Exercise-Induced Blood Flow Patterns in Patients with Coronary Artery Disease

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INTRODUCTION

- Coronary artery disease (CAD) is the leading cause of deaths attributable to cardiovascular disease in the United States.[1]
- Functional changes in endothelial cells (endothelial dysfunction) is seen in early stages of CAD.[1,2]
- Endothelial cells help maintain homeostasis of the vessel wall, and is regulated by blood flow-derived endothelial shear stress (ESS).[2]
- Aerobic exercise (AX) is known to have cardioprotective effects.[3,4] However, a decrease in traditional CAD risk factors explains only ~50% of the benefits of AX, leaving the remaining 50% of the benefits due to unknown factors.[4] One possibility is exercise-induced ESS.
- Exercise-induced blood flow patterns (BFP) in young, healthy individuals are bi-directional, intensity dependent, and mostly turbulent at higher intensities.[5]

PURPOSE

The aim of the present study was to determine exercise-induced BFP in patients with CAD.

METHODS

Subjects underwent 2 cycle ergometer exercise tests (ET). First, a graded, symptom-limited ET to determine peak oxygen uptake (VO_2peak) and lactate threshold to determine workloads of the second ET at 0-2 mmol/L (low intensity - LI), 2-4 mmol/L (moderate intensity - MI), and at >4 mmol/L (high intensity - HI).[6,7] VO_2, heart rate (HR), rate of perceived exertion (RPE), and La were measured at each workload during both ET. Brachial artery diameter (BAD) and blood flow velocity (BFV) of the right arm were measured simultaneously using high definition ultrasound imaging and Doppler. ESS was estimated using Womersley's approximation. Reynold's number (Re) and peak critical Re (Re_crit) were calculated to determine whether the flow was laminar or turbulent. A repeated measures 2-way ANOVA was used to calculate the differences between groups through SPSS (version 24.0). Alpha level was set at 0.05.

Table 1. Patient Demographics

	Control group	CAD group	p-value
n	6	7	
Sex (females)	2	2	
Age (mean (SD))	64.0 (7.5) yrs	64.4 (8.0) yrs	0.923
Height (mean (SD))	172.2 (7.5) cm	162.1 (6.8) cm	0.027*
Weight (mean(SD))	77.0 (14.8) kg	81.1 (13.3) kg	0.606
BMI (mean (SD))	25.9 (4.1) kg/m^2	30.8 (4.3) kg/m^2	0.058
Resting HR (mean (SD))	67 (14) bpm	67 (10) bpm	0.951
Resting SBP (mean (SD))	119 (20) mmHg	127 (10) mmHg	0.4
Resting DBP (mean (SD))	73 (12) mmHg	75 (9) mmHg	0.71
Hct (mean (SD))	45.3 (3.6) %	49.9 (4.6) %	0.275
VO_{2peak} (mean (SD))	28.5 (7.0) ml/kg/min	19.3 (4.4) ml/kg/min	0.015*
PO_{max} (mean (SD))	151.7 (29.3)	100.7 (27.0)	0.008*
$Lactate_{peak}$ (mean (SD))	4.6 (0.6) mmol/L	4.6 (1.0) mmol/L	0.92

BMI: body mass index; HR: heart rate; SBP: systolic blood pressure; DBP: diastolic blood pressure; Hct: hematocrit; PO_{max}: Maximal power output

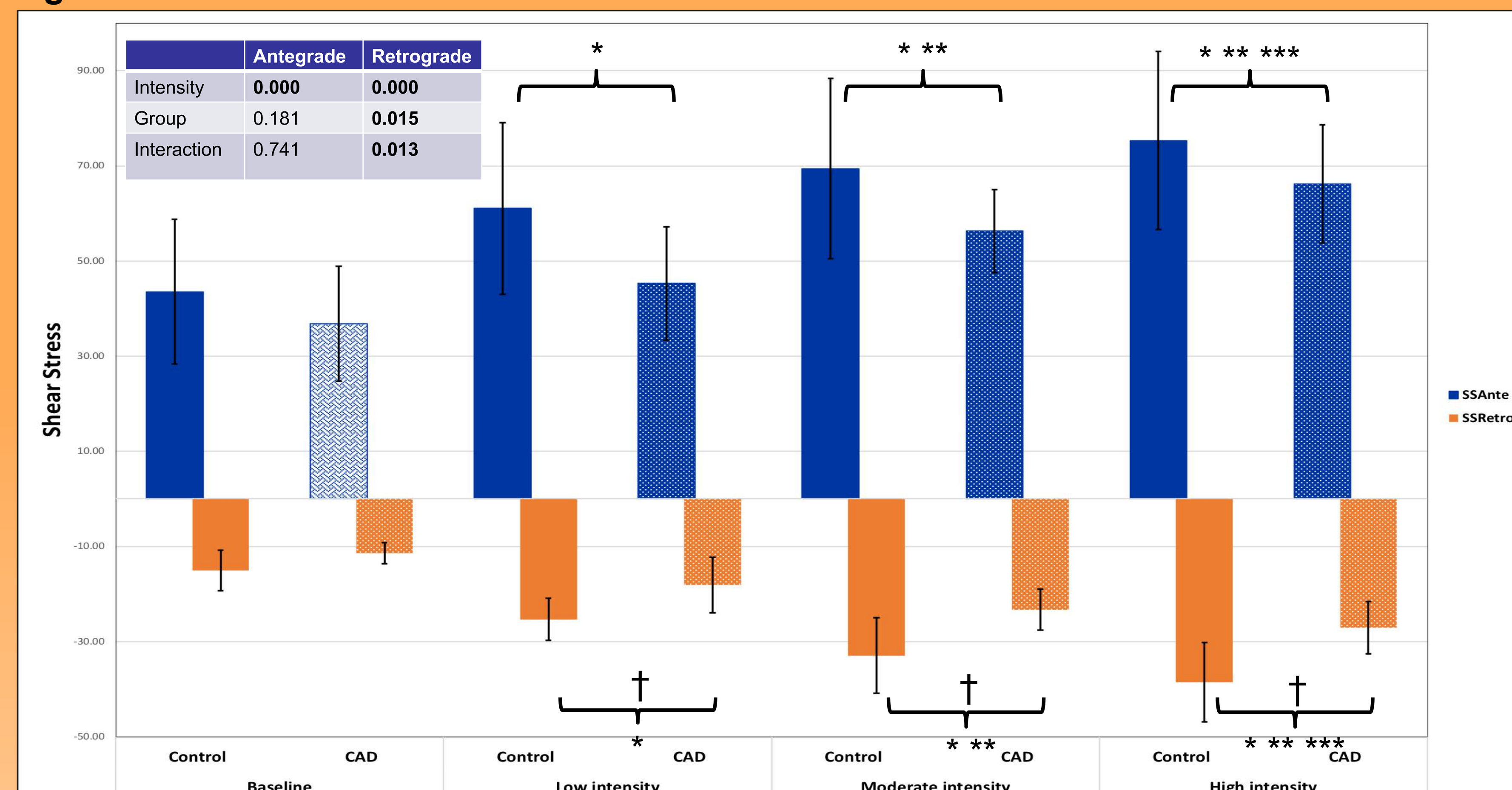
RESULTS

Table 2. Exercise Characteristics

	Control				CAD				2-way ANOVA, P values		
	BL Mean (SD)	LI Mean (SD)	MI Mean (SD)	HI Mean (SD)	BL Mean (SD)	LI Mean (SD)	MI Mean (SD)	HI Mean (SD)	Exercise Intensity	Group	Interaction
PO (W)		73.00 (31.26)	108.33 (34.45)	144.17 (39.04)		37.14* (17.29)	65.00* (23.09)	90.71* (25.73)	**0.000**	**0.017**	**0.014**
%PO		46.04 (12.89)	70.12 (10.93)	94.19 (11.49)		35.22 (8.99)	63.50 (8.82)	90.05 (7.64)	**0.000**	0.191	0.648
VO_2 (ml/kg/min)	3.03 (1.06)	15.82 (6.20)	22.48 (7.44)	27.33 (7.52)	3.64 (0.71)	9.64* (2.14)	13.41* (3.38)	17.13* (4.36)	**0.000**	**0.020**	**0.004**
$\%VO_2$	10.74 (3.10)	54.57 (11.72)	78.23 (12.43)	95.87 (8.28)	19.69* (5.62)	52.02 (15.94)	71.66 (20.30)	90.05 (17.70)	**0.000**	0.824	**0.045**
HR (bpm)	67.00 (14.17)	97.00 (15.70)	115.67 (14.65)	146.00 (17.93)	66.57 (10.15)	101.86 (33.52)	120.57 (32.16)	137.43 (30.19)	**0.000**	0.987	0.530
%HR	41.00 (8.34)	59.36 (8.86)	70.72 (6.85)	89.33 (9.29)	40.84 (5.91)	62.63 (21.05)	74.12 (19.99)	84.49 (18.69)	**0.000**	0.952	0.553
La (mmol/L)	1.20 (0.22)	1.67 (0.30)	2.53 (0.53)	4.63 (0.63)	1.31 (0.51)	1.76 (0.34)	2.99 (0.50)	4.59 (0.96)	**0.000**	0.444	0.950
RPE	6 (0)	9 (1)	12 (2)	15 (2)	6 (0)	9 (2)	12 (3)	14 (2)	**0.000**	0.674	0.562
Diameter (mm)	3.77 (0.82)	3.88 (0.96)	3.70 (0.83)	3.66 (0.81)	4.27 (0.74)	4.38 (0.72)	4.43 (0.59)	4.52 (1.21)	0.906	0.163	0.342

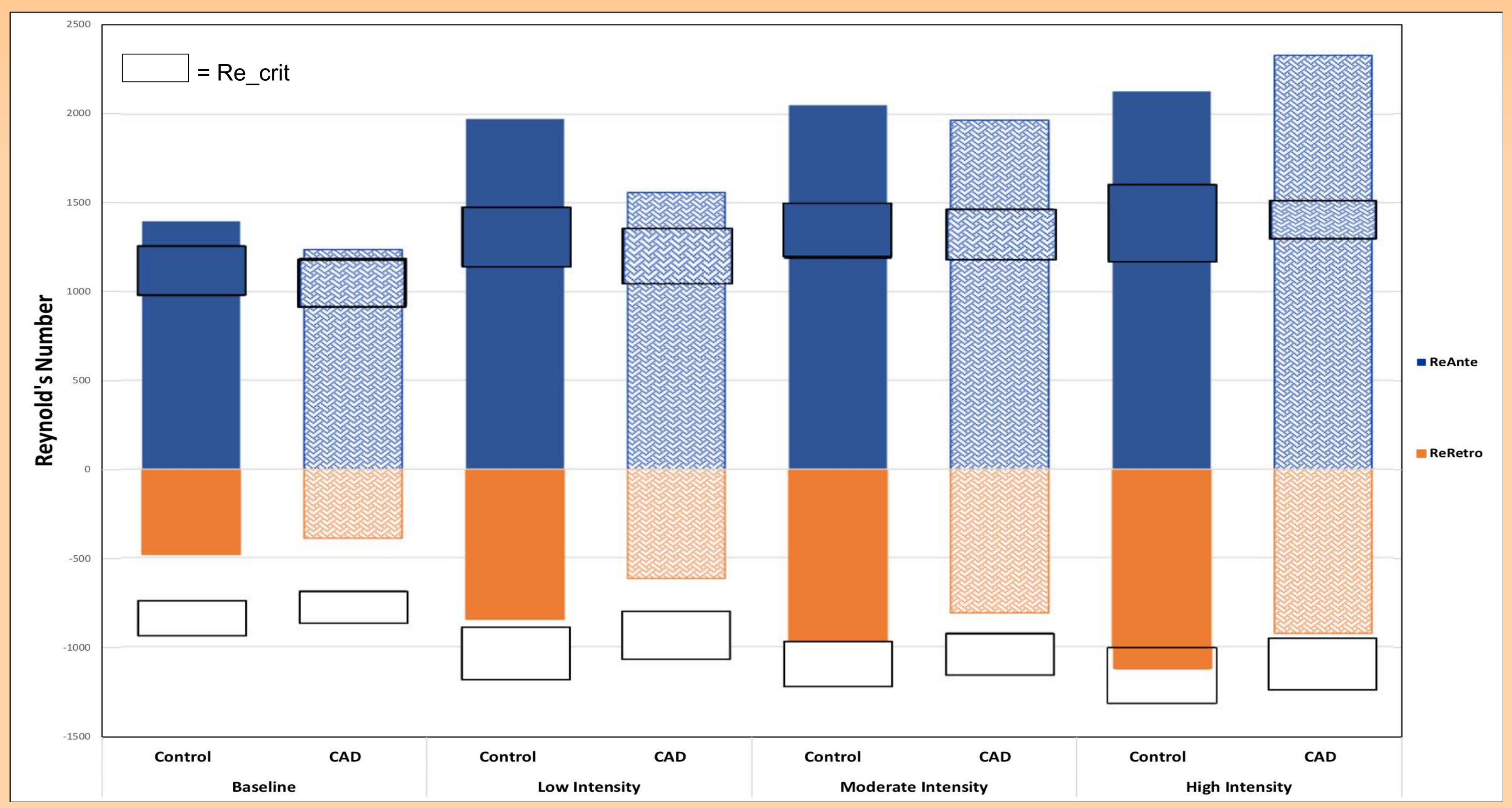
*statistically significant compared to control <0.05. PO: power output; %PO: PO percentage of max; VO_2%: VO_2 percentage of max; %HR: HR percentage of max

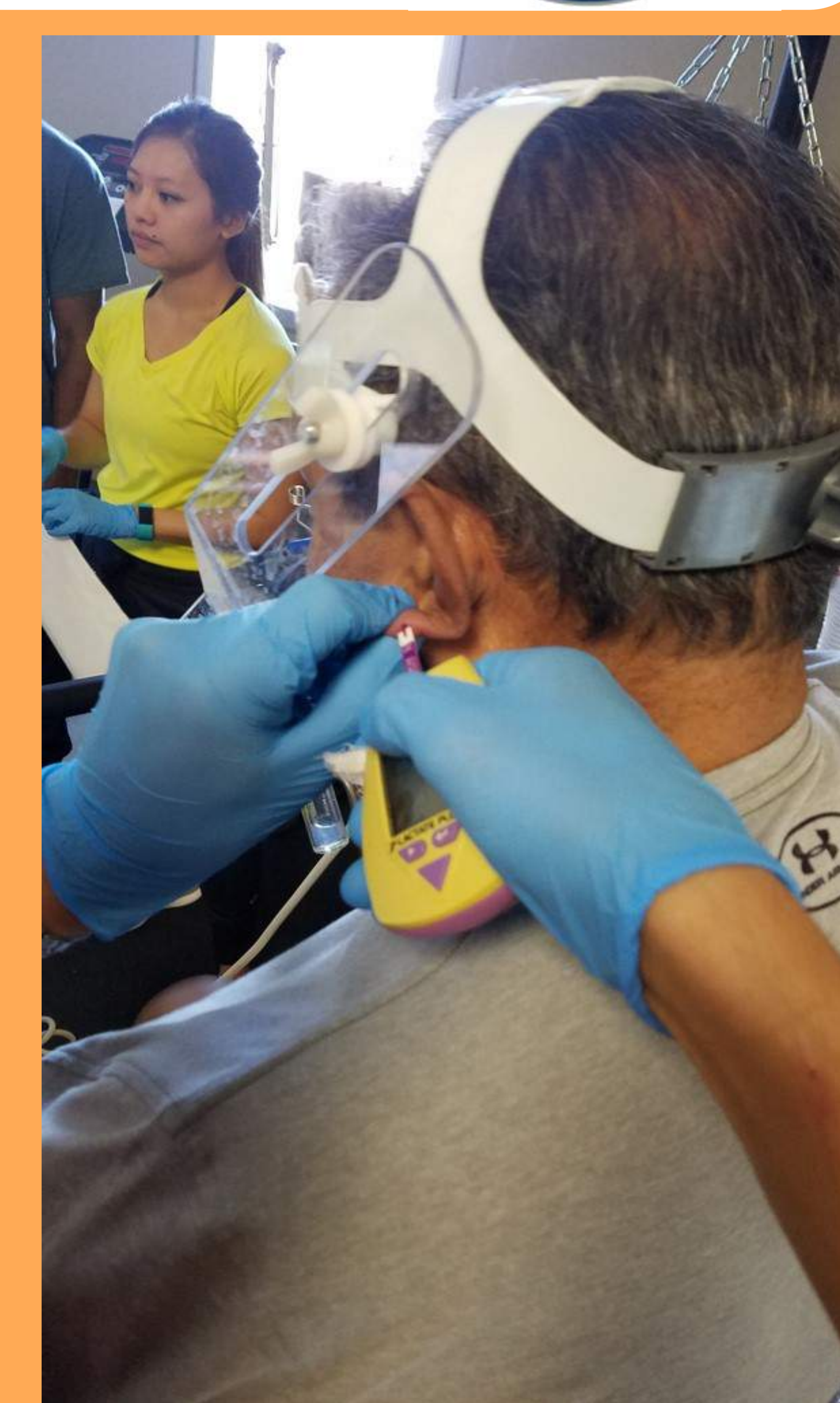
Figure 1. Shear Stress



* p<0.01 compared to BL; ** p<0.01 compared to LI; *** p<0.01 compared to MI; † p<0.03 between CAD and Control groups

Figure 2. Reynold's Number and Peak critical Reynold's Number





CONCLUSION

- Three major findings were identified in this study:
  1. BFP of patients with CAD are intensity dependent, bidirectional, and mainly turbulent
  2. BFP of patients with CAD are similar to active, healthy, aged-matched controls
  3. Blood flow velocity and ESS in the retrograde direction was significantly higher in the healthy, active controls compared to patients with CAD
- Regular exercise may improve retrograde ESS and may suggest a healthy endothelium.

REFERENCES

1. American Heart Association. Coronary artery disease-coronary heart disease. American Heart Association Website. http://www.heart.org/HEARTORG/Conditions/More/MyHeartandStrokenews/Coronary-Artery-Disease---Coronary-Heart-Disease_UCM_436416_Article.jsp#.W0LMv5Kn_MU. Published 2018. Accessed July 8,2018.
2. Young JL, Libby P. Atherosclerosis. In: Lilly LS, ed. *Pathophysiology of Heart Disease: A Collaborative Project of Medical Students and Faculty.* 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2015:118-140.
3. Kenney LW, Wilmore JH, Costill DL. Cardiovascular Disease and Physical Activity. In: Tocco AN, Maurer K, Walsh K, eds. *Physiology of Sport and Exercise.* 6th ed. Champaign, IL: Human Kinetics; 2015:529-548.
4. Mora S, Cook N, Buring JE, et al. Physical activity and reduced risk of cardiovascular events: Potential mediating mechanisms. *Circulation.*2007;116(19):2110-2118.
5. Coovert D, Evans LD, Jarrett S, et al. Blood flow patterns during incremental and steady-state aerobic exercise. *The J Sports Med Phys Fitness. 2018;58(10):1537-43*
6. Green DJ. Exercise training as vascular medicine: direct impacts on the vasculature in humans. *Exerc Sport Sci Rev.*2009;37(4):196-202.
7. Morales-Acuna F, Ratcliffe B, Harrison C, et al. Comparison between cuff-based and radial tonometry exercise-induced central blood pressure. *Eur J Appl Physiol.* 2019;119(4):901-911.

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