Fat Oxidation Differences in Deconditioned Normal Weight and Obese Individuals on a Lower Body Positive Pressure Treadmill

Toni T. LaSala

Jordan L. Cola

Michael A. Figueroa

Racine R. Emmons

David Hack

Department of Kinesiology
William Paterson University
300 Pompton Rd. Wayne, NJ 07470, USA

Abstract

Purpose: To determine the differences in peak fat oxidation (PFO), peak oxygen consumption (VO_{2peak}) and respiratory exchange ratio (RER) while walking at 100% and 75% on a lower body positive pressure treadmill (LBPP) in normal weight compared to obese men. Methods: Fourteen normal weight men (mean age 23.2 ± 2.4 years, BMI 27.5 ± 3.8 kg/m^2 and body fat % 14.22 ± 7.0%) and fourteen obese men (mean age 23.2 ± 2.4 years, BMI 36.5 ± 3.8 kg/m^2 and body fat % 38.6 ± 7.0%) were randomly assigned to walking on the LBPP treadmill at 100% and 75% of their body weight. Body composition was assessed by hydrostatic weighing. The protocol consisted of 3-minute stages at a constant speed of 3.3 mph where percent grade increased three minutes following the warm up from 3% to a maximum of 15%. PFO, RER and VO_{2peak} were measured using indirect calorimetry. Fat oxidation rates were calculated using stoichiometric equations. Results: There were no significant differences in VO_{2peak}, however according to Wilks's statistic, there was a significant effect on fat oxidation in the normal weight group compared to the overweight group, $\lambda = .70$, $F(2,25) = 5.36$, $p < .05$ in the 100% BW condition. There was also a significant effect on RER in the normal weight group compared to the overweight group, using Wilks's statistic, $\lambda = .74$, $F(2,25) = 4.54$, $p < 0\ .05$ in the 100% condition. Conclusion: The study suggests that100% of one's body weight increased carbohydrate use in the OW/OB population and can be due to the fact that their weight causes them to work anaerobically compared to the normal weight population. Therefore, the OW/OB population should work at a lower intensity to increase fat oxidation so they can become more fit, and the untrained NW subjects could exercise at higher intensities with similar results.

Keywords: lower body positive pressure, peak fat oxidation, peak oxygen consumption, respiratory exchange ratio.

1. Introduction

Exercise interventions targeting reduction of body fat, improvements of overall health and injury prevention are essential to maintain a good quality of life. Sedentary and overweight/obese individuals typically have poor cardiorespiratory endurance, and may have a number of issues in the lower extremities that make exercising more difficult.

The American College of Sports Medicine (ACSM, 2017) has recommended low to moderate intensity (40% to 65% VO_{2max}), and long duration exercises (>30 minutes) for those who are deconditioned and overweight/obese. One mechanism that triggers some of the favorable outcomes of exercise in deconditioned and obese individuals is the effect of exercise training on substrate utilization, or how the body utilizes fats and carbohydrates (Wilmore & Costill, 2004).

According to Brooks & Mercier, (1994) the "crossover concept" was introduced to imply that fat is the predominant fuel oxidized at rest and low exercise intensities, and carbohydrates at higher intensities. The crossover point (approximately 50% peak oxygen consumption (VO_{2peak})) indicates that as exercise intensity increases, there is a shift from fat utilization to carbohydrate utilization where carbohydrates eventually becomes the predominant fuel at >70% VO_{2peak} (Brun et al., 2012).

Walking can be a moderate intensity exercise that require no special skills, is free, low risk and can be incorporated into day-to-day activities.

During walking, the contribution of fat is dependent upon the effects of exercise intensity, nutritional status, gender, age, over training and previous exercise experience (Achten, Venables & Jeukendrup, 2003; Venables, Achten&Jeukendrup, 2005).

In normal weight individuals, fat is the preferred energy source at rest and low to moderate intensity exercise of long duration (Brooks & Mercer, 1994; O'Brien et al., 1993; Romijn et al., 1993; Thompson et al., 1998; Jeukendrup et al., 1997; Kanaley et al., 2001; van Loon et al., 1999). Similarly, Steffan, Elliott, Miller, &Fernhall, (1999) found an enhanced resting fat oxidation rate after endurance training and appears to have the capacity to increase fat oxidation in lean subjects. Additional literature supports Steffan, Elliott, Miller, & Fernhall (1999) in that the ability to utilize fat during exercise in normal weight individuals (Phillips et al., 1996; Friedlander et al., 1998) and in obese populations (van Aggel-Leijssen et al., 2002) is increased following endurance exercise training. However, individuals who are obese and/or have type 2 diabetes, have an impaired ability to utilize fat as a fuel during exercise (Blaak& Saris, 2002; Jeukendrup & Wallis, 2005; Achten & Jeudendrup, 2004). Furthermore, the impaired ability for fat mobilization and utilization in obese subjects might implicate that exercise training has a different effect on fat oxidation in obese compared with lean subjects. Therefore, exercise interventions to increase free fatty acid (FFA) oxidation in normal weight and obese individuals are important in weight management and may have the potential to reduce health risks and may have important clinical relevance (van Aggel-Leijssen et al., 2001, Achten & Jeudendrup, 2004).

During exercise of low to moderate intensity and long duration it is necessary to maintain adequate levels of circulating free fatty acids (FFA's) to provide energy (Kanaley et al., 2001) and given that obese individuals possess greater fat stores, exercise may be an ideal impetus to mobilize and oxidize fats (Philllips et al., 1996). Furthermore,for only a few hours a week a low-intensity program can be an effective means to improve insulin sensitivity in lean, obese and diabetic subjects (Schrauwen et al., 2002; van Aggel-Leijssen et al., 2002), and might be more appropriate for (obese) insulin-resistant subjects.

Measuring substrate utilization using indirect calorimetry on a cycle ergometer, Romijn et al., (1993) found fat oxidation increased from 25% to 65% of VO_{2peak} and declined again at 85%. In their study, they only investigated three exercise intensities, (25%, 65% and 85% of VO_{2peak}) and since the difference between intensities was large, fat oxidation rates may not be accurate. In another study (Achten et al., 2002), a protocol was developed to determine an intensity to elicit maximal fat oxidation rates with a larger number of exercise intensities and smaller increments. Their results show that peak fat oxidation rates occurred at 64% VO_{2peak}, which is in agreement with the results of Romijn et al., (1993). Higher fat oxidation rates during exercise in trained compared with sedentary men were reported after an overnight fast (Kelley, Goodpaster, Wing and, Simoneau, 1999, Poynten,et al., 2003, Numao, et al., 2006).

Exercise training in a reduced gravity environment such as the AlterG® can be an optimal modality for sedentary and obese individuals to improve overall health and injury prevention to improve quality of life in both sedentary and overweight men. To date, there is limited data that currently exists on the effects of lower body positive pressure (LBPP) treadmill walking on sedentary and obese men. Furthermore, little evidence exists on substrate utilization while walking at a low to moderate intensity on the AlterG® in sedentary, overweight/obese individuals. This study hypothesizes that changes in fat oxidation during walking are different in normal weight compared to overweight/obese young adult men. Therefore, the purpose of this study is to determine the differences in peak fat oxidation rates (PFO), VO_{2peak} and respirratory exchange ratio (RER) while walking on a body weight supported treadmill at 100% BW and 75% BW comparing untrained normal weight to overweight/obese males.

2. Methods

Data was collected on 28 subjects (14 untrained normal weight and 14 untrained overweight/obese men), were recruited. Physical characteristics of the study participants are summarized in Table 1.

Table 1. Participants' characteristics

Variables	NW (n=14)	OW (n=14)
Age (years)	22.62± 2.5	23.3± 2.7
Weight (kg)	79.11± 6.4	110.8 ± 19.1
Height (m)	1.70±.08	1.74 ±.08
Body Fat (%)	14.01± 4.9	38.06± 8.9
BMI (kg/m^2)	27.5 ± 2.6	36.4 ±4.4

NW= Normal weight; OW= Overweight

To standardize the testing conditions and to ensure the safety of the participants, the following pre-test instructions were given to each person before their first visit: (1) abstain from eating 12 hours before the test (2) abstain from consuming caffeine-containing products for a minimum of 12 to 24 hours before the test and (3) abstain from strenuous exercise for at least 24 hours before the test.

Subjects warmed-up on the AlterG® anti-gravity treadmill at 2.0 mph for three minutes. They began to walk at 3.3 mph at 0% grade and were randomly assigned one of two conditions (100% or 75% BW). The speed was held constant for the duration of the test where the gradient increased every three minutes by 3% up to 15% grade. Heart rate (HR) and rate of perceived exertion (RPE) were recorded during the last 5 seconds of each stage and blood pressure was recorded during the last 30 seconds of each stage.

The test was terminated if the subject experienced adverse signs or symptoms (ACSM, 2017) orreached volitional fatigue. Fat oxidation, VO_{2peak} and RER were measured using indirect calorimetry with the MedGraphicsUltima Series (St. Paul, MN) open circuit spirometer and calculations of oxygen uptake (VO_2) and carbon dioxide production (VCO_2) was averaged over the last two minutes of each exercise stage.

2.1 Subjects

Fourteen normal weight men (mean age 22.6 ± 2.5 years, BMI 27.5 ± 2.6 kg/m^2 and Body Fat % 14.01 ± 4.9%) and fourteen obese men (mean age 23.3 ± 2.7 years, BMI 36.4 ± 4.4 kg/m^2 and body fat % 38.1 ± 8.9%) were randomly assigned to walking on the LBPP treadmill at 100% and 75% of their body weight. Hydrostatic weighing assessed body composition. Characteristics of the study participants are summarized in Table 1. All subjects gave written informed consent after the experimental procedures were explained to them, which was by approved by William Paterson University's Institutional Review Board. Subjects were considered untrained based on their PAR-Q questionnaire.

Table 2. Differences in VO_{2peak}, FO, and RER

Variables	**100%**	**75%**	**F**	***p***
	M±SD	**M±SD**	**Between -Subjects**	
Fat Ox(g/min)				
NW				
OW	0.18 ±.17	0.15 ±.27		
	0.01±.24	0.16 ± .27	5.362	0.12*
VO_{2peak}(ml/kg/min)				
NW				
OW	17.45 ±2.64	14.01±3.73		
	16.81 ±3.2	12.89±3.40	0.972	0.70
RER				
NW	.9 ±.08	.88±.08		
OW	.98±.92	.92±.09	4.52	.02*

NW= Normal weight (N=14); OW= Overweight (N=14). Fat ox = Fat oxidation rate; VO2peak – peak oxygen consumption; RER= respiratory exchange ratio.*p< .05 compared for the groups (NW and OW) for the two BW Conditions.

2.2 General Design

The subjects attended the laboratory for two sessions separated by at least three but not more than seven days following the anthropometric and body density measurements. All sessions took place in the same laboratory where air temperature was 24.1 ± 3°C and relative air humidity was 20 ± 5%.

Session 1 - (Anthropometric Measurements and Body Density):

Subjects reported to the Human Performance Lab at William Paterson University where baseline measures of height, weight, and body density were measured. Body composition was determined by measuring body density using underwater weighing.

Session 2 and 3: Exercise Test: At both sessions, subjects were familiarized with the equipment and procedures. The subjects reported to the laboratory after a 12-hour overnight fast and no physical activity. Subjects reported to the laboratory approximately the same time for each of the two sessions to avoid variations in their circadian rhythms. Resting blood pressure was recorded and then the subjects were prepped for a 12-lead ECG placement to determine resting and exercise heart rates . Subjects were then fitted with a mask connected to a metabolic cart to collect expired gases to determine $\dot{V}O_{2peak}$.

Subjects were then instructed to put on the neoprene shorts and then they were zipped in to the treadmill aperture. Before the test, the air pressure in the chamber adjusted to apply the proper lifting force for each subject by way of a built in pressure feedback system. The treadmill tests were randomized where the subject began on the AlterG® at either 100% or 75% of their body weight.

After the calibration process a warm up of 2.0 mph for 3 minutes at 100% body weight was performed. The subjects, in random order (100% or 75% BW) began to walk at 3.3 mph at 0% grade. The speed was held constant for the duration of the test where the gradient increased every 3 minutes by 3% up to 15% grade. Heart rate and RPE were recorded during the last 5 seconds of each stage and blood pressure was recorded during the last 30 seconds of each stage. The test was terminated if the subject experienced adverse signs or symptoms (ACSM, 2017) or reached volitional fatigue. Additionally, participants believed to have reached their true $\dot{V}O_{2max}$ if the following conditions exist: (a) a plateau in $\dot{V}O_2$ (b) a heart rate within 5-10 beats of their age-predicted maximal heart rate (220-age x .85); (c) RPE of 18-20; and (d) a respiratory exchange ratio (RER) of 1.10. Finally, $\dot{V}O_{2peak}$ is the highest value of $\dot{V}O_2$ the subject attained on the test. All subjects participated in two tests on two separate days separated by at least three but no more than seven days once informed consent and the PAR-Q have been completed. The two tests were randomized and performed on the AlterG® anti-gravity treadmill at two different percentages of the subjects' original body weight (100% and 75%) to determine peak fat oxidation, $\dot{V}O_{2peak}$, and RER.

2.3. Statistical Analysis

Statistical analysis was performed using the SPSS IBM statistical package (v. 26, Chicago, IL). Differences between the two treadmill conditions (100% BW & 75% BW) for the following dependent variables: peak fat oxidation (PFO), peak oxygen consumption ($\dot{V}O_{2peak}$) and respiratory exchange ratio (RER) were determined by using a repeated-measures MANOVA design. Statistical significance was set at a $p < 0.05$ level, and data are expressed asmean ± standard deviation. A Kolmogorov-Smirnovtest for normality was completed on all variables to determine homogeneity of variances.

3. Results

VO_{2peak}

There was no significant difference in VO_{2peak} for normal weight and overweight/obese between 100% and 75% of BW. VO_{2peak}, was higher at 100% BW for normal weight individuals (17.45 ± 2.6 ml/kg/min) compared to overweight individuals (16.81 ± 3.2 ml/kg/min). VO_{2peak}, was higher at 75% BW for normal weight individuals (14.01 ± 3.7 ml/kg/min) compared to overweight/obese individuals, (12.89± 3.4 ml/kg/min) (Figure 1).

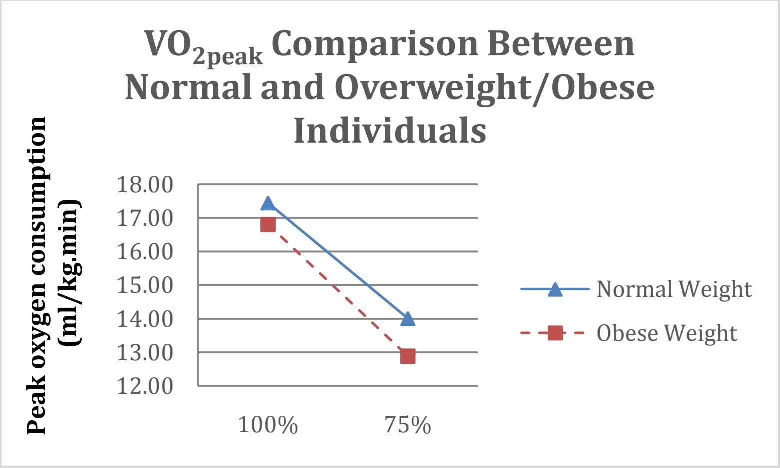

Figure 1. Comparison of VO2peak values compared between Normal and Obese participants in 100% and 75% lower body positive pressure conditions.

Fat Oxidation

There was a significant difference in fat oxidation at 100% BW in the normal weight group compared to the overweight/obese group, $\lambda = .70$, $F(2,25) = 5.36$, $p < .05$. Fat oxidation rates at 100% BW were lower in the obese group (0.18 g/min) compared to the normal weight group (0.01 g/min).

However, There were no significant differences at 75% BW for the normal weight group (0.145 g/min) compared to the overweight group (0.156 g/min)(Figure 2).

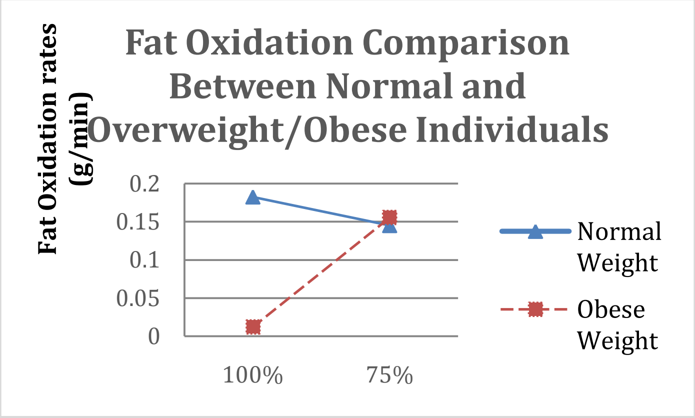

Figure 2. Comparison of Fat Oxidation values compared between Normal and Obese participants in 100% and 75% lower body positive pressure conditions.

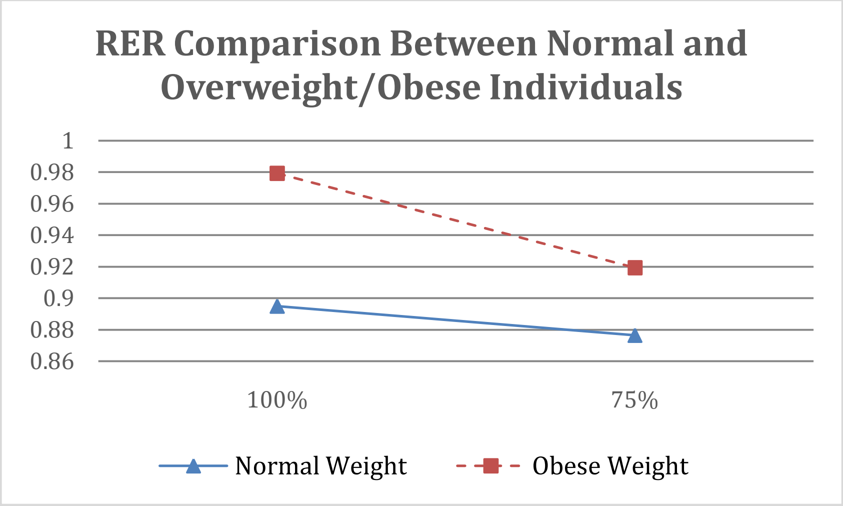

Figure 3. Comparison of Respiratory Exchange Ratio values compared between Normal and Obese participants in 100% and 75% lower body positive pressure conditions.

RER

There was also a significant difference in RER at 100% BW in the normal weight group compared to the overweight group, $\lambda = .74$, $F(2,25) = 4.51$, $p < .05$. A RER of 1 indicates carbohydrates are the primary fuel being utilized for the overweight population at 100% and 75% of BW (Figure3). Figure 3 shows the difference between the two treadmill conditions where OW/OB participants in the 100% BW group had a higher RER (*M* = .98, *SD*±.92) compared to the untrained NW group (*M*= .9, *SD*± .8). Additionally, participants in the 75% OW/OB group (*M*= .92, *SD*± .09), had ahigher RER than the NW group (*M*= .88,*SD*±.08).

Discussion

The purpose of the present study was to determine the differences in PFO, VO_{2peak}, and RER while walking at 100% and 75% on a LBPP treadmill between normal-weight and overweight/obese untrained men. The findings of our study indicated that although there were no significant differences in VO_{2peak} between groups and conditions we did see significant differences at 100% BW in between groups in PFO and RER.

In the present study, it was observed that during a standardized 18-minute exercise protocol, all participants' elicited significantly higher fat oxidation rates in the untrained normal weight group (.18 g/min). Furthermore, normal weight males oxidation rates were 0.17 g/min more than the untrained overweight/obese population (0.01 g/min).

This increase in fat oxidation in the normal weight untrained males may be related to the relative exercise intensity, mode of training and body composition. Although the overweight/obese population has more useable energy stored in adipose tissue, utilization is compromised with an increase in relative exercise intensity. This was observed by other studies where fax oxidation rates and workload at which fat oxidation occurs are reduced in obese subjects (Achten, Gleeson, Jeukendrup, 2002; Venables, Achten, & Jeukendrup, 2005; Norby, Saltin, B., & Helge, 2006;Stisen, et al., 2006). Furthermore, fat oxidation at different intensities in overweight/obese (OW/OB) individuals showed a lower rate of fat oxidation than normal weight individuals (Perez-Martin et al., 2001; Bogdanis et al., 2005).In contrast, other studies found that total fat oxidation was greater in obese than in normal weight (NW) individuals between obese and lean subjects during exercise on a cycle ergometer for 60 minutes (Goodpaster et al., 2002; Horowitz & Klein, 2000; Kanaley et al., 2001; Mittendorfer, Fields & Klein, 2004).

In the present study, those who were in the 100% BW conditions showed significant differences at 100% BW (0.18 g/min) in the NW group compared to (0.01 g//min) in the OW/OB group for FO. Significant differences were also evident at 100% BW (.89) in the NW group when compared to the OW group at 100% BW (.98) for RER. Consistent with this study, Ara et al. (2011) reported that young male obese individuals have higher exercise intensity than normal-weight individuals at their fat max. This study showed that NW had a decreased fat oxidation rate (0.145 g/min) at 75% BW compared to 100% BW (0.18 g/min), where the OW group had an increased fat oxidation rate (0.15 g/min) at 75% compared to 100% BW (0.012 g/min).

Compared with lean subjects, obese individuals have a higher percentage of fast twitch type II fibers, predominantly oxidizing carbohydrates. The percentage of slow twitch type I fibers with a much higher capacity to oxidize fat is reduced in obese subjects (Kriketos, Baur, O'Connor, Cary, King, Caterson, & Storlien, 1997)It has been shown that fat oxidation rates can be reproduced in one individual, however several studies indicate there is a large inter-individual variation as to where maximal fat oxidation occurs. A cross-sectional study demonstrated that large differences exist in the ability to oxidize fat during exercise (Venables et al., 2005).

In the same study, fat oxidation rates were shown to range from 0.18 to 1.01 g/min. They concluded that the lean body mass, physical activity levels, VO_{2max}, gender and fat mass accounted for 35% of the variation in peak fat oxidation rates, however 66% of the variance could not be explained. Although diet is likely to explain some the variance there is still a large part of the variance that remains unexplained. Geerling et al., (1994) looked at the relationship between body fat and fat oxidation and found no relationship and suggested that OW/OB individuals may have increased or decreased metabolic efficiency and/or insulin resistance that may be responsible for the shift in substrate use. As a result, a shift in substrate use during exercise may be mediated by insulin resistance and not body fat.

Our findings provide further insight that fatty acid mobilization from adipose tissue limits exercise induced fat oxidation in obese men, which may have implications for exercise programming. Regarding the intensity of this program, it may be sensible to have the NW subjects exercise at higher intensity and the OW individuals exercise at lower intensities.

During exercise of long duration it is necessary to maintain adequate levels of circulating FFA to provide energy (Kanaley et al., 2001) and given that obese individuals possess greater fat stores, exercise may be an ideal impetus to mobilize and oxidize fats (Philllips et al., 1996). However, in obese individuals impairments occur in their ability for the skeletal muscle to utilize FFA' s during exercise, as well as after weight loss (Blaak & Saris, 2002; Achten & Jeudendrup, 2004). Conversely, increased levels of fat oxidation can spare the use of muscle glycogen during exercise and contribute to fat loss (Brooks, 1987; Romijn et al, 1993). The literature supports that the ability to utilize fat during exercise in normal weight individuals (Phillips et al., 1996; Friedlander et al., 1998) and in obese populations (van Aggel-Leijssen et al., 2002) is increased following endurance exercise training. Therefore, exercise interventions to increase FFA oxidation in overweight and obese individuals are important in weight management and may have the potential to reduce health risks and may have important clinical relevance (van Aggel-Leijssen et al., 2001, Achten & Jeudendrup, 2004).

Conclusion

The study suggests that100% of one's body weight increased carbohydrate use in the OW/OB population and can be due to the fact that their weight causes them to work anaerobically compared to the normal weight population. Therefore, the OW/OB population should work at a lower intensity to increase fat oxidation so they can become fit, and the untrained NW subjects could exercise at higher intensities with similar results.

The present study has a few limitations. First, fat oxidation during exercise may be influenced by many factors (e.g., age, gender, body composition, activity duration, activity type, diet, and training status) accounted for 35% of the variation in peak fat oxidation rates, however 66% of the variance could not be explained. Although diet is likely to explain some the variance there is still a large part of the variance that remains unexplained. We did not measure insulin resistance, a known factor in the balance of substrate oxidation during exercise. Furthermore we did not monitor their nutritional intake prior to the test. Further studies need to be done to determine fat oxidation rates for the obese population during long-term training protocols.

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