

Rowing as an aerobic and resistance exercise for elderly people

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Abstract Aerobic and resistance exercises are recommended for elderly people to help maintain their health. Rowing involves almost all of the muscles in the body and may have elements of both aerobic and resistance exercise. Rowing and indoor rowing exercise using ergometers have been widely used among elderly adults and young individuals worldwide. Because rowing is practiced on a seat, less impact is placed upon the knee joints, making it safe for elderly people. It has been reported that elderly male rowers have higher aerobic capacity, greater muscle mass in the thigh and trunk, and a lower risk of atherosclerosis than age-matched sedentary men. In the authors' recent study, untrained elderly men participated in a 6-month rowing exercise training using a rowing ergometer; and the results indicated that the training increased the participants' aerobic capacity and muscle size, decreased their visceral fat, and improved their atherogenic index. Rowing exercise training, which offers combined aerobic and resistance training, does not unfavorably affect arterial stiffness or compliance, although resistance training alone induces arterial stiffening. Rowing exercise has both aerobic and resistance exercise health benefits in elderly people.

Keywords : rowing, elderly, aerobic capacity, muscle mass, lifestyle-related diseases, vascular function

Introduction

Many people are currently involved in aerobic exercise training (AET) for cardiorespiratory fitness (CRF) and resistance exercise training (RET) for muscle mass and function; and efforts to promote more participation in all forms of physical activity are being developed and implemented. Rowing, one of the oldest organized sports, involves participants ranging from children to elderly adults and has been very popular in Europe and North America. Rowing exercise using an ergometer has been widely practiced at sports gyms worldwide. Rowing involves both the lower and upper body, that is, almost all of the muscles in the body, and consists of rhythmical muscle contractions including extension and flexion of the arms, trunk, and legs¹⁾. The injury rate of rowing exercise is lower than that of other exercises; and because rowing exercise is practiced on a seat, it places less impact on the knee joints. These factors make rowing exercise safe for elderly people.

In this review article, we will introduce the available data about the effects of rowing exercise on physical fitness, including aerobic capacity and muscle strength, as well as health promotion and/or prevention of lifestyle-related diseases in elderly people.

American College of Sports Medicine Position Stand on Rowing Exercise for Older Adults

The American College of Sports Medicine (ACSM) Position Stand entitled *The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory Fitness, and Flexibility in Healthy Adults*²⁾ recommended rowing and any other activities that use large muscle groups continuously, rhythmically, and aerobically, such as walking/hiking, running/jogging, cycling, cross-country skiing, aerobic dancing, rope skipping, stair climbing, swimming, skating, and various endurance activities.

In the revision of the ACSM Position Stand *Exercise and Physical Activity for Older Adults*³⁾, the benefits of exercise and physical activity on health and functional capacity were summarized for various aerobic and resistance exercises. The benefits of AET to previously sedentary individuals have been summarized as follows: (1) AET programs of sufficient intensity, frequency, and length can significantly increase CRF in terms of $\dot{V}O_{2\max}$ in healthy middle-aged and older adults; (2) 3 or more months of moderate-intensity AET elicits cardiovascular adaptations in healthy middle-aged and older adults, which are evident at rest and in response to acute dynamic exercise; (3) moderate-intensity AET has been shown to be effective in reducing total body fat in overweight middle-aged and older adults; and (4) AET can induce a variety of favorable metabolic adaptations, including enhanced glycemic

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control, augmented clearance of postprandial lipids, and preferential utilization of fat during submaximal exercise.

On the other hand, the Position Stand of the ACSM³⁾ indicated that after RET, older adults can also substantially increase their (1) strength, (2) muscular power, and (3) muscle quality, defined as muscular performance (strength or power) per unit muscle volume or mass.

Several evidence-based conclusions can be drawn regarding exercise and physical activity in the older adult population: (1) a combination of AET and RET activities seems to be more effective than either form of training alone in counteracting the detrimental effects of a sedentary lifestyle on the health and functioning of the cardiovascular system and skeletal muscles; and (2) ideally, exercise prescriptions for older adults should include both aerobic and muscle strengthening exercises.

Rowing Exercise and Aerobic Capacity

There is an age-associated decline in aerobic capacity in terms of $\dot{V}O_2\text{max}$, which is a function of maximal cardiac output and maximal arteriovenous oxygen difference⁴⁾. Maximal cardiac output is produced by the maximal heart rate (HRmax) and stroke volume attained during exercise at $\dot{V}O_2\text{max}$. The decline in HRmax is an inevitable age-related phenomenon. In humans, the decline of $\dot{V}O_2\text{max}$ generally begins between 25 and 30 years of age, and this decline is approximately 10% per decade in healthy sedentary people⁴⁾. $\dot{V}O_2\text{max}$ decreases with physical inactivity and increases in response to regularly performed vigorous exercise.

Rowers need a large body size and high aerobic capacity and muscle power¹⁾. The association between performance time to row 2000 m on a rowing ergometer and $\dot{V}O_2\text{max}$ (L/min) suggests that a high level of CRF has a role in the rowing performance of elderly and young competitive rowers (Fig. 1A)⁵⁾. Although elderly rowers have a lower $\dot{V}O_2\text{max}$ than young rowers, their $\dot{V}O_2\text{max}$ is larger than that of sedentary men matched for age and body size (3.0 vs. 2.2 L/min) and similar to that of young sedentary men (Fig. 1B)⁶⁾. Thus, it is possible that regular rowing continued in advancing age delays the age-related decline in aerobic fitness. HR is a simple but useful parameter in clinical and physiologic exercise testing. HRmax decreases progressively with advancing age and is lower in elderly rowers than in young rowing-trained and sedentary men⁵⁾.

To examine the effect of rowing exercise on aerobic capacity in elderly people, we conducted an intervention study of rowing exercise training using a rowing ergometer for elderly untrained men aged 65–79 years. They submitted to a rowing exercise program on a rowing ergometer (Concept2 ModelC, Concept2 Inc., Morrisville, VT, USA) 3 times a week for 24 weeks (6 months). A rowing exercise program was set up based on the ACSM guideline^{2,7)}. It consisted of a 5-min warm-up, 2 sets of 10-min

workouts, and a 5-min cool down on the rowing ergometer. The damper of the ergometer was set at the lowest intensity, and the workout intensity was determined by the exercise watts displayed on the monitor corresponding to 65–80% HRmax during the 2 sets of 10-min workouts. In this study, the $\dot{V}O_2\text{max}$ of all the subjects in training increased in response to 6 months of rowing training, and the mean change rate was 22% without weight loss (Fig. 2)^{8,9)}.

These findings from elderly rowers and the exercise intervention study suggest that rowing is a very effective exercise for increasing the aerobic capacity of elderly people.

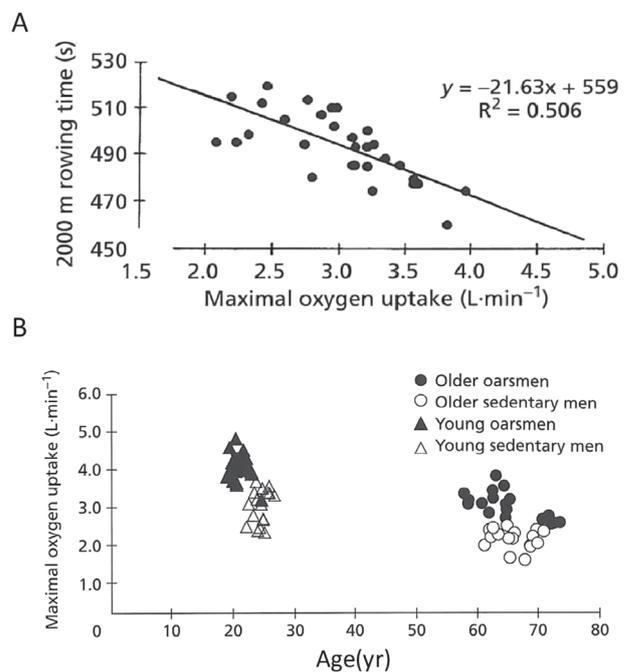


Fig. 1 A. Relationship between 2000-m rowing performance and maximal oxygen uptake ($\dot{V}O_2\text{max}$) in older men. B. Maximal oxygen uptake related to age. Cited from Yoshiga⁵⁾.

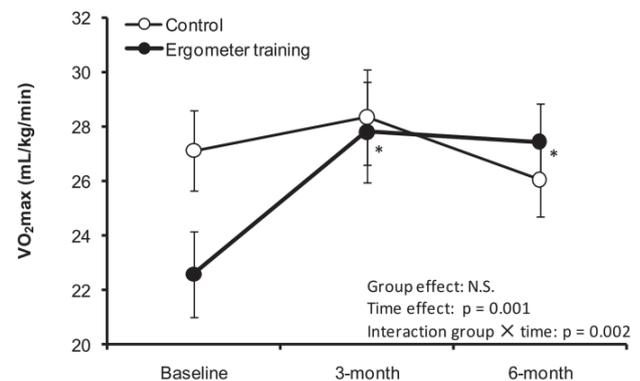


Fig. 2 Change in $\dot{V}O_2\text{max}$ throughout the 6-month rowing training for elderly people. Values are mean \pm SD, * $P < 0.05$ versus the baseline within the group. Data from Asaka and Higuchi (unpublished data).

Rowing Exercise and Skeletal Muscle

The loss of skeletal muscle mass and strength, called “sarcopenia,” is inevitable even in healthy elderly people. Total skeletal muscle mass gradually declines after 45 y of age¹⁰, and a loss of skeletal muscle strength has been observed in the knee extensor muscle, elbow flexors and extensors, and hand grip. Moreover, sarcopenia is observed as a site-specific loss of skeletal muscle¹⁰⁻¹³. The age-related reduction in skeletal muscle mass is greater in the lower body for both men and women than in the upper body¹⁰. It is also reported that muscle size decreases more in the trunk and thigh muscles than at other sites¹¹⁻¹³. Muscles of the trunk and lower body play an essential role in various movements, including walking, standing, raising the leg, and stabilizing the body¹⁴⁻¹⁷. The age-related decrease in muscle mass and strength is associated with the risk of falling, functional impairment, and physical disability in elderly people¹⁸⁻²⁰. Therefore, it is important to slow down the inevitable weakening of these muscles in order to ensure a higher quality of life (QOL) for elderly people.

RET can increase the skeletal muscle mass and function of even very old people²¹. Rowing exercise requires great muscular power, and rowing may have an aspect of resistance exercise. Several cross-sectional studies, using dual-energy X-ray absorptiometry and targeting elderly rowers, demonstrated that rowers have greater fat-free mass, leg, and trunk lean soft tissue mass than age-matched sedentary individuals²². These studies also included examination of leg extension muscle cross-sectional area by magnetic resonance imaging (Fig. 3A)²³. It also recently

demonstrated that elderly male rowers have greater leg and trunk muscle cross-sectional areas; in particular, the psoas major muscle was 64% larger in the rowers than in the age-matched untrained men (Fig. 3B)²⁴. Furthermore, elderly rowers had greater bilateral leg extension power and isometric trunk flexion force.

In the authors’ rowing exercise intervention study targeting elderly untrained men, trunk and thigh muscle sizes increased by 6% and 9%, respectively, after 6 months of rowing training, and there was a significant effect of rowing training on trunk muscle size after just 3 months (Fig. 4). Based on the data of age-related decrease in muscle size²⁵⁻²⁹, the muscle size of elderly men after the 6-month rowing training was likely to be similar to that of men who were more than 5–10 years younger. In addition, the percentage increase in thigh muscle size after 6 months of rowing training was similar or higher than that observed by alternative muscle-strengthening training for elderly people³⁰⁻³². Moreover, the 6-month rowing training increased the psoas major muscle by 25%; this muscle was most affected by the rowing exercise in the cross-sectional and exercise intervention studies. The psoas major muscle is likely to contract eccentrically during the finishing phase of the rowing motion. The size of the psoas major muscle significantly declines with aging³³ and has important implications for walking, stair climbing ability, and fall prevention in elderly people^{17,34,35}. Therefore, an increase in the psoas major size, that results from rowing exercise, may help elderly people maintain the ability to perform activities of daily life. On the other hand, isometric trunk flexion force and leg extension power did not improve with only the rowing exercise training; but the

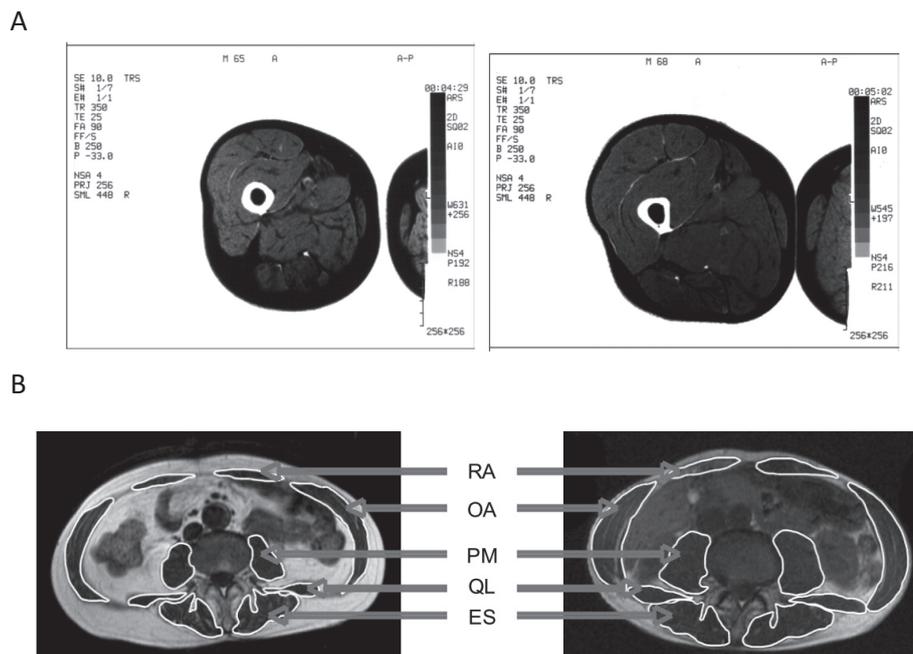


Fig. 3 Magnetic resonance images obtained at the mid-thigh (A) and trunk (B) of elderly sedentary men (left) and male rowers (right). RA, rectus abdominis; OA, oblique abdominal; PM, psoas major; ES, erector spinae; QL, quadratus lumborum. Cited from (A) Yoshiga et al.²³ and (B) Asaka et al.²⁴.

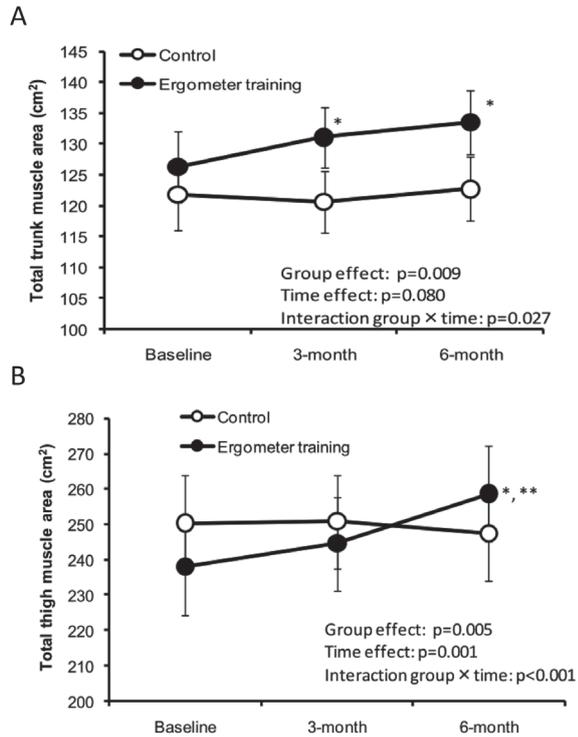


Fig. 4 Changes in trunk (A) and thigh (B) muscle size following the 6-month rowing training for elderly people. Values are means \pm SD, * $P < 0.05$ versus the baseline within the group. Data from Asaka and Higuchi (unpublished data).

change in the total trunk muscle size correlated with the change in isometric trunk flexion force. Further longitudinal rowing training may possibly improve the muscle function in elderly people. Moreover, many rowers generally experience lower back pain; but none of the subjects in this intervention study complained of lower back pain during the training period. Therefore, the findings suggest that rowing exercise for elderly people can be a safe resistance exercise to prevent sarcopenia and provide an alternative to muscle-strengthening training.

Rowing Exercise and Risk Factors of Lifestyle-Related Diseases

Body fat increases with age owing to reduced physical activity. In particular, increased visceral fat is associated with lifestyle-related diseases, such as type 2 diabetes and cardiovascular disease. It is well known that regular AET reduces the risk of these lifestyle-related diseases³⁶⁻³⁸. On the other hand, some studies have reported that RET also decreases the risk of lifestyle-related diseases³⁹⁻⁴². Because rowing exercise has elements of aerobic and resistance exercise, it may prevent and reduce the risks of lifestyle-related diseases.

Insulin resistance is an early and key defect of type 2 diabetes⁴³. Both aerobic capacity (CRF) and visceral fat accumulation are predictors of insulin resistance^{44,45}. Moreover, it was reported that men with high CRF levels

had less abdominal fat⁴⁶. However, although elderly rowers had high CRF levels, the cross-sectional area of visceral fat and insulin sensitivity, assessed by homeostasis model assessment as an index of insulin resistance, did not differ between the rowers and the controls. It has been suggested that visceral fat is a strong predictor of insulin resistance, even in the presence of high CRF. Needless to say, dietary habits considerably affect visceral fat accumulation, and alcohol intake contributes as well⁴⁷. A slight correlation was observed between alcohol intake and visceral fat area in elderly rowers. On the other hand, in the authors' study, visceral fat decreased in the elderly formerly-untrained men after undergoing 6 months of rowing training. In this intervention study, the maximal change value of the visceral fat area was -70 cm^2 , and the change rate of $\dot{V}O_2\text{max}$ was negatively correlated with that of the visceral fat area. However, there were 2 subjects in the training group whose visceral fat area increased at 6 months from the baseline. Although their dietary details were unknown in the study, some subjects felt increased appetite after rowing exercise, resulting in an increased dietary intake during the training period. Because rowing exercise is performed in a seated position, body weight is supported by the seat of the ergometer. This factor makes rowing a safe exercise whether or not there is an increase in the abdominal fat area and/or weight. Therefore, more consideration of dietary habits may be needed to reduce visceral fat. Moreover, insulin resistance in elderly untrained men improved after 3 months of rowing training; but this effect disappeared by 6 months.

Atherosclerosis is a cardiovascular disease that involves the buildup of fatty deposits called plaque in the arterial walls. Lipid profiles, such as concentrations of total cholesterol (Total-C), low-density lipoprotein cholesterol (LDL-C), high-density cholesterol (HDL-C), and triglycerides, are known to be risk factors for atherosclerosis. Yoshiga et al.⁶ and Sanada et al.²² reported that elderly rowers had higher HDL-C levels than age-matched sedentary men, whereas the indices of risk factors for atherosclerosis were lower than those in elderly and young sedentary men; although the indices were higher in elderly than in younger men (Fig. 5). Furthermore, after 6 months of rowing training in the elderly untrained men, we observed a 14% decrease in the atherogenic index calculated from the following formula: $(\text{Total-C}) - (\text{HDL-C}) / (\text{HDL-C})$. Therefore, rowing exercise using a rowing ergometer has positive effects on atherosclerosis prevention in elderly people.

Rowing Exercise and Vascular Function

Aerobic training induces favorable adaptations of vascular function, such as reduced arterial stiffness and increased arterial compliance⁴⁸. In contrast to AET, RET causes increased arterial stiffness and attenuates arterial

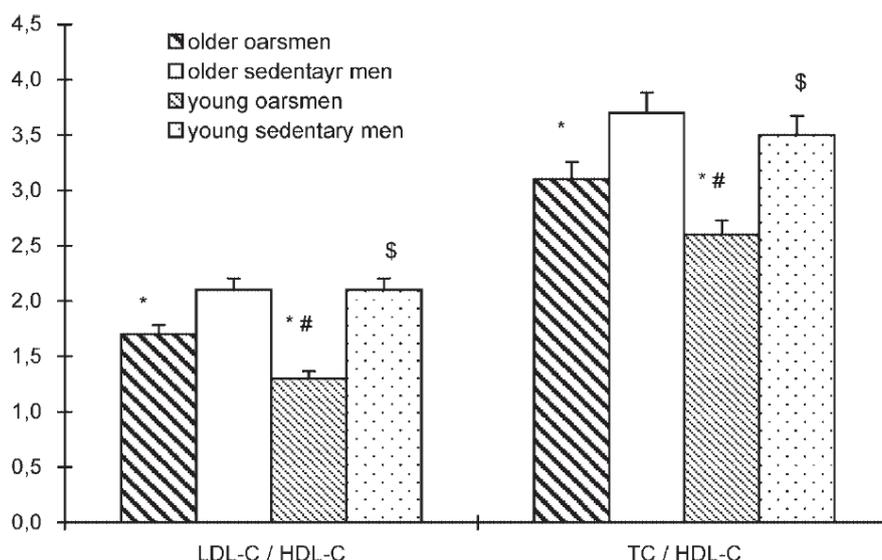


Fig. 5 Atherosclerosis indices (the ratio of low density lipoprotein, LDL-C, to high density lipoprotein-cholesterol, HDL-C, and that of total cholesterol, TC, to HDL-C). Values are means \pm SD, * $P < 0.05$ difference between oarsmen and sedentary men in the same age groups, # $P < 0.05$ difference between older oarsmen and young oarsmen, \$ $P < 0.05$ difference between older oarsmen and young sedentary men. Cited from Yoshiga et al.⁶⁾

compliance^{49,50}). We also reported that carotid arterial compliance and stiffness are not changed by combined AET and RET⁴⁹), suggesting that simultaneously performed AET prevents the central elastic artery stiffening caused by RET. Considering that rowers have greater aerobic capacity and muscular strength, we believe that there would be great interest in the effects of chronic rowing exercise on vascular functions, such as arterial compliance or stiffness. Rowing-trained men and women (37–71 years of age) have been reported to have greater central arterial compliance and less arterial stiffness (Fig. 6)⁵¹). Furthermore, Sanada et al.²²) reported that rowing-trained men demonstrated lower systemic arterial stiffening (pulse wave velocity) than the sedentary controls, independent of age (Fig. 7). On the other hand, neither Petersen et al.⁵²) nor the authors⁵³) observed such differences in vascular functions between rowers and sedentary controls, suggesting that the aerobic component of rowing exercise may negate arterial stiffening associated with the resistance exercise component. The discrepancy in the effects of habitual rowing exercise on arterial compliance and stiffness among these studies may be accounted for by differences in age, sex, or exercise component (status) and, in particular, the ratio of aerobic and resistance exercise volume or exercise intensity.

Some studies have tried to clarify the mechanism of vascular adaptation to habitual rowing exercise. Cook et al.⁵¹) showed that cardiovagal baroreflex sensitivity was greater in rowers than in the controls, similar to the higher arterial compliance in rowers. Other studies indicated that, compared with sedentary control men, rowing-trained men had normal levels of endothelium-dependent vasodilatation, assessed by flow-mediated dilatation (Fig.

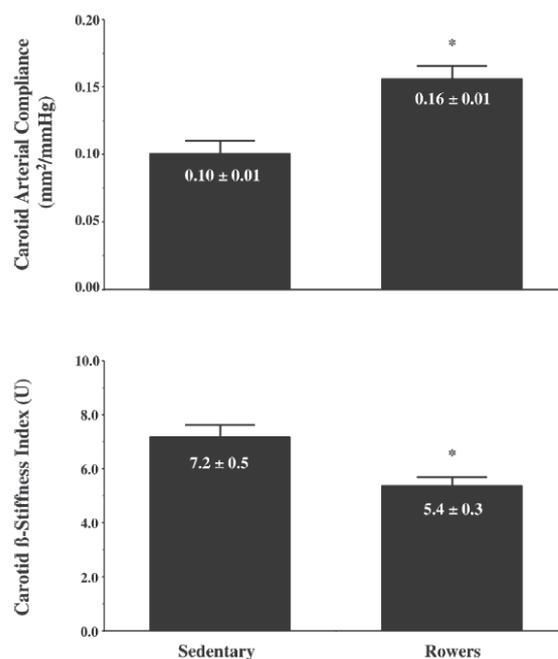


Fig. 6 Arterial compliance and β -stiffness in the carotid artery of sedentary men and rowers. Values are means \pm SEM. * $P < 0.05$ versus sedentary men. Cited from Cook et al.⁵¹).

8)⁵²), vasoconstrictors (plasma concentrations of endothelin-1), and vasodilators (plasma concentrations of nitrite/nitrate) (Fig. 9)⁵³). These observations were consistent with the results of arterial compliance and stiffness in the rowers in our studies. An interesting finding by Petersen et al.⁵²) shows that, in contrast to endothelium-dependent vasodilatation, endothelium-independent vasodilatation was lower in rowers than in the controls (Fig. 8). This finding may suggest that habitual rowing exercise in-

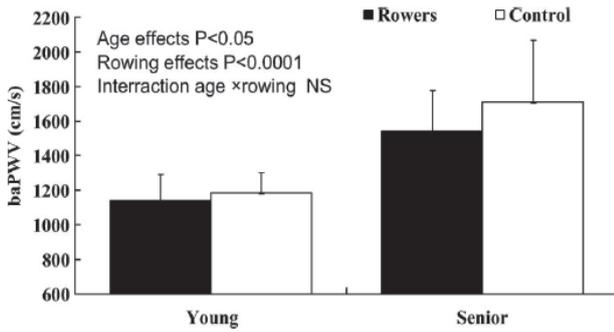


Fig. 7 Brachial ankle pulse wave velocity (baPWV) in young and senior controls and rowers. The 2-way analysis of variance indicated that all rowers had lower baPWV than age-matched controls independent of age ($P < 0.05$). Values are means \pm SD. Cited from Sanada et al.²².

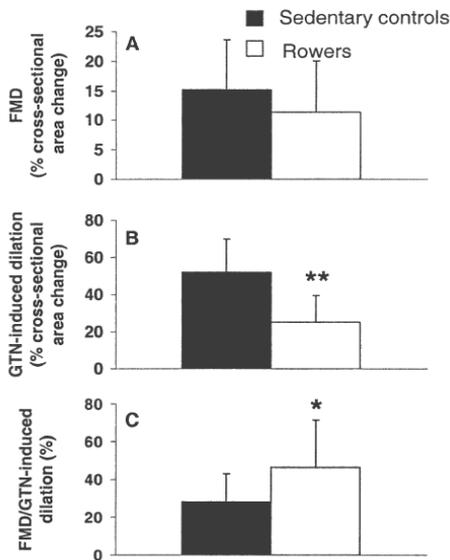


Fig. 8 Relative cross-sectional area changes induced by (A) hypermia (flow-mediated dilation (FMD) representing endothelium-dependent vasodilatation) and by (B) glyceryl trinitrate (GTN) endothelium-independent vasodilatation. (C) Ratio of FMD- to GTN-induced vasodilatation. * $P < 0.05$ and ** $P < 0.01$ versus sedentary controls. Values are means \pm SD. Cited from Petersen et al.⁵².

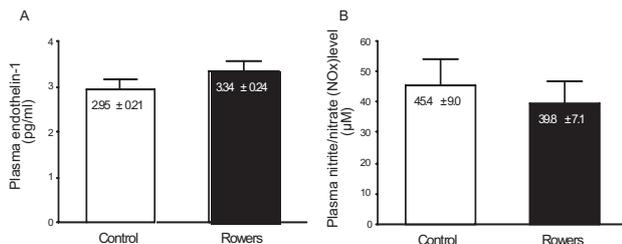


Fig. 9 Plasma concentrations of endothelin-1 (A) and nitrite/nitrate (B) in sedentary controls and rowers. Values are means \pm SEM. Cited from Kawano et al.⁵³.

creases endothelial nitric oxide production but that this increase is accompanied by smooth muscle cell desensitization to nitric oxide. Nevertheless, there are currently no detected unfavorable effects of habitual rowing exercise on vascular functions. Finally, the findings of these cross-sectional studies and their underlying mechanisms need to be prospectively confirmed with a future rowing training intervention study.

Conclusion

Rowing exercise has been recognized as an exercise that has aerobic and resistance exercise benefits, such as improved aerobic capacity, increased skeletal muscle size, and prevention of atherosclerosis and vascular dysfunction. Moreover, rowing exercise is a seated exercise that places low impact on the knee joints, allowing the elderly untrained men in the intervention to complete the 6-month rowing training without any injury or low back pain. Therefore, rowing is an efficient and safe exercise for elderly people to promote and maintain their health.

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