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EFFECT OF RESISTANCE TRAINING ON TOTAL, CENTRAL AND ABDOMINAL ADIPOSITY

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ABSTRACT

Despite the clear benefits that resistance training might have in weight management the effects of resistance training on adiposity in sedentary individuals are unsubstantiated. As such, the aim of the study was to determine the effect of resistance training on anthropometric measures of total, central and abdominal adiposity. Twenty-five healthy, sedentary males not on an energy-restricted diet were assigned to a non-exercising control group (CON) (n = 12) or a resistance training group (RES) (n = 13) to determine the effect of 16 weeks of resistance training on anthropometric measures of total, centrally located and abdominal adiposity. Resistance training was prescribed three times weekly using eight exercises for three sets of 15 repetitions at 60% of one-repetition maximum. Resistance training decreased three of the six anthropometric measures of total adiposity and increased body mass and body mass index (BMI). Resistance training had no impact on the measures of centrally located and abdominal adiposity. Body mass and BMI should be used with caution in risk calculations and measures of total adiposity in individuals engaging in resistance training due to this mode of training increasing lean mass (and thus body mass and BMI). Resistance training reduced total adiposity but did not provide an effective stimulus to lower centrally located and abdominal adiposity.

Key words: Body composition; Physical activity; Resistance training.

INTRODUCTION

Obesity and overweight are major risk factors for the development of chronic diseases and mortality (Irwin *et al*., 2003; Flegal *et al*., 2005; Mundt *et al*., 2006). Thus, the maintenance of optimal body composition is one of the key challenges in the prevention of obesity. The calories that a person takes in, in the form of food and fluids, has to be balanced by the energy lost. Some energy is used for maintenance of basic metabolic processes, during physical activity, for heat regulation or excreted in the faeces and urine. If energy input exceeds the output, then the excess calories will be stored as fat, thereby mounting the risk of becoming overweight or obese (Mahler *et al*., 2000). Anthropometry is widely used as an indicator of nutritional and health status (Goon *et al*., 2008) and accurate assessment of body composition, body fat distribution and metabolic risk profile is essential in many areas of health research. Adiposity, especially abdominal fat deposition, is particularly associated with an increased risk for a variety of health problems, metabolic disturbances and mortality (Caprio *et al*., 1996; Goran & Gower, 1999; Garaulet *et al*., 2000; Sientz *et al*., 2005) even in the absence of a high generalised obesity (Chartterjee *et al*., 2006; Ghosh, 2006). Anthropometric evaluation using surrogate measurements such as waist circumference (WC) is reliable when compared with more sophisticated methodologies (such as Dual Energy X-ray Absorptiometry) and is inexpensive, non-invasive and provides detailed information on the different components of body structure (Hwang *et al*., 2008).

Aerobic training has been found to induce the greatest alterations in adiposity (Gutin *et al*., 2002; Irwin *et al*., 2003; Slentz *et al*., 2005). When aerobic training is combined with resistance training, this combination of aerobic and resistance training does not typically enhance weight loss (Jakicic *et al*., 2001). Dieting alone without resistance training in a weight loss programme will result in the loss of fat and lean mass and a lower resting metabolic rate (Garrow, 1986; Jakicic, 2001; Meckling & Sherfey, 2007). In contrast, the inclusion of resistance training in weight loss or weight regain programme may reduce the decline in or even increase resting metabolic rate by preserving lean mass (Pratley *et al*., 1994; Lemmer *et al*., 2001). Controversy still exists whether resistance training can lead to favorable changes in total body fat, and more importantly, centrally located or abdominal fat. A number of studies have demonstrated that aerobic training is effective at reducing these measures of adiposity (Gutin *et al*., 2002; Irwin *et al*., 2003; Sientz *et al*., 2005; Ohkawara *et al*., 2007). However, few, if any, studies have examined the effect of resistance training on anthropometric measures of total, centrally located and abdominal adiposity in sedentary individuals not on an energy-restricted diet. Therefore, the aim of the study was to determine the effect of resistance training on anthropometric measures of total, central and abdominal adiposity.

METHODS

Participants

Twenty-five apparently healthy, males (mean age of 25 years and six months) were recruited for participation in this study and assigned to either a control group (CON) (n = 12) or resistance training group (RES) (n = 13) using a schedule generated from a table of random numbers. Demographic data are presented in table 1. The body mass of all the participants had to be stable for at least six months before the study. The participants had to be physical inactive at least six months before the study. Participants also underwent a screening history and physical examination and all participants completed a written informed consent and were allowed to discontinue the study at any time. This study was approved by the Institutional Review Board at the University of Johannesburg (formerly Rand Afrikaans University).

TABLE 1. **PARTICIPANT BASELINE CHARACTERISTICS**

Parameter	**Control group (CON) (n = 12)**	**Resistance training group (RES) (n = 13)**
Age (years)	25 ± 2.4	25 ± 3.5
Stature (centimetres)	179.3 ± 11.9	175.5 ± 5.6
Body mass (kilogrammes)	80.3 ± 12.8	69.1 ± 8.5

Values are means ± standard deviation

Anthropometric evaluation

All participants underwent an identical battery of tests before and after the 16-week intervention period in the post-absorptive state following a 12- to 14-hour fast and at least 48 hours prior to or following any exercise. Anthropometric measurements were carried out according to the methods proposed by the International Society for the Advancement of Kinanthropometry (ISAK) (Marfell-Jones *et al*., 2006). Stature was measured in centimetres (cm) (to the nearest 0.1 cm) via a standard wall-mounted stadiometer and body mass was measured in kilogrammes (kg) (to the nearest 0.1 kg) on a calibrated medical scale (Mettler DT Digitol, Mettler-Toledo AG, Ch-8606 GreiFensee, Switzerland) wearing only running shorts.

Stature and body mass data were used to calculate BMI as defined as the ratio of body mass to stature squared, expressed in kilogrammes per square metre ($kg.m^{-2}$). Seven skinfolds and waist and hip circumferences were measured prior to any exercise using a manual skinfold caliper (Harpenden John Bull, British Indicators Ltd., England) and a non-distendable anthropometric measuring tape (Holtain Ltd.). Waist circumference (WC) is one of the most currently and commonly used definitions of abdominal obesity (World Health Organization (WHO), 1999). Waist circumference (WC) was measured with the participant standing, by wrapping the tape at the level of the narrowest point between the lower costal (10^{th} rib) border and the iliac crest. Hip circumference was taken at the level of the greatest posterior protuberance of the buttocks which usually corresponds anteriorly to about the level of the symphysis pubis. The waist to stature ratio (WSR) has been proposed as an alternative, conveniently age-independent measure and was calculated using waist circumference and stature measurements (Sung *et al*., 2008). Percentage body fat (%BF) was calculated from seven-skinfold measurements (triceps, subscapular, supra-iliac, abdominal, frontal thigh, mid-axilla and pectoral skinfolds) using the equation of Jackson and Pollock (1978): percentage fat = 100 (4.95/body density (Db) – 4.5), where Db (g/cc) = 1.120 – 0.00043499 (sum of the seven skinfolds in millimetres (Σ7)) + 0.00000056 (Σ7) – 0.00028826 (age). Triceps and subscapular skinfolds were included in the Subscapular Triceps ratio (STR), to provide a more global index of adiposity (Mendoza *et al*., 2007).

Waist-to-hip ratio (WHR) was calculated using the following formula: WHR = waist circumference (cm)/hip circumference (cm). Conicity index (CI) was computed using the following formula: CI = waist circumference (metres (m))/(0.109)x√[weight (kg)/stature (m)] (Valdez *et al*., 1993). Fat mass was calculated by multiplying body mass with body fat percentage which was divided by 100. Lean mass was calculated as total body mass in kilogrammes less fat mass in kilogrammes. Central fat distribution was calculated using the four skinfolds assessment with the following equation: SS/Σ4SF = (subscapular + supraspinale skinfolds)/(subscapular + supraspinale + biceps + triceps skinfolds) (Monyeki *et al*., 2007).

Dietary intake evaluation

To account for the possible effect of exercise training on dietary intake, the participants had to complete an open-ended 24-hour seven-day self-reported dietary intake recall form at the pretest and posttest, specifying the type and quantity of food and fluids consumed. Portion sizes were illustrated with the aid of measuring cups, glasses, bowls and food items. The records were reviewed along with each participant to ensure completeness and accuracy of the recorded dietary intakes. The dietary records were analysed for total kilocalories consumed, carbohydrates, proteins and fats using the Dietary Manager® computer-based software programme (Dietary Manager, Programme Management, South Africa).

Muscular strength evaluation

Ten-repetition maximum (10-RM) evaluations took place at the start and completion of the study and every four weeks during the study. All participants in the CON and RES completed a 10-RM test for, shoulder press, latissimus dorsi pull-downs, seated chest press, low pulley row, abdominal crunches (modified sit-ups), unilateral leg press, unilateral knee extensions and unilateral prone hamstring curls. Each test commenced with a five minute warm-up, eight static stretching exercises followed by five to 10 repetitions of each of the prescribed exercises at 40% to 60% of each participant's estimated one-repetition maximum (1-RM). After a two-minute rest, the participants attempted to complete 10 repetitions at approximately 70% of estimated 1-RM. If the participant was successful at performing 10 repetitions at this weight increment, the weight was increased conservatively. After a three- to five-minute rest the participant was required to attempt to complete 10 repetitions at the new resistance increment. This procedure was continued until each participant completed no more than 10 repetitions. This value was then recorded as the weight lifted for the amount of repetitions and each participant's 1-RM value was then calculated using the following formula: 1-RM = weight lifted / [1.0278-(repetitions to fatigue x 0.0278)] (Heyward, 1997). In order to determine the number of repetitions to be utilised for abdominal crunches during subsequent training sessions, each participant performed a maximum number of repetitions during one minute (Manning *et al.*, 1991).

Training protocol

The participants in the CON were instructed to remain inactive during the 16-week period while the RES participants were required to exercise three times weekly, for a period of 16 weeks. All resistance training exercise sessions were preceded by five minutes of easy cycling at a heart rate of less than 100 beats per minute (bpm). Heart rate was measured using a telemetry strap and heart rate monitor (610, Polar Electro, Oy, Finland). The cycling was followed by eight stretching exercises each performed for two sets of 30 seconds. Exercise sessions were concluded with five minutes of easy cycling at a heart rate of less than 100 bpm. Each RES participant performed three sets of 15 repetitions using shoulder press, latissimus dorsi pull-downs, seated chest press, seated rows, crunches, unilateral leg press, unilateral knee extensions and unilateral prone leg curls at an intensity of 60% 1-RM. The participants were allowed a 60- to 90-second rest period between each set. For abdominal crunches, each participant was required to perform three sets of 60% of the maximum number of repetitions performed during the initial evaluation. Each RES participant's 1-RM was re-evaluated every four weeks and the exercise programme adjusted accordingly.

Statistical analysis

Standard statistical methods were used for the calculation of the means and standard deviations (SD) and to determine if a significant difference existed between the groups at pre-test. The present study also computed t-Tests to determine whether a significant difference existed between pre- and post-tests. Pearson's correlation coefficient was used to assess relationships among anthropometric measures and the measured dietary variables. Data was analysed using the Statistical Package for Social Sciences (SPSS) Version 14, (Chicago, IL) at a significance level of 95% or $p \leq 0.05$.

RESULTS

The CON and RES were homogenous at the baseline tests with regards to lean mass (p = 0.388), STR (p = 0.836), BMI (p = 0.054), SS/∑4SF (p = 0.079), WC (p = 0.399) and WSR (p = 0.625) whereas the groups were heterogeneous for body mass (p = 0.016), fat mass (p = 0.005), sum of skinfolds (p = 0.007), %BF (p = 0.010), CI (p = 0.000) and WHR (p = 0.019).

Anthropometric Measures of Total Adiposity

Control group (CON) measures of total adiposity remained unchanged over the 16-week experimental period. This is demonstrated by no significant ($p > 0.05$) changes from the pretest to posttest in body mass (p = 0.398), lean mass (p = 0.347), fat mass (p = 0.695), sum of skinfolds (p = 0.721), percentage body fat (%BF) (p = 1.000), STR (p = 0.160) and BMI (p = 0.443) (table 2). On the contrary, the RES group participants were found to have significantly ($p < 0.05$) changed body mass (p = 0.037), lean mass (p = 0.003), fat mass (p = 0.020), sum of skinfolds (p = 0.008), %BF (p = 0.011) and BMI (p = 0.037) over the 16-week training period. However, the STR of the RES group participants remained similar from the pretest to posttest (p = 0.472).

TABLE 2. **EFFECT OF RESISTANCE TRAINING ON ANTHROPOMETRIC MEASURES OF TOTAL, CENTRALLY LOCATED AND ABDOMINAL ADIPOSITY**

Parameter	Control group (CON) (n = 12)		Resistance training group (RES) (n = 13)	
	Pretest	**Posttest**	**Pretest**	**Posttest**
Lean mass (kilogrammes)	66.19 ± 12.84	65.52 ± 12.01	62.43 ± 7.89	65.59 ± 7.48*
Anthropometric measures of total adiposity				
Body mass (kilogrammes)	80.31 ± 12.84	79.59 ± 10.93	69.10 ± 8.50**	70.75 ± 9.48*
Fat mass (FM) (kilogrammes)	14.16 ± 6.56	13.91 ± 6.28	6.67 ± 5.50**	5.16 ± 4.25*
Sum of skinfolds (millimeters)	123.96 ± 41.59	124.40 ± 42.31	78.57 ± 34.64**	67.86 ± 26.96*
Percentage body fat (%BF) (%)	17.86 ± 7.86	17.79 ± 8.03	9.30 ± 7.33**	6.93 ± 5.26*
Subscapular Triceps ratio (STR)	1.39 ± 0.45	1.26 ± 0.48	1.38 ± 0.36	1.43 ± 0.41
Body mass index (BMI) ($kg.m^{-2}$)	24.66 ± 2.71	24.43 ± 2.52	22.45 ± 2.71	22.99 ± 3.02*
Anthropometric measures of centrally located and abdominal adiposity				
Subscapular + supraspinale skinfolds/sum of 4	0.63 ± 0.05	0.62 ± 0.06	0.59 ± 0.05	0.60 ± 0.06

skinfolds (SS/∑4SF)				
Conicity index (CI)	1.51 ± 0.11	1.53 ± 0.12	1.16 ± 0.09**	1.13 ± 0.05
Waist circumference (WC) (centimetres)	82.43 ± 9.07	82.79 ± 9.24	79.20 ± 9.64	77.94 ± 7.20
Waist to hip ratio (WHR)	0.85 ± 0.05	0.85 ± 0.05	0.81 ± 0.04**	0.81 ± 0.03
Waist to stature ratio (WSR)	0.46 ± 0.06	0.47 ± 0.06*	0.45 ± 0.06	0.44 ± 0.04

$kg.m^{-2}$: kilogrammes per square metre
Values are means ± standard deviation
*$p \leq 0.05$ compared to pretest
**$p \leq 0.05$ difference between groups at pretest

Anthropometric Measures of Central and Abdominal Adiposity

The CON participants demonstrated no significant changes in SS/∑4SF ($p = 0.224$), CI ($p = 0.151$), WC ($p = 0.890$) and WHR ($p = 0.655$). However, the WSR of the CON significantly increased from the pretest to posttest ($p = 0.039$). Sixteen weeks of resistance training resulted in no significant changes in the measures of central and abdominal adiposity as demonstrated the non-significant changes in SS/∑4SF ($p = 0.574$), CI ($p = 0.217$), WC ($p = 0.491$), WHR ($p = 0.399$) and WSR ($p = 0.615$).

Dietary Measures

At the end of the 16-week experimental period, the CON participants were found to have had no significant ($p > 0.05$) alterations in their total kilocalories ($p = 0.695$), carbohydrates ($p = 0.158$), proteins ($p = 0.388$) and fats consumed ($p = 0.937$) (table 3). Similarly, 16 weeks of resistance training did not result in any significant changes in mean dietary intakes of kilocalories ($p = 0.331$), carbohydrates ($p = 0.087$), proteins ($p = 0.249$) and fats ($p = 0.422$).

TABLE 3. **PRETEST AND POSTTEST KILOCALORIE AND MACRONUTRIENT INTAKES**

Parameter	**Control group (CON) (n = 12)**		**Resistance training group (RES) (n = 13)**	
	Pretest	**Posttest**	**Pretest**	**Posttest**
Total kilocalories	2438.61 ± 657.98	2300.91 ± 584.37	2200.00 ± 515.19	2045.10 ± 476.88
Carbohydrates (grammes)	264.38 ± 78.65	239.39 ± 56.15	245. 13 ± 59.95	223.05 ± 73.36
Proteins (grammes)	108.42 ± 35.78	98.76 ± 25.67	115.65 ± 51.49	94.96 ± 30.83
Fat (grammes)	100.31 ± 28.43	99.20 ± 30.80	83.91 ± 24.83	78.41 ± 26.57

Values are means ± standard deviation

Strength Measures

Sixteen weeks of resistance training significantly increased muscular strength during shoulder press ($p = 0.001$), latissimus dorsi pull-downs ($p = 0.001$), seated chest press ($p = 0.001$), low pulley row ($p = 0.001$), crunches ($p = 0.001$), leg press ($p = 0.001$), knee extensions ($p = 0.001$) and hamstring curls ($p = 0.001$) (table 4).

TABLE 4. **PRETEST AND POSTTEST STRENGTH MEASURES**

Parameter	Control group (CON) (n = 12)		Resistance training group (RES) (n = 13)	
	Pretest	Posttest	Pretest	Posttest
Shoulder press strength (kg)	41.50 ± 14.22	73.83 ± 15.24	45.15 ± 7.16	96.69 ± 25.06*
Lattisimus dorsi pull-down strength (kg)	53.25 ± 13.60	53.08 ± 15.23	54.69 ± 10.64	84.23 ± 8.80*
Seated chest press strength (kg)	48.33 ± 14.83	46. 67 ± 12.91	52.15 ± 8.35	82.38 ± 10.21*
Low pulley row strength (kg)	46.33 ± 9.06	43.92 ± 9.17	51.15 ± 9.31	85.62 ± 5.26*
Crunches strength (repititions.min^{-1})	43.42 ± 12.69	42.50 ± 12.51	47.69 ± 14.42	95.31 ± 14.56*
Leg press strength (kg)	80.67 ± 16.33	78.75 ± 19.46	85.15 ± 13.94	140.15 ± 20.40*
Knee extension strength (kg)	18.00 ± 2.34	19.00 ± 2.95	18.69 ± 5.88	41.46 ± 6.17*
Hamstring curl strength (kg)	10.17 ± 2.72	13.33 ± 3.45	13.85 ± 4.41	27.00 ± 2.45*

kg: kilogrammes
Values are means ± standard deviation
*$p \leq 0.05$ compared to pretest

DISCUSSION

The results of this study indicate that 16 weeks of resistance training significantly reduced total fat when compared to no exercise. Sixteen weeks of resistance training significantly decreased three of the six anthropometric measures of total fatness (i.e., fat mass, sum of skinfolds, and %BF) while significantly increasing body mass and BMI. These findings continue to highlight the inadequacies of BMI in the classification of obesity in resistance-trained athletes since BMI does not truly measure lean mass or fat mass (Rothman, 2008) and BMI only accurately reflects body fatness in about 73% of young men (Mullie *et al.*, 2008). Further, 16 weeks of resistance training had no effect on reducing anthropometric measures of centrally located and abdominal adiposity.

The research on the effects of resistance training on anthropometric measures of total, central and abdominal adiposity has been far less extensive than comparable studies utilising aerobic training. There is little consensus as to the effect that resistance training has on measures of total fatness, with several studies having demonstrated decreases in total fatness as measured by %BF (Fripp & Hodgson, 1987; Ullrich *et al*., 1987; Fleck & Kraemer, 1988; Boyden *et al*., 1993; Joseph *et al*., 1999b; Prabhakaran *et al*., 1999; Banz *et al*., 2003) while others did not show significant decreases in total fatness following resistance training as measured using %BF (Harris & Holly, 1987; Hurley *et al*., 1988; Kokkinos *et al*., 1988; Kokkinos *et al*., 1991; Joseph *et al*., 1999a; Vincent *et al*., 2002) and BMI (Fripp & Hodgson, 1987; Manning *et al*., 1991; Yeater *et al*., 1996; Joseph *et al*., 1999a; Joseph *et al*., 1999b; Banz *et al*., 2003). More importantly, resistance training as performed in this study did not support the finding that resistance training may reduce abdominal adiposity (Ross & Rissanen, 1994; Treuth *et al*., 1994; Treuth *et al*., 1995; Ross *et al*., 1996). However, the lack of change in total, central and abdominal adiposity following some resistance training programmes may be related to the low caloric expenditure typical of many resistance training programmes (Ballor *et al*., 1988) and may also be related to differences in participant characteristics, training programme design, and/or differences in the anthropometric measures utilised.

The results of this study also showed that resistance training improved strength on all of the eight prescribed exercises in healthy, sedentary males. This finding is in agreement with the reported literature for similar resistance training studies (Glowacki *et al*., 2004; Kalapotharakos *et al*., 2007; Reid *et al*., 1987).

Diet could be considered a possible limiting factor since diet is as important as exercise in regulating fat mass given that the over-consumption of energy-dense foods promotes an increase in adiposity (Donnelly & Smith, 2005). However, no statistically significant changes were found in the dietary intakes of the CON and RES. Despite a suggestion of a reduced caloric intake in both the CON and RES, only the RES demonstrated positive changes in anthropometric measures of total, centrally located and abdominal fat implying that the changes in anthropometric measures are likely to have been as a direct result of the resistance training itself.

In conclusion, resistance training can effectively reduce total adiposity but does not provide an effective stimulus to lower centrally located and abdominal adiposity. Importantly, resistance training reduced total adiposity while preserving lean mass. Thus, resistance training can assist in the maintenance of an optimal body composition in attempting to prevent overweight and obesity and the development of resultant comorbid chronic diseases and mortality. However, since a number of studies have demonstrated that aerobic training is effective at reducing measures of total, central and abdominal adiposity, future studies should examine the effect of simultaneous aerobic and resistance training on measures of total, central and abdominal adiposity to determine if an interference effect exists when using these two modes of exercise simultaneously or if these two modes of exercise result in an enhanced effect on measures of total, central and abdominal adiposity when performed simultaneously.

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