

University of Pretoria etd- Mentz, N (2003)

EFFICACY OF ELECTRICAL AND THERMOGENIC STIMULATION ON WEIGHT REDUCTION AMONG OBESE FEMALES

by

NICK MENTZ



Submitted in partial fulfillment of the requirements for the degree

Doctor Philosophiae

in the

DEPARTMENT BIOKINETICS, SPORT AND LEISURE SCIENCES

FACULTY OF ARTS

UNIVERSITY OF PRETORIA

**PRETORIA
MAY 2003**

The epidemic of obesity and inactivity is just as deadly – if not more so – than any virus, but it receives less attention because it acts slowly and because we have adjusted to its presence among us.

Like infectious disease epidemics, this epidemic can be stopped in its tracks – not with a vaccine, but with a formula of healthier eating and more activity that is well within our reach.
(Koplan, 2000)

ACKNOWLEDGEMENTS

I wish to express my thanks and gratitude to the following persons and institutions for their guidance and assistance, in the completion of this study:

DR H.J. VAN HEERDEN: (Department of Biokinetics, Sport and Leisure Sciences, University of Pretoria). For the valuable time afforded to me as promotor of this study, and his unstinted guidance, support and advice at all times.

PROF G.J. VAN WYK: (Head of the Department of Biokinetics, Sport and Leisure Sciences, University of Pretoria). For his interest and motivation.

PROF P.E. KRÜGER: (Director, Institute of Sport Research, University of Pretoria). For the use of the laboratory in conducting the study and financial support.

DR ZANET OSCHMAN: For conducting the ultra-sound sonography measurements.

SUBJECTS THAT PARTICIPATED IN THE PROJECT: Their involvement and willingness made this study possible.

CHRISTINE SMIT: For the assistance in the statistical analysis of the data.

TILLA BOSHOFF: For her diligent typing and editing of this thesis.

HEINRICH NOLTE, BYRON MALGA AND STEVEN BALL: For their assistance in compiling and editing the tabular and graphic presentation of data.

FAMILY AND FRIENDS: For their prayers encouragement and support throughout.

MY WIFE, RIANA: For her encouragement and loving support.

THE ALMIGHTY: In Him everything is possible.

SYNOPSIS

TITLE	:	Efficacy of Electrical and Thermogenic Stimulation on Weight Reduction among Obese Females
CANDIDATE	:	N. W. Mentz
PROMOTOR	:	Dr H.J. van Heerden
DEGREE	:	D.Phil

The primary aim of this study was to evaluate the effect of an eight-week programme of electrical muscle stimulation (EMS) performed on Slimline Slimming Machines in conjunction with (Group EST), and without (Group ESP), a thermogenic agent (Thermo Lean) and following a standardized diet (Group TS). In order to achieve this goal a pre-test-post test experimental groups design, with three levels of the independent variable, was adopted for the study. A group of 69 females between the ages of 25 - 40 years (mean age = 35.26 ± 6.02 years), who were recruited through newspaper advertisements, served as subjects. To be included in the study, subjects were required to be physically suitable for the intervention programmes; pre-menopausal; obese (BMI > 30); sedentary; and amenable to being assigned to any of three study groups. The following categories of dependent variables were measured: Anthropometry; Morphology; Ultrasound Sonography; Respiratory Quotient; Pulmonary Function; Haematology; Cardiovascular Responses; and Musculoskeletal Function.

There was a statistically significant difference between groups ($p \leq 0,05$) in the reduction of abdominal body girths measured at three different body sites viz. abdominal (level of greatest anterior protrusion); abdominal AB-1 (midway between the xyphoid process and the umbilicus); and abdominal AB-2 (level of the umbilicus). Group EST (6.02%) had the greatest reduction in girth at the abdominal body site. This reduction was significantly ($p \leq 0,05$) better than the reduction found in group ESP (4.79%) and group TS (4.69%). The same tendency was found at the abdominal AB-1 body site. Group EST (6.42%) had the greatest reduction in girth which was significantly ($p \leq 0,05$) better than the reduction found in group TS (4.35%) and group ESP (4.28%). Group ESP had the greatest reduction in girth at

the umbilicus level (7.39%). This reduction was significantly ($p \leq 0,05$) better than the reduction found in group TS (4.85%).

The greatest reduction of skinfold measurements was found at the tricep skinfold. Group EST had the greatest reduction (12.75%). This reduction was significantly ($p \leq 0,05$) better than the reduction found in both groups TS (9.27%) and ESP (6.63%). The second greatest reduction in skinfolds was found at the abdominal skinfold. Group EST had the greatest reduction (12.14%). This reduction was significantly ($p \leq 0,05$) better than the reduction found in both groups TS (11.80%) and ESP (10.36%). The third greatest skinfold reduction was found at the subscapular skinfold. Group EST had the greatest reduction (9.70%). This reduction was significantly ($p \leq 0,05$) better than the reduction found in both groups TS (8.64%) and ESP (3.93%). The observed significantly ($p \leq 0,05$) greater reduction in skinfold measurement at the abdominal site in group EST corresponded with the same significantly ($p \leq 0,05$) greater reduction in girth measurements at the abdominal body sites in the same group.

With respect to saggital height measurements, at the umbilicus body site (saggital umbi), group ESP (11.48%) had the greatest reduction. This reduction was similar to the reduction found in group EST (11.02%). At the saggital $\frac{1}{2}$ umbi body site, group EST (13.52%) had the greatest reduction in saggital height. This reduction was significantly ($p \leq 0,05$) greater than that found in both groups ESP (10.61%) and TS (10.60%). This significantly ($p \leq 0,05$) greater reduction in saggital height at the saggital $\frac{1}{2}$ umbi body site in group EST, corresponds with the significant ($p \leq 0,05$) decreases found in body girths and skinfolds in the same group.

A significantly reduced ($p \leq 0,05$) waist-to-hip ratio (WHR) was observed within two of the three experimental groups. The greatest reduction was found in group EST (2.53%) and this reduction was significantly ($p \leq 0,05$) better than the reduction found in group TS (1.27%) and group ESP (1.27%). The largest (3.03%) reduction in body surface area (BSA) was seen in group EST and this reduction was significantly greater ($p \leq 0,05$) than in group ESP (1.96%).

The ultrasound sonographic subcutaneous fat layer in group EST (21.22%) showed the greatest reduction. This reduction was significantly ($p \leq 0,05$) greater than the reduction in subcutaneous fat found in both groups TS (18.04%) and ESP (12.11%). The visceral fat layer

in group EST (27.74%) also showed the greatest reduction. This reduction was significantly ($p \leq 0,05$) greater than that found in both groups ESP (22.82%) and TS (21.87%). This significantly ($p \leq 0,05$) greater reduction in subcutaneous and visceral fat found in group EST, corresponds with the significant ($p \leq 0,05$) decreases found in body girths, skinfolds and sagittal height in the abdominal area in the same group.

In conclusion, obese females participating in a program of dietary restriction, thermogenic or electrical muscle stimulation with the aim of achieving weight-loss should note that: diet with or without electrical muscle stimulation (EMS) proved effective, but these modalities in conjunction with thermogenic stimulation proved the most effective intervention program after eight weeks.

KEY WORDS: ELECTRICAL MUSCLE STIMULATION; THERMOGENIC STIMULATION; CALORIE RESTRICTION; OBESE FEMALES; ABDOMINAL; SUBCUTANEOUS; VISCERAL; WEIGHT-LOSS.

SINOPSIS

TITEL	:	Effektiwiteit van Elektriese en Termogenetiese Stimulasie op Gewigsverlies by Obese Dames
KANDIDAAT	:	N. W. Mentz
PROMOTOR	:	Dr H.J. van Heerden
GRAAD	:	D.Phil

Die primêre doel van hierdie studie was om die effek te evalueer van 'n agt-weke program van elektriese spierstimulasie (ESS), uitgevoer op Slimline Verslankingsapparate, tesame met (Groep EST), en sonder (Groep ESP), 'n termogenetiese middel (Thermo Lean) asook 'n gestandaardiseerde dieet (Groep TS). 'n Voortoets- natoets eksperimentele groepsontwerp, met drie vlakke van die onafhanklike veranderlike, is gebruik vir die studie. 'n Totaal van 69 vroulike proefpersone tussen die ouderdom van 25 – 40 jaar (gemiddelde ouderdom 35.26 ± 6.02 jaar), wie deur koerantadvertensies gewerf is, het as proefpersone gedien. Insluitingskriteria vir die studie het vereis dat proefpersone fisies geskik was vir die intervensieprogramme, en premenoposaal; obees ($LMI > 30$); sedentêr en bereid moes wees om by enige van die drie studiegroepe ingedeel te word. Die volgende afhanklike veranderlikes is gemeet: Antropometrie; Morfologie; Ultraklank Sonografie; Respiratoriese Kwosiënt; Pulmonêre Funksie; Hematologie; Kardiovaskulêre Respons; en Muskuloskeletale Funksie.

Daar was 'n statisties beduidende verskil tussen groepe ($p \leq 0,05$) met die afname in abdominale liggaamsomtrekke by drie verskillende anatomiese liggings naamlik; abdominaal (vlak van grootste anterior uitsetting; abdominaal AB-1 (halfpad tussen die xiphoid proses en die umbilicus); en abdominaal AB-2 (vlak van die umbilicus). Groep EST (6.02%) het die grootste afname getoon by die abdominale ligging. Hierdie afname was beduidend ($p \leq 0,05$) beter as die afname in groep ESP (4.79%) en groep TS (4.69%). Dieselfde tendens is gevind by die abdominale AB-1 ligging. Groep EST (6.42%) het die grootste afname in omtreкке getoon wat beduidend ($p \leq 0,05$) beter was as die afnames in groep TS (4.35%) en groep ESP

(4.28%). Groep ESP het by die umbilicus die grootste afname in omtrekke getoon (7.39%). Hierdie afname was beduidend ($p \leq 0,05$) beter as die afname in groep TS (4.85%).

Die grootste afname in velvoumetings is gevind by die trisepvelvou. Groep EST het die grootste afname getoon (12.75%). Hierdie afname was beduidend ($p \leq 0,05$) beter as die afnames in beide groep TS (9.27%) en groep ESP (6.63%). Die tweede grootste afname is gevind by die abdominale-velvou. Groep EST het die grootste afname getoon (12.14%). Hierdie afname was beduidend ($p \leq 0,05$) beter as die afnames in beide groepe TS (11.80%) en ESP (10.36%). Die derde grootste velvou afname was by die subscapula-velvou. Groep EST het die grootste afname getoon (9.70%). Hierdie afname was beduidend ($p \leq 0,05$) beter as die afnames in beide groepe TS (8.64%) en ESP (3.93%). Die waargenome beduidend ($p \leq 0,05$) groter afname in velvoumetinge by die abdominale ligging in groep EST stem ooreen met dienoooreenkomstige beduidend ($p \leq 0,05$) groter afnames in omtrekmetinge by die abdominale liggings in dieselfde groep.

Met betrekking tot saggitalehoogte metinge, by die umbilicus ligging (saggitaal umbi), het groep ESP (11.48%) die grootste afname getoon. Hierdie afname was soortgelyk aan die afnames gevind in groep EST (11.02%). By die saggitaal $\frac{1}{2}$ umbi ligging het groep EST (13.52%) die grootste afname in saggitale hoogte getoon. Hierdie afname was beduidend ($p \leq 0,05$) beter as in beide groepe ESP (10.61%) en TS (10.60%). Die beduidend ($p \leq 0,05$) groter afname in saggitale hoogte by die saggitaal $\frac{1}{2}$ umbi ligging in groep EST, stem ooreen met die beduidende ($p \leq 0,05$) afnames gevind in liggaamsomtrekke en velvouemetinge in dieselfde groep.

Beduidende afnames ($p \leq 0,05$) in middel-tot-heup omtrekverhouding (MHV) is waargeneem in twee van die drie eksperimentele groepe. Die grootste afname is gevind in groep EST (2.53%) en hierdie afname was beduidend ($p \leq 0,05$) beter as die afnames in groep TS (1.27%) en groep ESP (1.27%). Die grootste (3.03%) afname in liggaamsoppervlakte meting (LOM) is waargeneem in groep EST en hierdie afname was beduidend beter ($p \leq 0,05$) as groep ESP (1.96%).

Die ultraklank sonografiese onderhuidse vetlaagmeting in groep EST (21.22%) het die grootste afname getoon. Hierdie afname was beduidend ($p \leq 0,05$) beter as die afnames in onderhuidse vet in beide groepe TS (18.04%) en ESP (12.11%). Die viserale vetlaag in groep EST (27.74%) het ook die grootste verlaging getoon. Hierdie verlaging was beduidend ($p \leq 0,05$) beter as in beide groepe ESP (22.82%) en TS (21.87%). Hierdie beduidende ($p \leq 0,05$) groter afname in onderhuidse en viserale vet in groep EST, stem ooreen met die beduidende ($p \leq 0,05$) afnames gevind in liggaamsomtrekke, velvoue en saggitale hoogte in die abdominale gebied binne dieselfde groep.

Ter afsluiting, obese dames wat deelneem aan 'n program van kalorie-inperking, termogenetiese of elektriese spierstimulasie met die oog op gewingsverlies moet kennis dra dat: dieet met of sonder elektriese spierstimulasie (ESS) effektief is, maar dat hierdie modaliteite in samewerking met termogenetiese stimulasie bewys is as die mees effektiewe intervensieprogram na agt-weke.

SLEUTELWOORDE: ELEKTRIESE SPIERSTIMULASIE; TERMOGENETIESE STIMULASIE; KALORIEBEPERKING; OBESE DAMES; ABDOMINALE-; ONDERHUIDSE-; VISERALE-; GEWIGSVRLIES.

TABLE OF CONTENTS

	Page No.
TITLE PAGE	i
PROLOGUE	ii
DEDICATION	iii
ACKNOWLEDGEMENTS	iv
SYNOPSIS	v
SINOPSIS	viii
TABLE OF CONTENTS	xi
LIST OF TABLES	xix
LIST OF FIGURES	xxi

CHAPTER 1 : THE PROBLEM

1.1 Introduction	1
1.2 Obesity Defined	2
1.3 Electrical Muscle Stimulation Defined	3
1.4 Thermogenic Stimulation Defined	4
1.5 Statement of the Problem	5
1.6 Motivation for the Study	6
1.7 Purpose and Aim of the Study	6
1.8 Hypotheses	7
1.9 Delimitation	7

CHAPTER 2 : LITERATURE REVIEW

2.1 Definition of Obesity	8
2.2 Epidemiology of Obesity	9
2.2.1 Obesity, economics and the industrial food system	12
2.2.2 Fast food as a fat delivery system	13
2.2.3 Automobile dependence and inactivity	15
2.2.4 Behaviour patterns, television and obesity	16
2.2.5 The ideology of fat versus thin	17

2.3	Prevalence of Obesity	19
2.4	Consequences of Obesity	20
2.4.1	Psychosocial aspects of overweight and obesity	21
2.4.1.1	Psychopathology and obesity	21
2.4.1.2	Binge eating disorder	22
2.4.1.3	Body image	23
2.4.1.4	Social stigmatisation	25
2.4.2	Health risks associated with being overweight or obese.	25
2.4.2.1	Hypertension	27
2.4.2.2	Coronary heart disease	28
2.4.2.3	Congestive heart failure	29
2.4.2.4	Stroke	30
2.4.2.5	Sleep apnea	31
2.4.2.6	Dyslipidemia	31
2.4.2.7	Diabetes mellitus	33
2.4.2.8	Gall-bladder disease and hypercholesterolemia	34
2.4.2.9	Gallstones	35
2.4.2.10	Pulmonary abnormalities	35
2.4.2.11	Osteoarthritis	35
2.4.2.12	Cancer	36
2.4.2.13	Musculoskeletal injury	38
2.4.2.14	Increased surgical risk	38
2.4.2.15	Menstrual irregularities and infertility	38
2.4.2.16	Pregnancy complications	38
2.4.3	Mortality and obesity	40
2.4.3.1	Association of body mass index with mortality	41
2.4.3.2	Weight loss and mortality	41
2.5	Etiology of Obesity	42
2.5.1	Genetic factors	44
2.5.2	Environmental factors	45
2.5.3	Nutritional factors	47
2.5.4	Physiological factors	47
2.5.5	Psychological factors	47
2.5.6	Cultural, economic and social factors	47

2.6	Pathophysiological Factors Underlying Obesity	49
2.6.1	Energy balance equation	49
2.6.2	Energy intake regulation in obesity	49
2.6.2.1	Neuropeptide Y	50
2.6.2.2	Melanin concentrating hormone	51
2.6.2.3	Serotonin	51
2.6.2.4	Lipoprotein lipase	52
2.6.2.5	Leptin	52
2.6.2.6	Ghrelin-growth hormone releasing peptide	54
2.6.3	Energy expenditure regulation in obesity	55
2.7	Bio-energetics of Metabolism	55
2.7.1	Fat metabolism	56
2.7.1.1	Beta oxidation	58
2.7.1.2	ATP production from fatty acids	60
2.7.1.3	Ketone bodies and ketosis	61
2.7.1.4	Respiratory quotient and low rates of fat oxidation	62
2.7.1.5	De novo lipogenesis	62
2.8	Cellular Basis of Obesity	63
2.9	Basal or Resting Metabolic Rate	67
2.9.1	Diet and resting metabolic rate	68
2.9.2	Exercise and resting metabolic rate	69
2.9.3	Weight cycling and resting metabolic rate	70
2.10	Thermogenesis	71
2.10.1	Impact of diet on the thermic effect of a meal	72
2.10.2	Impact of exercise on the thermic effect of a meal	72
2.10.3	Physical activity	73
2.10.4	Impact of exercise on food intake	73
2.10.5	Energy expenditure	74
2.11	Weight Control – Caloric Balance Equation	75
2.12	Body Weight Regulation	78
2.12.1	The “setpoint” hypothesis	79
2.12.2	The “settling-point” hypothesis	80

2.13	Metabolic Adaptation	82
2.13.1	Metabolic adaptation to overfeeding	83
2.13.2	Metabolic adaptation to underfeeding	85
2.14	Regional Fat Distribution	86
2.15	Prevention of Overweight and Obesity	89
2.15.1	Additional research needs in obesity prevention	92
2.16	Obesity Treatment Strategies	94
2.16.1	Pharmacotherapy	96
2.16.1.1	History of pharmacotherapy	97
2.16.1.2	Herbal preparation	99
2.16.1.3	Thermogenic agents	101
2.16.1.4	Lipase inhibitors	103
2.16.1.5	Noradrenergic agents	103
2.16.1.6	Serotonergic agents	104
2.16.1.7	Selective serotonin reuptake inhibitors	106
2.16.1.8	Other agents	107
2.17	Physical Activity and the Obesity Epidemic	112
2.17.1	Justification for inclusion of exercise for weight-loss	113
2.17.2	Exercise prescription considerations for weight-loss	115
2.17.3	Exercise duration and weight-loss	115
2.17.4	Exercise intensity and weight-loss	116
2.17.5	Lifestyle activity and weight loss	117
2.17.6	Intermittent exercise and weight-loss	118
2.17.7	Resistance exercise and weight-loss	118
2.7.18	Effectiveness of exercise in weight control	120
2.18	Behaviour Modification for Weight-Loss	121
2.18.1	What behaviour therapy can do	123
2.19	Dieting as a Weight-Loss Strategy	125
2.19.1	Popular diets for weight loss	127
2.19.2	Cost and consumer appeal of diet programs	130
2.19.3	Effectiveness of dieting in weight control	131
2.20	Surgery in Weight Control	133
2.20.1	Gastric surgery	134
2.20.2	Plastic surgery	138

2.21	Alternative Treatments for Weight Loss	138
2.21.1	Acupuncture and acupressure	139
2.21.2	Aromatherapy	140
2.21.3	Hypnosis	140
2.21.4	Electro-muscular stimulation	141
2.22	Recommendations for Weight Loss Treatments	144

CHAPTER 3 : METHODS AND PROCEDURES

3.1	Subjects	146
3.2	Study Design	147
3.3	Dependent Variables (Measurements)	148
3.3.1	Anthropometry	149
3.3.1.1	Stature	149
3.3.1.2	Body mass	149
3.3.1.3	Skeletal widths	150
3.3.1.4	Sagittal height	150
3.3.1.5	Skinfolds	152
3.3.1.6	Girth measures	153
3.3.2	Morphology	155
3.3.2.1	Percentage body fat	155
3.3.2.2	Lean body mass	156
3.3.2.3	Body mass index	156
3.3.2.4	Body surface area	156
3.3.2.5	Waist-to-hip ratio	157
3.3.2.6	Somatotype	157
3.3.2.7	Somatogram	158
3.3.3	Ultrasound sonography	160
3.3.4	Respiratory quotient	161
3.3.5	Pulmonary function	162
3.3.6	Haematology	163
3.3.7	Cardiovascular responses	163
3.3.7.1	Heart rate	163

3.3.7.2	Blood pressure	164
3.3.8	Musculoskeletal function	164
3.3.8.1	Hip flexion	164
3.3.8.2	Abdominal muscle endurance	165
3.4	Independent Variables (Intervention Programme)	165
3.4.1	Electrical muscle stimulation	165
3.4.2	Thermogenic stimulation	167
3.4.3	Standardized diet program	168
3.5	Statistical Analysis	170

CHAPTER 4 : RESULTS AND DISCUSSION

4.1	Anthropometry	174
4.1.1	Body girths	174
4.1.2	Skinfolds	181
4.1.3	Sagittal height	187
4.2	Morphology	190
4.2.1	Body mass	190
4.2.2	Percentage body fat	193
4.2.3	Percentage muscle	193
4.2.4	Lean body mass	194
4.2.5	Body mass index	194
4.2.6	Waist-to-hip ratio	194
4.2.7	Body surface area	198
4.2.8	Somatotype	198
4.2.8.1	Endomorphy (Somatotype I)	198
4.2.8.2	Mesomorphy (Somatotype II)	199
4.2.8.3	Ectomorphy (Somatotype III)	199
4.2.8.4	Somatogram	202
4.2.8.4a	Somatogram (x-axis)	202
4.2.8.4b	Somatogram (y-axis)	203
4.3	Ultrasound Sonography	203
4.4	Respiratory Quotient	207
4.5	Pulmonary Function	207

4.6	Haematology	214
4.6.1	Total Cholesterol	214
4.6.2	LDL-Cholesterol	217
4.6.3	HDL-Cholesterol	217
4.6.4	Triglycerides	218
4.6.5	Glucose	219
4.7	Cardiovascular Responses	219
4.7.1	Heart rate	222
4.7.2	Blood pressure	222
4.8	Musculoskeletal Function	223
4.8.1	Flexibility	223
4.8.2	Abdominal muscle endurance	226

CHAPTER 5 : SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1	General Considerations Regarding Weight	227
5.1.1	Evaluation of a weight-loss program	227
5.1.2	Recommendations for weight-loss programs	228
5.1.3	Pro-active steps for weight-loss	228
5.2	Specific Weight-loss Considerations Based on this Study	229
5.2.1	Relative efficacy of the interventions	230
5.2.2	Implication for weight-loss practice	234
5.2.3	Limitations of the study	235
5.3	Future Research Directions	235
5.3.1	Assessment methods	235
5.3.2	Intervention approaches	236
5.3.3	Causes and mechanisms of overweight and obesity	237
5.3.4	Abdominal fat, body weight and disease risk	237
	REFERENCES	238

Page No.**APPENDICES**

Appendix A : Informed Consent Form	287
Appendix B : Result Sheet	288
Appendix C : Somatotype Responses Between Groups	290
Appendix D : EMS Pad Placement Chart	291
Appendix E : Metabolism Diet	292
Appendix F : Randomized Trial Synopsis	296
Appendix G : Nomographic Chart	297

LIST OF TABLES

TABLE 3.1	:	Subjects Characteristics	148
TABLE 4.1a	:	Anthropometry: Body Girth Responses. Intra-Group Comparisons	176
TABLE 4.1b	:	Anthropometry: Body Girth Responses. Inter-Group Comparisons	177
TABLE 4.1c	:	Anthropometry: Sum of Body Girths Response. Intra-Group Comparisons	179
TABLE 4.1d	:	Anthropometry: Sum of Body Girths Response. Inter-Group Comparisons	179
TABLE 4.1e	:	Anthropometry: Skinfold Responses. Intra-Group Comparisons	182
TABLE 4.1f	:	Anthropometry: Skinfold Responses. Inter-Group Comparisons	183
TABLE 4.1g	:	Anthropometry: Sagittal Height Responses. Intra-Group Comparisons	188
TABLE 4.1h	:	Anthropometry: Sagittal Height Responses. Inter-Group Comparisons	188
TABLE 4.2a	:	Morphological Responses. Intra-Group Comparisons	191
TABLE 4.2b	:	Morphological Responses. Inter-Group Comparisons	191
TABLE 4.2c	:	Waist-to-Hip Ratio and Body Surface Area Responses. Intra-Group Comparisons	195
TABLE 4.2d	:	Waist-to-Hip Ratio and Body Surface Area Responses. Inter-Group Comparisons	195
TABLE 4.2e	:	Somatotype Responses. Intra-Group Comparisons	200
TABLE 4.2f	:	Somatotype Responses. Inter-Group Comparisons	200
TABLE 4.3a	:	Ultrasound Sonography Responses. Intra-Group Comparisons	204
TABLE 4.3b	:	Ultrasound Sonography Responses. Inter-Group Comparisons	206

	Page No.
TABLE 4.4a : Respiratory Quotient Response. Intra-Group Comparisons	208
TABLE 4.4b : Respiratory Quotient Response. Inter-Group Comparisons	208
TABLE 4.5a : Pulmonary Function Responses. Intra-Group Comparisons	210
TABLE 4.5b : Pulmonary Function Responses. Inter-Group Comparisons	210
TABLE 4.6a : Haematological Responses. Intra-Group Comparisons	217
TABLE 4.6b : Haematological Responses. Inter-Group Comparisons	217
TABLE 4.7a : Cardiovascular Responses. Intra-Group Comparisons	222
TABLE 4.7b : Cardiovascular Responses. Inter-Group Comparisons	220
TABLE 4.8a : Musculoskeletal Function Responses. Intra-Group Comparisons	224
TABLE 4.8b : Musculoskeletal Function Responses. Inter-Group Comparisons	224
TABLE 5.1 : Relative Efficacy of Interventions	230
TABLE 5.2 : Variables Showing Differences between Groups	233

LIST OF FIGURES		Page No.
FIGURE 2.1	: Conditions Associated with Obesity	21
FIGURE 2.2	: Body Weight-Associated Disease Risk	26
FIGURE 2.3	: Pathophysiological Model for the Risk of Developing Hypertension	27
FIGURE 2.4	: Pathophysiological Model for the Risk of Developing Congestive Heart Failure and Coronary Heart Disease	29
FIGURE 2.5	: Pathophysiological Model for the Development of Sleep Apnea	31
FIGURE 2.6	: Pathophysiological Model for the Development of Diabetes And Insulin Resistance	33
FIGURE 2.7	: Pathophysiological Model for the Metabolism of Cholesterol In the Development of Gall-Bladder Disease	34
FIGURE 2.8	: Relationship of Various Factors Associated with the Control of Obesity	42
FIGURE 2.9	: Illustrated Genotype – Etiological Basis of Obesity	43
FIGURE 2.10	: Genetic Factors Involved in the Development of Obesity	44
FIGURE 2.11	: Beta Oxidation	59
FIGURE 2.12	: Changes in Adipose Cell Size and Number with Growth	66
FIGURE 2.13	: White Adipose Cell	67
FIGURE 2.14	: Brown Adipose Cell	67
FIGURE 2.15	: The Energy Balance Equation (TEF Refers to the Thermic Effect of Food)	76
FIGURE 2.16	: Energy Expenditure	77
FIGURE 2.17	: Patterns of Fat Distribution	87
FIGURE 2.18	: Algorithmic Approach for Therapy Selection	94
FIGURE 2.19	: The First Law of Thermodynamics can be used to Identify the Place where Drug Treatment can be Effective	96

	Page No.
FIGURE 2.20 : The Relation of Physical Activity to the Energy Balance Equation	112
FIGURE 2.21 : Targets of Behavioral Therapy in the Energy Balance Diagram	121
FIGURE 2.22 : Identification of the Site at which Diet Works to Influence Energy Balance	125
FIGURE 2.23 : Energy Balance Diagram Showing where Surgical Treatment Has its Influence	133
FIGURE 3.1 : Sagittal Height ½ umbi	151
FIGURE 3.2 : Sagittal Height umbi	151
FIGURE 3.3 : Abdominal Girth AB ¹	154
FIGURE 3.4 : Abdominal Girth AB ²	155
FIGURE 3.5 : Somatogram	159
FIGURE 3.6 : Siemens (Sonoline Ellegra) Sonograph	160
FIGURE 3.7 : Sonographic Measurement of Subcutaneous and Intra-Abdominal Fat	161
FIGURE 3.8 : Slimline Electrical Muscle Stimulation (EMS) Machine	165
FIGURE 3.9 : Thermo Lean Label	167
FIGURE 3.10 : Composition of Thermogenic Agent and Placebo	168
FIGURE 4.1a : Anthropometry: Body Girth Responses between Groups	178
FIGURE 4.1b : Anthropometry: Sum of Body Girths Response between Groups	180
FIGURE 4.1c : Anthropometry: Skinfold Responses between Groups	184
FIGURE 4.1d : Anthropometry: Sagittal Height Responses between Groups	189
FIGURE 4.2a : Morphological Responses between Groups	192
FIGURE 4.2b : Waist-to-Hip Ratio and Body Surface Area Responses between Groups	196
FIGURE 4.2c : Somatotype Responses between Groups	201

	Page No.
FIGURE 4.3 : Ultrasound Sonography Responses between Groups	205
FIGURE 4.4 : Respiratory Quotient Responses between Groups	209
FIGURE 4.5 : Pulmonary Function Responses between Groups	211
FIGURE 4.6 : Haematological Responses between Groups	216
FIGURE 4.7 : Cardiovascular Responses between Groups	221
FIGURE 4.8 : Musculoskeletal Function Responses between Groups	225