Article

Head tilt exercise significantly lowers blood pressure: A case study

WenJun Zhang[1], **YanHong Qi**[2]

[1]School of Life Sciences, Sun Yat-sen University, Guangzhou 510275, China

[2]Sun Yat-sen University Library, Sun Yat-sen University, Guangzhou 510275, China

E-mail: zhwj@mail.sysu.edu.cn, wjzhang@iaees.org, qiyh@mail.sysu.edu.cn

Received 2 January 2025; *Accepted 3 January 2025*; *Published online 7 January 2025*; *Published 1 June 2025*

Abstract

In present study, the effect of head tilt excise for lowering blood pressure is experimented. The results show that there is a significant difference between systolic blood pressures before and during one-time excise, between diastolic blood pressures before and during one-time excise, and between cardiac rates before and during one-time excise. Systolic blood pressure and diastolic blood pressure will decline 7 mmHg and 3 mmHg during one-time head tilt excise. Cardiac rate will decline 2 beats/min during one-time head tilt excise. Systolic blood pressure benefits mostly from one-time head tilt excise, seconded by diastolic blood pressure, and cardiac rate benefits least from one-time head tilt excise. The effect of one-time head tilt excise for lowering systolic blood pressure and cardiac rate significantly increases with systolic blood pressure and cardiac rate respectively. There is a significant difference between systolic blood pressures before and after 15-min head tilt excise, and between diastolic blood pressures before and after 15-min head tilt excise. Systolic blood pressure and diastolic blood pressure will decline 8 mmHg and 5 mmHg respectively after 15-min head tilt excise. There is not significant difference between cardiac rates before and after 15-min head tilt excise. Systolic blood pressure benefits mostly from 15-min head tilt excise, seconded by diastolic blood pressure, and cardiac rate may not benefit from 15-min head tilt excise. The effect of 15-min head tilt excise for lowering systolic blood pressure, diastolic blood pressure and cardiac rate significantly increases with systolic blood pressure, diastolic blood pressure and cardiac rate respectively. The effect of 15-min head tilt excise in lowering diastolic blood pressure significantly increases with time (days). In average, diastolic blood pressure declines 6 mmHg after one month. The effect in systolic blood pressure slightly increases with time. However for cardiac rate, the effect is not significant. On the mechanism of head tilt excise in lowering blood pressure, we hold that tilting head back interferes with the transmission of nerve signals from the brain to the organs, weakens sympathetic nerve activity, stimulates vagus nerve activity, decreases the secretion of angiotensin and some other blood pressure related substances to blood vessels, and reduces cardiac rate. Finally, we conclude that head tilt excise can be used as an effective treatment measure for instantly or permanently lowering blood pressure.

Keywords head tilt excise; blood pressure; hypertension; cardiac rate; rehabilitation; cure.

Network Pharmacology
ISSN 2415-1084
URL: http://www.iaees.org/publications/journals/np/online-version.asp
RSS: http://www.iaees.org/publications/journals/np/rss.xml
E-mail: networkpharmacology@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

Hypertension is the leading cause of stroke and cardiovascular disease and the largest risk factor for mortality worldwide (Hagberg et al., 2000; Lim et al., 2012; Pescatello et al., 2015). The causes of hypertension are complex and ultimately mainly due to problems with the nervous system and endocrine system. Blood pressure regulation depends largely on the sodium excretion regulation system, which mainly involves kidney function (Guyton, 1991; Murase et al., 2023). Increased activity of the sympathetic nervous system can also lead to the development of hypertension (Guyenet, 2006; Malpas, 2010; Grassi et al., 2015; Murase et al., 2023). The ventrolateral medulla (RVLM) located in the brainstem plays a key role in determining the activity of the sympathetic nervous system, and its functional integrity is essential for maintaining basal vasomotor tone and regulating blood pressure (Guyenet, 2006).

Sympathetic nervous system-associated angiotensin II is the major bioactive peptide of the renin-angiotensin system (RAS), which regulates blood pressure as well as other biological processes such as cell growth, apoptosis and migration as well as inflammation and fibrosis (Fyhrquist, 2008; Murase et al., 2023). The biological effects of angiotensin II are mediated by its interaction with two different high-affinity G protein-coupled receptors, angiotensin II type 1 (AT1R) and type 2 (AT2R) receptors. Angiotensin II and angiotensin II antagonists injected into the RVLM have been reported to enhance both pressor and hypotensive responses in spontaneously hypertensive rats (SHR) (Muratani et al., 1993; Ito et al., 2002). Although pharmacological intervention of the angiotensin II-AT1R system has been shown to be an effective strategy for treating hypertension (Li et al., 2014), mechanical attenuation of AT1R signaling has not yet been used clinically as an antihypertensive measure.

Exercise can effectively treat and prevent a variety of physical diseases (Murase et al., 2023. It has been previously shown that running on a treadmill at a moderate speed can reduce sympathetic nerve activity (Nabika et al., 2012). Murase et al. (2023) demonstrated that in the rodent prefrontal cortex (PFC), fluid shear stress caused by moderate mechanical intervention modulates serotonin signaling in neurons.

According to traditional Chinese medicine, the excises that tilt head back can lower blood pressure. In traditional Chinese sports such as Ba Duan Jin and Tai Chi, and in many other sports, there are various head excises. Based on such knowledge, they may be beneficial for the rehabilitation of some blood diseases. Therefore, in present study we made an experiment on the effect of head tilt excise for lowering blood pressure.

2 Material and Methods

A case with hypertension is used in present experiment. The health status and other conditions of the case remain constant and stable during the experiment.

2.1 One-time head tilt excise

Excise: Tilt head back and stare at the ceiling for 20~30 seconds to squeeze the back of the neck.

Measure blood pressure (mmHg) and cardiac rate (i.e., resting heart rate, beats/min) just before and during the excise (Fig. 1). Repeat the excise and measurement several times every day (1st~31th December, 2024).

2.2 15-min head tilt excise

Excise: Tilt head back and stare at the ceiling for 8~12 seconds to squeeze the back of the neck, then lower head and look straight ahead for 1-3 seconds to take a break. Repeat the excise for 15 minutes (Fig. 2).

Measure blood pressure and cardiac rate three times just before and just after the excise (Fig. 2). Repeat the excise and measurement 2 or 3 times (mostly 3 times) every day (1st~31th December, 2024).

2.3 Measurement of systolic blood pressure and diastolic blood pressure

Measure systolic blood pressure and diastolic blood pressure in different periods and times (Aug-Sept 2015,

Aug-Sept 2018, Aug-Sept 2020, Dec 2024).

2.4 Statistcial analysis

Linear regression, paired-samples *t*-test, and effect sizes (Cohen's *d*, Glass effect size, effect size CLES, etc.), etc., are used in the analysis (Zhang, 2016, 2018, 2020, 2021, 2022a-b, 2023; Zhang and Qi, 2024).

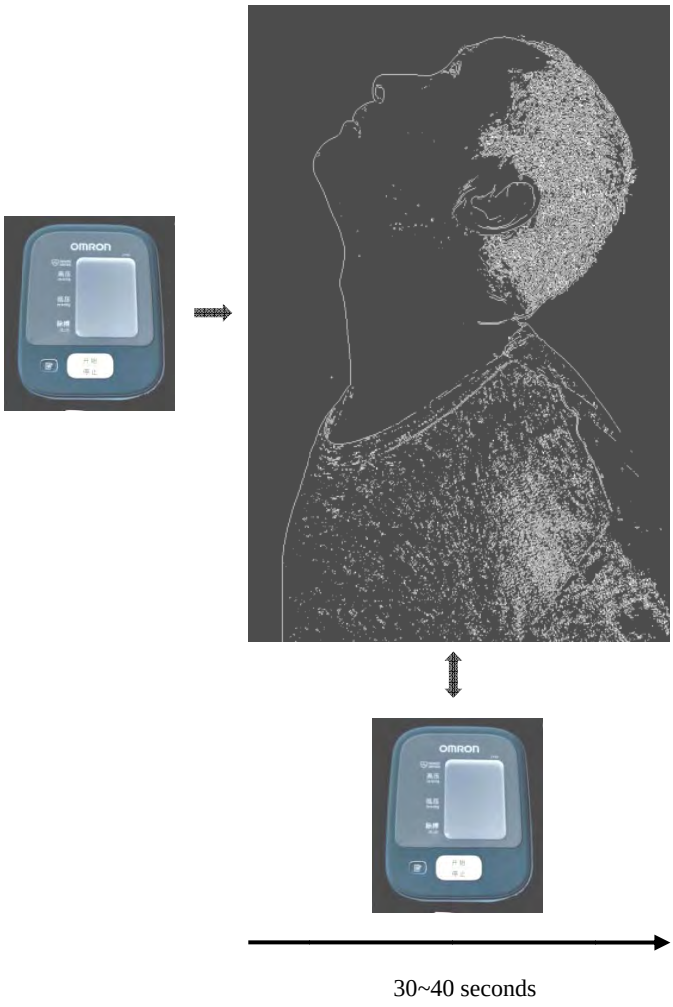

Fig. 1 One-time head tilt excise and measurement of blood pressure.

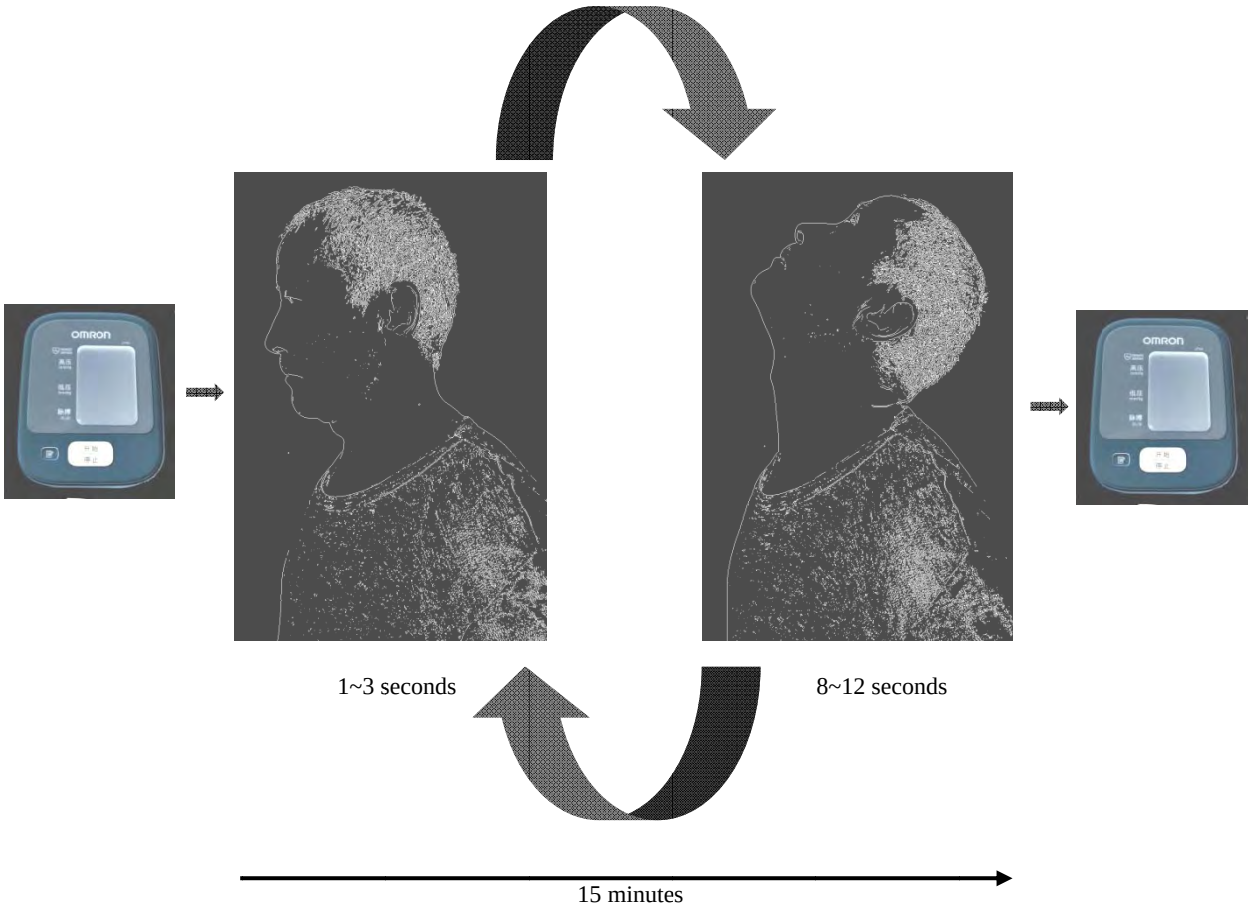

Fig. 2 15-min head tilt excise and measurement of blood pressure.

3 Results and Analysis

3.1 One-time head tilt excise

3.1.1 Effect of one-time head tilt excise

There are totally 39 sets of blood pressures and cardiac rates were recorded in one-time head tilt excise (before and during excise). The paired-samples *t*-tests and effect sizes are calculated as follows (Fig. 3):

Systolic blood pressure (high blood pressure)
Mean before excise=115.6923, standard deviation=9.0004
Mean during excise=108.2821, standard deviation=7.6912
t=9.1339, p=3.98*10^{-11}
Cohen's d=0.8852, Glass effect size=0.8233, effect size CLES=0.7343
There is a significant difference between systolic blood pressures before and during one-time excise. Systolic blood pressure will decline 7 mmHg during one-time head tilt excise.

Diastolic blood pressure (low blood pressure)
Mean before excise=64.2308, standard deviation=4.5333
Mean during excise=61.9744, standard deviation=4.6875
t=5.1964, p=7.17*10^{-6}

Cohen's *d*=0.4893, Glass effect size=0.4977, effect size CLES=0.6353
There is a significant difference between diastolic blood pressures before and during one-time excise. Diastolic blood pressure will decline 3 mmHg during one-time head tilt excise.

Cardiac rate
Mean before excise=67.9744, standard deviation=4.8149
Mean during excise=66.1026, standard deviation=4.8221
t=3.2474, *p*=0.0024
Cohen's *d*=0.3885, Glass effect size=0.3888, effect size CLES=0.6082
There is a slightly significant difference between cardiac rates before and during one-time excise. Cardiac rate will decline 2 beats/min during one-time head tilt excise.

In general, systolic blood pressure benefits mostly from one-time head tilt excise, seconded by diastolic blood pressure, and cardiac rate benefits least from one-time head tilt excise.

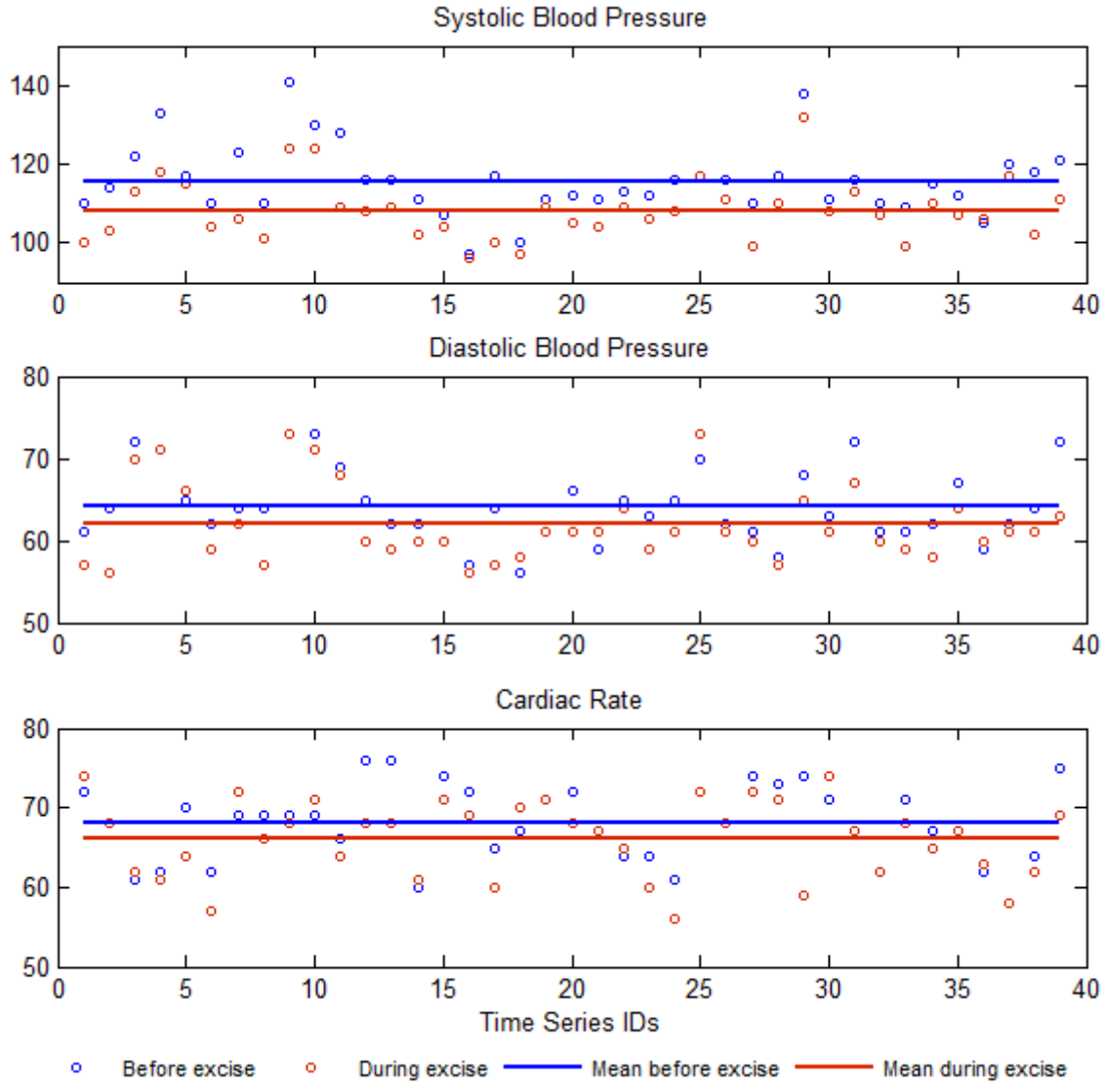

Fig. 3 Effect of one-time excise.

3.1.2 Relationships between base measurements and effect of one-time head tilt excise

From Table 1, we can conclude that the effect of one-time head tilt excise for lowering systolic blood pressure and cardiac rate significantly increases with systolic blood pressure and cardiac rate respectively. Systolic blood pressure and cardiac rate will approximately decrease 20 mmHg and 11 beats/min with base measurements 160 mmHg and 100 beats/min respectively. The effect of one-time head tilt excise will disappear at less than 90 mmHg and 61 beats/min for systolic blood pressure and cardiac rate respectively.

Table 1 Relationships between base measurements and effect of one-time head tilt excise*.

y	*a*	*b*	r^2	*F*	*P*
Systolic blood pressure	-26.5244(±18.5702)	0.2933(±0.1600)	0.2715	13.7902	0.0007
Diastolic blood pressure	-7.0125(±12.4506)	0.1443(±0.1934)	0.0582	2.2863	0.139
Cardiac rate	-17.0221(±15.7521)	0.2780(±0.2312)	0.1382	5.9354	0.0198

*Linear regression: y_{before}-y_{during}=a+b y_{before}. ±: half width of confidence interval, p=0.05.

3.2 15-min head tilt excise

3.2.1 Effect of 15-min head tilt excise

There are totally 71 sets of averaged blood pressures and cardiac rates were recorded in 15-min head tilt excise (before and after excise). The paired-samples *t*-tests and effect sizes, etc., are calculated in Table 2.

From the results in Table 2, there is a significant difference between systolic blood pressures before and after 15-min head tilt excise. Systolic blood pressure will decline 8 mmHg after 15-min head tilt excise. There is a significant difference between diastolic blood pressures before and after 15-min head tilt excise. Diastolic blood pressure will decline 5 mmHg after 15-min head tilt excise. There is not significant difference between cardiac rates before and after 15-min head tilt excise (Fig. 4).

In general, systolic blood pressure benefits mostly from 15-min head tilt excise, seconded by diastolic blood pressure, and cardiac rate may not benefit from 15-min head tilt excise.

Table 2 Effect of 15-min head tilt excise.

	Systolic blood pressure	Diastolic blood pressure	Cardiac rate
Mean before excise	118.5399	65.0704	69.1455
Standard deviation	8.2734	3.8828	4.6184
Mean after excise	110.2441	61.5258	68.5399
Standard deviation	7.764	3.9185	4.8352
t-value	11.8141	9.0037	1.4443
p	0	$2.60*10^{-13}$	0.1531
Cohen's *d*	1.034	0.9087	0.128
Glass effect size	1.0027	0.9129	0.1311
Effect size CLES	0.7677	0.7397	0.5361

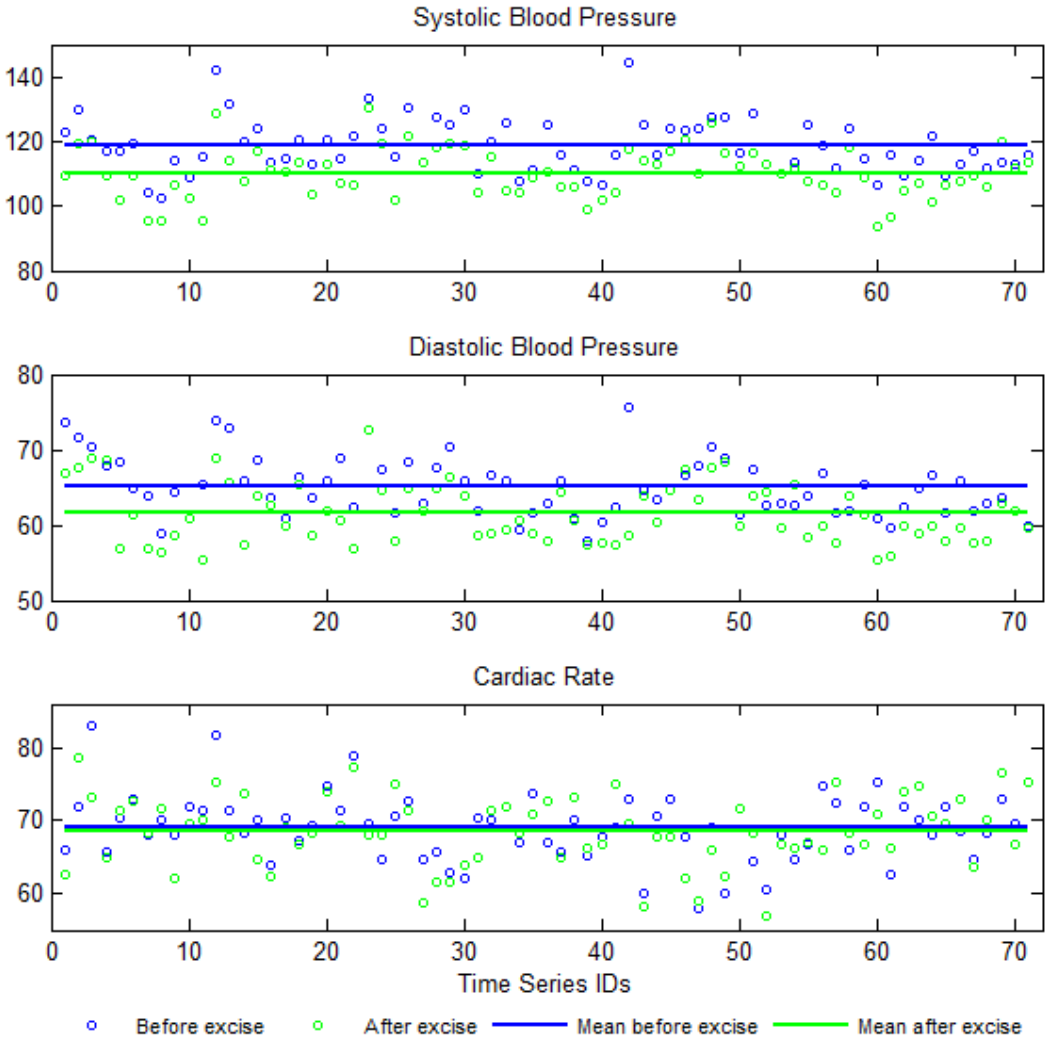

Fig. 4 Effect of 15-min head tilt excise.

3.2.2 Relationships between base measurements and effect of 15-min head tilt excise

From Table 3, we can conclude that the effect of 15-min head tilt excise for lowering systolic blood pressure, diastolic blood pressure and cardiac rate significantly increases with systolic blood pressure, diastolic blood pressure and cardiac rate respectively. Systolic blood pressure, diastolic blood pressure and cardiac rate will approximately decrease 21 mmHg, 16 mmHg and 8 beats/min with base measurements 160 mmHg, 100 mmHg and 100 beats/min respectively. The effect of 15-min head tilt excise will disappear at less than 92 mmHg, 55 mmHg, and 67 beats/min for systolic blood pressure, diastolic blood pressure and cardiac rate respectively.

Table 3 Relationships between base measurements and effect of 15-min head tilt excise*.

y	*a*	*B*	r^2	*F*	*p*
Systolic blood pressure	-29.0918(±18.3166)	0.3154(±0.1541)	0.1945	16.6613	0.0001
Diastolic blood pressure	-19.6017(±12.1602)	0.3557(±0.1865)	0.1734	14.4698	0.0003
Cardiac rate	-16.3067(±12.0639)	0.2446(±0.1741)	0.1022	7.8559	0.0066

*Linear regression: y_{before}-y_{after}=a+b y_{before}. ±: half width of confidence interval, p=0.05.

3.2.3 Time-dependent effect of 15-min head tilt excise

In general, the effect of 15-min head tilt excise in lowering diastolic blood pressure significantly increases with time (days). In average, diastolic blood pressure declines 6 mmHg after one month. The effect in systolic blood pressure slightly increases with time. For cardiac rate, the effect is not significant (Table 4, Fig. 5).

Table 4 Time-dependent effect of 15-min head tilt excise*.

	y	*a*	*b*	r^2	*F*	*p*
Before excise	Systolic blood pressure	121.4114(±4.6482)	-0.2030(±0.2901)	0.0767	2.0757	0.1621
	Diastolic blood pressure	68.5370(±2.2830)	-0.2403(±0.1425)	0.3254	12.0611	0.0019
	Cardiac rate	69.4215(±2.5413)	-0.0170(±0.1587)	0.002	0.0489	0.8268
After excise	Systolic blood pressure	110.6915(±4.4461)	-0.0162(±0.2775)	0.0006	0.0144	0.9054
	Diastolic blood pressure	63.6179(±2.2406)	-0.1401(±0.1399)	0.1455	4.2572	0.0496
	Cardiac rate	67.4277(±2.6977)	0.0734(±0.1683)	0.0312	0.8052	0.3781

* Linear regression: $y=a+bt$, where t: days from the beginning of the experiment, y: dependent variable. ±: half width of confidence interval, p=0.05, n=27.

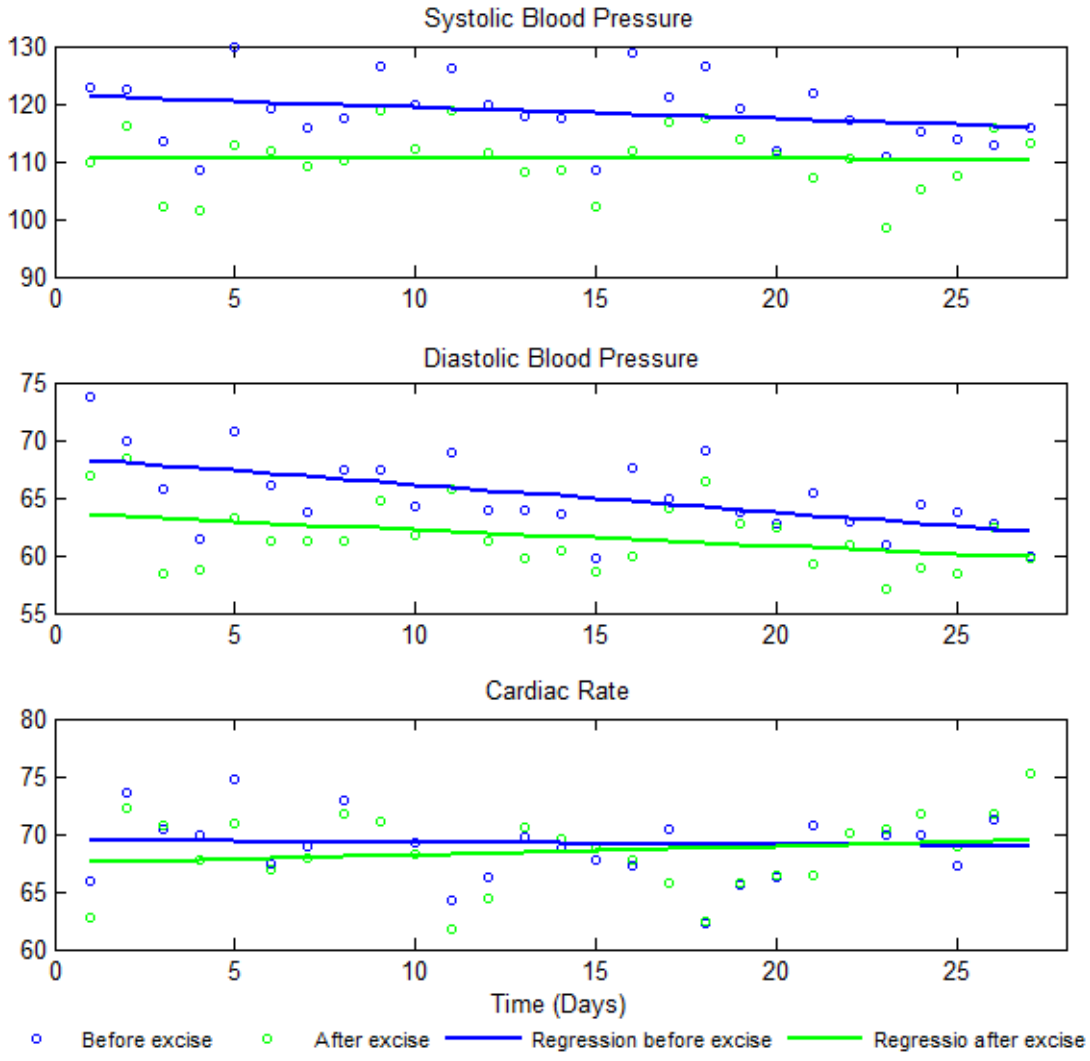

Fig. 5 Time-dependent effect of 15-min head tilt excise (See Table 4 for regression equations).

3.3 Relationships between systolic blood pressure, diastolic blood pressure and cardiac rate

There are totally 878 sets of blood pressures were recorded. Relationship between systolic blood pressure and diastolic blood pressure (n=878) is fitted as the following linear regression (Table 5, Fig. 6):

y=56.6141+0.8906x
r^2=0.5823, F=1221.1131, p=0

where x: diastolic blood pressure (low blood pressure), y: systolic blood pressure (high blood pressure).

It can be found that systolic blood pressure increases with diastolic blood pressure, and the physiological factors (atherosclerosis and angiotensin, etc.) for diastolic blood pressure explain 60% of variation in systolic blood pressure.

The approximate relationship between systolic blood pressure and diastolic blood pressure (n=878) is calculated as: y=1.7102x, where x: diastolic blood pressure (low blood pressure), y: systolic blood pressure (high blood pressure). It indicates that 1 mmHg increase of diastolic blood pressure means 1.7 mmHg (mean=1.7102, standard deviation=0.1513) increase of systolic blood pressure.

Relationship between systolic blood pressure and cardiac rate (n=878) is fitted as the following linear regression (Table 5):

y=87.72+0.4368x
r^2=0.0978, F=94.9582, p=0

where x: cardiac rate, y: systolic blood pressure (high blood pressure).

It can be found that systolic blood pressure increases with cardiac rate, and cardiac rate explains 10% of variation in systolic blood pressure.

Table 5 Relationships between systolic blood pressure, diastolic blood pressure, and cardiac rate*.

Variables	Period	*A*	*B*	r^2	*F*	*p*	*n*
x: diastolic blood pressure (low blood pressure), *y*: systolic blood pressure (high blood pressure)	2015 Aug-Sep	39.7355(±21.3104)	1.0917(±0.2603)	0.3835	69.0612	4.56E-08	113
	2018 Aug-Sep	53.962(±18.4365)	0.8991(±0.2349)	0.3219	57.4339	4.56E-08	123
	2020 Aug-Sep	35.5254(±17.6962)	1.1443(±0.2315)	0.4126	95.5297	0	138
	2024 Dec	17.1483(±7.7443)	1.5311(±0.1220)	0.5474	607.2262	0	504
	Total	**56.6141(±3.0211)**	**0.8906(±0.0500)**	**0.5823**	**1221.1131**	**0**	**878**
x: cardiac rate, *y*: systolic blood pressure (high blood pressure)	2015 Aug-Sep	146.0756(±12.1015)	-0.2148(±0.1508)	0.0670	7.9698	0.0056	113
	2018 Aug-Sep	112.4808(±17.2081)	0.1991(±0.2173)	0.0265	3.2877	0.0723	123
	2020 Aug-Sep	120.2185(±16.0969)	0.0340(±0.2161)	0.0007	0.0965	0.7565	138
	2024 Dec	110.2903(±11.3331)	0.0544(±0.1648)	0.0008	0.4204	0.5171	504
	Total	**87.7200(±6.4006)**	**0.4368(±0.0880)**	**0.0978**	**94.9582**	**0**	**878**
x: cardiac rate, *y*: diastolic blood pressure (low blood pressure)	2015 Aug-Sep	93.3500 (±6.7579)	-0.1458(±0.0842)	0.0959	11.7771	0.0008	113
	2018 Aug-Sep	67.2797(±10.6539)	0.1936 (±0.1346)	0.0628	8.1099	0.0052	123
	2020 Aug-Sep	77.3115(±9.0372)	-0.0149(±0.1172)	0.0004	0.0588	0.8038	138
	2024 Dec	61.7085(±5.4770)	0.0227(±0.0797)	0.0006	0.3146	0.5751	504
	Total	**29.2484 (±5.0791)**	**0.5690 (±0.0698)**	**0.2261**	**255.8687**	**0**	**878**

*±: half width of confidence interval, p=0.05.

Relationship between diastolic blood pressure and cardiac rate (n=878) is fitted as the following linear regression (Table 5):

y=29.2484+0.569x
r^2=0.2261, F=255.8687, p=0

where x: cardiac rate, y: diastolic blood pressure (low blood pressure).

It can be found that diastolic blood pressure increases with cardiac rate, and cardiac rate explains 23% of variation in diastolic blood pressure.

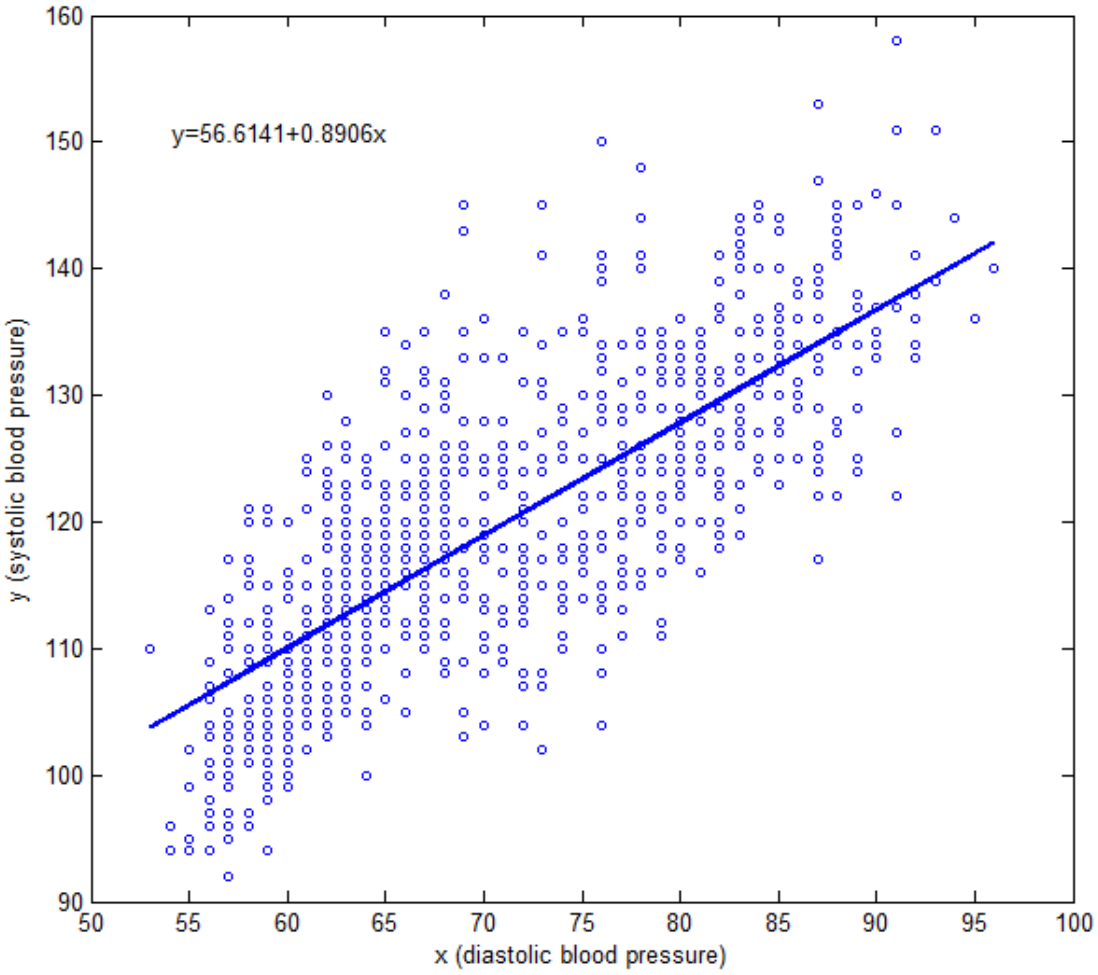

Fig. 6 Relationship between systolic blood pressure and diastolic blood pressure.

4 Conclusions

There is a significant difference between systolic blood pressures before and during one-time excise, between diastolic blood pressures before and during one-time excise, and between cardiac rates before and during one-time excise. Systolic blood pressure and diastolic blood pressure will decline 7 mmHg and 3 mmHg during one-time head tilt excise. Cardiac rate will decline 2 beats/min during one-time head tilt excise. Systolic blood pressure benefits mostly from one-time head tilt excise, seconded by diastolic blood pressure, and cardiac rate benefits least from one-time head tilt excise. The effect of one-time head tilt excise for lowering systolic blood pressure and cardiac rate significantly increases with systolic blood pressure and cardiac rate respectively.

There is a significant difference between systolic blood pressures before and after 15-min head tilt excise, and between diastolic blood pressures before and after 15-min head tilt excise. Systolic blood pressure and diastolic blood pressure will decline 8 mmHg and 5 mmHg respectively after 15-min head tilt excise. There is not significant difference between cardiac rates before and after 15-min head tilt excise. Systolic blood pressure benefits mostly from 15-min head tilt excise, seconded by diastolic blood pressure, and cardiac rate may not benefit from 15-min head tilt excise. The effect of 15-min head tilt excise for lowering systolic blood pressure, diastolic blood pressure and cardiac rate significantly increases with systolic blood pressure, diastolic blood pressure and cardiac rate respectively.

The effect of 15-min head tilt excise in lowering diastolic blood pressure significantly increases with time (days). In average, diastolic blood pressure declines 6 mmHg after one month. The effect in systolic blood pressure slightly increases with time. However for cardiac rate, the effect is not significant. Finally, we conclude that head tilt excise can be used as an effective treatment measure for instantly or permanently lowering blood pressure.

Systolic blood pressure increases with diastolic blood pressure and the physiological factors (atherosclerosis and angiotensin, etc.) for diastolic blood pressure explain 60% of variation in systolic blood pressure. Systolic blood pressure increases with cardiac rate and cardiac rate explains 10% of variation in systolic blood pressure. Diastolic blood pressure increases with cardiac rate and cardiac rate explains 23% of variation in diastolic blood pressure.

5 Discussion

On the mechanism of head tilt excise in lowering blood pressure, we hold that tilting head back interferes with the transmission of nerve signals from the brain to the organs, weakens sympathetic nerve activity, stimulates vagus nerve activity, decreases the secretion of angiotensin and some other blood pressure related substances to blood vessels, and reduces cardiac rate. All these lead to decline of blood pressure (Fig. 7). We hold that head tilt excise is a possible cure for rehabilitation treatment of hypertension (e.g., as a first aid measure or permanent measure) and deserves further research and application. Furthermore, it is also a possible cure for cardiac rate.

In practical applications, some adjustments on head tilt excise can be made according to individual circumstances. For example, the elderly can tilt their head back for a shorter time, while the young can tilt their head back for a longer time. We hope that more and further research will verify and improve the results of the present study in the future.

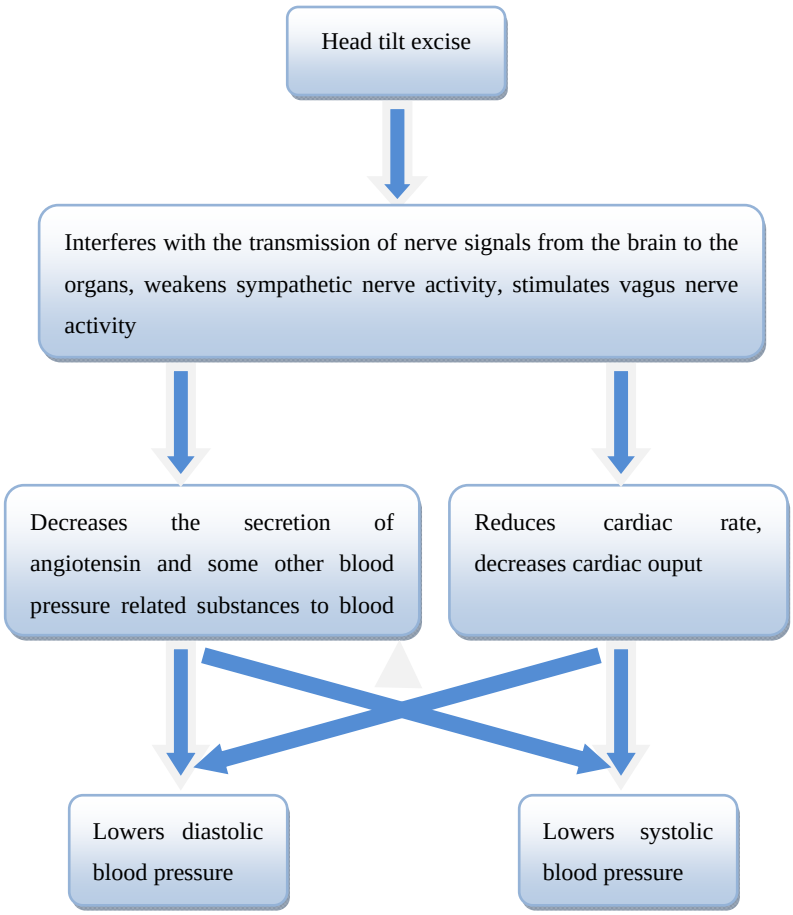

Fig. 7 The mechanism of head tilt excise in lowering blood pressure.

References

Hagberg JM, Park JJ, Brown MD. 2000. The role of exercise training in the treatment of hypertension: an update. Sports Medicine, 30: 193-206

Forrester SJ, et al. 2018. Angiotensin II signal transduction: an update on mechanisms of physiology and pathophysiology. Physiological Reviews, 98: 1627-1738

Fyhrquist F, Saijonmaa O. 2008. Renin-angiotensin system revisited. Journal of Internal Medicine, 264: 224-236

Lim SS, et al. 2012. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet, 380: 2224-2260

Guyton AC. 1991. Abnormal renal function and autoregulation in essential hypertension. Hypertension, 18: III49-III53

Guyenet PG. 2006. The sympathetic control of blood pressure. Nature Reviews Neurosciences, 7: 335-346

Grassi G, Mark A, Esler M. 2015. The sympathetic nervous system alterations in human hypertension.

Circulation Research 116: 976-990

Ito S, Komatsu K, Tsukamoto K, Kanmatsuse K, Sved AF. 2002. Ventrolateral medulla AT1 receptors support blood pressure in hypertensive rats. Hypertension, 40: 552-559

Li EC, Heran BS, Wright JM. 2014. Angiotensin converting enzyme (ACE) inhibitors versus angiotensin receptor blockers for primary hypertension. Cochrane Database of Systematic Reviews, 2014: CD009096

Malpas SC. 2010. Sympathetic nervous system overactivity and its role in the development of cardiovascular disease. Physiological Reviews, 90: 513-557

Murase S, Sakitani N, Maekawa T, et al. 2023. Interstitial-fluid shear stresses induced by vertically oscillating head motion lower blood pressure in hypertensive rats and humans. Nature Biomedical Engineering, 7: 1350-1373. https://doi.org/10.1038/s41551-023-01061-x

Muratani H, Ferrario CM, Averill DB. 1993. Ventrolateral medulla in spontaneously hypertensive rats: role of angiotensin II. American Physiological Society, 264: R388-R395

Nabika T, Ohara H, Kato N, Isomura M. 2012. The stroke-prone spontaneously hypertensive rat: still a useful model for post-GWAS genetic studies? Hypertension Research, 35: 477-484

Pescatello LS, MacDonald HV, Lamberti L, Johnson BT. 2015. Exercise for hypertension: a prescription update integrating existing recommendations with emerging research. Current Hypertension Reports, 17: 87

Zhang WJ. 2016. Selforganizology: The Science of Self-Organization. World Scientific, Singapore. https://www.worldscientific.com/worldscibooks/10.1142/9685#t=aboutBook

Zhang WJ. 2018. Fundamentals of Network Biology. World Scientific Europe, London, UK. https://www.worldscientific.com/worldscibooks/10.1142/q0149#t=aboutBook

Zhang WJ. 2020. imageProcAnal: A novel Matlab software package for image processing and analysis. Network Pharmacology, 5(1-2): 1-32. http://www.iaees.org/publications/journals/np/articles/2020-5(1-2)/Matlab-software-package-for-image-processing-and-analysis.pdf

Zhang WJ. 2021. Causality inference of linearly correlated variables: The statistical simulation and regression method. Computational Ecology and Software, 11(4): 154-161. http://www.iaees.org/publications/journals/ces/articles/2021-11(4)/causality-inference-of-linearly-correlated-variables.pdf

Zhang WJ. 2022a. Confidence intervals: Concepts, fallacies, criticisms, solutions and beyond. Network Biology, 12(3): 97-115. http://www.iaees.org/publications/journals/nb/articles/2022-12(3)/confidence-intervals-fallacies-criticisms-solutions.pdf

Zhang WJ. 2022b. Dilemma of *t*-tests: Retaining or discarding choice and solutions. Computational Ecology and Software, 12(4): 181-194. http://www.iaees.org/publications/journals/ces/articles/2022-12(4)/dilemma-of-t-tests.pdf

Zhang WJ. 2023. A desktop calculator for effect sizes: Towards the new statistics. Computational Ecology and Software, 13(4): 136-181. http://www.iaees.org/publications/journals/ces/articles/2023-13(4)/4-Zhang-Abstract.asp

Zhang WJ, Qi YH. 2024. ANOVA-nSTAT: ANOVA methodology and computational tools in the paradigm of new statistics. Computational Ecology and Software, 14(1): 48-67. http://www.iaees.org/publications/journals/ces/articles/2024-14(1)/4-Zhang-Abstract.asp