Short-Term Effects of Air Pollution and Temperature on Arterial Stiffness: Findings from the DEpICT Study

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INTRODUCTION

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ARTERIAL STIFFNESS

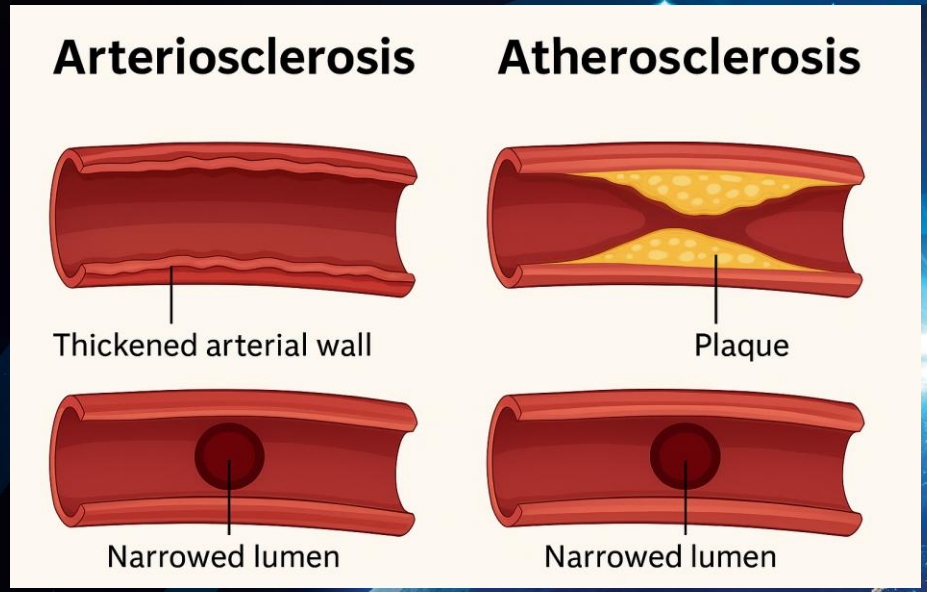
Arterial stiffness is defined as the resistance of the artery to deform to pressure changes in each heartbeat and may be due to biological aging and **arteriosclerosis**.

Thomas Sydenham's Quote: "A man is as old as his arteries" (17th century)

The principal pathological changes are:

- Wall thickening (remodeling)
- Loss of elastic properties (stiffening)

Atherosclerosis is a type of arteriosclerosis sharing common risk factors (e.g., aging, diabetes, obesity, smoking, dyslipidemia) hypertension is the most influential modifiable risk factor in the development and progression of arteriosclerosis.



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ARTERIAL STIFFNESS

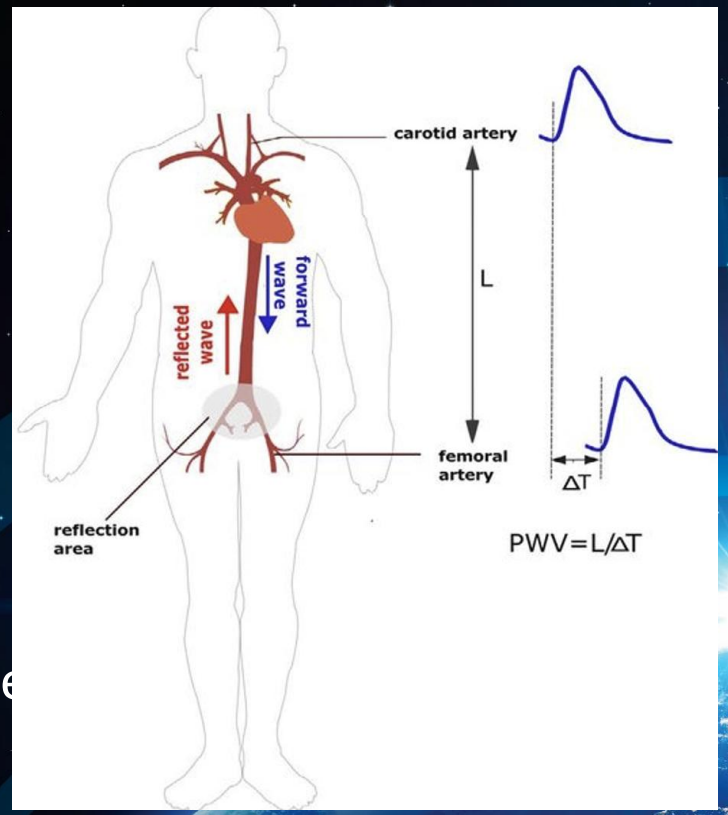
As arteries stiffen, particularly the aorta and proximal elastic arteries:

↑ systolic and pulse pressures

↓ diastolic pressure, especially post-40

- affects left ventricular afterload, alters pressure pulsatility, impacts microvasculature of organs (brain, kidneys).

- ***Pulse Wave Velocity (PWV):*** is the "gold standard" and it measures the speed at which the arterial pressure waves travel along the aorta and large arteries. Non-invasive, inexpensive, and reproducible.



Types: cfPWV (carotid-femoral) , baPWV (brachial-ankle) and ePWV (estimated PWV)

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ARTERIAL STIFFNESS AND CARDIOVASCULAR RISK

Increased arterial stiffness :

- is an important indicator of subclinical organ damage(e.g. brain and kidneys)
- increasing cardiovascular events such as arterial hypertension, myocardial infarction, stroke, hypercholesterolemia, smoking, T2DM, and visceral adiposity.
- linked with coronary artery calcification (CAC) and higher risk for cardiovascular disease.

PWV can predict cardiovascular risk and mortality

Studies:

- Framingham Heart Study: Aortic PWV predictive of cardiac events, independent of traditional risk factors.
- Rotterdam Study: PWV >14.6 m/s in men, >14.2 m/s in women, associated with higher CVD risk.
- Long-Term Prospective Studies: High PWV associated with higher risk for CVD, coronary artery disease, and mortality and correlates with the development of type 2 diabetes.

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AIR POLLUTION

According to World Health Organization **(WHO)**, the following environmental pollutants stand out for their effects on health:

- Carbon monoxide (CO),
- Nitrogen dioxide (NO2),
- tropospheric Ozone (O3),
- suspended particles (PM10 and PM2.5)
- Sulphur dioxide (SO2)

Table 1. Main components of air pollution

Gaseous substances	Carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), nitric oxide (NO_3), sulphur dioxide (SO_2), ozone (O_3), volatile organic compounds (hydrocarbons, quinones)
Particulate matter (PM)*	Metals, coarse particles (PM_{10}), fine particles ($PM_{2.5}$), ultrafine particles ($PM_{0.1}$), nanoparticles

*Particulate matter is distinguished according to its aerodynamic diameters in coarse, fine and ultrafine particles; numbers after the abbreviation indicate the maximum value in μM.

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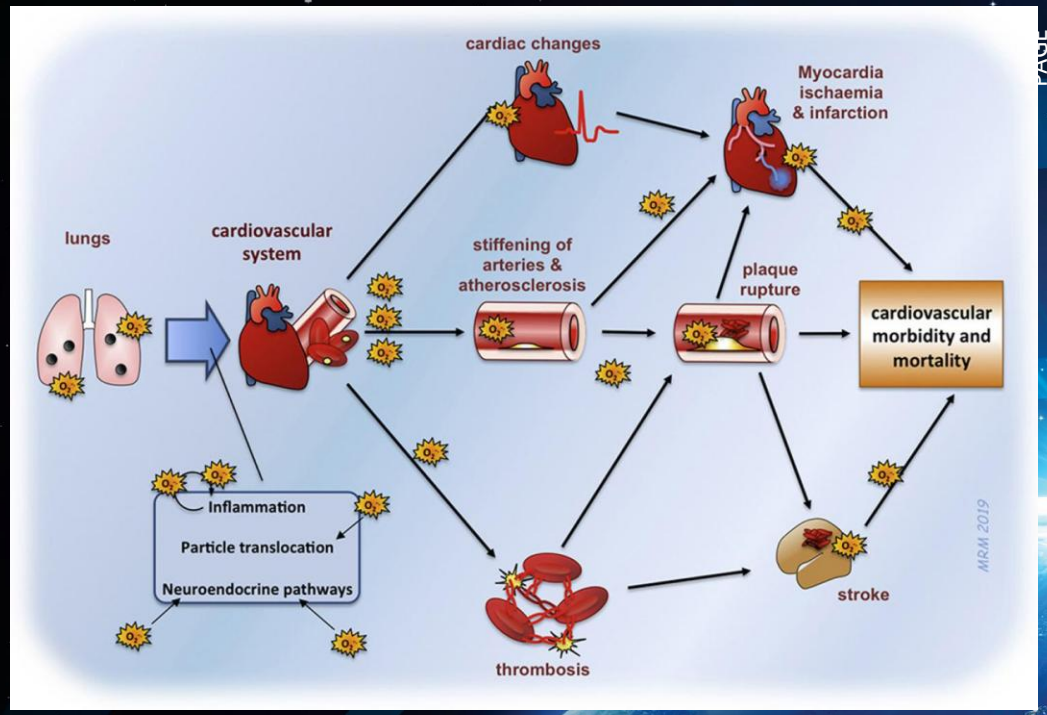
AIR POLLUTION

These small particles pass into the bloodstream, damaging the inner wall of the vessels, causing

- their narrowing and hardening,
- endothelial dysfunction and vasoconstriction,
- increased blood pressure (BP),
- prothrombotic and coagulant changes,
- systemic inflammatory and oxidative stress responses,

autonomic imbalance and arrhythmias

- the progression of atherosclerosis, consequently, producing arteriosclerosis and an increase in cases of CVD.



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AIR POLLUTION AND CARDIOVASCULAR RISK

Epidemiological Evidence - Studies

- Large studies (US & Europe): +10 µg/m³ PM_{10} → ~0.7% ↑ cardiovascular mortality
- Short-term exposure linked to:
  - ↑ hospitalizations (IHD, heart failure)
  - ↑ acute myocardial infarction (AMI) risk
  - ↑ stroke events
- **Framingham Heart Study**
  - Living near major roads → ↑ carotid-femoral PWV (+0.11 m/s)
  - Suggests traffic-related pollution affects vascular function
- Panel study (Belgium–Italy–Sweden):
  - +10 µg/m³ NO_2 → ↑ PWV (~0.09–0.10 m/s)
  - Also ↓ arterial compliance → ↑ stiffness
- Hypertensive patients: $PM_{2.5}$ associated with progression of PWV over time

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AIM OF THE STUDY

This study aimed to investigate the short-term effect of air pollution and ambient temperature with arterial stiffness measured by carotid–femoral pulse wave velocity (cfPWV) in an adult population sample

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METHODOLOGY

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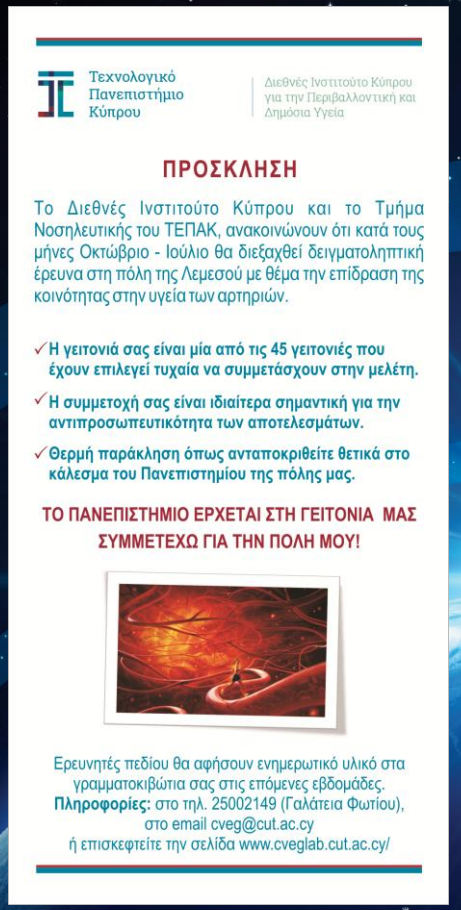
STUDY DESIGN OVERVIEW

Data were derived from the DEpICT study-Decoding the effect of social gradient and area indicators on arterial health: (DEpICT). From the community to the individual and back

- A single-centre, cross-sectional study among at least 316 participants across neighbourhoods in Limassol between 2018 and 2023
- Included individuals aged 40 years or older, Greek as a first language to ensure fluency in Greek for the self-administered questionnaires
- Able to provide informed written consent and residents in the same neighborhood in the municipality of Limassol for at least the previous five years.

› Phase 1 of the DEpICT study was conducted in an existing stratified sample of 45 neighborhoods in Limassol to reflect the entirety of the socioeconomic gradient based on census area-level data and

› Phase 2 there was an open recruitment to all neighborhoods in the municipality of Limassol.


Τεχνολογικό Πανεπιστήμιο Κύπρου

Διεθνές Ινστιτούτο Κύπρου για την Περιβαλλοντική και Δημόσια Υγεία

ΠΡΟΣΚΛΗΣΗ

Το Διεθνές Ινστιτούτο Κύπρου και το Τμήμα Νοσηλευτικής του ΤΕΠΑΚ, ανακοινώνουν ότι κατά τους μήνες Οκτώβριο - Ιούλιο θα διεξαχθεί δειγματοληπτική έρευνα στη πόλη της Λεμεσού με θέμα την επίδραση της κοινότητας στην υγεία των αρτηριών.

✓Η γειτονιά σας είναι μία από τις 45 γειτονιές που έχουν επιλεγεί τυχαία να συμμετάσχουν στην μελέτη.

✓Η συμμετοχή σας είναι ιδιαίτερα σημαντική για την αντιπροσωπευτικότητα των αποτελεσμάτων.

✓Θερμή παράκληση όπως ανταποκριθείτε θετικά στο κάλεσμα του Πανεπιστημίου της πόλης μας.

ΤΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΕΡΧΕΤΑΙ ΣΤΗ ΓΕΙΤΟΝΙΑ ΜΑΣ
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Ερευνητές πεδίου θα αφήσουν ενημερωτικό υλικό στα γραμματοκιβώτια σας στις επόμενες εβδομάδες.
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WHAT WAS MEASURED..

- cfPWV ,'arterial age' and central pressure waveforms was assessed using the Complior Analyse device (ALAM Medical).
- Two seated BP measurements were taken after 5 minuted of rest using Tensoval Duo Control upper arm monitor with Duo Sensor Technology
- Anthropometric Measures(e.g. height,weight,etc)
- Questionnaires:

- Sociodemographic, Clinical history and self-reported behavioral risk factors questionnaire
- Quality of life - short form-12) -SF-12 questionnaire
- Physical activity - IPAQ questionnaire
- Depression symptoms - GHQ-12 questionnaire
- MedDiet Score
- PLACE Standard Tool

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AIR POLLUTION AND TEMPERATURE DATA

- Daily concentrations of major air pollutants (PM_{10}, NO_2, O_3, CO and SO_2) and meteorological data were obtained from official environmental monitoring sources.

- Exposure levels were classified according to established air quality categories.

- Both air pollutants and temperature were taken for the day of measurement(lag0), the day before measurement(lag1) and the average of 3 days before measurement(MA3).

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STATISTICAL ANALYSIS

- ✓ Descriptive statistics: Means ± SD or medians (IQR) for continuous variables; frequencies (%) for categorical variables.
- ✓ Linear regression analyses between air pollutants, mean temperature and cfPWV **for the day of measurement** and **for the 3-day moving average of measurement**.
- ✓ Multivariate Regression analyses were conducted to adjust for confounders:

  Model 1: Age, sex, body mass index (BMI), smoking status, pollution level and mean temperature

  Model 2: Age, sex, body mass index (BMI), smoking status, pollution level, mean temperature and systolic blood pressure (sBP)
- ✓ Model diagnostics (e.g., normality checks) were performed.
- ✓ $p < 0.05$ was considered statistically significant for all tests.

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RESULTS

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UNIVARIABLE LINEAR REGRESSION ANALYSES

Table 1. Univariate associations between air pollutants, temperature and cfPWV for the day of measurement.

Exposure	β coefficient	95% CI	p-value
PM_{10} (μg/m^3)	-0.009	(-0.027,0.008)	0.299
NO_2 (μg/m^3)	0.004	(-0.013, 0.022)	0.639
SO_2 (μg/m^3)	0.094	(-0.050,0.237)	0.201
CO (μg/m^3)	0.0007	(-0.0009,0 .0022)	0.411
O_3 (μg/m^3)	-0.009	(-0.021, 0.003)	0.137
Temperature (°C)	-0.077	(-0.110, -0.042)	**<0.001**

Table 2. Univariate associations between air pollutants, temperature and cfPWV of the 3-day moving average of measurement.

Exposure	β coefficient	95% CI	p-value
PM_{10} (μg/m^3)	-0.003	(0.02, 0.01)	0.672
NO_2 (μg/m^3)	0.001	(-0.02,0.02)	0.879
SO_2 (μg/m^3)	0.09	(-0.08,0.26)	0.283
CO (μg/m^3)	0.0007	(-0.0009, 0.002)	0.383
O_3 (μg/m^3)	-0.008	(-0.023,0.007)	0.318
Temperature (°C)	-0.075	(-0.11, -0.04)	**<0.001**

- **ONLY** temperature showed a statistically significant association with cfPWV($p<0.001$)
- **PM_{10}** were not significantly associated with PWV due to limited exposure variability, the use of categorical pollution measures, and the relatively small short-term effects of particulate matter compared to temperature.

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MULTIVARIABLE LINEAR REGRESSION ANALYSES (MODEL 1)

- Due to limited variability and collinearity among pollutants, only PM_{10} was included in the final analysis.

Table 3. Multivariate regression analyses (Model 1): cfPWV- PM_{10} for the day of measurement(lag0).

Variable	β coefficient	95% CI	p-value
Age	0. 05	(0.025, 0.07)	**<0.001**
Sex	-1.02	(-1.40, -0.64)	**<0.001**
BMI	0.03	(-0.01, 0.07)	0.170
Smoking Status	-0.17	(-0.55, 0.21)	0.380
PM_{10} ($\mu g/m^3$)	0.08	(-0.44, 0.6)	0.767
Temperature (°C)	-0.06	(-0.1, -0.02)	**0.001**

Table 4. Multivariate regression analyses (Model 1): cfPWV- PM_{10} for the 3-day moving average of measurement (MA3).

Variable	β coefficient	95% CI	p-value
Age	0. 05	(0.024, 0.07)	**<0.001**
Sex	-1.02	(-1.40, -0.64)	**<0.001**
BMI	0.03	(-0.01, 0.07)	0.170
Smoking Status	-0.17	(-0.55,0.21)	0.372
PM_{10} ($\mu g/m^3$)	0.08	(-0.45, 0.6)	0.781
Temperature (°C)	-0.05	(-0.9, -0.02)	**0.001**

- BMI ,smoking status and short-term exposure to PM_{10} were not significantly associated with PWV in either lag0 or the 3-day moving average.
- Age was positively associated with cfPWV.
- Female sex was associated with lower cfPWV values.
- Higher ambient temperature was significantly associated with lower cfPWV. Each 1°C increase in mean temperature was associated with a decrease in cfPWV at both.

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MULTIVARIABLE LINEAR REGRESSION ANALYSES (MODEL 2)

- Due to limited variability and collinearity among pollutants, only PM_{10} was included in the final analysis.

Table 5. Multivariate regression analyses (Model 2): cfPWV- PM_{10} for the day of measurement(lag0).

Variable	β coefficient	95% CI	p-value
Age	0. 03	(0.01,0.05)	**0.003**
Sex	-0.74	(-1.12, -0.35)	**<0.001**
BMI	0.008	(-0.03, 0.05)	0.668
Smoking Status	-0.13	(-0.49, 0.23)	0.485
PM_{10} (μg/m^3)	0.08	(-0.41, 0.59)	0.732
Temperature (°C)	-0.04	(-0.07, -0.005)	**0.024**
AVSBP	0.03	(0.02, 0.05)	**<0.001**

Table 6. Multivariate regression analyses (Model 2): cfPWV- PM_{10} for the 3-day moving average of measurement (MA3).

Variable	β coefficient	95% CI	p-value
Age	0. 03	(0.01,0.05)	**0.004**
Sex	-0.74	(-1.12, -0.36)	**<0.001**
BMI	0.008	(-0.03, 0.05)	0.665
Smoking Status	-0.13	(-0.5, 0.23)	0.475
PM_{10} (μg/m^3)	0.1	(-0.45, 0.64)	0.724
Temperature (°C)	-0.04	(-0.07, -0.004)	**0.028**
AVSBP	0.03	(0.02, 0.05)	**<0.001**

- After further adjustment for systolic blood pressure, the association between temperature and cfPWV remained significant, although attenuated, indicating that the effect on cfPWV was over and above the effect of blood pressure.

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CONCLUSIONS

- Short-term ambient temperature was associated with arterial stiffness, with higher temperatures linked to lower cfPWV values, suggesting a possible acute vasodilatory effect.
- In contrast, short-term PM_{10} exposure was not associated with cfPWV in this population.

These findings highlight the importance of considering environmental and meteorological factors when evaluating determinants of cardiovascular health, both long-term and acutely.

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