

Original Research

The Effect of Transdermal Application of Ananas comosus Peel Extract on Lowering Blood Pressure: A Randomized Controlled Trial



Eva Riantika Ratna Palupi¹, Yudisa Diaz Lutfi Sandi^{1*}, Rahmi Rahmawati², & Tatang Hidayah³

¹*School of Health Sciences, Politeknik Negeri Subang, Subang, Indonesia*

²*Department of Agriculture, Politeknik Negeri Subang, Subang, Indonesia*

³*Kalijati Public Health Center, Subang, Indonesia*

Article Info	Abstract
Article history: Received: 05 December 2025 Accepted: 21 April 2026	<i>Introduction:</i> This study examined whether transdermal application of Ananas comosus peel extract could effectively reduce blood pressure in elderly hypertensive patients within a primary health care setting. <i>Methods:</i> A randomized controlled trial was conducted in which participants were allocated to an intervention group receiving transdermal Ananas comosus peel extract plus usual care or a control group receiving usual care alone. The intervention group received daily transdermal application of Ananas comosus peel extract with usual care, while the control group usual care only, over seven consecutive days. Blood pressure was followed up each evening. Data were analysed using generalized estimating equations (GEE) to assess group, time, and group-by-time interaction effects. <i>Results:</i> GEE showed a significant group-by-time interactions were observed for SBP, DBP, and MAP. Compared with the control group, the intervention group demonstrated significant reductions in these blood pressure during the early intervention period, with the largest effects starting from 4–5 days. Interaction analyses indicated that reductions in blood pressure were significantly greater in the pineapple balm group compared with the control group during the later observation period. The blood pressure lowering effect trend diminished towards the end of the observation period. <i>Conclusion:</i> Transdermal application of Ananas comosus peel extract statistically significant and time-dependent reduction in blood pressure, with continued improvement until one week. These findings support its potential as a non-pharmacological adjunct in managing essential hypertension among older adults.
Keywords: elderly, flavonoid, hypertension, ananas comosus, randomized controlled trial	

*Corresponding Author:

e-mail: yudisadiaz@gmail.com



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INTRODUCTION

Hypertension remains a leading cause of morbidity and mortality globally and contributes significantly to cardiovascular disease burden. The World Health Organization reported that approximately 1.3 billion adults worldwide suffer from hypertension, with a growing prevalence in low- and middle-income countries (LMICs) [1]. Worldwide, approximately one of five adults have their hypertension under control, but in LMICs only one of ten controlled hypertension [2]. The pathophysiology of hypertension involves multiple factors, including endothelial dysfunction, sympathetic overactivation, oxidative stress, and renin angiotensin aldosterone system (RAAS) dysregulation [3], [4]. Chronic oxidative stress causes vascular inflammation and remodeling [5] and metabolic disorder such as obesity [6], leading to increased peripheral resistance and sustained elevation of blood pressure.

Pharmacological interventions such as angiotensin-converting enzyme (ACE) inhibitors, β -blockers, and calcium channel blockers are effective, but they often produce undesirable side effects and require lifelong administration [7]. This challenge encourages the exploration of phytopharmacological alternatives with lower toxicity and multi-target mechanisms. Among various natural products, pineapple (*Ananas comosus*) peel often discarded as agricultural waste has emerged as a rich source of bioactive compounds including flavonoids, bromelain, tannins, and phenolic acids [8].

Pineapple peel, previously considered agricultural waste, contains bioactive compounds with high pharmacological potential, such as flavonoids (quercetin, kaempferol, rutin), bromelain, tannins, and phenolic acids [9]. These similar compounds have been reported to have antihypertensive activity through various mechanisms, including inhibition of ACE, increased endothelial nitric oxide (NO) production, and decreased expression of endothelin-1, which plays a role in vasoconstriction [10], [11]. A previous experimental studies stated that flavonoid-rich extracts can reduce systolic (SBP) and diastolic blood pressure (DBP) through improved nitric oxide bioavailability and suppression of vascular oxidative damage [12].

Despite these promising data, most previous studies focused on oral or systemic administration of pineapple or flavonoid extracts [13], [14]. These routes may suffer from limited bioavailability due to first-pass hepatic metabolism, gastrointestinal degradation, and variable absorption rates [15]. Furthermore, research evaluating the antihypertensive potential of pineapple peel flavonoids in topical or transdermal delivery forms is virtually absent. The skin, being richly vascularized and capable of systemic absorption through lipophilic pathways, offers a novel and patient-friendly route for sustained delivery of active compounds [16]. However, transdermal phytotherapy may not produce immediate systemic effects, as absorption through the skin is often gradual and may lead to a delayed but cumulative pharmacological response.

Another critical research gap is the lack of human clinical evidence, particularly in a controlled, community-based setting. Existing animal studies have confirmed biochemical effects but rarely translate these findings into clinically measurable blood pressure outcomes or comprehensive monitoring of hemodynamic parameters such as mean arterial pressure (MAP) in human subjects [17]. Moreover, the integration of biomolecular quantification with pharmacodynamic outcomes in topical formulations has not yet been investigated.

To address these gaps, this present study proposes aims to examine the effectiveness of a flavonoid-enriched pineapple peel extract formulated as a topical balm applied over the parotid pulse region in hypertensive adults. This approach is expected to enable gradual transdermal absorption and sustained vascular effects while minimizing systemic side effects, and it is particularly relevant in LMIC settings, where accessible, low-cost, and non-invasive therapeutic alternatives are critically needed.

METHODS

Study Design and Randomization

This study employed a randomized controlled trial (RCT) design involving 86 older adults (≥ 60 years) with a documented history of hypertension. Participants were randomly allocated by researcher using sealed envelope into intervention and control groups in a 1:1 ratio. Participants were not informed about the randomization process and were not explicitly told which study group they were

assigned to. This approach was intended to minimize expectation bias. Outcome assessment was standardized using automated blood pressure devices to minimize measurement bias. The trial was conducted over a 7-day period, with daily monitoring of blood pressure parameters. The study adhered to Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) guidelines [18].

Study Setting Participants

The study was conducted at Kalijati Public Health Centre (Puskesmas Kalijati), a primary health centre in West Java, Indonesia. All procedures were supervised by Penyakit Tidak Menular (PTM) program officer, who ensured protocol adherence and participant safety throughout the trial.

Participants were recruited from the facility's chronic disease registry. Inclusion criteria comprised: (1) age ≥ 60 years; (2) diagnosis of stage 1 - 2 essential hypertension according to Indonesian Hypertension Guidelines [19]; (3) stable antihypertensive medication regimen for at least 4 weeks prior to enrolment; and (4) Participants were required to have access to a mobile phone with WhatsApp (either personal or via a caregiver) for daily reporting.. Exclusion criteria included: secondary hypertension, severe comorbidities (e.g., heart failure NYHA class III-IV, end-stage renal disease), skin conditions at application sites, known allergy to pineapple products, or cognitive impairment preventing reliable self-

measurement and reporting of blood pressure.

Sample Size Calculation

Sample size was determined using G*Power 3.1 software [20] based on a one-tailed with $\alpha = 0.05$, power $(1-\beta) = 0.80$, and an effect size (Cohen's d) of 0.65 with t-test family, statistical test mode: Mean difference between independent means (two groups), derived from prior studies evaluating natural antioxidant-based antihypertensive interventions [13]. The calculation yielded 30 participants per group. To account for an anticipated 5% dropout rate, the total target sample was increased to 63 participants in total or 32 per group as minimum.

Flavonoid Extraction and Balm

Formulation Standard

The development of an effective and stable balm formulation is a critical step to ensure consistent dosing and optimal absorption of bioactive compounds. Topical balm formulations must consider the physicochemical properties of flavonoids, which are generally lipophilic and exhibit poor aqueous solubility [21]. Petroleum jelly (white Vaseline) was frequently employed as a balm base due to its ability to dissolve lipophilic compounds, low toxicity, and strong adhesive properties [21].

The initial step involves the extraction of flavonoids from pineapple peel. In the present study, conventional maceration was employed due to its accessibility. The process involved drying pineapple peel at 60°C until a constant dry weight was achieved [22]. The

raw materials were derived from *Ananas comosus*. Once dried, the peel was ground into fine powder, which was subsequently extracted with 70% ethanol for 24 hours at room temperature.

Following extraction, the filtrate was evaporated to obtain crude extract in the form of a paste or dense powder. The next step was standardization to determine the total flavonoid content (TFC). This standardization is essential to ensure that each batch of balm contains a uniform flavonoid dose. Spectrophotometric methods, such as the AlCl_3 assay was employed to quantify TFC [23]. This indicates that the flavonoid content in MD2 pineapple peel is more than twice that of the core. These values serve as the basis for standardized flavonoid composition.

Elevated topical doses were necessary because only a fraction of the compound is absorbed through the skin. For this study, a realistic dose estimation is required. Considering that topical doses typically range between 500–1000 mg/day, a 5 mg balm per application appears insufficient to achieve systemic antihypertensive effects. Each gram of crude extract contains approximately 10 mg of flavonoids.

Intervention Group

Participants in the intervention group applied a flavonoid-based balm topically to the parotid region approximately 1 gram of flavonoid balm per application (total amount), which was evenly distributed between the right and left parotid regions region three times daily for 7 consecutive days at morning, midday, and evening.

Participants were instructed to perform a gentle circular massage for 2 minutes, which increases absorption through the skin [24]. Participants continued their prescribed antihypertensive medications throughout the study period. Adherence and compliance were monitored daily through direct reporting and verification by researchers via WhatsApp.

Control Group

Participants in the control group received standard care, consisting of antihypertensive medications prescribed by the primary health centre. Control group received usual care. No placebo or sham intervention was administered. Similar with the intervention group, adherence to prescribed medications was verified through daily WhatsApp reporting. Adherence and compliance were similarly monitored to ensure comparability between groups.

Outcome Measure

The primary outcomes measured were morning SBP, DBP, and MAP measured daily for seven consecutive days. Blood pressure was measured using validated digital sphygmomanometers after a minimum 5-minute rest in seated position. All devices were calibrated prior to study. Measurements were performed at home by participants who received standardized training on proper technique by registered nurse prior to study initiation. Due to the limited availability of sphygmomanometers, data collection was conducted in alternating sessions rather than simultaneously across all participants. Each

measurement was scheduled according to the study protocol, with participants adhering to the designated timing for blood pressure assessment and subsequent intervention procedures. Due to limited device availability, measurements were conducted in scheduled sessions across participants. All participants received standardized training on measurement procedures, and assessments were performed according to a predefined protocol. This approach safeguarded methodological rigor and preserved the validity of the findings by minimizing potential bias related to equipment availability.

Data Collection

Blood pressure (SBP, DBP, and MAP) report was collected once daily (evening) for 7 consecutive days, in both intervention or control group. Participants reported their blood pressure via WhatsApp to the research team, ensuring real-time monitoring and minimizing missing data. Daily reminders were sent to enhance compliance. Follow-up was completed for all participants over the 7 days study period.

Data Analysis

Statistical analyses were performed using SPSS version 28.0 (IBM Corp., Armonk, NY) with a two-tailed significance threshold of $\alpha = 0.05$. Continuous variables are presented as mean and standard deviation (SD), as appropriate, while categorical variables are presented as frequencies and percentages.

To evaluate the intervention effects on SBP, DBP, and MAP over time, a generalized

estimating equation (GEE) unstructured model was used. GEE was chosen to account for within-subject correlations arising from repeated measurements and to provide robust estimates of population means. The models were specified using a Gaussian distribution with an identity link function, appropriate for continuous outcome variables (SBP, DBP, and MAP). Separate GEE models were constructed for each outcome variable, including group (intervention vs. control), time (day), and the group $\times$ time interaction as independent variables. The control group and the last observation day were designated as reference categories.

Ethical Considerations

Ethical approval for this study was obtained from the Ethics Committee of Stikes Muhammadiyah Ciamis (identifier number: 141/KEPK-STIKESMUCIS/X/2025). All research procedures were conducted in full compliance with international ethical guidelines, specifically the Declaration of Helsinki. Participants were provided with detailed information regarding the study objectives, potential benefits, risks, and their rights. Written informed consent was obtained from all participants prior to enrolment.

The study protocol incorporated measures to minimize risk. As the intervention involved topical application, systemic risks were considered minimal; however, local risks required careful evaluation. The primary anticipated risk was the occurrence of cutaneous allergic reactions (irritant or allergic contact dermatitis). To

mitigate this, all raw materials (pineapple peel, petroleum jelly, and other excipients) were verified for safety. Prior to randomization, each prospective participant underwent a tolerance test on a small skin area to ensure no irritation or allergic response to the balm base. The application site (parotid pulse region) was selected for its relative safety compared to other areas, despite its proximity to vital head structures. Explicit instructions were provided to avoid vigorous massage, thereby minimizing potential risks to the carotid sinus.

In addition, strict safety management procedures were implemented. Participants were instructed to promptly report any dermatological changes (erythema, pruritus, swelling) or systemic symptoms (dizziness, headache) via a WhatsApp-based reporting system integrated with the rapid-response health services of the local primary health centre, enabling timely medical intervention. Data collectors examined the application site at each visit. All adverse events were documented, assessed for their relationship to the intervention, and managed according to protocol. Associations between treatment groups and adverse events were analysed to evaluate the safety profile of the balm.

RESULTS

Participant Characteristics

A total of 64 elderly participants were enrolled, with 32 assigned to the intervention group and 32 to the control group. As shown in Table 1, no statistically significant differences were observed between groups in

baseline characteristics, including age, sex, duration of hypertension, body weight, BMI, diabetes mellitus status, family history of hypertension, and smoking status (all $p > .05$). The mean age was 64.8 ± 3.9 years in the intervention group and 65.1 ± 4.2 years in the control group ($p = .712$). These findings confirm that both groups were demographically and clinically homogeneous at baseline, these findings indicate that both groups were comparable at baseline.

Effect on Systolic Blood Pressure

The findings revealed a significant group-by-time interaction for SBP, indicating different SBP trajectories between the intervention and control groups across the 7-day follow-up (Table 2). At baseline, there was no statistically significant difference in SBP between groups ($B = 0.41$, $SE = 1.96$, $\chi^2 = 0.04$, $p = .836$), indicating initial comparability.

Within the intervention group, SBP decreased progressively and significantly from baseline over time. Significant reductions were observed from day 2 onward ($B = -2.22$, $SE = 1.01$, $p = .028$), with the magnitude of reduction increasing across the observation period, indicating a cumulative treatment effect.

The interaction terms represent the difference in SBP change between the control group and the intervention group. No significant interaction effects were observed on day 2 and day 3 ($p = .271$; $p = .073$), respectively. However, from day 4 onward, significant interaction effects emerged ($B = 5.22$, $SE = 2.13$, $p = .014$), indicating that the reduction in SBP was significantly greater in

the intervention group compared with the control group during the later observation period.

Overall, these findings demonstrate a significant time-dependent treatment effect, with the intervention group showing a progressively greater reduction in SBP compared with the control group, particularly from day 4 onward.

Effect on Diastolic Blood Pressure

For DBP, the GEE model demonstrated a significant group-by-time interaction, suggesting differential DBP responses between groups over time (Table 3). At baseline, there was no significant difference in DBP between groups ($B = 0.41$, $SE = 1.71$, $p = .813$), confirming comparability prior to intervention.

Within the intervention group, DBP decreased progressively over time relative to baseline. Statistically significant reductions were observed from day 4 onward ($B = -3.72$, $SE = 1.35$, $p = .006$), with greater reductions observed across subsequent days, indicating a cumulative treatment effect. Reductions on day 2 ($p = .305$) and day 3 ($p = .077$) were not statistically significant ($p > .05$).

The interaction terms represent the difference in DBP change between the intervention group and control group. No significant interaction effects were observed during the early observation period (day 2–day 4; $p > .05$). However, significant interaction effects emerged from day 5 onward ($p < .05$), indicating that the reduction in DBP was greater in the intervention group

compared with the control group during the later observation period.

These indicate a significant time-dependent treatment effect, with the intervention group demonstrating progressively greater reductions in DBP compared with the control group, particularly from day 5 onward.

Effect on Mean Arterial Pressure

Analysis of MAP using GEE revealed a significant group-by-time interaction, indicating different MAP trends between the intervention and control groups. At baseline, no significant difference in MAP was observed between groups ($B = 0.44$, $SE = 1.72$, $p = .800$), indicating comparability prior to treatment initiation (Table 4).

Within the intervention group, MAP decreased progressively over time relative to

baseline. Statistically significant reductions were observed on day 3 onward ($B = -3.25$, $SE = 1.53$, $p = .034$). The reduction on day 2 did not reach statistical significance ($p = .093$).

The interaction effects represent the difference in MAP change between the intervention group and control group. No significant interaction effects were observed during the early observation period (day 2–day 4; $p > .05$). However, significant interaction effects emerged from day 5 onward ($p > .05$), indicating that the reduction in MAP was greater in the intervention group compared with the control group during the later observation period.

Overall, these findings indicate a significant time-dependent treatment effect, with the intervention group demonstrating progressively greater reductions in MAP compared with the control group, particularly from day 5 onward.

Table 1.

Demographic elderly characteristic (N=64)

Variable	Intervention	Control	p-value
Age (years)	64.8 ± 3.9	65.1 ± 4.2	0.712 ^a
Sex (Male/Female)	18 / 14	17 / 15	0.802 ^b
Duration of hypertension (years)	5.2 ± 2.0	5.0 ± 2.1	0.684 ^a
Body weight (kg)	64.2 ± 9.1	65.0 ± 8.7	0.682 ^a
BMI (kg/m ²)	25.2 ± 3.1	25.4 ± 3.3	0.774 ^a
Diabetes mellitus (%)	28.1%	25.0%	0.777 ^b
Family history of hypertension (%)	68.8%	71.9%	0.781 ^b
Smoking status (active, %)	18.8%	21.9%	0.752 ^b

^a= t-test ^b= Chi-square

Table 2.

Effectiveness on SBP (N=64)

Parameter	B	SE	95% CI	Wald χ^2	p
Baseline Difference between groups	0.41	1.96	-3.43 – 4.25	0.04	.836
Time Effects (vs Baseline)					
Day 2	-2.22	1.01	-4.20 – -0.24	4.80	.028
Day 3	-4.72	1.31	-7.30 – -2.14	12.88	<.001
Day 4	-7.06	1.65	-10.30 – -3.82	18.24	<.001
Day 5	-8.78	1.70	-12.11 – -5.45	26.75	<.001
Day 6	-10.25	1.55	-13.29 – -7.21	43.56	<.001
Day 7	-11.19	1.63	-14.38 – -8.00	47.24	<.001
Group*Time					
Day 2	1.50	1.36	-1.17 – 4.17	1.21	.271
Day 3	3.25	1.81	-0.30 – 6.80	3.22	.073
Day 4	5.22	2.13	1.05 – 9.39	6.01	.014
Day 5	6.63	2.25	2.21 – 11.04	8.67	.003
Day 6	7.81	2.28	3.35 – 12.28	11.77	.001
Day 7	8.47	2.34	3.88 – 13.06	13.07	<.001

Note. SE= Standard error; CI= Confidence interval

Table 3.

Effectiveness on DBP (N=64)

Parameter	B	SE	95% CI	Wald χ^2	p
Baseline Difference between groups	0.41	1.71	-2.95 – 3.76	0.06	.813
Time Effects (vs Baseline)					
Day 2	-1.19	1.16	-3.46 – 1.08	1.05	.305
Day 3	-2.47	1.40	-5.20 – 0.27	3.13	.077
Day 4	-3.72	1.35	-6.37 – -1.06	7.54	.006
Day 5	-4.88	1.38	-7.58 – -2.17	12.48	<.001
Day 6	-5.47	1.27	-7.96 – -2.98	18.56	<.001
Day 7	-5.72	1.33	-8.32 – -3.11	18.52	<.001
Group*Time					
Day 2	0.72	1.46	-2.15 – 3.58	0.24	.623
Day 3	1.94	1.80	-1.60 – 5.47	1.15	.283
Day 4	3.06	2.02	-0.89 – 7.02	2.31	.129
Day 5	4.16	2.09	0.05 – 8.26	3.94	.047
Day 6	4.47	1.99	0.57 – 8.36	5.06	.025
Day 7	4.66	2.21	0.32 – 8.99	4.43	.035

Note. SE= Standard error; CI= Confidence interval

Table 4.

Effectiveness on MAP (N=64)

Parameter	B	SE	95% CI	Wald χ^2	p
Baseline Difference in between groups	0.44	1.72	-2.94 – 3.81	0.06	.800
Time Effects (vs Baseline)					
Day 2	-1.53	0.91	-3.32 – 0.26	2.82	.093
Day 3	-3.25	1.53	-6.25 – -0.25	4.51	.034
Day 4	-4.84	1.68	-8.14 – -1.55	8.30	.004
Day 5	-6.22	1.73	-9.61 – -2.83	12.92	<.001
Day 6	-7.06	1.67	-10.34 – -3.78	17.80	<.001
Day 7	-7.59	1.80	-11.13 – -4.06	17.72	<.001
Group*Time					
Day 2	1.06	1.31	-1.51 – 3.63	0.66	.418
Day 3	2.44	1.93	-1.34 – 6.21	1.60	.205
Day 4	3.88	2.10	-0.25 – 8.00	3.40	.065
Day 5	5.00	2.31	0.47 – 9.53	4.68	.030
Day 6	5.53	2.35	0.93 – 10.13	5.55	.018
Day 7	5.97	2.47	1.13 – 10.81	5.84	.016

Note. SE= Standard error; CI= Confidence interval

DISCUSSION

This randomized controlled trial demonstrated that transdermal application of *Ananas comosus* peel extract, when combined with usual care, produced significant reductions in SBP, DBP, and MAP compared with usual care only.. The effect of the intervention was not immediate but became statistically significant after several days of repeated application and increased progressively over time. Importantly, no significant temporal changes were observed in the control group, supporting the specificity of the intervention effect. These findings suggest that *Ananas comosus* peel extract may exert a time-dependent blood pressure-lowering effect when delivered via the transdermal route.

The observed reduction in blood pressure may be partially explained by a plausible but unconfirmed pathway, namely by the bioactive constituents of *Ananas*

comosus rind, particularly bromelain and polyphenolic flavonoids. Bromelain, a proteolytic enzyme complex abundant in pineapple by-products, has been reported to exhibit anti-inflammatory, antithrombotic, and fibrinolytic properties, which may contribute to improved endothelial function and reduced peripheral vascular resistance [25], [26]. Inflammatory processes and endothelial dysfunction are well-recognized contributors to hypertension, and modulation of these pathways could potentially contribute to the early blood pressure reductions observed in this study.

In addition, pineapple peel is rich in flavonoids and other phenolic compounds with antioxidant activity [27]. Dietary flavonoids have been consistently associated with modest reductions in blood pressure through mechanisms involving enhanced nitric oxide bioavailability, attenuation of oxidative stress, and improvement of vascular compliance [28], [29], [30], [31]. However,

most existing evidence derives from oral intake, the extent to which these mechanisms apply to transdermal delivery remains uncertain.

The transdermal delivery route itself may play a role in the observed effects. Transdermal application allows gradual systemic absorption while bypassing gastrointestinal degradation and hepatic first-pass metabolism, potentially enabling bioactive compounds to exert systemic effects [32], [33]. The delayed and progressively increasing effect observed in this study may reflect gradual absorption dynamics, limited penetration depth, or cumulative exposure over repeated applications over repeated applications.

While direct evidence on transdermal *Ananas comosus* peel extract is lacking, the present findings are broadly consistent with prior research demonstrating antihypertensive effects of plant-derived polyphenols and bromelain-containing preparations. Previous studies of flavonoid-rich interventions have reported modest but significant reductions in SBP and DBP, particularly during exposure [34], [35]. Similarly, review and clinical studies have suggested cardiovascular benefits of bromelain through hemodynamic and anti-inflammatory pathways, although blood pressure outcomes have rarely been the primary endpoint [26].

Compared with oral interventions, the present study highlights the feasibility of a non-oral, adjunctive approach. The delayed onset and progressively increasing effect observed here differs from the more sustained responses reported in long-term

dietary studies, suggesting that transdermal delivery may be more suitable for or complementary blood pressure modulation rather than long-term monotherapy.

From a clinical perspective, the findings suggest that transdermal *Ananas comosus* peel extract may offer short term complementary potential in supporting blood pressure management alongside usual care. The intervention demonstrated measurable effects without replacing standard treatment, aligning with integrative and complementary care frameworks commonly used in nursing and community health settings. The non-invasive nature of transdermal application may enhance patient acceptability, particularly among individuals who have experience difficulty with oral therapies. Additionally from a nursing perspective, these findings highlight the involvement of nurses in integrating patient-centred complementary interventions into hypertension management, particularly in community settings, where this support reflects a practical and non-coercive nursing approach to enhancing self-management in any conditions [36].

However, the observed time-dependent effect observed underscores that this intervention should not be interpreted as a substitute for established antihypertensive treatment. Instead, it may have potential utility for blood pressure control, symptom relief, or as part of a multimodal lifestyle-based intervention.

LIMITATIONS

Several limitations should be acknowledged.

First, blood pressure measurements were self-administered by participants at home, which may introduce measurement variability and potential reporting bias despite standardized training and use of validated devices. Second, data collection relied on participant self-reporting via WhatsApp, which may be subject to reporting inaccuracies or delayed submission, although daily monitoring was implemented to enhance compliance. Third, the relatively small sample size may limit the statistical power to detect smaller effect sizes and reduce the generalizability of the findings to broader populations. Last, the short duration of follow-up restricts conclusions regarding long-term efficacy and sustainability of the observed blood pressure-lowering effects.

CONTRIBUTION TO GLOBAL NURSING PRACTICE

This study provides preliminary evidence supporting the practice of transdermal *Ananas comosus* to reduce SBP, DBP, and MAP within seven days of application. These findings support the integration of a low-cost, complementary intervention into nursing strategies for accompanying hypertension modality, particularly in elderly populations. The efficacy was beginning on Days 4–7 strengthen the intervention's clinical relevance and offer nurses an evidence-based accompaniment to enhance cardiovascular care and patient self-management practices.

IMPLICATIONS FOR FUTURE RESEARCH

Future studies should explore longer

intervention periods, repeated dosing strategies, and standardized extract formulations to evaluate whether the antihypertensive effects can be sustained. Incorporation of biochemical markers, such as inflammatory mediators, oxidative stress indicators, and endothelial function measures, would strengthen mechanistic inference. Comparative studies examining transdermal versus oral delivery of pineapple-derived compounds may further clarify the advantages and limitations of each route.

Larger, multicentre trials with rigorous usual care and chemical profiling of the extract are also needed to establish reproducibility, dose–response relationships, and clinical relevance. Such research would help define the role of *Ananas comosus* peel extract within evidence-based complementary blood pressure management strategies.

CONCLUSION

In conclusion, this randomized controlled trial provides evidence that transdermal application of *Ananas comosus* rind extract, when used in conjunction with usual care, is associated with significant reductions in SBP, DBP, and MAP. The antihypertensive effect was most pronounced starting 4–5 days after the intervention over time, suggesting a transient physiological response. In less than 4 days, no differences in blood pressure changes were observed compared to standard care alone.

These findings suggest that *Ananas comosus* rind extract administered via the transdermal route has potential as a non-

invasive complementary approach for short-term blood pressure modulation. However, given the limited duration of effect and the lack of long-term outcome data, this intervention should not be considered a substitute for standard antihypertensive therapy. Further, well-designed studies with longer follow-up, standardized extract characterization, and mechanistic assessment are needed to confirm efficacy, optimize application protocols, and clarify clinical relevance.

AUTHORS' CONTRIBUTION

The conception and design of the study, acquisition of data, analysis and interpretation of data (ERRP, YDLS, RR). Drafting the article or revising it critically for important intellectual content (ERRP, YDLS, TH). Final approval of the version to be submitted (ERRP, YDLS, RR).

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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