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The Effects of Left Common Carotid Artery Diameter in Different Static Postures

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Abstract

To explore the variation of left common carotid artery diameter (LCCAD) in different body positions, and to provide theoretical basis for prevention and treatment of carotid atherosclerosis. 165 volunteers from Anqing Normal University were divided into three age groups by the methods of literature review, experiment and mathematical statistics. Philips color Doppler cv850 color ultrasound was used to test the LCCAD in four different postures: head up tilt, supine position, head down tilt -30° and head down tilt -90°. Results: There were significant differences in the LCCAD in different postures in three age groups: under 25 years old (excluding 25 years old), 25-59 years old, 60 years old and above. The LCCAD increased with age in the remaining 5 groups (young women, young men, middle-aged women, middle-aged men and old men). The LCCAD increased with age in the order of head down up, supine position, head down tilt -30° and head down tilt -90°. The LCCAD of human body will change greatly with the change of body position, especially in the elderly. With the increase of age, the performance of systemic atherosclerosis in carotid artery is more obvious, and the possibility of a series of diseases is greater. Therefore, no matter the old, middle-aged and young people, we should strengthen the training on the artery to achieve the effect of prevention and treatment of arterial disease. This study reveals the influence of body position change on blood vessel diameter, which has important guiding significance for human body to stimulate blood vessel training through posture change.

Keywords:*Different Positions, left common carotid artery diameter, atherosclerosis.*

I. INTRODUCTION

Arterial compliance, also known as arterial elasticity, refers to the buffering capacity of the vessel wall. It is the change of the diameter or volume of the arterial vessel caused by the change of the pressure in the lumen, which depends on the size of the lumen and the hardness or expansibility of the wall [1]. With the increase of age, the elastic function of the arterial wall gradually declines, showing an increase in stiffness, a decrease in buffering capacity, a decrease in expansibility and an increase in pulse pressure In addition, it belongs to the early change of arteriosclerosis [2]. Abnormal carotid hemodynamics is also one of the manifestations of atherosclerosis [3]. Relevant studies have proved that long-term aerobic training can reduce arterial stiffness by changing arterial compliance [4].

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Carotid atherosclerosis, namely carotid atherosclerosis, is the manifestation of systemic atherosclerosis in the carotid artery. Atherosclerosis is a complex process of cardiovascular inflammatory disease, and is a disease that seriously endangers human health [5]. It usually occurs in adolescence and gradually worsens with age. In the early stage of carotid atherosclerosis, intima-media thickening is the first manifestation, and then atherosclerotic plaque is gradually developed [6]. For this reason, the younger trend of atherosclerosis needs to be paid attention to [7]. A large number of studies have shown that physical activity can prevent and help treat the risk factors of atherosclerosis [8], stabilize the development trend of the disease and even reverse the disease state [9], including fascia self relaxation [10], sleep regulation [11] and Aerobic exercise [12,13] is a better way, regardless of the elderly, middle-aged and young people, appropriately increase sports activities and reduce sedentary time [14], in order to improve life expectancy, reduce mortality, reduce risk factor exposure and relative risk, improve population health, enhance physical activity level, improve quality of life, and promote human health [15,16].

The common carotid artery is the main artery of the head and neck, so as to ensure the work requirements of the brain and the normal work of organs and tissues such as the head and face. Whether the diameter of common carotid artery is normal or not is directly related to individual's health status. However, previous studies on the changes of common carotid artery diameter characteristics of normal people's posture changes are relatively rare. Especially, the influence characteristics of handstand training on the internal diameter of human common carotid artery are not clear. Therefore, this study will explore the influence of four static body positions on the characteristics of left common carotid artery diameter(LCCAD). It is assumed that the LCCAD increases when the human body is in head up tilt (HUT), supine position(SP), head down tilt -30° (HDT-30°)and head down tilt -90° (HDT-90°).

II. METHODS

Participants

The subjects of this study are 165 students, in-service teachers and retired teachers from Anqing Normal University. See Table 1 for details. The study protocol was approved by the ethics committee of Anqing Normal University (Ethical Application Ref: ANU2017018), and written informed consent was obtained from all study participants. Participants with hypertension (systolic blood pressure ≥ 140 mmHg, diastolic blood pressure ≥ 90 mmHg), hypotension (systolic blood pressure ≤ 90 mmHg, diastolic blood pressure ≤ 60 mmHg), congenital heart disease, cardiogenic shock and other diseases were excluded from the study.

Table 1. List of subjects

Age bracket	Gender	Number	Age	Height(cm)	Weight(kg)	BMI
≤25	female	40	21±3.2	158±5.5	54±6.7	21.6
≤25	male	59	21±2.4	175±8.6	75±8.9	24.4
26≤X≤59	female	18	42±6.8	158±7.4	58±6.9	23.2
26≤X≤59	male	17	43±8.8	173±6.8	69±10.6	23.0
≥60	female	17	66±10.8	158±11.2	65±7.7	26.0

≥60	male	14	71±8.6	171±7.5	72±9.7	24.6

Study Design

In this study, neither doctors nor participants were informed of the aim of the experiment. Only researchers know. According to the training action of HDTT, four kinds of postures were designed: HUT, SP, HDT - 30°, HDT- 90°. In these four positions, doctors used ultrasound to test the LCCAD.

Experimental Equipment

The main testing instrument is Philips color Doppler cv850 color ultrasound and Handstand apparatus et al.

Experimental Site and Test Environment

Ultrasound department of Navy AnQing Hospital of PLA, temperature 26 °and humidity 66.

Experimental Process

In the ultrasound department of Navy anqing hospital, experienced ultrasound doctors used Philips color Doppler cv850 to measure the relevant indicators. Each subject was measured statically in four postures: HUT, SP, HDT - 30° and HDT - 90°, as shown in Figure 1.In the method of body position arrangement, all participants were asked to rest for about 10 to 20 minutes before the test. They were required to relax and breathe calmly during the carotid characteristics were examined in four positions respectively.

All positions refers to the tester's feet close together, straight legs, upright upper body, natural chest, natural sagging arms, straight head and neck. Four positions require muscle relaxation, and the duration of each position should be after the measured index value is stable.

The average test time is 40-50 minutes, and the interval time of each pose test is set as 2-3 minutes. During the test, two full-time personnel strengthened the protection of the subjects. During the test, the subjects tried to keep relaxed and normal breathing.

Statistical Analysis

The samples conform to the normal distribution, and the two sample heteroscedasticity t-test is used for the comparison of men and women in the same body position; the two sample equal variance t-test is used for the comparison of the same gender, left and right, and different body positions, and all tests were one-tailed, the significant difference is set as $P < 0.05$, and the very significant difference is set as $P < 0.01$. Data analyses were performed using the SPSS software (version 20.0, IBM Corporation, Armonk, NY, USA).

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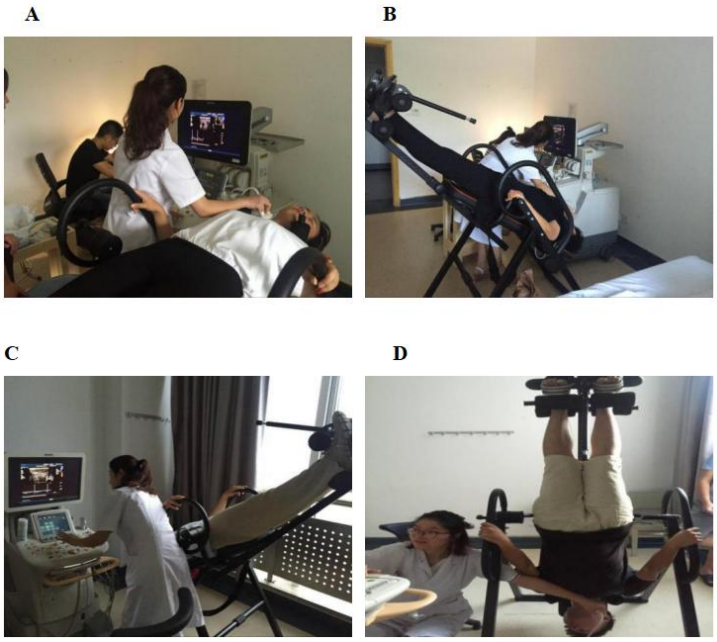

Figure 1.The experimental site

Notes: the above pictures are all approved by the tester and the subjects.A HUT, B SP, C HDT -30°, D HDT -90°

III. RESULTS

As shown in Table 2 and Figure 2, when the position sequence of young female, young male, middle-aged female, middle-aged male and elderly male group changes from HUT, SP, HDT - 30° to HDT - 90°, **LCCAD** shows a gradual upward trend, that is, HUT < SP < HDT- 30°< HDT- 90°, while that of elderly female group changes from HUT, SP, HDT - 30° to HDT - 90°,when the sequence changed, LCCAD increased first, then decreased and increased, that is, HUT < HDT- 30°< SP < HDT- 90°.

Table 2. Mean and standard deviation of LCCAD (mm)

HUT	SP	HDT-30°	HDT-90°
5.84±0.60	5.86±0.58	6.00±0.68	6.20±0.64
5.92±0.50	6.07±0.52	6.28±0.58	6.29±0.54
5.94±0.50	6.17±0.72	6.29±0.70	6.68±0.77
6.26±0.70	6.62±0.79	6.75±0.70	6.76±0.62
6.78±0.83	6.56±0.86	6.71±0.90	6.48±0.67
6.74±0.69	6.97±0.78	7.00±0.83	8.23±0.67

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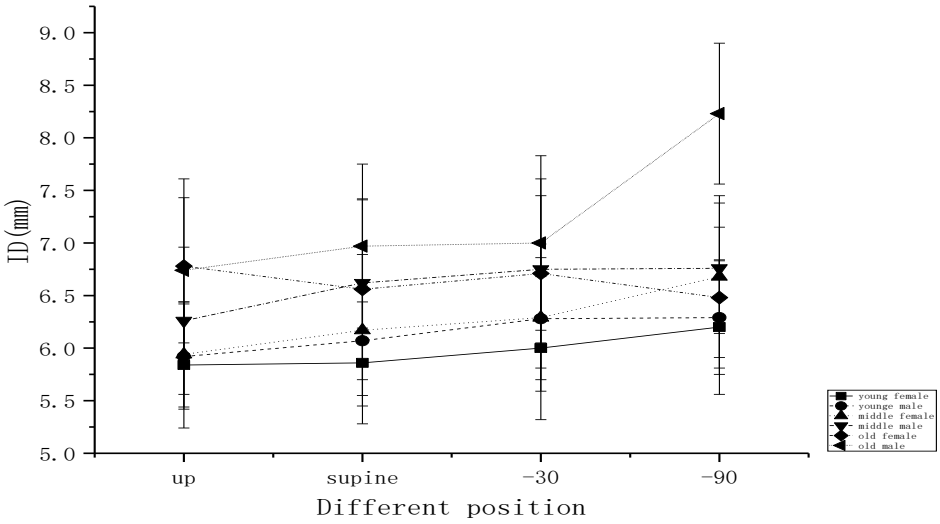

Figure 2. Comparison of left common carotid artery diameter characteristic broken line in different body positions

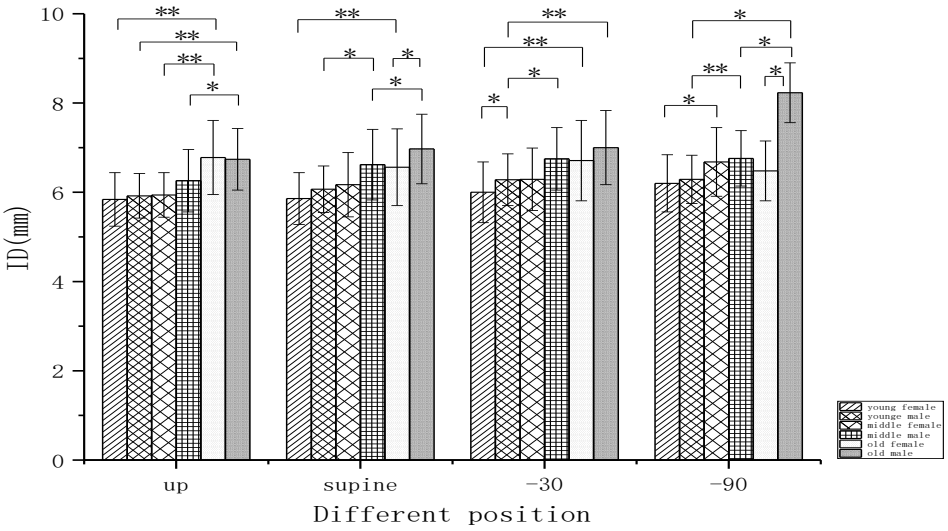

Figure 3. Comparison of left common carotid artery diameter characteristics in different static postures of human body

Notes: (* P <0.05, * * P <0.01)

As shown in Figure 3, there is a significant difference between the young female group and the young male group at HDT- 30°(P = 0.018), and between the elderly female group and the elderly male group in the SP (P = 0.042) and HDT- 90°(P = 0.011), and between the young female group and the middle-aged female group in HDT- 90°(P = 0.026);There was significant difference between young men and middle-aged men in SP(P = 0.0103) and HDT - 30°(P = 0.015). There was a significant

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difference between young men group and old man group in HDT- 90° (P = 0.019), between middle-aged men group and old man group in HUT (P = 0.012) and in SP (P = 0.033). Middle aged men group and old man group had significant difference in HDT - 90°.There was significant difference in male and female (P = 0.019).

There was a significant difference between young women group and elderly women group in HUT (P = 0.00017), SP (P = 0.0003), HDT- 30 °between young women group and old woman group(P = 0.008), and HUT between middle-aged women group and old women group (P = 0.00071), There was a highly significant difference between the young men group and the middle-aged man group in HDT - 90°(P = 0.008), between the young men group and the old man group in the HUT (P = 0.0002) and HDT- 30°(P = 0.001).

There was a highly significant differences between middle-aged and young women in HUT, middle-aged women and old women, young men and old men,young and middle-aged women and elderly women in SP(P < 0.01). There was a significant difference between middle-aged men and old men, old men and old women, young men and middle-aged men, young men and old men, middle-aged men and old women in SP and between middle-aged men and old men in HDT - 30° (P< 0.05). There was a highly significant differences between middle-aged women and old women, young men and old men in HDT - 30° (P < 0.01). There was significant difference between young men and young women, young men and middle-aged men (P < 0.05), and between middle-aged men and middle-aged men ,between old men and old women, young women and middle-aged women, young men and old men, middle-aged men and old men (P < 0.05).

IV. DISCUSSION

Relevant studies have shown that the proportion of left carotid artery stenosis or occlusion in young and middle-aged experimental groups is lower than that in elderly experimental groups [17]. The incidence of left carotid artery stenosis increases with the increase of human age [18]. Age is the main risk factor affecting the formation of carotid atherosclerotic plaque [19]. With the increase of age, the vascular physiological structure changes, and the chance of contacting with various risk factors increases [20,21], which gradually causes the intima-media thickening, plaque formation, wall elasticity weakening and inner diameter increasing of cervical artery, which indicates the characteristics of gradual hardening of cervical artery, and these changes can be considered. It is the result and performance of aging in the body [22]. In recent years, with the growth of aging in China, the incidence of cardiovascular and cerebrovascular diseases presents an upward trend. Therefore, it is of great significance to observe the influence of age on carotid atherosclerosis for the prevention and treatment of cardiovascular and cerebrovascular diseases [23]. Carotid atherosclerosis in young people may be related to genetic factors, hyperlipidemia, obesity, hypertension and diabetes. Therefore, early prevention should be given priority to. Those who are over middle age and have risk factors related to carotid atherosclerosis should be listed as key prevention objects [24].

Many studies have shown that with the growth of age, the morphological indexes of carotid artery have different degrees of change: among them, the arterial diameter presents a trend of widening gradually; the artery gradually thickens with the increase of age; the incidence of atherosclerotic plaque is also gradually increased, and these morphological changes in men are significantly earlier than those in women; The blood flow velocity and elastic index of carotid artery hemodynamic indexes showed a downward trend, and the changes in men were earlier than those in women; the degree of carotid atherosclerosis was gradually aggravated, and the degree of carotid atherosclerosis in male was higher than that in female, and the increase of plaque

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number and plaque area in men was more obvious than that in women [25-27]. Therefore, the inner diameter changes of elderly men in four different positions are quite different, and the degree of arteriosclerosis is more serious, and it increases with age. The prevalence of carotid atherosclerosis in men is higher than that in women [28]. More attention should be paid to physical activity related exercise, and walking is an effective and relatively labor-saving exercise method [29], so as to reduce the movement formed in the aging process Pulse hardening reduces incidence rate and mortality of cardiovascular diseases by [30], improves autonomy and prolongs [31].

The reason for the other five groups may be that with the increase of age, atherosclerosis relatively increases, which changes the content and arrangement direction of elastic fibers of blood vessels, so that their elasticity and toughness decrease, the elastic modulus increases, the hardness of the wall increases [32], and the viscoelasticity of aortic vessels decreases The relaxation degree of carotid artery wall increases, especially the head down posture increases the blood pressure at the common carotid artery, which leads to the decrease of the blood flow velocity and the expansion of the common carotid artery diamete [33], which makes the difference more obvious. Head down tilt is one of the most widely used ground simulation methods of weightlessness [34]. Due to the different tilt angle and duration, the changes of various body systems are complicated, and the change mechanism is also diverse. Some mechanisms are still unclear, and the research space is very large. Therefore, the body with different tilt angle and different duration is applied to sports Fitness, this aspect of research is rare, worthy of in-depth discussion of the academic community [35].

The reason why the elderly women group is different from other groups is that the BMI index [36] of elderly women in the experimental group is 26.0, overweight tends to be obese, with the increase of BMI, the muscle strength of related joints of elderly women decreases [37], and with the growth of age, vascular stiffness increases [38], blood viscosity increases, blood viscosity is one of the three major factors of the coronary artery resistance. Blood cell aggregation and blood lipid increase can increase blood viscosity. Blood viscosity increased, increased coronary resistance, reduced coronary blood flow [39]. The muscle strength of smooth muscle decreased, the amplitude of vasoconstriction decreased, and the vasodilation function decreased [40]. Therefore, the arterial diameter of elderly women in the experimental group did not change much under different postures.

There were significant differences in the LCCAD in different postures in three age groups, and six experimental groups. Except for the old women, the general trend of the remaining five groups was that the LCCAD increased with age; when the body position was in the order of HUT, SP, HDT- 30° and finally HDT - 90°, The LCCAD increased, which was consistent with the research hypothesis.

Generally speaking, the LCCAD of young people, middle-aged people and elderly people has great difference under different positions. With the increase of age, the greater the change range, so the fitness awareness should be enhanced with the growth of age. Regardless of the elderly, middle-aged and young people, appropriate aerobic exercise should be emphasized. As an effective non drug treatment method, aerobic exercise can improve vascular smooth muscle function, restore vascular elasticity, slow down the thickening rate of arterial wall, delay the aging of arterial wall structure [42], and change the structure and function of artery, It can increase the compliance of aorta and great artery, reduce the peripheral resistance of blood vessel [43,44], effectively increase the artery diameter of normal weight population [45], improve atherosclerosis [46], delay the development of atherosclerosis [47].

V. CONCLUSION

The left common carotid artery diameter of human body will change greatly with the change of body position, especially in the elderly. With the increase of age, the performance of systemic atherosclerosis in carotid artery is more obvious, and the possibility of a series of diseases is greater. Therefore, no matter the old, middle-aged and young people, we should strengthen the training on the artery to achieve the effect of prevention and treatment of arterial disease.This study reveals the influence of body position change on blood vessel diameter, which has important guiding significance for human body to stimulate blood vessel training through posture change.

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REFERENCES

[1]Jinao Chen,Lin Zhang,Yafeng Li,et al.(2014)Effect of long-term resistance exercise on carotid compliance in middle-aged and elderly people.CHINA SPORT SCIENCE,34(02):60-67.

[2]Jinao Chen,Lin Zhang,Liu Chen,et al.(2015)The effect of vibration training on arterial elasticity in young aged people.Journal of Physical Education, 22(02):120-126.

[3]Wenrong Wang,Kaiyu Xiong, Hui He (2018) Correlation of carotid WSS with FMD, IMT and cardiovascular risk factors in middle-aged people. Journal of Beijing Sport University, 41(03):76-81.

[4]Peng Sun,Shichang Li,Liu Ji,et al.(2012)Acute effects of aerobic exercise on carotid compliance and pulse pressure amplification.CHINA SPORT SCIENCE,32(12):42-49.

[5]Ping Zhao,Guotai Li,Chengyin Huang,et al.(2010)Effect of exercise regulating gas signal molecular system on atherosclerosis.Journal of Wuhan Institute of Physical Education,44(02):71-75.

[6]Yun Lin,Wenhe Chen (2011)Research Progress on the relationship between obesity and atherosclerosis.Journal of Shanghai University of Sport,35(05):52-56.

[7]Yun Lin,Wenhe Chen(2012)Effect of 4-week aerobic exercise on atherosclerosis related factors in obese children and adolescents.CHINA SPORT SCIENCE AND TECHNOLOGY, 48(04):131-136.

[8]Xiangquan Wang,Xiaofeng Wang,Liwei Zhang(2018)Research frontier and hot spot evolution of exercise rehabilitation in foreign countries.Journal of Wuhan Institute of Physical Education,52(03):75-82.

[9]Dizhi Wang,Peizhen Zhang(2018)Research progress of exercise on reversing mechanism of atherosclerotic plaque.CHINA SPORT SCIENCE,38(09):65-71.

[10]Haohao Huang,Huanbin Zhao(2018)Research progress of fascia self relaxation effect.Journal of Wuhan Institute of Physical Education, 52(04):92-100.

[11]McAlpine Cameron S,Kiss Máté G,Rattik Sara,He Shun,Vassalli Anne,et al.(2019) Sleep modulates haematopoiesis and protects against atherosclerosis. Nature,566(7744).

[12]Honglin Qu,Jun Xie,Jiaqin Chen,et al.(2019)Aerobic exercise mediates hippocampal inflammatory response in cums depression mice via TLR4 / mir-223 / NLRP3 signaling pathway axis.CHINA SPORT SCIENCE,39(02):39-50.

[13]Xiaojing Lin,Lin Lu,Xiaohui Wang(2017)The role of inflammatory factor Chemerin in the improvement of blood lipid and aortic sclerosis by aerobic exercise in atherosclerotic rats.Journal of Shanghai University of Sport,41(04):49-56.

[14]Grossman David C,Bibbins-Domingo Kirsten,Curry Susan J, et al. (2017)Behavioral Counseling to Promote a Healthful Diet and

July-August 2020
ISSN: 0193-4120 Page No. 3738 - 3747

Physical Activity for Cardiovascular Disease Prevention in Adults Without Cardiovascular Risk Factors: US Preventive Services Task Force Recommendation Statement. JAMA,318(2).

[15]Kyle J Foreman,Neal Marquez,Andrew Dolgert,et al. (2018)Forecasting life expectancy, years of life lost, and all-cause and cause-specific mortality for 250 causes of death: reference and alternative scenarios for 2016–40 for 195 countries and territories. The Lancet,392(10159).

[16]Jeffrey D Stanaway,Ashkan Afshin,Emmanuela Gakidou,Stephen S Lim,et al. (2018)Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. The Lancet,392(10159).

[17]Wenke Wang,Xiaoshn Jing,Lingjun Zhang,et al.(2018)Distribution of intracranial and carotid artery stenosis and related factors in patients with cerebral infarction of different ages.Guangxi Medical Journal,40(19):2349-2351.

[18]Hongwei Dai(2016)Clinical study and exploration of carotid artery stenosis in patients with ischemic cerebrovascular disease of different ages.World Latest Medicine Information,16(53):77+84.

[19]Zuojun Tian,Lei Liu,Yaxian Dong,et al.(2008)Clinical analysis of factors influencing carotid plaque formation.Chinese Journal of Neuromedicine|Chin J Neuromed,(11):1168-1173.

[20]Qian Wang,Yun Zhang,Wei Zhang,et al.(2004)Ultrasonic detection of carotid atherosclerosis and its relationship with risk factors.Chinese Journal of Arteriosclerosis,(04):449-451.

[21]Dong Yu, Meilian Wei,Juan Li,et al.(2015)Age characteristics of carotid plaque in physical examination population.Chinese Journal of Medicine,50(03):87-89.

[22]Baowei Ding,Yuguang Xia,Weiping Tang,et al.(2014)Ultrasonographic features of extracranial carotid and vertebral arteries in adults.Chinese Journal of Gerontology,34(24):6935-6937.

[23]Jiaying Han,Qing Zhang,Zhu Meng,Dalin Song(2018)Study on the relationship between the nature of carotid plaque and stenosis and age.Chin J Geriatr Heart Brain Ves Dis,20(05):466-469.

[24]Qian Yang, Deilin Yu (2012)Ultrasonic observation on the influence of age and sex on carotid atherosclerosis.Journal of Ultrasound in Clinical Medicine,14(08):573-574.

[25]Lirong Liang(2008) Epidemiological characteristics and influencing factors of carotid atherosclerosis progression in middle-aged and elderly natural population.Peking Union Medical College.

[26]Jiajia Qian(2013) The study of carotid ultrasound imaging characteristics and related factors in 20-59 years old population.Nanjing Normal University.

[27]Yunyun Cao(2013) Ultrasonic detection of carotid intima-media thickness and plaque status in middle-aged and elderly people in Minhang District of Shanghai.Fudan University.

[28]Jiayi Sun,Dong Zhao,Jing Liu,et al.(2016)Gender differences in carotid atherosclerosis in hospitalized patients with ischemic stroke in China.Journal of Cardiovascular and Pulmonary Diseases,35(02):81-86.

[29]Elaine M Murtagh,Linda Nichols,Mohammed A Mohammed,et al.(2014) Walking to improve cardiovascular health: a meta-analysis of randomised control trials. The Lancet,384.

[30]Thompson Angela M,Hu Tian,Eshelbrenner Carrie L,et al. Antihypertensive treatment and secondary prevention of cardiovascular disease events among persons without hypertension: a meta-analysis. JAMA,305(9).

[31]Benetos Athanase,Rossignol Patrick,Cherubini Antonio,et al.(2015) Polypharmacy in the Aging Patient: Management of Hypertension in Octogenarians. JAMA,314(2).

[32]Donghui Xu,Shuhua Huang,Xinying Li,Dongyuan Li(2017)Comparative analysis of rheological characteristics of common carotid artery between young and old corpses.J Clin Rehabil Tis Eng Res,21(16):2527-2533.

[33]Guoxuan Zhao,Zhihong Hu,Jingsheng Yang,Congfa Zhong(1998)Characteristics of head and neck blood flow changes in patients with different endurance under head down (-30 °) bed rest.Space Medicine & Medical Engineering,(05):324-328.

[34]Bin Wu,Ping Wu,Yueying Xue,etal.(2008)Repeated posture change training can improve the human head down endurance.Chin J Appl Phys,(01):116-120.

[35]Lian Xue,Biao Sun(2005)Effect of head down tilt on blood circulation and respiratory system.Joournal of Nanjing Institute of Physical Education:Natural Science,(02):13-17.

[36]Chunhua Zhang,Weimo Zhu,Benhao Fan,Peijie Chen(2014)Analysis on the trend of BMI and grip strength of elderly women in Shanghai.Chinese Journal of Sports Medicine,33(08):764-767.

[37]Xiaoyu Pan,Weijie Fu,Xie Wu,et al.(2016)Analysis on the change trend of BMI and grip strength of elderly women in Shanghai during the past 10 years.Chinese Journal of Sports Medicine,35(04):317-320.

[38]Kaess Bernhard M,Rong Jian,Larson Martin G,et al. (2012)Aortic stiffness, blood pressure progression, and incident hypertension. JAMA,308(9).

[39]Xiaozhi Zheng,Deibin Li,Tingsheng Zhang(2012)Analysis of 178 patients with coronary heart disease and experience of Drug Administration.Chinese And Foreign Medical Research,10(25):143-144.

[40]Yanmiao Zhang,Hanmeng Zhang,Lijun Shi, Hucheng Zhao(2014)Aging down regulates BK in smooth muscle cells_ (CA) channels α and β_ Expression of subunits 1 changes the contractility of mesenteric artery.Chinese Journal of Arteriosclerosis,22(08):757-762.

[41]Lin Zhang,Hanmeng Zhang,Fang Ye,Lijun Shi(2015)Aerobic exercise inhibits the up regulation of BKCa channel protein subunits in mesenteric artery of hypertensive rats.Journal of Tianjin University of Sport,30(01):42-46+65.

[42]Songtao Wang,Yungui Ceng,Anli Wang(2007)Effects of aerobic exercise on cardiovascular autonomic nervous regulation in rats.Journal of Physical Education,(03):41-45.

[43]Guangxu Tang,Hanmeng Zhang,Xianshuang Yuan,Lijun Shi(2015)Effect of aerobic exercise on RhoA / Rho kinase activity in arterial smooth muscle of spontaneously hypertensive rats.Chinese Journal of Sports Medicine,34(05):450-455+461.

[44]Horta Pedro Paulo,de Carvalho Jorge José,Mandarim-de-Lacerda Carlos Alberto(2005) Exercise training attenuates blood pressure elevation and adverse remodeling in the aorta of spontaneously hypertensive rats. Life sciences,77(26).

[45]Wenxia Shi,Haibin Liu,Yubing Ceng,Ling Cao(2019)Effect of aerobic exercise on hemodynamic indexes of common carotid artery in obese adolescents.Science Technology and Engineering,19(14):78-83.

[46]Yuguang Guan(2005)Effects of aerobic exercise on angiotensin II in plasma and myocardium during the development of atherosclerosis in rats.CHINA SPORT SCIENCE,(07):31-34.

[47]Yan Sun,Xuanming Hao,Qingqing Geng,et al.(2014)Anti inflammatory mechanism of aerobic exercise on atherosclerotic lesions.Journal of Beijing Sport University,37(04):62-67.