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Comparing Power and Oxygen Uptake During Treadmill Exercise Testing in PWH and PWOH Hispanic Adults

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Abstract

Background: Daily engagement in physical activity requires the capacity of skeletal muscle to generate power and utilize the oxygen needed for muscle power generation, concepts associated with mechanical and energy efficiency. People living with HIV (PWH) experience metabolic dysfunctions including reduced muscle mass, fat distribution changes known as lipodystrophy, and low capacity for oxygen uptake (VO2max), potentially affecting their mechanical and energy efficiency. Aims and Objectives: To evaluate and compare oxygen uptake (%VO_2max) and power output at different stages during a treadmill exercise test in PWL with lipodystrophy (PWL-Lipo), PWL without lipodystrophy (PWL-NoLipo), and adults without HIV infection (PWOH). Materials and Methods: Hispanic adults (45 women, 43 men) of similar sex and age distribution: 29 PWH-Lipo (17 women, 12 men), 29 PWH-NoLipo (13 women, 16 men), and 30 PWOH (15 women, 15 men). Anthropometric measures of weight, height, percent body fat, and waist and hip circumference were obtained. Participants completed a graded exercise test on a treadmill until volitional fatigue using the modified Bruce protocol. To compare oxygen uptake (%VO_2) and power output (W) between stages during the treadmill protocol, repeated measures ANOVA and Tuckey post hoc was used. Results: Differences by sex and group in power output and oxygen uptake during the treadmill exercise protocol stages were observed. While women in the three groups showed similar power in each protocol stage, men in the PWH-NoLipo group showed lower power output during the last stages of the protocol compared with the other groups of men. Percentage of VO_2max was higher in each stage for men in the PWH-Lipo group compared with the other groups of men, and also higher in women in the PWH-Lipo group but only during stages 2nd and 3rd of the protocol, suggesting that there are lipodystrophy-associated metabolic dysfunction explaining a lower mechanical efficiency in all exercise intensities in men and during intermediate exercise intensities in women. Conclusion: Exercise intervention studies must consider and evaluate mechanical efficiency as a critical factor to explain improvements in functional capacity not only in PWH but also, in adults with metabolic complications and lipodystrophy, also reported in diabetes, hypertriglyceridemia, and liver disease.

Keywords: Mechanical efficiency, Metabolic dysfunction, Modified Bruce protocol, HIV.

INTRODUCTION

Essential for daily engagement in physical activities is the capacity of skeletal muscle to generate power and utilize the oxygen required for muscle power generation, concepts associated with mechanical and energy efficiency [1,2]. Generating high levels of muscle strength and power with a relatively low energy cost defines mechanical efficiency. People with low mechanical efficiency tend to have limited capacity for daily physical activities, and low participation in recreational and sport activities [3,4]. Low mechanical efficiency among adults with obesity and older adults have been associated increased visceral and subcutaneous fat accumulation, reduced muscle mass and power, and low cardiorespiratory fitness [5-7]. Cardiorespiratory fitness measured by the capacity for maximal oxygen uptake (VO_2max) is critical for maximal energy production and muscle power generation during exercise. A high VO_2max implies a high capacity for energy production, and a high mechanical efficiency implies a high power output with a lower oxygen demand. Physical activity and exercise interventions have shown improvements in mechanical efficiency among women with obesity [8] and in older adults [9].

People living with HIV (PWH) experience metabolic and neuromuscular changes suggesting a premature physiological aging [10,11]. Reduced muscle mass and fat distribution changes including loss of peripheral fat and increased central fat accumulation, known as lipodystrophy, and low VO_2max are some of the metabolic dysfunctions observed in PWH [12,13] which are linked to metabolic syndrome and risk of

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cardiovascular disease [14]. PWH with lipodystrophy have a higher prevalence of metabolic syndrome with high glucose intolerance and abdominal adiposity and low VO_2peak compared with those without lipodystrophy [15]. Although the new generation of metabolically "less toxic" antiretroviral therapies (ART) have made lipodystrophy almost insignificant among PWH, metabolic pathways leading to adipocyte tissue dysfunction persist in this population [16]. It is possible that metabolic dysfunction in PWH affects their mechanical efficiency, potentially explaining the high proportion of PWH living a physically inactive lifestyle [17]. However, no previous published study has evaluated mechanical efficiency during exercise testing in PWH. Therefore, the purpose of this study was to evaluate and compare oxygen uptake (%VO_2max) and power output at different stages during a treadmill exercise test in PWL with lipodystrophy (PWL-Lipo), PWL without lipodystrophy (PWL-NoLipo), and adults without HIV infection (PWOH). We hypothesized that PWH-Lipo will demonstrate a low mechanical efficiency characterized by a higher oxygen demand (%VO_2max) for a similar power output compared with PWH-NoLipo and PWOH.

MATERIALS AND METHODS

Secondary data analyses were conducted from the Cardiometabolic Risk Assessment Study in PWH, in which a group of 88 Hispanic adults (45 women, 43 men) of similar sex and age distribution were recruited to participate in this cross-sectional comparative study, of which 29 were PWH-Lipo (17 women, 12 men), 29 PWH-NoLipo (13 women, 16 men), and 30 PWOH (15 women, 15 men). Lipodystrophy status was determined by at least two of the following: 1) waist to hip ratio above 1.0 for males and above 0.85 for females, 2) physician's diagnosis, 3) self-reported changes in body size (fat accumulation in the abdomen, fat loss in the gluteal area and extremities, and changes in clothing size during the previous five years). The study protocol was approved by IRB of the University of Puerto Rico, Medical Sciences Campus. Anthropometric measures of weight, height, percent body fat, and waist and hip circumference were obtained with a Tanita (BF-522W) digital scale, Seca 217 stadiometer, and Gulick anthropometric tape, respectively. Body mass index (BMI) and waist to hip ratios were determined. Participants also completed a graded exercise test on a treadmill until volitional fatigue using the modified Bruce protocol [18] in which oxygen uptake (VO_2) and carbon dioxide production (VCO_2) were continuously recorded (Schiller CS200 Ergo Spirometer, Surgo Surgical Supply, Ontario, Canada). The following steps [19] were used to determine power output in each stage of the exercise protocol:

1. Determine vertical distance (m) = velocity (meters/min) multiplied by the percent inclination and time (min)

2. Determine work = body weight (kg) multiplied by the vertical distance (m)

3. Determine power (kg·m/min or Watts) = work/min

Percent VO_2max for each stage in each participant was determined (= (VO_2/VO_2max) x 100). Because the modified Bruce protocol has cero inclination during the first stage, power output was determined starting at the second stage. All participants (100%) completed the second and third stage, 95% completed the 4th stage, 85% completed the 5th stage, 35% completed the 6th stage, and 5% completed the 7th stage. Therefore, our analyses included participants who completed from the 2nd to the 5th stage. Statistical analyses included means and standard deviations for all variables and ANOVA with Tukey post-hoc to detect sex and group differences. To compare oxygen uptake (%VO_2) and power output (W) between stages during the treadmill protocol, repeated measures ANOVA and Tuckey post hoc was used. All statistical analyses were conducted with the Statistical Package for the Social Sciences (SPSS), version 23, using an alpha less than 0.05 to detect significant differences.

RESULTS

Descriptive characteristics of study participants divided by sex and group (PWH-Lipo, PWH-NoLipo, and PWOH) are presented in Table 1. Mean age was 48 years for women and 51 years for men, without significant differences by sex or between groups. Men were taller with less percent body fat than women, but height, percent body fat, and fat free mass was not different within groups by sex. Men in the PWOH group were heavier compared with the PWH-NoLipo group. Women in the PWH-NoLipo group had higher BMI and men in the same group had lower BMI compared with the other groups. Men and women PWH-Lipo had higher waist and waist to hip ratio compared with the other groups. Resting blood pressure was not different by sex or between groups. Men in the PWOH group had a lower resting heart rate compared to women in the same group, and men in this group had lower resting heart rate compared with men in the PWH-Lipo group. VO_2max was lower in women compared to men in the PWH-NoLipo and PWOH groups. Men in the PWH-Lipo group had a lower VO_2max than men in the other two groups. Maximal heart rate was different between women, being higher in the PWOH group and lower in the PWH-Lipo group. All described differences were statistically significant ($P<0.05$)

Mean VO_2, heart rate and respiratory exchange ratio by sex and group in each stage of the modified Bruce protocol are presented in Table 2. All variables increased with increasing stage in all groups during the treadmill exercise testing protocol. Mean VO_2 in each stage was not different by group among women and men. Figure 1-4 show the power output and percent VO_2max for men (Figure 1 and 3) and women (Figure 2 and 4) in each stage of the exercise protocol. Power output in the PWH-NoLipo men was lower in stages 3-5 compared with the other groups of men (Figure 1), however, mean power output in each stage between the groups of women were not different (Figure 2). Percentage of VO_2max was higher among men in the PWH-Lipo group in all stages compared with the other groups of men (Figure 3), but PWH-Lipo women had lower percent VO_2max only on the 2nd to 4th stage of the protocol compared with the other groups of women (Figure 4).

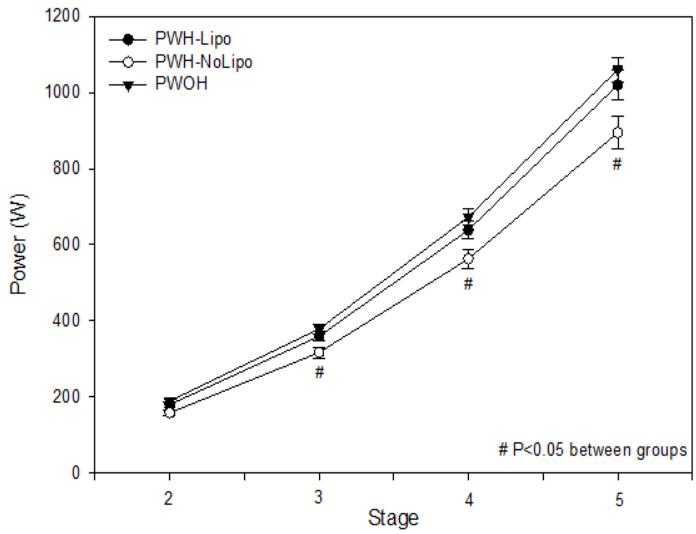

Figure 1: Power output (W) by stage during the treadmill exercise protocol between men in the PWH-Lipo, PWH-NoLipo and PWOH group (mean ± standard error)

Table 1: Descriptive characteristics of study participants by group and sex (mean ± standard deviation)

Variables	PWH-Lipo		P	PWH-NoLipo		P	PWOH		P
	Women (n=18)	Men (n=12)		Women (n=13)	Men (n=16)		Women (n=15)	Men (n=15)	
Age (years)	49.5 ± 7.6	51.2 ± 6.8	0.507	45.8 ± 4.8	50.4 ± 8.0	0.077	48.3 ± 6.9	52.1 ± 6.9	0.141
Height (cm)	159.3 ± 6.7	171.9 ± 6.6	0.001	160.9 ± 7.8	171.4 ± 7.0	0.001	160.6 ± 6.8	174.9 ± 6.7	0.001
Weight (kg)	76.5 ± 14.6	79.9 ± 10.2	0.492	77.5 ± 23.6	70.4 ± 12.8†	0.311	74.3 ± 16.0	84.2 ± 10.1†	0.052
BMI (kg/m^2)	30.3 ± 6.4	27.1 ± 3.8	0.128	29.5 ± 7.1	23.9 ± 3.6†	0.010	28.7 ± 5.2	27.6 ± 3.3	0.481
%Fat	40.4 ± 5.6	24.5 ± 8.7	<0.001	38.8 ± 8.9	17.3 ± 4.9	<0.001	37.6 ± 6.8	23.2 ± 8.5	<0.001
FFM (kg)	51.6 ± 8.3	51.8 ± 11.0	0.962	51.6 ± 9.6	54.2 ± 12.0	0.543	54.7 ± 9.5	52.7 ± 12.4	0.619
Waist C. (cm)	101.5 ± 12.8*	99.0 ± 7.3†	0.540	93.2 ± 14.7	85.1 ± 8.9	0.078	89.9 ± 9.9	94.9 ± 10.7	0.200
Hip C. (cm)	105.9 ± 13.2	99.3 ± 7.2	0.123	108.8 ± 18.9	91.7 ± 6.7	0.002	107.3 ± 9.9	101.4 ± 6.7	0.068
WHR	0.96 ± 0.07*	0.99 ± 0.03†	0.102	0.86 ± 0.05	0.93 ± 0.06	0.005	0.84 ± 0.06	0.93 ± 0.06	0.001
Resting SBP (mmHg)	111.3 ± 27.7	120.6 ± 7.9	0.272	124.4 ± 16.6	118.4 ± 17.3	0.358	121.7 ± 12.5	124.3 ± 13.6	0.589
Resting DBP (mmHg)	77.3 ± 8.9	77.0 ± 5.3	0.924	79.9 ± 10.4	74.7 ± 8.6	0.150	76.1 ± 7.2*	81.0 ± 8.4	0.131
Resting HR (bpm)	74.9 ± 8.4	74.9 ± 11.4†	0.986	75.3 ± 10.2	69.3 ± 9.9	0.117	74.5 ± 10.6*	62.9 ± 8.5†	0.003
VO_2max (ml.kg^{-1}.min^{-1})	25.1 ± 5.7	29.4 ± 8.2†	0.97	27.0 ± 6.5	36.3 ± 6.9	0.001	28.3 ± 6.8	39.2 ± 8.3	0.001
HRmax (bpm)	153.0 ± 20.6*	146.9 ± 24.1	0.453	164.2 ± 14.1*	158.6 ± 17.4	0.352	176.8 ± 21.6*	161.6 ± 17.1	0.31

Note: BMI = body mass index, C. = circumference, SBP = systolic blood pressure, DBP = diastolic blood pressure, HR = heart rate, bpm = beats per minute. †P<0.05 between groups of men y *P<0.05 between groups of women (values with the same symbol are significantly different)

Table 2: Physiologic response in each stage of the exercise test protocol by sex and group (mean ± standard deviation)

Variables	Women			Men		
	PWH-Lipo	PWH-NoLipo	PWOH	PWH-Lipo	PWH-NoLipo	PWOH
Stage 2	**N= 18**	**N= 13**	**N= 15**	**N= 12**	**N= 16**	**N= 15**
VO_2 ($ml.kg^{-1}.min^{-1}$)	11.0 ± 2.3	11.2 ± 2.7	11.1 ± 1.6	11.9 ± 2.1	12.7 ± 4.9	11.3 ± 2.0
HR (bpm)	95.2 ± 12.1	93.8 ± 12.9	97.7 ± 11.1	87.0 ± 10.6	86.6 ± 23.6	79.3 ± 10.6†
RER	0.83 ± 0.08*	0.80 ± 0.03*	0.77 ± 0.05*	0.78 ± 0.05†	0.83 ± 0.11†	0.76 ± 0.05
Stage 3	**N= 18**	**N= 13**	**N= 15**	**N= 12**	**N= 16**	**N= 15**
VO_2 ($ml.kg^{-1}.min^{-1}$)	14.5 ± 2.8	14.2 ± 2.7	14.3 ± 1.2	15.2 ± 1.9	15.7 ± 4.8	14.5 ± 2.8
HR (bpm)	110.1 ± 12.5	106.1 ± 13.9	112.6 ± 12.3	98.4 ± 11.8	94.9 ± 21.9	89.9 ± 12.8†
RER	0.90 ± 0.09	0.86 ± 0.05	0.84 ± 0.06	0.84 ± 0.07	0.88 ± 0.10†	0.81 ± 0.05†
Stage 4	**N= 18**	**N= 13**	**N= 15**	**N= 12**	**N= 16**	**N= 15**
VO_2 ($ml.kg^{-1}.min^{-1}$)	19.7 ± 3.9	18.4 ± 3.5	19.0 ± 1.7	19.9 ± 2.6	19.7 ± 2.5	19.9 ± 3.9
HR (bpm)	133.3 ± 19.1	127.5 ± 15.9*	135.9 ± 13.5*	114.5 ± 14.3†	105.4 ± 10.1	107.3 ± 16.7
RER	1.0 ± 0.11*	0.95 ± 0.07	0.94 ± 0.07	0.91 ± 0.08^	0.94 ± 0.06	0.87 ± 0.08†
Stage 5	**N= 10**	**N= 11**	**N= 14**	**N= 11**	**N= 15**	**N= 15**
VO_2 ($ml.kg^{-1}.min^{-1}$)	24.9 ± 3.5	24.5 ± 4.5	25.1 ± 3.7	25.9 ± 4.4	26.7 ± 2.7	28.1 ± 4.8
HR (bpm)	151.9 ± 17.5	153.9 ± 17.0*	164.9 ± 9.6*	134.7 ± 18.8	128.5 ± 11.9	134.7 ± 20.1
RER	1.0 ± 0.07	1.1 ± 0.06	1.1 ± 0.08	1.0 ± 0.07	1.1 ± 0.10†	1.0 ± 0.12

Note: VO_2 = oxygen uptake, HR = heart rate, RER = respiratory exchange ratio. *P<0.05 between groups of women, †P<0.05 between groups of men (values with the same symbol are significantly different).

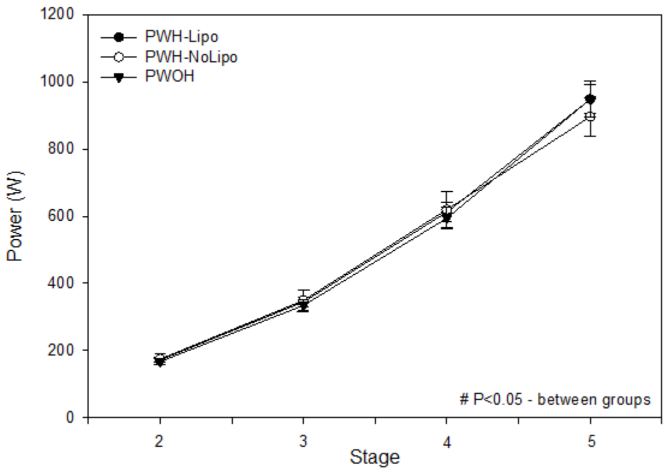

Figure 2: Power output (W) by stage during the treadmill exercise protocol between women in the PWH-Lipo, PWH-NoLipo and PWOH group (mean ± standard error)

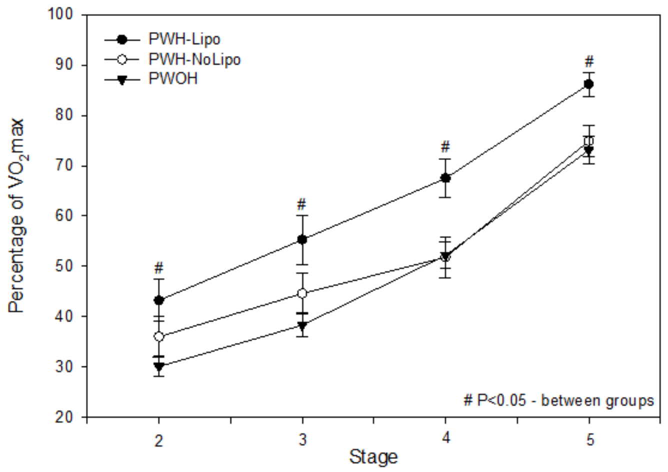

Figure 3: Percentage of VO_2max by stage during the treadmill exercise protocol between men in the PWH-Lipo, PWH-NoLipo and PWOH group (mean ± standard error)

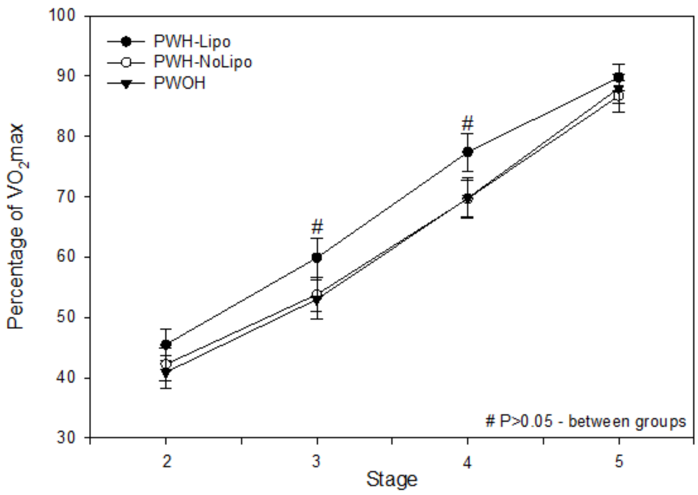

Figure 4: Percentage of VO_2max by stage during the treadmill exercise protocol between women in the PWH-Lipo, PWH-NoLipo and PWOH group (mean ± standard error)

DISCUSSION

Differences by sex and group in power output and oxygen uptake during the treadmill exercise protocol stages is a mayor study finding. While women in the three groups showed similar power in each protocol stage, men in the PWH-NoLipo showed lower power output during the last three stages of the protocol compared with the other groups of men. It is possible that this difference could be explained by a lower body weight in this group in comparison to the other two groups of men, however percent body fat and fat free mass (which is mostly muscle mass) was not different between the groups of men. Also, this difference in power ouput was not observed in the percentage of VO_2max relative to body weight where PWH-NoLipo was similar to the PWOH group of men. Percentage of VO_2max was higher in each stage for men in the PWH-Lipo group compared with the other groups of men, and also higher in women in the PWH-Lipo group but only during stages 2nd and 3rd of the protocol, suggesting that there are lipodystrophy-associated metabolic dysfunction explaining a lower mechanical efficiency in all exercise intensities in men and during intermediate exercise intensities in women.

Lipodystrophy has been associated with glucose intolerance, diabetes, elevated blood triglyceride levels and lower HDL in comparison with groups without lipodystrophy [14, 15]. Also, lower cardiorespiratory fitness has been reported among PWH-lipo adults compared to PWH-NoLipo and HIV- adults [20]. Our results suggest that anthropometric and metabolic changes experienced by PWH-Lipo possibly explain their lower mechanical efficiency. The previously reported premature aging characterized by hormonal changes increasing the risk of osteopenia, sarcopenia, excess body fat, reduced functional capacity and fragility among PWH [10, 21] would suggest a lower mechanical efficiency in both PWH groups: with and without lipodystrophy. However, our results suggest that only the metabolic dysfunction associated with lipodystrophy results in poorer mechanical efficiency. Therefore, premature aging in PWH with lipodystrophy could result in lower capacity to engage in daily physical activities as suggested by other studies reporting lower mechanical efficiency among older adults [5-7].

CONCLUSION

With a lower mechanical efficiency, PWH-Lipo adults could experience a higher metabolic cost of daily physical activities, including recreational sports activities, potentially explaining a low functional capacity. Implementing intervention programs integrating physical activity and healthy nutritional habits could help improve mechanical efficiency and functional capacity in PWH with lipodystrophy and/or adipose tissue dysfunction as recently described with the increasing use of integrase inhibitors [16]. Exercise intervention studies must consider and evaluate mechanical efficiency as a critical factor to explain improvements in functional capacity not only in PWH but also, in adults with metabolic complications and lipodystrophy, such as reported among people with diabetes, hypertriglyceridemia, and liver disease.

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Conflicts of interest

None declared.

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