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Static versus Passive Stretching: Effects on Inflammatory Biomarkers (IL-6 and CRP) in Hypertensive Elderly

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Abstract: Chronic low-grade inflammation, reflected by elevated interleukin-6 (IL-6) and C-reactive protein (CRP), increases cardiovascular risk in hypertensive older adults, yet the specific influence of stretching—commonly recommended as a safe, low-intensity activity—on systemic inflammatory markers remains unclear. This randomized controlled experimental trial aimed to determine whether static stretching differs from passive stretching in reducing serum IL-6 and CRP levels among hypertensive elderly individuals. Forty participants (mean age 62.95 years; 20 males and 20 females) were randomly assigned to either a static stretching program involving active muscle elongation with 30-second holds or a passive stretching protocol performed with therapist assistance; both were conducted three times per week for eight weeks. Blood samples were obtained before and after the intervention and analyzed using high-sensitivity ELISA, while two-way ANOVA was applied to evaluate group differences. The results showed No statistically significant differences were observed between groups for IL-6 ($F = 2.68$, $p = 0.110$) or CRP ($F = 0.73$, $p = 0.397$), and no significant interactions with gender, with both groups exhibiting minimal, non-significant changes from baseline. These findings suggest that an eight-week stretching program, whether static or passive, does not meaningfully modify systemic inflammation in hypertensive older adults, indicating that stretching alone may be insufficient to reduce inflammatory risk in this population.

Keywords: CRP, IL-6, Elderly, Hypertension, Passive Stretching, Static Stretching, Biomarker

1. Introduction

Hypertension represents a major global health challenge, particularly among the elderly, where it is recognized as a leading contributor to morbidity and mortality [1]. Between August 2021 and August 2023, epidemiological data indicate that nearly half of adults (47.7%) are affected by hypertension, with prevalence rates increasing significantly with age 23.4% in adults aged 18–39, 52.5% in those aged 40–59, and 71.6% in persons over 60 years old[2]. Furthermore, men were somewhat more likely to be affected than women (50.8% vs. 44.6%, respectively)[2]. The variation in hypertension prevalence across populations can be attributed to differences in modifiable risk factors such as excessive dietary sodium, insufficient potassium intake, obesity, physical inactivity, and suboptimal dietary habits[3]. Multiple studies have established that a sedentary lifestyle is strongly associated with increased body fat and elevated body mass index (BMI) in older adults, which in turn heightens the risk of obesity and subsequent hypertension[4]. Notably, the prevalence of hypertension is significantly higher in obese individuals (45.7%) compared to those who are overweight (32.2%) or with normal weight (18.2%), underscoring the critical role of obesity in the development of hypertension[5]. Hypertension in the elderly is also linked to reduced quality of life, particularly in domains such as physical functioning, pain, and role limitations due to health problems[6]. Psychological well-being is also negatively affected, albeit to a lesser extent. Elderly individuals with hypertension face an elevated risk of severe cardiovascular and cerebrovascular complications, including heart failure, stroke, myocardial infarction, dementia, physical disability, and fragility fractures[7]. The increased pulse pressure observed in older hypertensive patients is a robust predictor of adverse cardiovascular outcomes, highlighting the importance of early and effective management[7]. The systemic and cerebral complications of hypertension present considerable challenges for both individual health and public healthcare systems[8]. Vascular aging represents a central mechanism underlying the development and progression of hypertension in the elderly. The accumulation of metabolic by-products such as cholesterol plaques (atherosclerosis), oxidative stress from reactive oxygen species (ROS), telomere shortening in endothelial cells, and chronic low-grade inflammation ("inflamm-aging") all contribute to vascular endothelial dysfunction and arterial stiffening with advancing age[9]. These pathophysiological changes increase systolic blood pressure and pulse pressure, further amplifying cardiovascular risk[10]. Chronic low-grade inflammation, characterized by elevated levels of interleukin-6 (IL-6) and C-reactive protein (CRP), is commonly observed in elderly individuals with hypertension. IL-6, a pleiotropic cytokine, increases with age and is considered a biomarker of systemic inflammation and comorbidity risk in older adults[11]. Elevated serum IL-6 is associated with an increased risk of cardiovascular, neurodegenerative, metabolic, and musculoskeletal disorders, as well as general frailty[11], [12]. The secretion of IL-6 from contracting skeletal muscle during exercise suggests its dual role as both a pro-inflammatory and myokine signaling molecule[13]. While IL-6 is a key player in vascular inflammation, several studies indicate that circulating CRP a downstream marker of IL-6 activity may be an even more robust and consistent predictor of hypertension risk in older adults, independent of traditional risk factors[14]. Notably, high-sensitivity CRP levels above 3 mg/L are associated with elevated blood pressure in geriatric populations[15]. Both IL-6 and CRP are associated with arterial stiffness, endothelial dysfunction, and increased susceptibility to cardiovascular events in the elderly[13], [16]. Recent rehabilitation-based approaches have emphasized the role of non-pharmacological interventions in modulating chronic low-grade inflammation among older adults. Studies published in the *Journal of Balneology* have demonstrated that structured therapeutic exercise and balneotherapy programs may contribute to improvements in inflammatory and cardiovascular parameters in elderly populations. These findings suggest that controlled physical interventions can influence systemic inflammatory pathways, although the magnitude and consistency of such effects remain variable across modalities. In this context, interventions aimed at reducing systemic inflammation may offer a therapeutic avenue for mitigating hypertension-related complications in aging populations. Existing evidence suggests that physical activity and structured exercise programs can modulate the inflammatory profile and contribute to improved vascular health in older adults. Static and passive stretching exercises are commonly prescribed for improving flexibility and mobility, particularly in individuals with physical limitations or contraindications to more vigorous exercise. Stretching interventions have been shown to reduce arterial stiffness and diastolic blood pressure in middle-aged and older adults [17], [18]. Relaxation intervals during intermittent stretching may further enhance arterial compliance and reduce vascular stiffness[19]. Moreover, passive stretching regimens improve local blood flow and may confer persistent vascular benefits[20], [21]. Nevertheless, the comparative effects of static versus passive stretching on systemic inflammatory biomarkers specifically IL-6 and CRP in hypertensive elderly individuals remain poorly understood. While some reports suggest modest cardiovascular benefits, the extent to which these interventions influence vascular inflammation and, consequently, long-term cardiovascular risk, has not been systematically investigated. Therefore, the present study aimed to determine whether static stretching differs from passive stretching in reducing serum IL-6 and CRP levels among hypertensive older adults. We hypothesized that both modalities would induce modest reductions in inflammatory biomarkers, with potential differences related to muscle activation patterns and vascular responses.

2. Results

The mean IL-6 and CRP levels for both study groups are presented in the table below (all values in pg/mL for IL-6 and mg/L for CRP). This chart directly visualizes the modest changes in IL-6 and CRP post-intervention, with both groups showing slight increases, though these differences were not statistically significant.

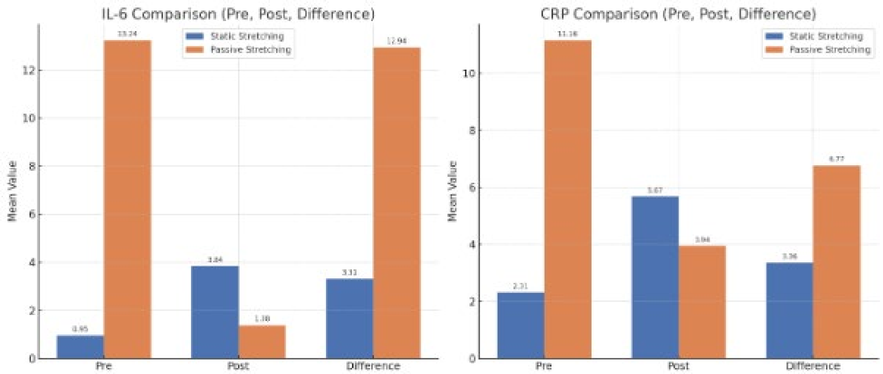

Figure 1. Comparison of IL-6 and CRP Levels Between Static and Passive Stretching Groups (Pre-Test, Post-Test, and Mean Differences).

The figure illustrates the mean IL-6 and CRP values for static and passive stretching groups at pre-test, post-test, and the resulting differences. For IL-6, the passive stretching group shows markedly higher baseline values compared with the static group, with both groups displaying only small and inconsistent reductions after the intervention. The mean differences also remain minimal, indicating limited impact. A similar pattern appears for CRP, where the passive group begins with higher pre-test levels, followed by modest and non-uniform changes in both groups. Overall, the charts demonstrate that neither static nor passive stretching produced meaningful alterations in IL-6 or CRP levels, supporting the conclusion that the eight-week stretching intervention did not significantly influence systemic inflammation in hypertensive older adults.

Statistical analysis using two-way ANOVA revealed no significant main effects or interactions for either IL-6 or CRP. For IL-6, the effect of stretching modality was non-significant ($F = 2.682$, $p = 0.110$), as were effects of gender ($F = 0.797$, $p = 0.378$) and the interaction between stretching and gender ($F = 0.577$, $p = 0.452$). Similarly, for CRP, there were no significant effects of stretching ($F = 0.734$, $p = 0.397$), gender ($F = 1.407$, $p = 0.243$), or their interaction ($F = 0.001$, $p = 0.972$). Blood pressure changes were also non-significant between groups.

The present study aimed to investigate whether static and passive stretching modalities differentially affect systemic inflammatory biomarkers, specifically interleukin-6 (IL-6) and C-reactive protein (CRP), in elderly individuals with hypertension. Our findings revealed no significant differences in serum IL-6 or CRP levels after eight weeks of either intervention. Notably, this absence of effect was consistent across gender, with no significant interaction observed between stretching type and gender, as confirmed by two-way ANOVA. In addition to statistical significance testing, effect size analysis (partial eta squared) indicated trivial-to-small effect magnitudes for both IL-6 and CRP, suggesting limited practical impact of the intervention.

Although minor numerical changes were observed in both groups, these variations did not reach thresholds considered clinically meaningful for cardiovascular risk modification.

These results diverge from observations made in studies focusing on aerobic or resistance exercise, which generally report more consistent reductions in IL-6 and CRP among older adults. While such dynamic exercises are known to induce acute inflammatory responses followed by chronic adaptation and anti-inflammatory effects, stretching regardless of its modality appears to exert a less pronounced influence on systemic inflammation. This discrepancy may be attributed to the differing physiological demands imposed by dynamic versus static interventions. For instance, aerobic and resistance exercises typically involve significant muscle contraction, increased energy expenditure, and hormonal responses, all of which can modulate inflammatory pathways directly. In contrast, stretching, even when performed regularly and systematically as in the present protocol, may not sufficiently alter the metabolic and immunological milieu to produce measurable changes in circulating inflammatory markers.

A 2025 systematic review demonstrating that aerobic exercise significantly reduces IL-6, CRP, and TNF-α in older adults, recommending moderate to high-intensity aerobic programs performed regularly (60–80% HRmax, 30-60 minutes, 2-3 times per week)[22]. A 2024 study reporting that aerobic exercise improves endothelial function and vascular health, producing notable decreases in CRP and IL-6 through mechanisms including enhanced oxidative metabolism and nitric oxide release, while resistance exercise shows a smaller effect on IL-6[23]. A 2024 meta-analysis finding resistance training significantly reduces CRP and IL-6 levels in elderly populations, especially with interventions longer than 12 weeks and performed at least 3 times weekly[24]. A 2025 meta-regression analysis concluding resistance training reduces CRP and enhances functional capacity in older adults, but shows no significant effect on IL-6; noting the need for further research on underlying mechanisms.

In contrast, our study found that neither static nor passive stretching resulted in significant reductions in serum IL-6 or CRP levels among hypertensive elderly after eight weeks, as confirmed by two-way ANOVA analysis. These findings contrast with a substantial body of literature showing consistent declines in inflammatory markers following aerobic and resistance exercise protocols in older adults. For instance, Abd El-Kader and colleagues reported significant decreases in IL-6 and CRP following six months of supervised aerobic exercise, while simultaneous reductions were also observed for resistance training, albeit less pronounced. Recent meta-analyses affirm that aerobic exercise, particularly at moderate to high intensity, elicits robust anti-inflammatory effects across various clinical populations. The discrepancy between our results and those from dynamic exercise studies may be attributable to the lower metabolic demand, muscle contraction, and hormonal responses associated with stretching, which could be insufficient to provoke meaningful changes in systemic inflammation. It is also possible that stretching confers benefits restricted to vascular compliance and flexibility, as documented in previous reviews, without substantial impact on systemic biomarkers. Taken together, our study extends current understanding by clarifying the limited impact of stretching-alone interventions on chronic inflammatory status in elderly hypertensive individuals, highlighting the need for future research to optimize exercise prescriptions for inflammation modulation [25]–[28].

The absence of a significant effect on IL-6 and CRP concentrations in this study does not imply that stretching is ineffective for elderly hypertensive individuals. Instead, the primary benefits of stretching in this population may relate to improvements in flexibility, muscle compliance, and possibly arterial stiffness, as demonstrated by previous meta-analyses. However, if the therapeutic goal is to modify systemic inflammation a key mediator of cardiovascular risk in the elderly alternative exercise modalities or multimodal interventions may be necessary to achieve meaningful biomarker modulation.

Furthermore, several methodological considerations may account for these findings. First, the relatively short intervention duration of eight weeks may be insufficient to elicit detectable changes in chronic inflammatory markers, which typically require longer periods to manifest. Second, the inherent physiological heterogeneity among elderly individuals, compounded by comorbidities and medication use, may limit the responsiveness of systemic inflammation to exercise interventions. Third, Previous studies investigating vascular adaptations have demonstrated improvements in arterial compliance following stretching interventions; however, the present findings suggest following stretching, the present findings indicate that such adaptations may not translate into detectable systemic reductions in circulating IL-6 and CRP under the current protocol.

It is worth noting that our results align with emerging evidence highlighting the limited impact of stretching on inflammatory biomarkers compared to more vigorous forms of exercise. This should not diminish the potential value of stretching as a safe, feasible, and well-tolerated adjunct to lifestyle management for elderly individuals with limited mobility or contraindications to dynamic exercise.

Several limitations should be acknowledged. First, the eight-week duration may have been insufficient to induce measurable changes in chronic inflammatory biomarkers, which often require longer interventions. Second, despite efforts to control medication stability and lifestyle factors, residual confounding cannot be entirely excluded. Third, systemic biomarkers may not fully capture localized vascular or muscular anti-inflammatory adaptations induced by stretching. Future research should consider longer intervention periods, larger sample sizes, tighter dietary monitoring, and inclusion of additional biomarkers such as TNF-α or endothelial function indices.

3. Discussion

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

4. Materials and Methods

Experimental Design and Participants

This study employed a 2 x 2 factorial randomized controlled trial design to systematically evaluate the effects of stretching modality (static versus passive stretching) and gender (male versus female) on serum levels of interleukin-6 (IL-6) and C-reactive protein (CRP) in hypertensive elderly individuals. Purposive sampling was used to enroll 40 hypertensive elderly participants (20 men, 20 women; mean age 62.95±5.10 years) from local nursing homes in Surakarta, Indonesia. Eligibility criteria included a diagnosis of hypertension (systolic blood pressure ≥140mmHg or diastolic blood pressure ≥90mmHg), age ≥60 years, and ability to participate in the stretching protocol. Exclusion criteria involved the presence of acute inflammatory conditions, malignant diseases, or recent changes in antihypertensive or anti-inflammatory medication in the three months prior to the study. To minimize confounding effects, participants were required to maintain stable antihypertensive medication regimens throughout the study period. Individuals who experienced medication changes within three months prior to or during the intervention were excluded. Participants were also instructed to maintain habitual dietary intake and physical activity levels, and compliance was verbally confirmed at weekly check-ins. All procedures were approved by the relevant institutional ethics committee, and written informed consent was obtained from each participant prior to enrollment.

Intervention Protocol

Participants were randomly allocated into two intervention groups:

a. Static Stretching Group (n=20): Participants performed active, voluntary muscle elongation of major muscle groups (hamstrings, quadriceps, calves, chest, and upper back). Each stretch was held for 30 seconds and repeated 3-5 times per muscle group.
b. Passive Stretching Group (n=20): Participants received therapist-assisted stretching (performed by a trained physical therapist) on the same muscle groups. The duration (30 seconds hold, 3-5 repetitions) and target muscle groups were identical to the static stretching protocol.

Both groups conducted their stretching sessions for 15 minutes, 3 times per week, over an 8 week intervention period. To ensure protocol fidelity, all sessions were standardized and directly supervised by trained personnel. Participants were instructed to maintain their usual level of physical activity and dietary habits throughout the study. Adherence was monitored through supervised attendance records. Participants were required to attend at least 85% of the scheduled sessions to be included in the final analysis. No adverse events were reported during the intervention period.

Sample Collection and Biochemical Analysis

Blood sampling was performed by qualified staff under standardized conditions both prior to the initiation of the intervention and immediately following the final session. Blood was collected, promptly processed, and serum aliquots were stored at -20°C until analysis. Serum IL-6 and CRP concentrations were measured in duplicate using commercial high-sensitivity enzyme-linked immunosorbent assay (ELISA) kits, strictly following the manufacturer's instructions and utilizing appropriate quality controls.

Statistical Analysis

Statistical analysis was conducted using standard parametric methods. The assumption of distribution normality was confirmed using the Kolmogorov-Smirnov test, and homogeneity of variance was assessed via Levene's test. A Two-way Analysis of Variance (ANOVA) was used to evaluate the main effects of stretching modality (static vs. passive) and gender (male vs. female), as well as their potential interaction, on the post-intervention concentrations of IL-6 and CRP. The level of statistical significance was set at $p < 0.05$.

5. Conclusions

This study found no significant differences in IL-6 or CRP levels between static and passive stretching, indicating that neither modality produced meaningful anti-inflammatory effects in hypertensive older adults under the current eight-week protocol. These findings are consistent with existing evidence showing that stretching mainly improves mobility rather than inflammatory status, and that aerobic or resistance exercise is more effective for reducing systemic inflammation. The short intervention period, advanced age, and comorbidity burden of participants may have limited measurable physiological responses, while potential uncontrolled factors may also have contributed to the minimal changes observed. Although stretching did not reduce inflammatory markers, it remained safe and feasible, and may still serve as an adjunct for individuals with limited exercise tolerance. Longer interventions with larger sample sizes and tighter control of confounders are recommended to better clarify the potential role of stretching in modulating inflammation in this population.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board Research Ethics Committe Faculty of Medicine Universitas Sebelas Maret (No 109/UN27.06.11/KEP/EC/2024).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable

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Conflicts of Interest: The authors declare no conflict of interest and the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Appendix B

Figure 1. Comparison of IL-6 and CRP Levels Between Static and Passive Stretching Groups (Pre-Test, Post-Test, and Mean Differences).

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