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The Effectiveness of Averrhoa Bilimbi L. Juice Combined with Stevia on Reducing Blood Pressure

Miftahunnisa Danti Ilato[1]*, Ida Leida Maria[1], Ridwan Amiruddin[1], Wahiduddin[1], Apik Indarty Moedjiono[2]

[1]Department of Epidemiology, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia
[2]Department of Biostatistics, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia
Email: miftailato@gmail.com
*Corresponding Author

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ABSTRACT
Management of hypertension can be done through complementary therapy using herbal plants, one of which is Averrhoa bilimbi L. which contains active compounds that can lower blood pressure. This study aims to determine the effectiveness of giving stevia-combined star fruit juice in lowering blood pressure in patients with hypertension. This experimental research uses a Non Randomized Pretest-Posttest Control Group study design. A total of 70 respondents who met the criteria were divided into two groups, namely 35 people in the intervention group who were given stevia-combined star fruit juice and consumption of antihypertensive drugs and 35 people in the control group who only took antihypertensive drugs. Blood pressure was measured before and after 7 days of intervention and analyzed using t-dependent. The mean blood pressure measurement in the intervention group before treatment was 148.08 mmHg and after was 134.28 mmHg, with a p value = 0.000. While in the control group, the average blood pressure measurement before treatment was 147.37 mmHg and after 140.91 mmHg, with a p value = 0.000. Consumption of drugs and herbal formulations such as stevia-combined star fruit juice can be an alternative that has minimal side effects and reduces toxic effects compared to synthetic drugs.

Keywords: averrhoa bilimbi l., stevia, blood pressure, hypertension.

INTRODUCITON

Hypertension is still a cause of sudden death because it often does not show any symptoms for a long time so not all people with hypertension are aware of the disease they suffer. WHO estimates that 1 in 4 people have hypertension which can be the leading cause of premature death in the world. As many as 1.28 billion adults aged 30-79 years worldwide are estimated to suffer from hypertension and 46% of them do not realize they have hypertension. While in Indonesia, hypertension is still a big challenge which is the most common occurrence in primary health care in Indonesia(Maria et al., 2022).

Related data also show that in 2023, the proportion of hypertensive patients who are irregular in hypertension treatment, in this case taking antihypertensive drugs, is still high at 36.4% and 16.9% do not take antihypertensive drugs. This shows that people with hypertension who get treatment are still low. In developing countries, the burden of disease caused by non-communicable diseases is increasing rapidly. If the current increase is left unaddressed and uncontrolled there could be significant economic and health burden consequences for the population, which in turn could threaten to overwhelm health services(Noor & Arsin, 2022).

Management of hypertension can be done through complementary therapy using herbal plants that can also control blood pressure. Consumption of herbal medicines and formulations can be an alternative that has minimal side effects and reduces toxic effects compared to synthetic drugs. Wuluh star fruit (Averrhoa bilimbi L.) is one of the herbal plants that contains active substances that can reduce blood pressure. Flavonoids in wuluh star fruit will inhibit the change of angiotensin I into angiotensin II by affecting the work of ACE. This causes a reduction in aldosterone secretion resulting in natriuresis. Decreased water and salt retention and water absorption result in decreased blood volume and thus decreased blood pressure(Syamsuddin & Puluhulawa, 2021).

Vitamin C contained in wuluh star fruit acts as a strong vasidilator antioxidant that can reduce oxidative stress and improve endothelial function through the production of nitric oxide or nitrogen oxide (NO). If there is an

increase in NO levels in the body, it will cause the endothelial relaxation process so that it can reduce blood pressure(Rahayu et al., 2022).
Star fruit has a sour taste, so to suppress the sour taste, star fruit can be combined with stevia to balance and add sweetness to the juice. Steviosid contained in stevia leaves has an antihypertension effect, this significantly suppresses systolic and diastolic blood pressure in experimental animals and humans(Raini, M., & Isnawati, 2012). In addition, glycosides in stevia extracts have also been found to dilate blood vessels and increase sodium output(Limanto Agus, 2017). To inhibit the growth of bacteria that can potentially grow in star fruit juice, ingredients that have antibacterial activity are needed, one of which is honey(Hidayatullah et al., 2022).
Based on the description described above, in an effort to reduce blood pressure through the utilization of the rich content of star fruit and stevia as a form of non-pharmacological treatment that is practical and easily accessible to the community, and no research has been conducted regarding the effect of consumption of a combination of star fruit juice with stevia, this study aims to determine the effectiveness of giving a combination of star fruit juice and stevia on changes in blood pressure in hypertensive patients in the working area of Tamalanrea District, Makassar City in this case Tamalanrea Health Center and Antara Health Center, Makassar City in 2024.

MATERIAL AND METHODS

The type of research used is Experimental in this case Quasi Experiment using a Non Randomized Pretest-Posttest Control Group study design. This study involved two groups, namely the intervention group which was given star fruit juice with a combination of stevia and antihypertensive drugs, and the control group which was only given antihypertensive drugs. This study was conducted in the working areas of Tamalanrea Health Center and Antara Health Center in Makassar City in August-October 2024.

Population and Sample

The population in this study amounted to 8,915 people with hypertension registered at the Tamalanrea Health Center and Antara Health Center in Makassar City. The sample size was determined using the Federer formula. Sample selection was carried out by purposive sampling based on inclusion and exclusion criteria. The inclusion criteria in this study are as follows: (1) Respondents are hypertensive patients registered at the Tamalanrea Health Center and Antara Health Center, (2) Domiciled in the kelurahan which is the working area of the Tamalanrea Health Center and Antara Health Center, (3) Do not have allergies to starfruit, and (4) Willing to become respondents and willing to be given intervention. While the exclusion criteria include: (1) Hypertensive patients who have a history of comorbidities such as impaired renal function, especially chronic renal failure and DM, (2) Hypertensive patients who have systolic blood pressure >180 mmHg, and (3) Pregnant and lactating women.
A total of 70 respondents who met the inclusion and exclusion criteria were divided into two groups, namely 35 people in the intervention group and 35 people in the control group. Participants of the Prolanis program of Tamalanrea Health Center were included in the intervention group and from Antara Health Center were included in the control group.

Juicing Preparation

The star fruit was first washed thoroughly and then cut each end of the star fruit. A total of 100 grams of star fruit was then soaked in water for 5 minutes at 70ºC using the blanching method for 1 minute. The star fruit was put into a slow juicer to produce star fruit juice plus 75 ml of water. Pure honey as much as 15 grams and stevia as much as 2 drops were added to the juice. All mixed results were put into 100 ml bottles to be given to each respondent.

Experimental Procedures

Initial blood pressure measurements were taken before the intervention using a tensimeter by health workers at the health center and interviews were conducted to collect information related to the general and clinical characteristics of the respondents. The intervention was carried out for 7 days with a team of enumerators by distributing 100 ml of stevia-combined star fruit juice to each respondent in the Tamalanrea Health Center working area. To see the development of respondents' blood pressure, measurements were taken on days 1, 3, 5, 7, and 8. Measurement on day 8 marked the end of data collection in the field.

Ethical Considerations

This study has been examined and obtained permission from the Research Ethics Commission of the Faculty of Public Health, Hasanuddin University, with number 1859/UN4.14.1/TP.01.02/2024. All respondents, both in the intervention and control groups, were given an explanation of the purpose of the intervention and the procedures to be carried out. The identity and privacy of respondents were kept confidential, and respondents were asked to sign a consent form before the study took place.

Data Analysis

Data were processed using STATA software version 14. This study applied two types of analysis, namely univariate and bivariate. Bivariate analysis was used to evaluate the effect of independent variables on the dependent variable with a significance level (P value) of 0.05. Independent T test was used to identify differences in blood pressure before treatment in the intervention and control groups. Meanwhile, the Mann-Whitney test was used to identify differences in blood pressure after treatment in the intervention and control groups. In addition, Dependent T test was used to analyze the difference in systole blood pressure before and after treatment in each group. Meanwhile, Wilcoxon test was used to analyze the difference in diastole blood pressure before and after treatment.

RESULTS

Phytochemical Analysis

Phytochemical analysis was conducted at the Makassar Health Laboratory Center, South Sulawesi, Indonesia, under the number 24020949-24027520/LHU/BBLK-MKS/VII/2024, to identify active compounds, such as flavonoid, vitamin C, and oxalate acid in averrhoa bilimbi l. juice combined with stevia.

Table 1 shows that the results of phytochemical tests on stevia-combined star fruit juice found several active compounds. In some cases, antioxidants can react with molecular oxygen and are reducing agents that can act as prooxidants (Sotler et al., 2019). Therefore, it is important to conduct phytochemical tests before intervening on the samples so that safety and consumption thresholds are maintained.

Table 1. Phytochemical Test Results

Tested Materials	Phytochemical Compounds	Unit	Results
Combination of averrhoa bilimbi l. juiceand stevia	Flavonoid	mg/L	11,42
	Vitamin C	mg/L	306,61
	Oxalic Acid	mg/g	24,00

Sample Characteristics

Based on Table 2, the majority of respondents were female (77.14%). The distribution in the intervention and control groups had the same proportion of 77.14% each. This is due to matching on the gender variable. Based on age group, most respondents were in the age group of 40-59 years with the highest number in the control group at 71.43%, while the lowest number in the intervention group was 60%. Overall, 65.71% of respondents were in this age group. Based on education, most respondents had a high school education background (64.39%), with the highest distribution of respondents in the intervention group (68.57%), while the lowest group was in the control group (60%). In terms of employment, the majority of respondents worked as housewives (55.71%). The highest distribution of respondents working as housewives was found in the control group (57.14%) compared to the intervention group (54.29%).

Table 2. Socio-Demographic Characteristics of The Sample

General Characteristics of Respondents	Intervention		Control		Total	
	n	%	n	%	n	%
Gender						
Male	8	22,86	8	22,86	16	22,86
Female	27	77,14	27	77,14	54	77,14
Age Group						
40-59 years old	21	60,00	25	71,43	46	65,71
≥60 years	14	40,00	10	28,57	24	34,29
Education						
Completed elementary school	3	8,57	4	11,43	7	10,00
Completed middle school	3	8,57	8	22,86	11	15,71
Completed high school	24	68,57	21	60,00	45	64,29
Completed bachelor's degree	4	11,43	2	5,71	6	8,57
Completed masters's degree	1	2,86	0	0,00	1	1,43
Jobs						
Housewife	19	54,29	20	57,14	39	55,71
Self-emplyoed	4	11,43	7	20,00	11	15,71

Labor	5	14,29	5	14,29	10	14,29
Civil servants	1	2,86	3	8,57	4	5,71
Retired	6	17,14	0	0,00	6	8,57
Marriage Status						
Marry	30	85,71	33	94,29	63	90,00
Divorce Life/Death	5	14,29	2	5,71	7	10,00

Table 3 compares clinical characteristics and health-related factors between intervention (n = 35) and control group (n = 35). Most respondents were in the overweight - obesity II BMI category, as many as 65.71%. Based on smoking behavior, most respondents did not smoke (85.71%). In terms of family history of hypertension, most respondents did not have a family history of hypertension (57.14%). Overall, 60% of respondents suffered from hypertension for ≥5 years. Based on respondents physical activity, 54.29% of respondents did not do physical activity.

Table 3. Clinical Characteristics of Samples

General Characteristics of Respondents	Intervention		Control		Total	
	n	%	n	%	n	%
Body Mass Index						
Underweight	1	2,86	1	2,86	2	2,86
Normal	9	25,71	13	37,14	22	31,43
Overweight	10	28,57	6	17,14	16	22,86
Obesity I	14	40,00	15	42,86	29	41,43
Obesity II	1	2,86	0	0,00	1	1,43
Smoking Behaviour						
Smoking	4	11,43	6	17,14	10	14,29
Non-smoking	31	88,57	29	82,86	60	85,71
Family History						
Yes	16	45,71	14	40,00	30	42,86
No	19	54,29	21	60,00	40	57,14
Duration of Suffering						
<5 years	13	37,14	15	42,86	28	40,00
≥5 years	22	62,86	20	57,14	42	60,00
Physical Activity						
Yes	17	48,57	15	42,86	32	45,71
No	18	51,43	20	57,14	38	54,29

Blood Pressure Analysis Before and After Intervention

Based on the results of the analysis in Table 4shows that both the intervention group and the control group both experienced a decrease in blood pressure after the intervention. However, the decrease in blood pressure was higher in the intervention group compared to the control group. In systole blood pressure, the intervention group have a significantly higher percentage reduction (9,31% with the avarage 148,08 mmHg to 134 mmHg, P = 0,000 vs 4,38% with the avarage 147,37 mmHg to 140,91 mmHg, P = 0,000). The result showed something similar for diastole blood pressure (9,97% with the avarage 95,94 mmHg to 86,37 mmHg, P = 0,000 vs 3,02% with the avarage 94,31 mmHg to 89,71 mmHg, P = 0,000).

Table 4. Analysis of Blood Pressure Decrease Before and After Intervention

Group	Variable	Mean (mmHg)	Standard Deviation	Δ Mean	P-Value
Systolic Blood Pressure					
Intervention	Pre-Test	148,08	11,71	13,80	0,000*
	Post-Test	134,28	7,78		
Control	Pre-Test	147,37	11,97	6,45	0,000*
	Post-Test	140,91	12,46		
Diastolic Blood Pressure					
Intervention	Pre-Test	95,94	10,04	9,57	0,000**
	Post-Test	86,37	4,35		

Control	Pre-Test	94,31	6,28	4,60	0,000**
	Post-Test	89,71	6,09		

notes: *dependent t-test, **wilcoxon test

Differences in Pre-Test and Post-Test Blood Pressure Between Groups

Table 5 shows that the average size of systole blood pressure at pre-test was higher in the intervention group (148,08 mmHg vs 147,37 mmHg, P = 0,400). While at the post-test, the average size of systole blood pressure was higher in the control group (140,91 mmHg vs 134,28 mmHg, P = 0,007). As for the diastole blood pressure, the average size of blood pressure at pre-test was higher in the intervention group (95.94 mmHg vs 94.31 mmHg, P = 0.209). While at the post-test, the average size of diastolic blood pressure was higher in the control group (89.71 mmHg vs 86.37 mmHg, P = 0.000).

Table 5. Analysis of Pre-Post Test Blood Pressure Differences between Groups

Groups	Variable	Mean (mmHg)	Standard Deviation	∆ Mean	P-Value
Systolic Blood Pressure					
Pre-test	Intervention	148,08	11,71	0,71	0,400*
	Control	147,37	11,97		
Post-test	Intervention	134,28	7,78	- 6,62	0,007**
	Control	140,91	12,46		
Diastolic Blood Pressure					
Pre-test	Intervention	95,94	10,04	1,62	0,209*
	Control	94,31	6,28		
Post-test	Intervention	86,37	4,35	- 3,34	0,000**
	Control	89,71	6,09		

notes: *indendent t-test, **mann-whitney test

DISCUSSION

The results showed a decrease in blood pressure in the intervention and control groups. The intervention group showed better results because star fruit contains active compounds that have an effect in lowering blood pressure. Research conducted by Kusuma et al. showed that the results of antioxidant activity screening tests conducted on star fruit using the DPPH method identified the presence of flavonoids, alkaloids, saponins, and terpenoids, while other secondary metabolite tests such as tannin, phenol, and steroid tests did not have positive results(Kusuma et al., 2023).

Phytochemical tests conducted on stevia-combined star fruit juice produced important findings related to the content of bioactive compounds such as flavonoids, vitamin C, and oxalic acid. The flavonoid content and its derivative compounds are proven to help relax the vascular endothelium through the activation of endothelial nitric oxide synthase (eNOS) which can trigger an increase in NO production which will stimulate the release of prostacyclin which is a strong vasodilator so that its release causes dilatation of blood vessels (Yani et al., 2022). ACE plays a role in the mechanism of hypertension through the formation of angiotensin II from angiotensin I by ACE. A higher concentration of ACE will result in an increased concentration of angiotensin II. High angiotensin II can cause a progressive increase in blood pressure through two mechanisms: vasoconstriction in the peripheral arteries and increased excretion of salt and water by the kidneys. The retention of sodium and water in the kidneys causes plasma volume to increase so that venous return blood flow to the heart also increases. Thus, there is an increase in cardiac output which leads to an increase in arterial pressure(Kalangi et al., 2015). With the inhibition of ACE by flavonoids, the process will also be inhibited so that blood vessels canvasodilate, resulting in a decrease in total perypheal resistance (TPR). In addition, the excretion of water and salt in the kidneys will also decrease so that cardiac output and blood pressure also decrease (Mulyani et al., 2019).

Vitamin C content in star fruit is a strong antioxidant to reduce oxidative stress and improve endothelial function through NO production. Vitamin C will increase the concentration of intracellular tetrahydribioprotein which is a cofactor of endothelial NO synthase so that the production and bioactivity of NO can increase which will ultimately cause vasodilation or dilation of blood vessels in the body (Safitri & Candra, 2015). If there is a decrease in NO levels, it can cause the endothelial relaxation process to be disrupted, resulting in hypertension. Conversely, if there is an increase in NO levels in the body, it will cause the endothelial relaxation process so that it can reduce blood pressure (Rahayu et al., 2022).

The stevia-combined star fruit juice was made based on previously established procedures. The process of making stevia-combined star fruit juice was carried out in the Product Development Laboratory. This can

support the quality of the stevia-combined star fruit juice because the tools used have been sterilized in advance based on sterilization procedures to avoid the growth and pollution of other microorganisms that are not expected during the product manufacturing process(Azizah et al., 2020).

The intervention was conducted for 7 days on a regular basis which influenced the decrease in blood pressure in hypertensive patients, especially in the intervention group. After the intervention, blood vessels become wider which is associated with an increase in NO concentration. NO in the blood will affect the cardiovascular system positively by stimulating vasodilation of the muscle wall in blood vessels, inhibiting the adhesion of inflammatory cells, and inhibiting the formation of leukocyte thrombosis on the blood vessel wall(Solfaine et al., 2021). The results of this study are consistently in line with research conducted by which revealed the presence of alkaloid phytochemical compounds, carbohydrates, phenols, flavonoids, saponins, and tannins in star fruit extract. The discovery of these compounds in belimbing wuluh explains the antioxidant activity of the plant(Suluvoy & Berlin Grace, 2017).

Behind the benefits of star fruit, star fruit has a high oxalate acid content which can cause health problems if consumed excessively. This occurs due to the deposition of calcium oxalate crystals in the renal tubules. Oxalate nephropathy can occur in primary and secondary hyperoxaluria. Secondary hyperoxaluria may occur due too increased intake of oxalate from the diet, increased absroption of oxalate from the gut (enteric hyperoxaluria), and increased oxalate production. Enteric hyperoxaluria is mainly caused by fat malabsroption leading to increased absroption of soluble oxalate from the colon. Calicum will bind to free fatty acids that cannot be absrobed. This reduces the normal precipitation of calcium oxalate in the feces thus allowing the absroption of soluble oxalate from the intestine (Wang et al., 2022).

In addition, star fruit contains high oxalic acid, so the daily consumption of star fruit must be taken into account. The safe level of oxalate consumption for the body is no more than 1.25 grams per day for six consecutive weeks. This study was conducted for 7 days, meaning that the total level of oxalic acid consumed for 7 days was 8.4 grams. This shows that the stevia-combined star fruit juice containing oxalic acid levels of 1.2 g/100 g of star fruit does not exceed the lethal dose of oxalic acid in adult humans so it is safe for consumption for 7 days. In addition, in this study, soaking or boiling of star fruit before blending was carried out to anticipate high levels of oxalic acid in star fruit. The boiling process can reduce oxalic acid levels by increasing oxalic acid levels in the water of the wuluh star fruit stew(Nabila Afri & Audina, 2020). Boiling is done with the blanching method, which is by putting the star fruit into water that has been boiling at 70ºC for a short time. This is done to maintain compounds such as flavonoids and vitamin C which have antihypertensive effects (Sapkota et al., 2022).

In this study, a combination with stevia was carried out as an alternative sweetener for sugar substitutes that is low in calories and safe for consumption by diabetics and other disease sufferers. In stevia leaf extract, stevioside and rebaudioside are the main sweet components with a sweetness level 300 times sweeter than sucrose. The level of sweetness possessed by stevia causes researchers to only use two drops of stevia in star fruit juice, which is able to cover a little sour taste in star fruit. In its use, stevia can be consumed directly or processed first into powder or liquid form. The research conducted used stevia in liquid form which was added to the final process of making wuluh star fruit juice (Limanto Agus, 2017).

Star fruit is acidic, high in fiber, calcium, phosphorus, iron, and potassium. In addition, star fruit also contains chemical compounds, namely formic acid, citric acid, ascorbic acid (vitamin C), saponins, tannins, flavonoids, glucosides, riboflavin, vitamin B1, niacin, ascorbic acid, carotene, and vitamin A. Star fruit juice combined with stevia is also added with pure honey to reduce the sour taste of star fruit. The selection of honey as an ingredient in reducing the sour taste is also based on the properties of honey which also plays a role in blood pressure because it contains antioxidants(Sulistiawati & Putriningtyas, 2023). In addition, honey also has broad-spectrum antimicrobial activity, namely as anti-bacterial, anti-fungal, anti-viral, and antioxidant so that it can prevent spoilage in products or extend shelf life(Suwito et al., 2024).

CONCLUSION

The conclusion of this study shows that there is a significant difference in blood pressure between the intervention group and the control group with an average decrease in blood pressure in the intervention group of 13.8 mmHg with a percentage decrease of 9.31%, while in the control group was 6.45 mmHg with a percentage decrease of 4.38%, so it can be said that by consuming star fruit juice combined with stevia and consumption of antihypertensive drugs can reduce blood pressure 2.12 times more effective than just taking antihypertensive drugs.

Conflict of interest

The authors certify that there is no conflict of interest with any financial organization regarding the materian discussed in the manuscript.

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Authors' contributions
Miftahunnisa Danti Ilato, Ida Leida Maria, Ridwan Amiruddin, Wahiduddin, and ApikIndarty Moedjiono contributed equally to the manuscript. All authors read and approved the final version of the manuscript.

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