Combined aerobic and resistance training and vascular function：effect of aerobic exercise before and after resistance training

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Article introduction

Title：*Combined aerobic and resistance training and vascular function: effect of aerobic exercise before and after resistance training*

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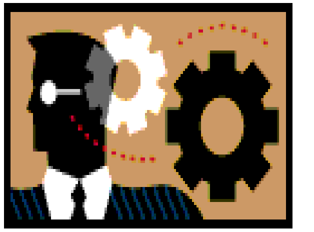
Motivation



Does aerobic exercise before RT positively not affect vascular function

! ?

What is Shear stress ？

What is Endothelial cell？

What is NO （nitric oxide） ？

Aerobic exercise was performed after RT in almost all previous studies

Aerobic exercise before RT as previously examined could improve vascular function is *unknown*

How aerobic exercise & RT effect on cardiovascular respectively ？

How about combined ？

short - term
aerobic training

short - term
resistance training

improve

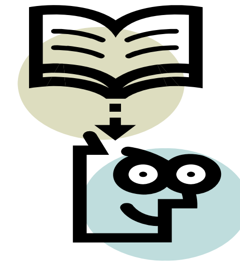
endothelium-dependent nitric oxide (NO)-mediated vascular function in both conduit and resistance vessels

AE bf / aft RT？

Q：

Might these effects positively influence when the AE takes place before RT？！

Methods



Subjects

- 33 healthy nonsmoking males and females (11 male, 22 female; age 18.6±0.1 yr)

- Some subjects who had an exercise habit in the past were included, most of the subjects had not exercised for more than 1 yr and had not engaged in RT.

- Health examination ： anamnesis, blood pressure, dipstick test, electrocardiogram, and chest X-ray. Blood examination was not performed. → No abnormal findings

Subjects were randomly assigned 3 groups ：

AE before RT (BRT, *n*＝11, *4 male & 7 female)*

AE after *RT* (ART, *n*＝11, *4 male* & 7 female)

remain sedentary (SED, *n*＝11, *3 male & 8 female)*

Table 1. *Physical characteristics of subjects*

Variables	SED	BRT	ART
Male/female	3/8	4/7	4/7
Age, yr	18.8±0.2	18.5±0.2	18.5±0.2
Height, cm	159.1±2.4	162.1±2.5	162.4±2.8
Body mass, kg			
Before training	58.4±2.2	58.4±3.2	59.2±2.7
After training	59.0±2.0	59.3±3.3	60.1±2.4
After detraining	58.8±2.0	59.3±3.1	60.5±2.4
Body mass index, kg/m^2			
Before training	23.1±0.9	22.1±0.7	22.8±1.3
After training	22.8±0.8	22.2±0.7	22.9±1.2
After detraining	22.8±0.8	22.4±0.6	23.1±1.1
Body fat, %			
Before training	23.1±2.3	20.0±2.2	21.3±2.1
After training	22.7±2.1	17.1±1.8*†	18.6±1.8*
After detraining	23.0±2.2	20.7±2.2	22.1±2.0
Heart rate, beats/min	68.7±2.2	66.3±3.2	66.5±3.3
Systolic pressure, mmHg	113.9±3.1	113.6±3.4	113.5±4.3
Diastolic pressure, mmHg	63.3±2.1	62.5±2.2	64.5±1.9

Values are means ± SE in groups that ran before resistance training (BRT; n = 11), after resistance training (ART; n = 11), or remained sedentary (SED; n = 11). *P < 0.05 vs. before training. †P < 0.05 vs. SED group.

Table.1 from ＜Combined aerobic and resistance training and vascular function: effect of aerobic exercise before and after resistance training ＞ *J Appl Physiol* 103: 1656, 2007.

Study Design

- Combination of treadmill running and RT performed and proceeded twice weekly between 2:00 and 6:00 PM.

- SED group were instructed not to alter their normal activity levels throughout the study period.

Aerobic Training

- Running ： set at 60% of the target heart rate using a heart rate monitor

- The Carbonen method （also called Karvonen method）：

  target HR＝[maximal HR (220－age) －resting RT] × 0.6 (exercise intensity 60%) ＋ resting HR

- BRT group run before RT for 20 min

- ART group run after RT for 20 min

Resistance Training

- 2 times/ week for 8 wks
- Training program：chest press, arm curl, seated row, shoulder press, leg curl, leg press, and abdominal bent (sit up)
- Training load：80% of 1RM；5sets；8 –10 repetitions / set
- Rest period：2min / set to set
- 1RM need to be measured again after 4 wks from the start of training, and the load are adjusted based on a new 1RM

Measurements

＊ brachial-ankle pulse wave velocity （baPWV）

＊ brachial artery flow-mediated dilation （FMD）、normalized FMD

＊ brachial blood pressure and heart rate

＊ brachial artery hemodynamics

（brachial artery's diameter、mean blood velocity、BF、hyperemic BV、hyperemic BF；VC；VR）

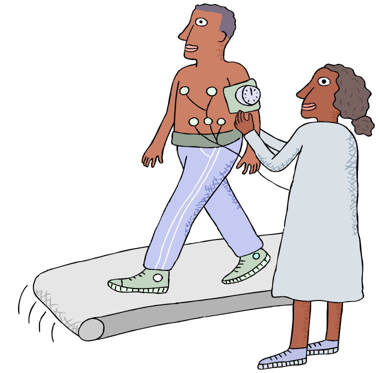
↓

before training （baseline）

after training（8wks, completion of training）

after detraining（4wks, completion of detraining）

Results



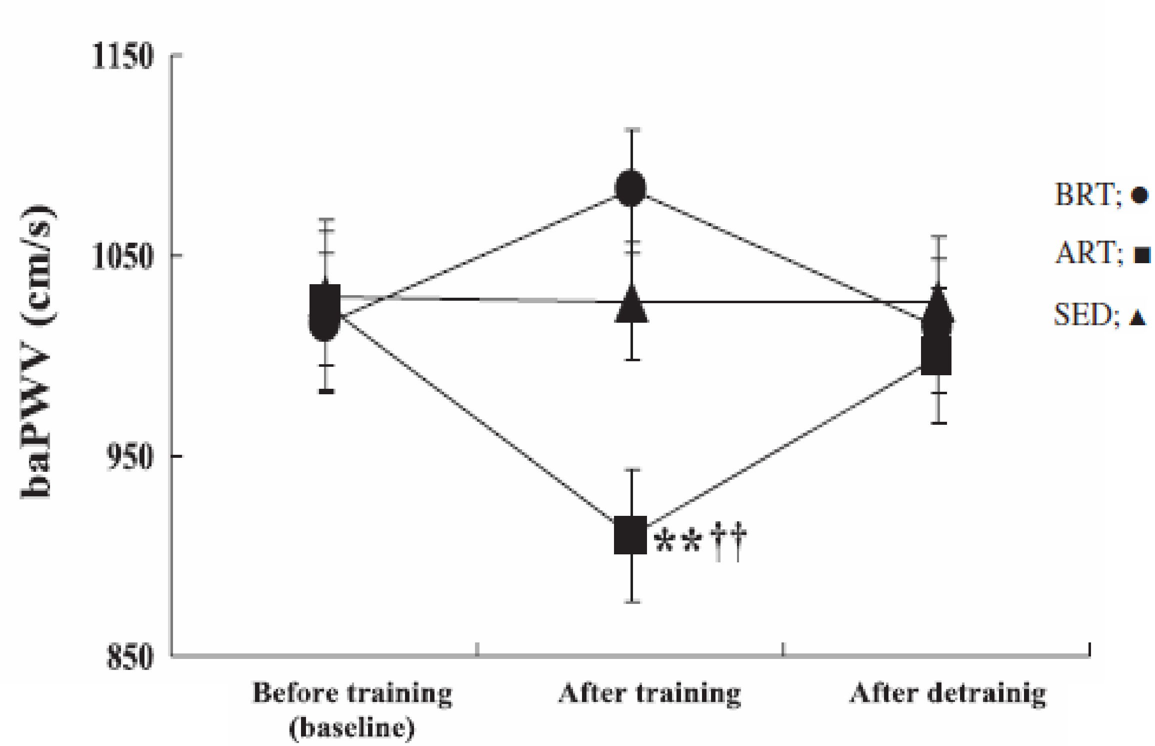
- Changes in 1RM
- Changes in baPWV
- Changes in brachial artery FMD and normalized FMD
- Changes in brachial blood pressure and heart rate
- Changes in brachial artery hemodynamics

Changes in 1RM

BRT	**Shoulder press 13%**	**Seated row 15%**	**Arm curl 33%**	**Leg press 16%**	**Leg curl 16%**	**Chest Press 18%**
ART	**Shoulder press 17%**	**Seated row 16%**	**Arm curl 52%**	**Leg press 39%**	**Leg curl 29%**	**Chest press 20%**

No significant differences in the chest press

Changes in baPWV



∗ baPWV may provide information qualitatively similar to that derived from central arterial stiffness

Fig . from ＜Combined aerobic and resistance training and vascular function: effect of aerobic exercise before and after resistance training ＞ *J Appl Physiol* 103: 1657, 2007.

Changes in brachial artery FMD and normalized FMD

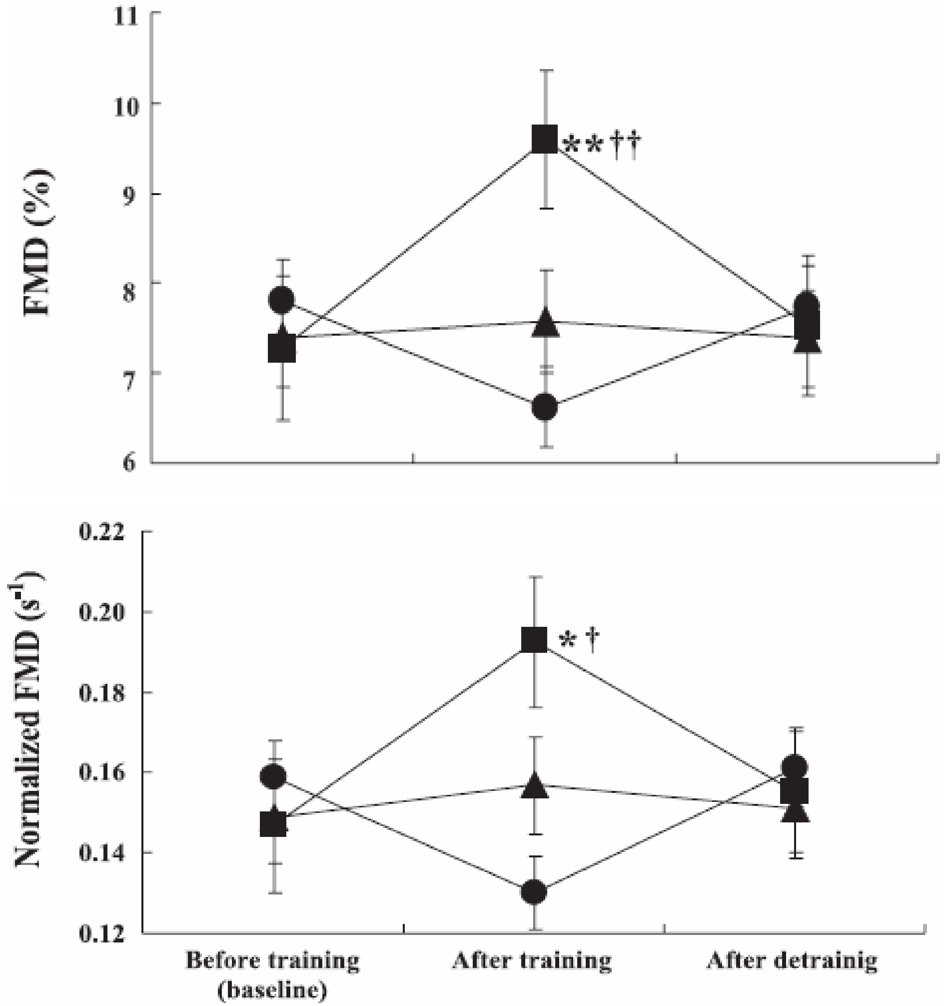


Fig . from ＜Combined aerobic and resistance training and vascular function: effect of aerobic exercise before and after resistance training ＞ *J Appl Physiol* 103: 1657, 2007.

Changes in brachial blood pressure and heart rate

Variables	Before Training (Baseline)	After Training	After Detraining
Systolic pressure, mmHg			
SED	113.9±3.1	112.5±2.1	112.4±2.6
BRT	113.6±3.4	111.2±3.0	108.9±3.5
ART	113.5±4.3	110.1±3.7	110.7±3.7
Diastolic pressure, mmHg			
SED	63.3±2.1	61.5±1.4	63.1±1.7
BRT	62.5±2.2	60.5±2.0	59.8±2.1
ART	64.5±1.9	59.3±2.5	60.3±2.9
Mean pressure, mmHg			
SED	83.0±2.3	78.5±0.8	80.9±2.0
BRT	82.7±2.9	79.1±2.7	80.8±2.9
ART	83.2±2.8	78.6±2.9	81.0±2.5
Pulse pressure, mmHg			
SED	50.6±2.7	51.0±1.3	49.3±1.9
BRT	51.2±1.9	50.6±1.6	49.1±2.2
ART	48.9±3.0	50.8±2.0	50.5±2.3
Heart rate, beats/min			
SED	68.7±2.1	68.6±2.7	68.3±2.3
BRT	66.3±2.2	63.8±3.9	64.8±3.6
ART	66.5±1.9	65.4±1.9	66.5±2.4

Values are means ± SE.

Table from ＜Combined aerobic and resistance training and vascular function: effect of aerobic exercise before and after resistance training＞ *J Appl Physiol* 103: 1658, 2007.

Changes in brachial artery hemodynamics

Variables	Before Training (Baseline)	After Training	After Detraining
Brachial artery diameter, mm			
SED	3.9±0.2	4.0±0.2	3.9±0.2
BRT	4.0±0.3	4.3±0.3[ad]	4.0±0.3
ART	4.0±0.3	4.3±0.3[ad]	4.0±0.3
Brachial artery mean blood velocity, cm/s			
SED	4.21±0.17	4.11±0.22	4.14±0.20
BRT	4.21±0.15	4.63±0.16[cf]	4.15±0.11
ART	4.28±0.13	4.70±0.15[cf]	4.18±0.12
Brachial artery hyperemic blood velocity, cm/s			
SED	21.07±0.25	20.57±0.31	20.68±0.28
BRT	21.05±0.22	23.16±0.24[cf]	20.76±0.16
ART	21.38±0.19	23.44±0.26[cf]	20.90±0.18
Brachial artery blood flow, ml/min			
SED	30.8±3.0	30.4±3.6	30.3±3.3
BRT	31.7±5.8	39.9±6.2[be]	31.8±5.7
ART	32.5±4.6	40.7±5.9[be]	31.8±4.3
Brachial artery hyperemic blood flow, ml/min			
SED	177.8±5.4	176.2±6.7	174.7±6.0
BRT	183.9±9.6	226.7±10.5[be]	184.3±9.3
ART	187.2±7.8	243.3±10.2[be]	183.7±7.1
Vascular conductance, $ml \cdot min^{-1} \cdot mmHg^{-1}$			
SED	0.37±0.04	0.39±0.05	0.38±0.04
BRT	0.38±0.06	0.51±0.07[cf]	0.40±0.06
ART	0.40±0.07	0.52±0.07[cf]	0.39±0.05
Vascular resistance, $mmHg \cdot ml^{-1} \cdot min$			
SED	2.71±0.30	2.66±0.32	2.69±0.30
BRT	2.66±0.44	2.01±0.28[cf]	2.59±0.42
ART	2.60±0.48	1.96±0.33[cf]	2.58±0.35

Values are means ± SE. [a]$P < 0.05$; [b]$P < 0.01$; [c]$P < 0.001$ vs. baseline. [d]$P < 0.05$; [e]$P < 0.01$; [f]$P < 0.001$ vs. SED group.

Table from ＜Combined aerobic and resistance training and vascular function: effect of aerobic exercise before and after resistance training＞ *J Appl Physiol* 103: 1657, 2007.

Discussion

RT & AE & Vascular function

Previous studies：

- That simultaneous endurance and resistance training may negate potentially negative effects of arterial stiffening. —Cook et al.（2006）
- Aerobic exercise after RT might prevent the stiffening of carotid arteries associated with RT in healthy young men. —Kawano et al.（2006）

arterial stiffness

BRT no changed ！

ART reduced ！

FMD

ART increased ！

* Aerobic exercise before RT does not favorably affect vascular function and do not support the notion that aerobic exercise always exerts a beneficial effect on vascular function
* That 8 wks of aerobic exercise training performed <u>after</u> RT resulted in reduced arterial stiffness in healthy young adults

Consistent with the study !

aerobic exercise combined with RT improves endothelial NO function —Green et al. （2004）

FMD：
ability of a conduit artery ⇧
internal diameter ⇧
BF and shear stress ⇩

?

BRT's FMD
no change

ART 's FMD
increased

BRT does not promote arterial flexibility

but

BRT seems to improve vascular function

That significant changes in FMD and PWV in the ART group might be explained by greater cardiovascular benefits

Controversial point

- RT does not confer unfavorable effects on vascular function！ —Rakobowchuk. et al（2005）
- RT does it！ —Bertovic. et al （1999）, Cortez-Cooper et al.（2005）, DeVan et al.（2005）, Ebenbichler et al.（2001）, Miyachi et al.（2004）, Okamoto et al.（2006）.
- Further investigations must assess the beneficial effects of resistance training on vascular function

Brachial artery diameter

The expansion of the femoral arterial lumen diameter in previously sedentary middle-aged and elderly men after 3 mo of aerobic exercise intervention
— Dinenno et al. （2001）

It reported that RT enlarges brachial and femoral artery diameter
— Miyachi et al. （2005）, Rakobowchuk. et al（2005）

ART

Both aerobic exercise and RT increase brachial or femoral arterial diameter, enlargement at the level of the major conduit arteries

BRT
?

Arterial expansion seems to relate to structural remodeling or reduced vascular smooth muscular tone
and helps to decrease peripheral arterial stiffness

HR & blood pressure

HR & BP are remained unchanged among the 3 groups

The effects of sympathetic nervous tone after resistance training cannot be excluded. — Maiorana et al. （2000）

- Aerobic exercise suppresses increases in blood pressure

—Martin et al. （1990）， Paffenbarger （1993）

- Aerobic exercise before RT might suppress a subsequent increase in blood pressure induced by RT

- The favorable effects of aerobic exercise are negated by subsequent RT

The alterations in vascular function in the ART group primarily resulted from changes in arterial distension

Brachial artery hemodynamics

Previous studies ：

- Calf VR is reduced after aerobic exercise.

  —Halliwill et al. （1996）

- Short term RT increases femoral BF and VC in healthy middle aged and older adults. —Anton et al.（2006）

- RT affects basal limb perfusion through a mechanism underlying its effects on glucose uptake. —Anton et al.（2006）

In this study：

- The brachial MBV, hyperemic BV, BF, hyperemic BF, VC, and VR in the BRT and ART groups significantly changed from baseline.

- Aerobic exercise before RT does not seem to improve vascular function

Result：

- The hemodynamic improvement induced by aerobic and resistance training is important.

- The physiological mechanisms underlying the changed hemodynamics in RT remain obscure.

1 RM

Previous studies :

- The growth hormone (GH) response to resistance exercise is attenuated by prior endurance exercise.

  —Goto et al. （2005）

- The strength gains were consistently smaller in a group that performed combined training compared with a group that had performed only high intensity RT.

  —Kawano et al. （2006）

Combined training may favorably affect vascular function but suppress increases in muscular strength

Conclusion

- Aerobic exercise after, but not before RT improves vascular function.

- Speculating that habitual RT promotes an increase in blood flow through an impact on skeletal muscle mass, it does not improve vascular function.

Further study

- To determine the effects of resistance exercise on arterial hemodynamics and vascular function.
- To measure aerobic fitness.
- To measure GH reponse.

Functions of GH

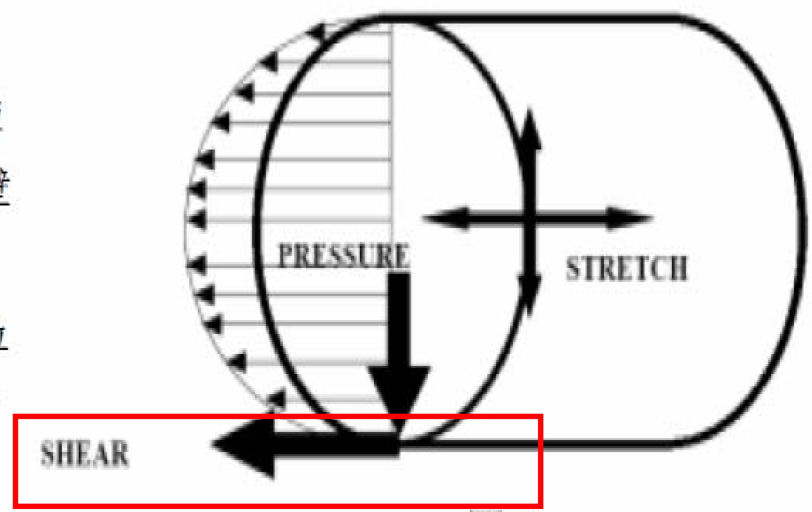
- Increases muscle mass through the sarcomere hyperplasia

- Reduces liver uptake of glucose

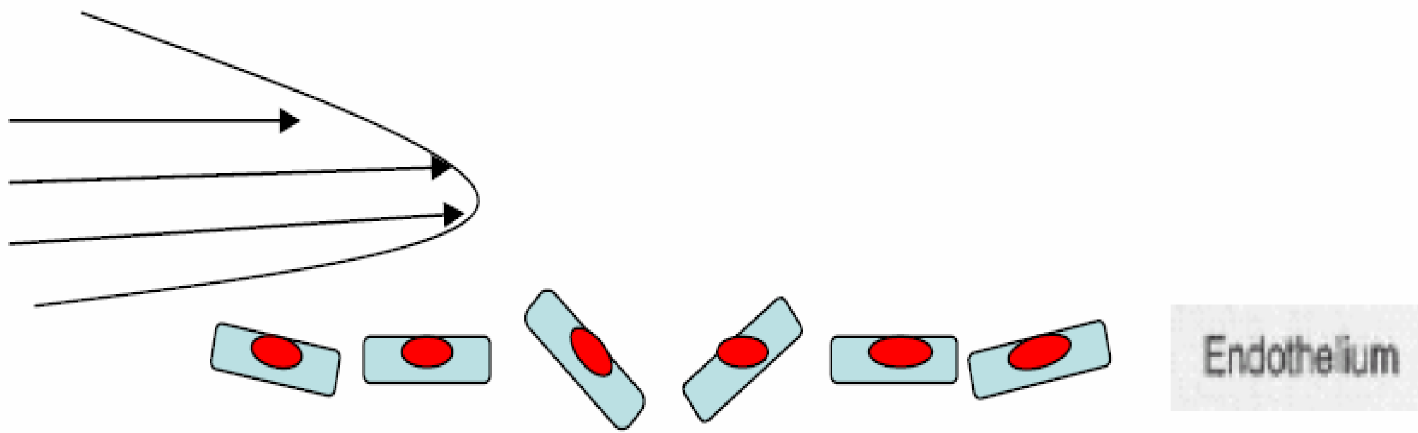
- 和血液相關之力

血液在血管流動中主要會對血管造成三個力：一是垂直管壁的壓力 pressure；另一種是平行管壁的剪應力 shear stress；最後是管壁上細胞抵抗備撕裂的張力。(如右圖三)

須注意的是，由於血液中有血球等大顆粒固體物質，所以在真正血液流動時，血球本身也會受到剪應力的影響。



圖三

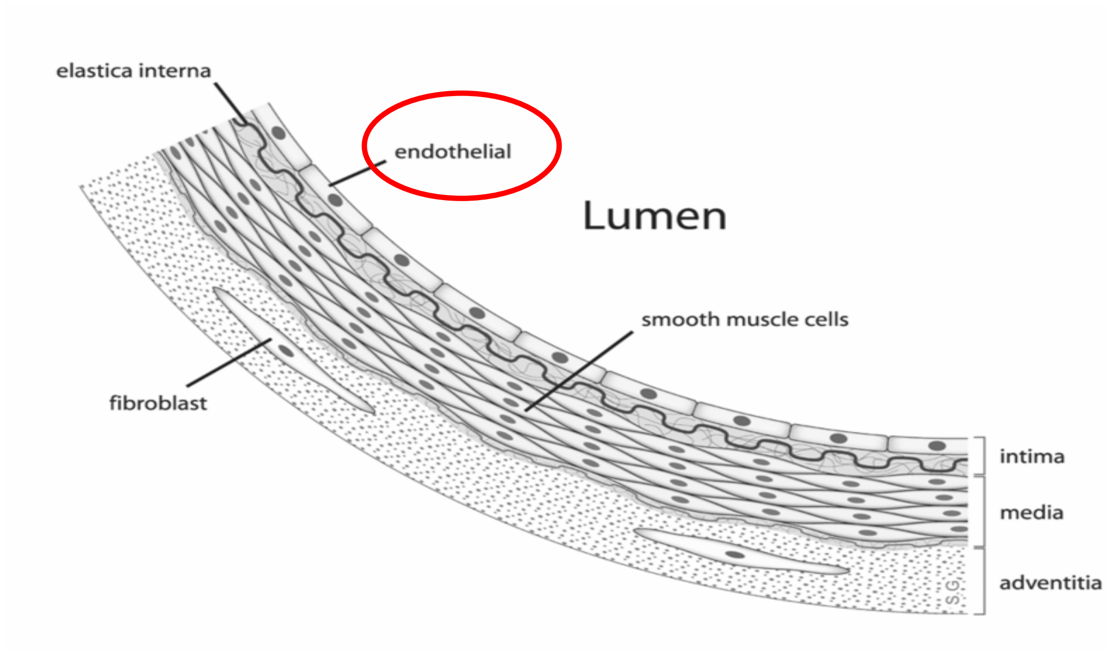


切應力太大，使得內皮細胞的剝離，造成血管受傷。

切應力的大小對血管是否會形成動脈硬化具有絕大的關係

摘錄自網路＜流體力學的基本原理＆血液基本特性＞

在人體的循環系統中，內皮細胞形成單一細胞厚度的血管內壁，提供血液與其他系統間極重要的生理介面，藉由內皮細胞分泌特殊細胞訊息分子，以調控血管的生理功能，並負責營養物質的穿透與傳輸，扮演著血液與血管間平衡循環的角色。



圖摘自＜內皮細胞＞ 維基百科

NO在血管內皮是使血管的平滑肌細胞放鬆而擴張血管，可以降低血壓。摘錄自＜1998年諾貝爾生理或醫學獎一氧化氮的重要發現與應用＞黃項立 美國哥倫比亞大學生物有機化學博士

正常人類內皮細胞可持續分泌一氧化氮以維持血管恆定舒張。它可降低切應力，減低血管阻力，改善局部血流。一旦內皮依賴型血管擴張受損，可見於傳統的心血管危險因子(甚至在無動脈硬化時業可見到)。摘錄自＜精氨酸－－一氧化氮路徑：從基礎到臨床應用＞林廷燦 屏東市國仁醫院 內科部

血管內皮細胞損傷及功能失常影響內皮細胞釋放血管活性物質，如內皮細胞放鬆因子(一氧化氮)為導致接續而來動脈硬化的發生。摘錄自＜動脈硬化疾病的發生與預防＞ 蘇大成 台大醫院內科部主治醫師

- Regular aerobic exercise helps to prevent and treat cardiovascular disease and reverse arterial stiffening
- Aerobic exercise for 30 min after RT prevents carotid artery stiffening
- Aerobic exercise intervention improves impaired endothelial function, and the induced increase in blood flow velocity elicits endothelial shear stress
- One bout of intense aerobic exercise has been shown to decrease arterial compliance acutely

- AE performed before RT might not favorably affect vascular function to the same degree as when the aerobic stimulus occurs after the blood pressure- elevating resistance exercise bout

- Blood pressure and arterial stiffness that has been increased by RT can be decreased by subsequent aerobic exercise

最大反覆（Repetition Maximum，RM）：某肌群在規定反覆次數下在疲勞發生前所能完成的最大負荷。

參考網站：

運動生理學網站 http://epsport.ccu.edu.tw

網路健身教練 http://www.training.idv.tw/nfi/