

**Neck static stretching acutely reduces blood pressure through reduction of tissue stiffness: A randomized crossover trial**

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## Study Protocol

### *Objective and design*

This study hypothesised that static stretching (SS) of the right posterolateral cervical region would elicit a reduction in blood pressure (BP), potentially mediated by specific physiological mechanisms. Accordingly, the aim of this study was to investigate the acute effects of SS of the posterolateral neck region on BP and to explore the potential moderating roles of tissue hardness (TH) and heart rate variability (HRV). Twenty-five healthy participants were enrolled in a randomised crossover design. Each participant completed two experimental conditions: a SS session (SS) and a control condition (CC). The order of conditions was randomly determined using the website [www.randomizer.org](http://www.randomizer.org). During each visit, measurements were obtained at two time points: baseline (T0, upon arrival) and immediately after the assigned condition (T1). At each assessment point, outcomes were collected in a standardised sequence: BP was measured first, followed by bilateral assessments of TH adjacent to the seventh cervical vertebra (C7), and subsequently by recordings of HRV and heart rate (HR). Between T0 and T1, participants either performed the SS protocol or completed a 6-minute seated rest period (CC), with the duration of the control period matched to that of the stretching intervention. The study was approved by the Bioethics Committee of the University of Palermo (protocol n°306/2025) and conducted in accordance with the Declaration of Helsinki and the European Union recommendations for good clinical practice.

### *Methods*

All assessments were performed by the same investigator to ensure methodological consistency and minimise inter-examiner variability.

Systolic and diastolic BP were measured in the seated position using a validated oscillometric device (Omron MX3 Plus). Prior to measurement, participants remained seated for 5–10 minutes to achieve haemodynamic stabilisation. Mean arterial pressure (MAP) was calculated using the standard formula:  $MAP = DBP + \frac{1}{3}(SBP - DBP)$ .

TH was assessed using a portable tissue hardness meter (NEUTONE TDM-N1; TRY-ALL Corp., Chiba, Japan), which quantifies indentation depth under a constant compressive load of 14.71 N (1.5 kgf). In the cervical region, the spinous process of the seventh cervical vertebra (C7) served as the anatomical landmark.

Measurements were obtained bilaterally, 2 cm lateral to the C7 spinous process, with participants positioned prone on a medical examination table.

HRV and HR were recorded using a Polar H10 chest strap sensor (Polar Electro Oy, Kempele, Finland).

Participants rested in the supine position for 5 minutes before data collection, followed by a 5-minute recording period under spontaneous breathing. The sensor was positioned at the level of the xiphoid process and secured around the thorax with the integrated strap. Once a stable signal was detected, the device automatically paired and transmitted data to the Elite HRV<sup>©</sup> mobile application (Elite HRV, Asheville, NC, USA). Frequency-domain analyses were performed to assess autonomic modulation, including low-frequency (LF) and high-frequency (HF) spectral components, and the LF/HF ratio was calculated as an index of sympathovagal balance. The mean RR interval was computed as the average time between consecutive heartbeats, the standard deviation of normal-to-normal intervals (SDNN) was used as a global measure of variability, and the root mean square of successive differences (RMSSD) represented short-term, vagally mediated fluctuations. Mean HR values were derived from HRV recordings. All HRV data were processed and analysed using Kubios HRV Standard software (Kubios Oy, Kuopio, Finland).

The SS intervention specifically targeted the right posterolateral cervical region. The protocol consisted of four 45-second sets of static stretching, each separated by a 45-second rest interval, for a total intervention duration of 3 minutes. While seated on a chair, participants performed the stretch by gently flexing the head forward and toward the left in an anterolateral direction, using the contralateral (left) hand to assist the motion and ensure selective stretching of the right posterolateral neck musculature.

During the control condition (CC), participants remained seated quietly for 6 minutes, equivalent to the total duration of the SS session, without performing any active movements, between the T0 and T1 assessments.