Athero-preventive hemodynamic changes of the abdominal aorta after mild leg stretch & bend exercise assessed with 3D cine phase contrast MRI

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BACKGROUND
Majorities of physiological evidences indicate that the locally decreased wall shear stress (WSS) alter arterial endothelial phenotype to atherogenic state (1). Likewise, the increase of Oscillatory Shear Index (OSI) produces an expression of pro-atherogenic genes (2). Recently, moderate exercise has been postulated to prevent advancement of arteriosclerosis by an increase of WSS and decrease of OSI. Both WSS and OSI can be calculated by measuring blood flow velocity changes at each coordinates. Previous investigators reported human in-vivo WSS measurement was feasible using 2D cine PC technique and 0.5T open MR scanner with a custom-built MR-compatible ergometer (3, 4). We herein present our simple method allowing more detailed 4D depictions of WSS mapping under easier way of exercise loading.

PURPOSE
The aim of this study was 1) to test whether hemodynamic assessment of the abdominal aorta is feasible with 3D cine PC during rest and exercise using simple way of exercise loading with wide bore clinical 3.0T MR scanner and 2) to test if the stress-MR can detect the change of WSS and OSI under progressive lower limb exercise modes.

METHODS
Five normal male volunteers were enrolled. They were examined on a wide bore 3.0T MR scanner. In a prone position, axial 3D cine PC of the infrarenal abdominal aorta was performed using following parameters; TR(ms)/TE(ms)/FA(degree)/ of 4/2/10, 12 slices, 12 phases/cardiac cycle. The data were acquired during three progressive modes of exercise, i.e. rest, mild (125% of resting heart rate) and maximum (150% of resting heart rate). On the prone position, volunteers were requested to continue "leg bend and stretch exercise" with a load of 7.2 – 12.8kg weight. Once their heart rates reached the designated level, the 3D cine PC commenced data acquisitions, and while imaging, the volunteers were requested to keep their legs in a position of 45 degrees bent with the weights loaded upon them. Acquired data were post processed with offline flow analysis software. Mean WSSs in each cardiac cycle were calculated and the average value (Ave WSS), the maximum value (Max WSS), the minimum value (Min WSS) and OSIs were calculated and depicted in color coded 3D models for each cases.

RESULTS
3D cine PC data were successfully acquired in all individuals. In each case, WSSs and OSI were post processed with use of flow analysis software (Table 1) (Fig 1). Mean WSS of five volunteers became higher as exercise level progressed from rest to maximum level. Whereas, OSI became small as exercise mode progressed. To assess the individual data, there was a uniform trend that the WSS increased to the progress of exercise mode; however, in two fifths of the cases, the values of WSS reached almost plateau at the mild exercise mode (Graph 1). As regards OSI, the values uniformly decreased at mild exercise mode; however, it increased when they reached the maximum exercise mode (Graph 2).

DISCUSSION
We observed hemodynamic changes during progressive exercise levels with latest wide bore clinical 3.0T MR scanner, which allowed us to acquire a set of full spatial and temporal data in a short period of time during lower leg exercise. We confirmed the increase of WSS and decrease of OSI during exercise, which was in agreement with previous literature; however, in some cases, the WSS reached plateau after mild exercise level, and the OSI increased when it reached the maximum exercise level. These data suggested that the optimal exercise level for anti-atherogenesis is the "mild exercise mode" with heart rate around 125%.
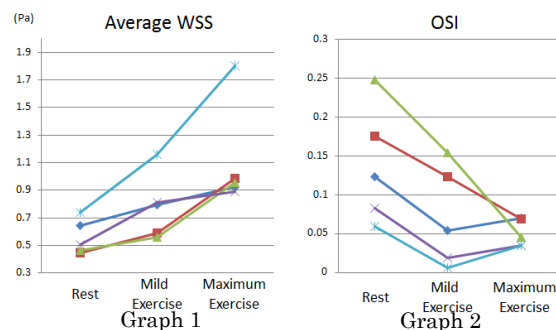
CONCLUSION
We could assess WSS and OSI during rests and exercise with rapid 3D cine PC. Mild exercise will contribute to an adequate WSS of the aortic wall, which will potentially be important in maintaining vascular integrities.

REFERENCES
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	Rest	Mild Exercise	Maximum Exercise
Flow volume (mm3/sec)	19155	30542	49070
Ave WSS (Pa)	0.56	0.78	1.11
Min WSS (Pa)	0.18	0.26	0.40
Max WSS (Pa)	1.70	2.16	2.65
OSI	0.138	0.071	0.051

Table 1

Graph 1

Graph 2

Figure 1