coat, most of the aleurone layer, and embryo. Meanwhile, white rice has whitish appearance (Figure 1.4). It only has an inner starchy endosperm comprised of traces of aleurone and sub-aleurone layers (Bautista and Counce, 2020). As a result, white rice has caused losses of beneficial nutrients compared with brown rice (Upadhyay and Karn, 2018).

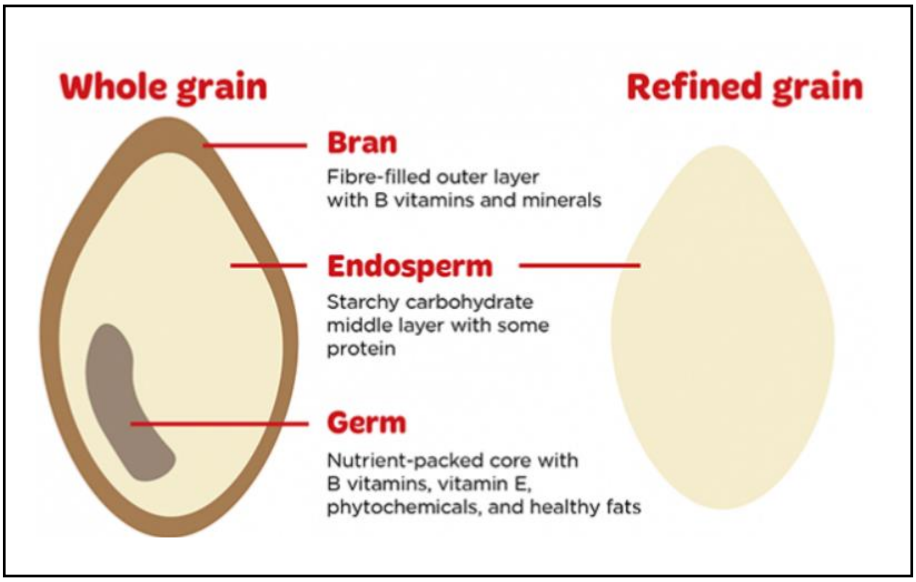


Figure 1.1 General structure of whole grain and refined grain
(Adopted from Heart Foundation, 2022)

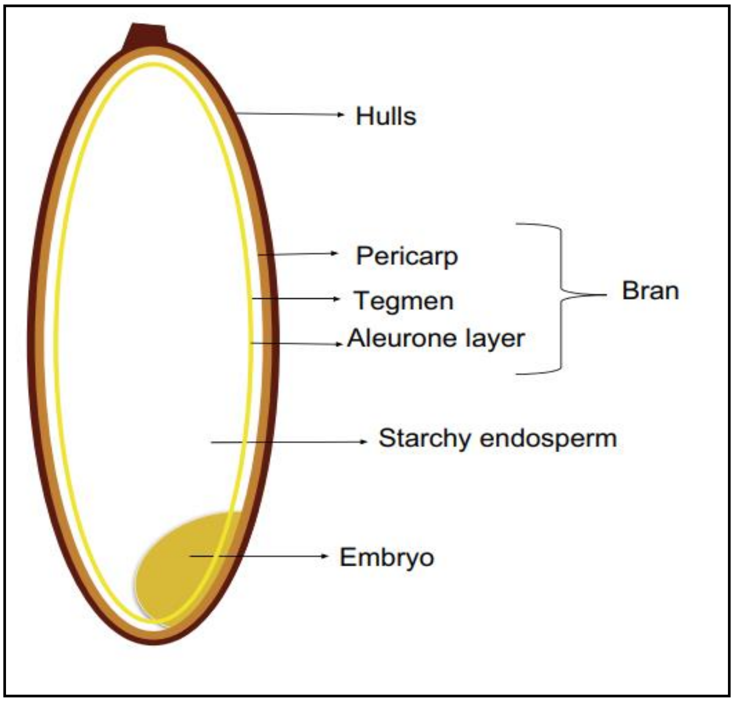


Figure 1.2 General structure of rice
(Adopted from Cozzano *et al.*, 2018)

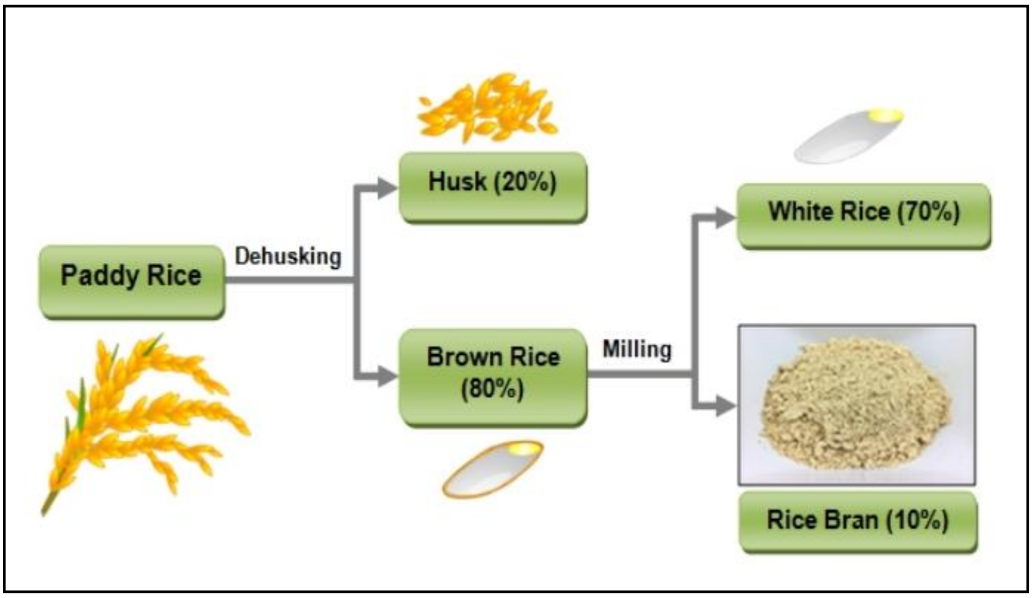


Figure 1.3 The dehusking of paddy rice and milling of brown rice process (Adopted from Phongthai *et al.*, 2017)

Figure 1.4 Physical appearance of brown rice (Left) and white rice (right)

More than 50 % of the world population, especially those who live in Asia countries, such as India, China, Indonesia, Vietnam, and Thailand, regularly consume rice (*Oryza sativa* L.*)* as one of the most valuable cereal crops and staple food (Jain *et al.*, 2012; Rohman *et al.*, 2014). The migration of some Asian populations to Western countries has influenced rice consumption as a staple diet (Jain *et al.*, 2012; Rohman *et al.*, 2014; Se *et al.*, 2015). Rice is the primary source of carbohydrate content in the rice-eating region (Bhavadharini *et al.*, 2020), including Malaysia. The Malaysian population generally consumes rice as a staple diet. Approximately 97% of the Malaysian population consumed rice twice daily, with around 2 ½ plates per day (Norimah *et al.*, 2008). The per capita rice consumption accounted for 500 to 799 calories per day. The paddy production increase from 2014 to 2016 predicts a gradual increase in rice production in the next four years, particularly in Kedah, known as Malaysia's rice bowl (Yusof *et al.*, 2019).

Brown rice appears to be one of the best options for whole grain to be incorporated into a weight-loss regimen since whole food has higher dietary fibre and low glycaemic index, qualities to reduce body weight (Lee *et al.*, 2019a; Zahra and Jabeen, 2020). The previous meta-analysis showed that brown rice might be used as a daily consumption replacement for white rice since it has a weight loss effect and could improve lipid profile (Rahim *et al.*, 2021). In Malaysia, weight loss intervention has been conducted in various clinical settings to alleviate obesity and NCDs (Khan *et al.*, 2020; Mohamad Nor *et al.*, 2018; Yaacob and Azidah, 2018). However, no scientific evidence has been documented in Malaysia regarding brown rice as part of behavioural weight loss intervention programmes in humans, particularly among the Malay population.

1.2 Problem statement

For the past two decades, like many countries in South East Asia, Malaysia has experienced a nutrition transition since rapid and marked socioeconomic advancement brought significant changes in communities' lifestyles (Popkin, 2021). The economic development in Malaysia has improved the agriculture sector to food processing technology (Davey *et al.*, 2013). Moreover, the nutrition transition moves toward a more convenient and processed global diet that includes ultra-processed food (Baker *et al.*, 2020). The westernisation of lifestyle has caused the gradual replacement of traditional diet with westernising global eating habits, which has been the main factor in the obesity crisis in low-and middle-income countries (Blüher, 2019).

The obesogenic environment has been described as a collective influence exerted by the environment, life circumstances and opportunities that lead to obesity in society or individuals (Swinburn *et al.*, 1999). The accessibility to ultra-processed food rich in sodium, sugar, and fat and deficient in dietary fibre has increased because of the growing emergence of fast-food chains (Barbalho, 2021; Barber *et al.*, 2020). Hence, eating outside the home has become a norm in current society (Barbalho, 2021). Besides, the increased availability of low-cost processed foods such as sugar-sweetened beverages and refined grains are low in dietary fibre, deficient in nutritional quality, and calorie-dense (Malik *et al.*, 2020). Furthermore, health knowledge about whole grains, such as brown rice, is lacking. Therefore, the community prefers consuming refined grains (Barrett *et al.*, 2020). Moreover, the other obesogenic environment, such as computer-based work dominating most occupations and leisure time dependent on information technology, has increased sedentary lifestyles and the chances of obesity (Blüher, 2019).

Excess intake of high glycaemic food, such as white rice, has increased the risk of obesity and obesity-related diseases (Chopra *et al.*, 2020; Mohan *et al.*, 2018). A prospective study conducted in Hospital USM, Malaysia, with self-administered Food Intake Questionnaires revealed that rice, sugar, evaporated milk, full cream milk, and cordial drink were significantly associated with obesity risk among the patients visiting the hospital (Afolabi *et al.*, 2020). In the Philippines, white rice feeding in rats led to weight gain and increased blood glucose levels compared to brown rice (Chua *et al.*, 2018). Furthermore, in Malaysia, white rice feeding in the animal study showed significantly higher fasting blood glucose, insulin resistance, and triglycerides than a high-fat diet (Osman *et al.*, 2022). Moreover, a high white rice intake was positively associated with type 2 diabetes in human studies, especially in Asian countries (Bhavadharini *et al.*, 2020; Ren *et al.*, 2021).

The increased ultra-processed food has poor nutrients and energy-dense in the current food environment. Therefore, increased intake of a fibre-rich diet such as whole grain is beneficial in reducing the prevalence of obesity and obesity-related diseases (Aung *et al.*, 2021; Khan *et al.*, 2022). A high-fibre diet helps improve glycaemic control, blood lipids, body weight, and inflammation (Reynolds *et al.*, 2020). The studies on dietary fibre intake in Malaysia provide a wide range of finding. However, none of the results achieved the recommended daily intake of at least 25 g (MOH, 2021). Higher dietary fibre intake could be achieved by increased consumption of whole grains such as brown rice (Barrett *et al.*, 2020) and increased total intake of plant-based food (Seljak *et al.*, 2021). Higher consumption of dietary fibre than recommended is required to meet the needs of the human microbiome to preserve the colon and whole-body health and prevent the progression of obesity-related diseases

(O'Keefe, 2019). Besides, dietary fibre could help in glycaemic control through a decrease in gastric emptying and prolonged satiety, therefore, helping in body weight regulation (Bozzetto *et al.*, 2018). Therefore, replacing refined grain products with whole grain foods, such as brown rice, is one practical way to increase dietary fibre (Reynolds *et al.*, 2020).

Besides, based on an observational cohort study in the United Kingdom, obesity showed higher resource utilisation costs with an increasing body mass index. The cost is further higher for those with obesity with non-communicable diseases, especially diabetes mellitus (Le Roux *et al.*, 2018). Similarly, in Japan, overweight and obesity increase the financial burden of high medical costs among different age groups and gender (Fujita *et al.*, 2018). According to Economist Intelligent Unit (2017), the direct and indirect costs of medical treatment to combat obesity in Malaysia are estimated to be approximately 1 to 2 billion US dollars (about 4.26 to 8.53 billion Malaysian Ringgit) each year. The total cost of treatment of obesity is equivalent to 10% to 19% of national healthcare spending. Thus, the deteriorating health condition has increased the burden on Malaysia's residents, employers, and government.

Furthermore, increased medical claims and medical leave have caused a significant loss of human resources and profits to employers or working institutions (Tan *et al.*, 2011). The residents who face obesity, too, increase indirect expenses, for instance, enrolling in expensive weight loss programs or shopping for different costly weight loss products, which most of them are not sustainable (Avery, 2018; Bray *et al.*, 2018). Besides, weight bias and discrimination among overweight and obese individuals have impaired health-related quality of life due to the increasing incidence of obesity (Kitiş *et al.*, 2019). Therefore, it is crucial to conduct an immediate weight management program to lessen the severe health complications on healthcare costs and services (Le Roux *et al.*, 2018).

In recent years, Malaysia has improved public health dietary communication with the evolution of Malaysian dietary guidelines and the introduction of the visually-oriented Malaysian Food Pyramid and Malaysian Health Plate (Lee *et al.*, 2020). However, health information might not be practicable for some communities due to different understanding levels, environments and cultural backgrounds (Lee *et al.*, 2020). Besides, most studies emphasised a cross-sectional study to identify the prevalence and associated factors of overweight and obesity, including the National Health and Morbidity Survey (IPH, 2019). Moreover, the weight loss studies related to obesity in Malaysia were implemented in different settings, such as a hospital (Ramadas *et al.*, 2018), universities (Thu *et al.*, 2019), schools (Sharif Ishak *et al.*, 2020), army (Fuad *et al.*, 2019), and workplace (Rusali *et al.*, 2018). However, there is limited community-based intervention study in Malaysia for weight loss, although the prevalence of obesity is rising (IPH, 2019). The researchers from Institute for Public Health conducted a community weight loss program, "My Body is Fit and Fabulous (MyBFF)", among Malay housewives living in low-cost flats and working adults in government sectors in Kelantan in MyBFF@Home (Ambak *et al.*, 2018) and MyBFF@Work (Ismail *et al.*, 2018), respectively. However, the study of MyBFF@Work is a workplace study by food provision; hence, it is very costly (Ismail *et al.*, 2018). Therefore, conducting a cost-effective, clinical-based intervention study in the local community is essential to clarify the health messages better and increase their motivation to practise a healthy lifestyle.

1.3 Justification of the study

Obesity prevention and management have been highlighted in the Eleventh Malaysian Plan as important Nutrition Research Priorities (MOH, 2016). According to the National Plan of Action for Nutrition for Malaysia III (NPANM III) in the year 2015 and 2016, the national strategy of 'Preventing and controlling obesity' has been identified as one of the principal aims to accomplish the target of ideal nutritional well-being of Malaysian (MOH, 2016). The Ministry of Health aims to reduce obesity by 2025 (MOH, 2016). Besides, the Malaysian government has also initiated various campaigns such as 10 000 Steps A Day, My Weight My Health, and MySihat (Verma *et al.*, 2013). However, although international non-governmental organisations (NGOs), national government organisations, and various communities have implemented strategies to prevent obesity, the prevalence of obesity continues to rise (WHO, 2022b).

Lifestyle modification programs with a combination of diet, physical activity, and behavioural modification approaches have become research interest in weight loss studies since the weight loss and weight maintenance effect is prominent and longer-lasting (Kushner, 2018; Wadden *et al.*, 2020). Besides, healthy and moderate weight loss is vital to reduce the prevalence of overweight and obesity, improve health-related quality of life, improve antioxidant status, decrease the total cost of medical treatment, duration of hospitalisation, and postoperative complications (Bray *et al.*, 2016; McMurray *et al.*, 2016). Currently, in Malaysia, the scientific evidence for substituting whole grain (brown rice) as part of a weight loss program for human have not been reported. To the best of my literature search, presently, no study is available to measure anthropometric, body composition, and oxidative stress biomarkers after participating in a behavioural weight loss program incorporating brown rice as a daily dietary regimen among overweight and obese participants in Malaysia. Thus, the study used a novel approach to integrate brown rice provision as part of a short-term weight loss regimen and alternative to refined white rice among the Malaysian population.

According to Mattei *et al.* (2015), a global research effort has been implemented across countries to participate in Global Nutrition and Epidemiologic Transition Initiative (GNET) to improve the carbohydrate quality of staple food. The acceptability and preference of brown rice have been evaluated in a qualitative focus group discussion and sensory evaluation in China (Zhang *et al.*, 2010), India (Kumar *et al.*, 2011; Sudha *et al.*, 2013), Tanzania (Muhihi *et al.*, 2012), Costa Rican (Monge-Rojas *et al.*, 2014), Nigeria (Adebamowo *et al.*, 2017), and Indonesia (Helmyati *et al.*, 2020). Most consumers in the focus group discussion indicated an interest in the dietary replacement of white rice with brown rice if the information about brown rice was provided and brown rice was available at an affordable price (Adebamowo *et al.*, 2017; Monge-Rojas *et al.*, 2014). Through GNET effort, a few randomised controlled trials have been conducted to evaluate the impact of brown rice in replacing white rice as a daily diet regimen, for instance, in China (Zhang *et al.*, 2011) and India (Mohan *et al.*, 2014; Malik *et al.*, 2019), but none in Malaysia. These studies showed inconsistent findings, which may be due to different study designs and cultural practices. Besides, many contributing factors lead to overweight and obesity apart from refined grain consumption as a staple food, such as physical inactivity and sedentary lifestyles.

Malaysia is a multiracial country with an abundance of delicious cuisine (Najib *et al.*, 2014). Kelantan, one of the states of Malaysia, has been recognised as the 'Cradle of Malay Culture.' The image of Kelantan food represents the Malay food image since few last generations. However, geographical and other cultural influences also might affect the measurement of the food image of the region (Hanan and Abd Hamid, 2017). According to an article from World Atlas, Malaysia is a multiracial country. Malay is the largest ethnic population in Malaysia, with approximately 50.1% of Malaysia's total demographic composition (Sawe, 2019). Furthermore, the Malay population are categorised among the highest risk of being overweight and obese, in Malaysia (IPH, 2019). A few determinant-social factors for obesity among the Malay obese community in Malaysia were identified in a systematic review, such as low esteem, deprived diet and eating habits, physical inactivity, and poor health knowledge (Ullah *et al.*, 2018). The present study helps provide a weight loss protocol for Malaysians, especially the Malay ethnic in Malaysia, which has a high prevalence of overweight and obesity (IPH, 2019). Besides, this study manages to educate the local community in Kelantan to have better health awareness and improve health-related quality of life through participation in the weight-loss study.

This current study also took opportunities to evaluate the nutritional quality and glycaemic index of several brown rice varieties commercially available in Malaysia and the most popular and highly consumed white rice among the Kelantanese. This is because there is limited data regarding elemental levels and the ultrastructure of brown rice and favourable white rice commercially available in Malaysia. The glycaemic index of rice is vital in classifying carbohydrate foods and guiding food choices (Trinidad *et al.*, 2013). Brown rice haIs a lower glycaemic index compared to refined white rice in a few varieties of brown rice from Malaysian and Thailand (Ishak *et al.*, 2016; Madan *et al.*, 2016; Yusof *et al.*, 2005). Thus, the present study provides a better comparison of famous brown rice and white rice available in Malaysia regarding proximate composition, minerals, textural, structural differences, and glycaemic index. This analysis would deliver a better understanding and insights into healthier food choices among consumers.

Most studies showed that brown rice (*Oryza sativa* L.) has health benefits as a whole grain. The increased consumption of whole grains could contribute to increased weight loss and improvement of obesity indices such as waist-hip ratio, waist circumference, and lipid and glucose status and reduce the oxidative stress level in the body (Vincent *et al.*, 2007). Besides, whole grains are also rich in phenolic compounds, phytochemical compounds, and antioxidants. Antioxidants are essential to reverse the negative effect of free radicals, which might cause the pathogenesis of obesity-related diseases (Slavin, 2004). Thus, there has been an increased interest in using whole grain as a research tool to develop a weight-loss program and improve individuals' general health (Roby *et al.*, 2013). For instance, the Great-Child Trial, a quasi-experimental study on whole grains with a healthy balanced diet, has been conducted to manage childhood obesity in Malaysia (Koo *et al.*, 2018). However, none of the studies attempted to integrate brown rice into adults' clinical settings of weight loss programs. Thus, the COMBINE-BROWN research was the pilot study to assess the effect of brown rice provision and white rice among the overweight and obese Malay population in Malaysia in three months quasi-experimental study of a clinical weight loss program.

1.4 Research questions

Are there any significant changes in body weight, body fat percentage, and oxidative stress level between the COMBINE Group (control group) and COMBINE-BR Group (intervention group) after 12 weeks and during follow-up at week-24 of COMBINE-BROWN clinical weight loss program among overweight and obese adults?

1.5 Research Hypothesis

1.5.1 Null hypothesis

There is no significant improvement in body weight, body fat percentage, and oxidative stress level between the COMBINE Group (control group) and COMBINE-BR Group (intervention group) after 12 weeks and during follow-up at week-24 of COMBINE-BROWN clinical weight loss program among overweight and obese adults.

1.5.2 Alternative hypothesis

There is significant improvement in body weight, body fat percentage, and oxidative stress level between the COMBINE Group (control group) and COMBINE-BR Group (intervention group) after 12 weeks and during follow-up at week-24 of COMBINE-BROWN clinical weight loss program among overweight and obese adults.

1.6 General objectives

To assess the effect combination of behavioural intervention and nutrition education with brown rice (COMBINE-BROWN) weight loss program on body compositions and oxidative stress between the COMBINE Group (control group) and the COMBINE-BR Group (intervention group) after 12 weeks (post-intervention) and at week-24 (follow-up) clinical weight loss program among overweight and obese adults.

1.6.1 Specific objectives

1. To determine the nutritional compositions and glycaemic index of brown rice in COMBINE-BROWN clinical weight loss program among overweight and obese adults.

2. To determine mean difference of body weight, anthropometric and body composition measurements after 12 weeks (post-intervention) and at week-24 (follow-up) COMBINE-BROWN clinical weight loss program among overweight and obese adults.

3. To determine the mean difference in oxidative stress and biochemical parameters (lipid profile, fasting blood glucose, renal profile) after 12 weeks (post-intervention) COMBINE-BROWN clinical weight loss program among overweight and obese adults.

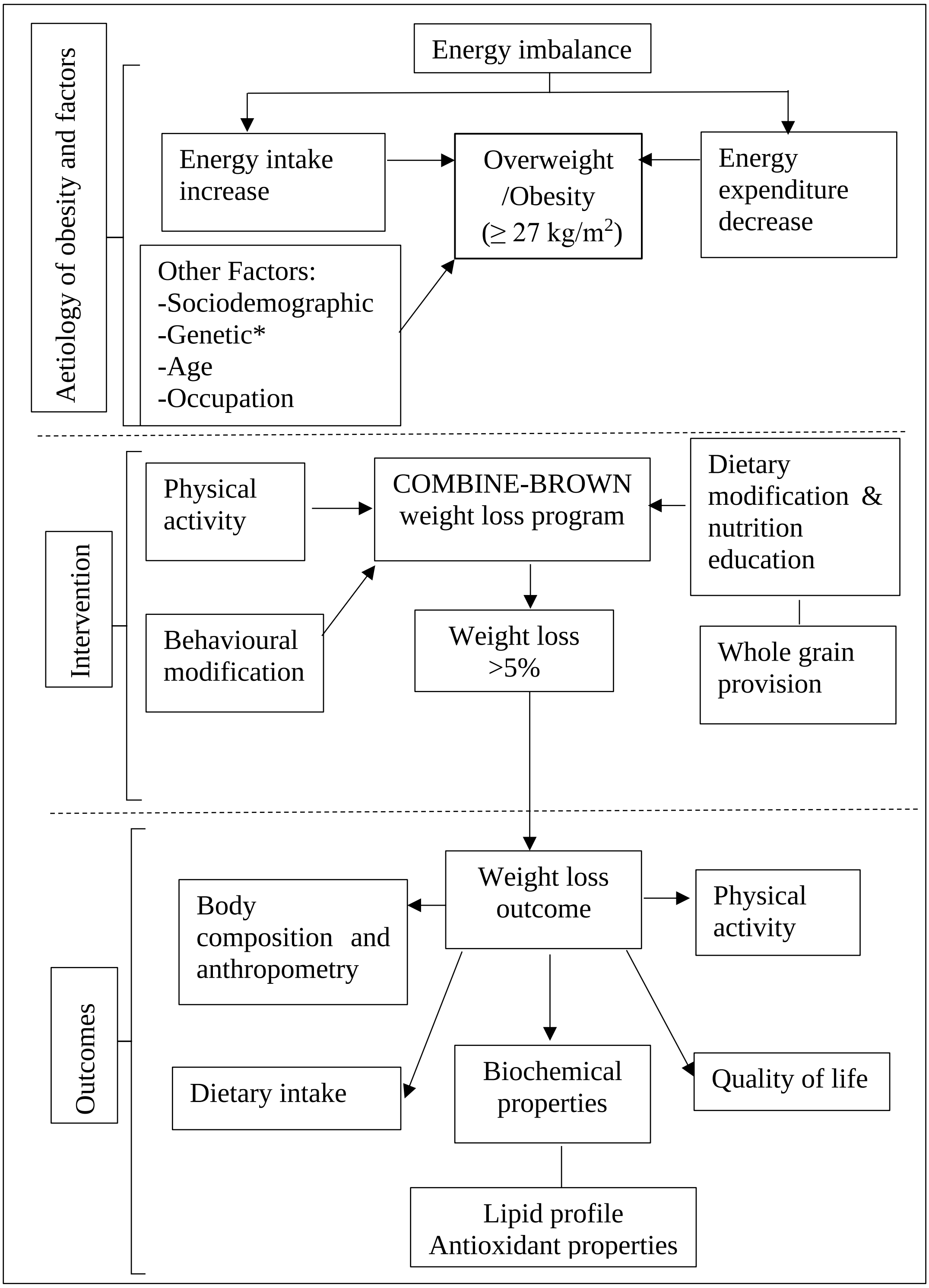
4. To assess the changes in physical activity level after 12 weeks (post-intervention) and at week-24 (follow-up) COMBINE-BROWN clinical weight loss program among overweight and obese adults.

5. To assess the changes in nutrient intake after 12 weeks (post-intervention) and at week-24 (follow-up) COMBINE-BROWN clinical weight loss program among overweight and obese adults.

6. To assess the mean difference in score of impact of weight on quality of life after 12 weeks (post-intervention) and at week-24 (follow-up) COMBINE-BROWN clinical weight loss program among overweight and obese adults.

1.7 Conceptual framework

The conceptual framework based on the energy balance hypothesis in weight change of the COMBINE-BROWN study is shown in Figure 1.5. Overweight or obesity results from energy imbalance due to excess energy intake or lack of energy expenditure. Other factors that might influence weight change, such as socioeconomic factors, include age, gender, household income, personal income, occupation and genetic factors. The COMBINE-BROWN weight loss study was a clinical-based weight loss program. The study evaluated the effect of a combination of behavioural modification approach, nutrition education, and integrated provision of brown rice as an alternative to substitute refined white rice consumption within a three-month trial. Success weight loss for at least 5 per cent subsequently improves the health status



Notes: *variables not studies

Figure 1.5 Conceptual framework based on energy balance hypothesis of overweight or obese individuals (Jensen *et al.*, 2014; Santos *et al.*, 2017). Furthermore, healthy weight loss might improve anthropometric body measurement, including reduction of weight, waist circumference and waist-hip ratio, and body composition, such as increasing lean mass and decreasing fat mass in the body. The increase in total physical activity and reduced calorie intake of food in the weight loss intervention can increase energy expenditure and thus contribute to a shift toward energy balance. Successful weight loss can also improve the impact on energy balance. Success weight loss can also enhance the effect of weight on quality of life, such as physical function, self-esteem, pubic distress, and working, apart from reducing obesity-related diseases and mortality. Besides, weight loss might improve the biochemical variables such as lipid profile which consist of triglyceride (TGs), total cholesterol (TC), low-density lipoprotein-cholesterol (LDL-C), and high-density lipoprotein-cholesterol (HDL-C). Moreover, weight loss might improve the antioxidants in the body, such as glutathione peroxidase (GPX) and catalase (CAT).

1.8 Theory of energy balance of dysregulation

The energy balance is regulated by the complex interaction of genetic and environmental factors. Excessive weight is due to an energy imbalance between calorie intake and expenditure (WHO, 2022b). Meanwhile, according to a positive statement by the World Obesity Federation, the interaction of excessive food intake, low levels of physical activity, and a few environmental factors with genetic factors lead to positive energy balance (Bray *et al.*, 2017). The storage of excess energy in fat cells leads to the enlargement of fat cells and the infiltration of fat cells into other organs, particularly the liver (ectopic fat). As a result, the enlarged fat cells and ectopic fats cause inflammation and damage in organs, such as the heart, arteries, and liver (Bray *et al.*, 2017).

Meanwhile, the previous review illustrates the energy balance, which can only be achieved when energy intake and energy expenditure in an equilibrium (Racette *et al.*, 2003). Based on the first law of thermodynamics, energy cannot be created or destroyed. Similarly, energy balance uses the thermodynamics theory. The excess energy intake is converted and stored as fats (triacylglycerol) in adipose tissue. Besides, positive energy balance during adulthood might contribute to adipocyte hypertrophy, in which fat cells increase in thousand times for lipid storage, resulting in weight gain (Racette *et al.*, 2003). The energy balance that leads to differences in body weight is shown in Figure 1.6 (Norman-Mckay, 2014).

The primary hypothesis of obesity is the ‘Thrifty gene theory,’ which postulates that humans have the gene for building adipose tissue for survival, hunger and starvation, and daily energy usage at an early age (Fernández-Sánchez *et al.*, 2011; Speakman, 2007). However, sedentary lifestyles and overconsumption of extra calories lead to positive energy balance, causing excessive fat deposition and weight gain (Heymsfield and Wadden, 2017). Meanwhile, an active lifestyle, such as increased exercise training, showed negative energy balance, especially among overweight and obese (Westerterp, 2018). Besides, the ‘foetal origin hypotheses of chronic disease postulate that poor maternal nutrition and poor foetal growth might contribute to the failure of the signalling pathway of body metabolism and appetite and hence cause obesity (Fernández-Sánchez *et al.*, 2011). According to findings from the Great Chinese Famine from 1959 to 1961, early life exposure to famine and

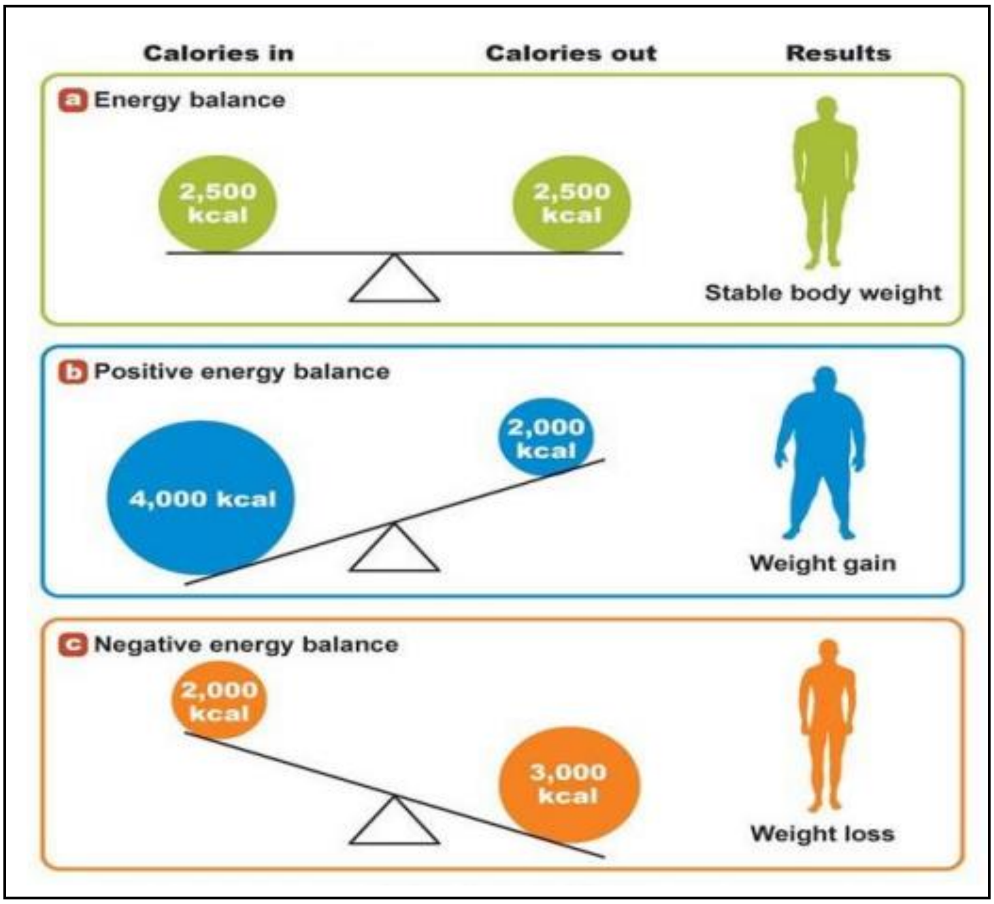
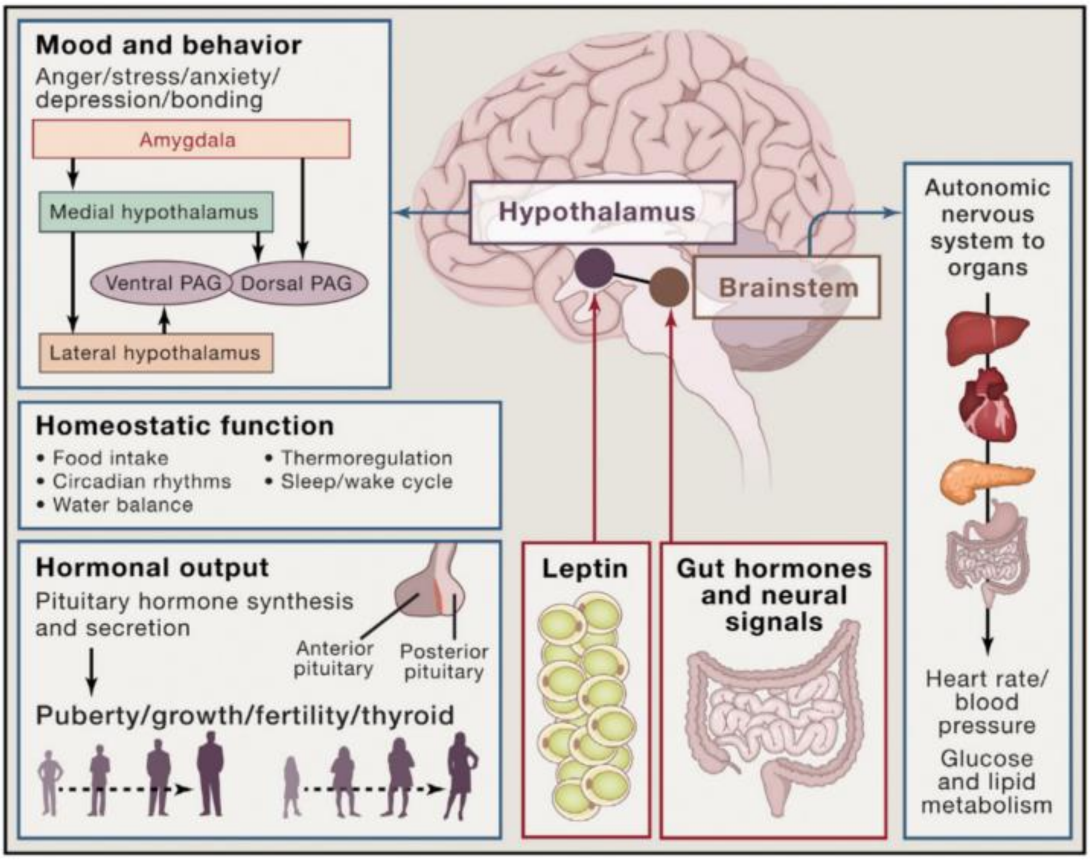


Figure 1.6 The energy balance that contributes to variation in body weight (Adopted from Norman-Mckay, 2014)

undernutrition may cause abdominal obesity in adulthood, especially in females who live in urban areas and have a sedentary lifestyle (Liu *et al.*, 2019). Thus, a healthy lifestyle, primarily increased physical activity, is vital for preventing chronic disease development (Liu *et al.*, 2019).

As shown in Figure 1.7, the hypothalamus helps in maintaining energy balance in body weight regulation (van der Klaauw and Farooqi, 2015). Hypothalamus regulates autonomic nervous system activation, which indirectly affects many metabolic processes in peripheral tissue, such as the liver, pancreas, heart and gut. Nutrition depletion in the human body will stimulate leptin, the adipocyte-derived



Notes:

As shown in red arrows, the hormone leptin signals nutritional depletions. Thus, to maintain energy balance, the signal initiates a series of changes in energy intake, energy expenditure, autonomic nervous system, and neuroendocrine functions, represented by blue arrows.
Abbreviation: periaqueductal gray (PAG)

Figure 1.7 The illustration of energy balance and neuroendocrine pathways (Adopted from van der Klaauw, 2015)

hormone, to initiate a series of changes in energy homeostasis, thus contributing to weight change. The hypothalamus functions: i) to regulate mood and behaviours through neuronal connections to the amygdala and ventral and dorsal periaqueductal gray (PAG), ii) to regulate homeostatic function, such as circadian rhythms and sleep, iii) regulates hormonal output through pituitary hormone synthesis and secretion, iv) through connections to the brainstem, neurons in the hypothalamus modulates autonomic nervous system, which in turn affect several metabolic processes in peripheral tissues, such as regulation of blood pressure, heart rate, glucose and lipid metabolism (van der Klaauw and Farooqi, 2015).

An unhealthy lifestyle induces stress which exceeds the regulatory system's ability. Hence, it breaks the energy homeostasis balance and causes obesity development. The brain might reset an increased body weight as a new reference. Therefore, weight loss becomes a therapeutic challenge due to the broken energy homeostasis and slowing metabolic rate (Ghanemi *et al.*, 2018).

1.9 Operational definition

1. Proximate analyses

Proximate analyses are defined as the analytical analyses of moisture, ash, crude fat, crude protein, and crude fibre of samples. Ash analysis is the method to determine mineral content in samples. Moisture analysis is used to determine the shelf-life of samples. Energy value analysis was used to measure the available amount of energy derived from food samples via cellular respiration (AOAC, 2005). The current study determines the proximate analyses of uncooked brown rice and white rice samples.

2. Texture analysis

The texture analysis is the method to evaluate the physical and mechanical properties of food structure (AOAC, 2005). The current study analyses the hardness and stickiness of cooked brown rice and white rice samples.

3. Scanning electron microscope-energy dispersive X-ray Spectroscopy (SEM-EDX)

The SEM is a microscopy technique used to identify structure and images of samples and mineral content of selected region of samples (Zadora and Brożek-Mucha, 2003). The present study analysed the ultrastructural and elemental analysis of cooked and uncooked brown rice and white rice samples. The SEM photograph was captured in 100x, 1000x, and 5000x magnification for both cross-sectional and longitudinal view for each rice samples.

4. Inductively coupled plasma mass spectrometry (ICP-MS)

ICPMS is an instrumental analytical method to measure low concentrations (range: ppb=parts per billion and ppt=parts per trillion) for multi-element analysis (Thomas, 2003). The ICPMS analyses was only measured for uncooked brown rice and white rice in this study.

5. Inductively coupled plasma-optical emission spectrometry (ICP-OES)

ICP-OES is an instrumental analytical technique to determine low concentrations (range: ppb=parts per billion) for multi-element analysis (Khan, 2019). The ICP-OES analyses were only measured for cooked brown rice and white rice in this study.