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Abstract. Cardiovascular (CV) diseases are leading cause of mortality and arterial stiffness is a very important risk marker. It can be obtained by non-invasive measurements of carotid-femoral pulse wave velocity (cfPWV), recommended as a gold-standard marker of CV risk by European Society of Cardiology (ESC). Previous works proved that arterial stiffness's increase with ageing, sedentary lifestyle, smoking habits, etc. Central aortic pressure (CAP) is an important marker to evaluate blood pressure, in order to prevent cerebral vessels diseases, the most frequent causes of stroke and dementia. The present work reports a CAP and cfPWV data in order to characterize profile on different cohorts of Portuguese population: young adults with no associated diagnosis (NAD), adults with diagnosed axSpA and elderly with Sarcopenia. All measurements were performed using a novel, portable and low-cost device and developed protocol.

Keywords: Cardiovascular (CV) risk; Arterial Stiffness; Pulse Wave Velocity (PWV); Central Aortic Pressure (CAP); Sarcopenia; Axial Spondyloarthritis (axSpA).

1 Introduction

Arterial Stiffness

Mechanical properties of large arteries are complex and difficult to be measured [1]. This difficult is essentially caused by anisotropy and nonlinear viscoelastic properties, that are specific to each single arterial segment. Arterial stiffening is characterized by a reduced compliance and distensibility emerged as another distinctive feature of cardiovascular risk, which is related to endothelial dysfunction.

Increased aortic stiffness can be associated with decreased DBP (diastolic blood pressure); coronary ischemia and excessive DBP-lowering are therefore likely consequences, with cardiovascular accidents as a potential outcome [2]. Arterial stiffness is

related to age, heart rate, and mean arterial pressure, and in hypertensive diabetic subjects, to diabetes mellitus duration and insulin treatment, a finding that is very important [3].

Pulse Wave Velocity – PWV

Pulse waves travel faster in stiffer arteries so, arterial stiffness, could be characterized by Pulse Wave Velocity (PWV). Carotid-femoral PWV (cfPWV) is the gold standard for assessing aortic stiffness and one of the most valuable independent predictors of cardiovascular events.

Noninvasive assessment of cf-PWV has shown aortic stiffening to be consistently higher in patients with both hypertension and type 2 diabetes mellitus than in nondiabetic hypertensive subjects, for the same BP level [3].

Previous studies demonstrated also that exercise shows beneficial effects in physically active young individuals, appearing to perform as a protective factor against cardiovascular diseases, in keeping with an overall better preservation of arterial distensibility in youths [4].

Central Hemodynamic

Nowadays, it is still very important to measure brachial BP in order to assess the cardiovascular risk associated with hypertension and assess the beneficial effect of treatment for lowering blood pressure [5]. In addition, there is also a big difference in the effects caused by vasoactive drugs on central and peripheral pressure, hence the need to evaluate both. [6].

Currently, the interest of the medical community has been increasing in improving the estimates of cardiovascular risk through medical devices, using the more accurate measurement of central aortic blood pressure compared to those obtained by traditional methods, such as brachial cuff BP methods.

Hypertension vs Arterial Stiffness

Intrinsic carotid arterial stiffness was only detected as elevated, independently of BP, in young hypertensives, which was not verified in older patients. Temporal relationship between carotid and aortic stiffness, and incident hypertension, suggests that arterial stiffening is precursor for future changes to the systolic hemodynamic load. However, in hypertension, arterial stiffness increases because of increases in distension pressure. Aortic stiffness may also be influenced by remodeling of small resistance arteries that are closely independent in sustained grade I hypertension, and likely during the early phases of prehypertension. The clinical combination of hypertension and arterial stiffness marks an important step toward the development of cardiovascular disease and the need for complete assessment of cardiovascular risk [7].

Aging effect on Arterial Stiffness

With ageing, the elastic arteries, like the aorta, undergo significant morphological changes, such as the stiffening and thickening of the arterial walls, which leads to changes in the arterial pulsatility [8] due to lower distensibility. As a result of these pathophysiological changes, inflammatory events can take place and induce endothelium dysfunction, which in turn can exacerbate the existent arterial stiffness and cause the establishment of chronic vascular inflammation [9].

Mean annual SBP (systolic blood pressure) levels increased significantly with age and were higher in men than in women [10].

In very old subjects (≥75 years), arterial stiffness remains a determinant of cognitive decline, morbidity and mortality [11]. The impact of SBP levels and arterial stiffness can be very different, possibly because low SBP levels mainly reflect age-related comorbidities and conditions of malnutrition or dehydration, whereas in relatively younger and more robust individuals, low SBP levels mainly reflect lower arterial stiffness and better arterial health [10].

Although hypertension and ageing are known factors contributing to arterial stiffness, the role of inflammation in arterial stiffness pathogenesis has been inciting interest within the scientific community, evidencing a strong tie between arterial stiffness and systemic inflammation.

Sarcopenia.

Sarcopenia is characterized by muscle mass loose and skeletal musculature strength decreasing on older population, due to aging process. It affects about 29% of the elderly and 33% of patients using long-term care services [12].

Recently, it was found that increased arterial stiffness is associated with declining muscle mass, suggesting a relationship between arterial stiffening and the existence of sarcopenia [13], which may be explained by the loss of muscle mass that is often associated with chronic inflammation [14].

2 Contribution to Life Improvement

According to data provided by the World Health Organization (WHO), cardiovascular diseases (CV) are the main cause of death, causing 31% of deaths worldwide [15]. Because of this, there is a greater concern to develop more reliable methods of CV risk assessment. As arterial stiffness of the aorta is a well-known independent marker of CV morbidity and mortality [7], research and development of new methods for its measurement are very important for the general population.

Currently, there is a growing interest among clinicians towards improving CV risk estimates. Therefore, there is a need to develop or adapt current technologies that would provide accurate values for central aortic BP.

To answer this need, a new non-invasive, painless, portable, wireless and low-cost device is presented. Moreover, values of important CV markers were successfully measured with this novel device.

Obtained results showed that its implementation in clinical routine will help the health providers to get additional information, for instance, improved cardiovascular assessment and risk management.

3 Research Study & Innovation

Pulse Wave Velocity and Central Arterial Pressure were measured using an innovative low-cost, portable and wireless device – VasoCheck – developed by the Portuguese company NMT, S.A [16]. VasoCheck system is composed of main control unit and up to 4 signal acquisition units, allowing for up to 4 signal sampling points on one single object. VacoCheck device communicate with any computer by USB connection and a user interface VasoCheck Record Software. Signal acquisition is performed by sensors based on photoplethysmography technology, which is a big innovation on PWV and CAP measurements.

3.1 Age effect on Cardiovascular Risk

Experimental measurements of cfPWV and Central Arterial Pressure (CAP) were performed at healthy people and a population diagnosed [1] with cardiovascular diseases (CVD) (dyslipidemia, hypertension, diabetes, and others) at FCT UNL, CEDOC, Santa Casa da Misericórdia de Almada (SCMA) and HSO Guimarães.

Pulse Wave Velocity was recorded in 110 subjects (50 male and 60 female) in different age ranges (see table 1). Brachial SP was measured in all the subjects, in order to verify which marker better defines the population: BP or cfPWV. Figure 1 represents the linear regression model for age as the independent variable and cfPWV as the dependent one, being the p-value for age <0.001. In addition, the arterial stiffness was analyzed by measuring cfPWV, for subjects with hypertension, dyslipidemia and diabetes mellitus type II (table 2). It was verified that cfPWV is higher in hypertensive subjects for both genders, but more severe in men. The same trend was seen for patients with dyslipidemia and diabetes.

Measurements for Sarcopenia and arterial stiffness evaluation were performed on 38 elderly (27 female and 11 male) over 67 years of age at SCMA. SCMA Measurement Protocol was established considering published studies for the sarcopenia suffering diagnosis. Among the most commonly techniques used in clinical practice, the following ones were selected for each sarcopenia diagnostic criteria: BIA for muscle mass, handgrip strength test for muscle strength, and gait speed test for muscular performance. In order to correlate sarcopenia with arterial stiffness, blood pressure and cfPWV was also acquired using VasoCheck. The differences observed in the mean cfPWV for the existence and type of sarcopenia in the elders is shown figure 2. Obtained data show a positive correlation for cfPWV with the sarcopenia severity degree, which represents an increasing arterial stiffness and might be explained by the fact that the loss of muscle mass is often associated with chronic inflammation [17].

Table 1. Measured values for cf-PWV for deferent age groups.

Age Range		Height (m)	Weight (kg)	BMI (kg/m2)	SP (mmHg)	DP (mmHg)	HR (bpm)	cfPWV (m/s)
<30	Mean	1,7116	67,978	23,036	118,545	70,255	66,89	4,781
	Min	1,51	48,0	17,1	95,0	57,0	47	2,5
	Max	1,87	110,0	32,0	149,0	94,0	99	14,1
	% of N	50,5%	50,9%	52,4%	50,0%	50,0%	50,0%	50,0%
30-60	Mean	1,6769	71,460	25,775	127,029	78,853	75,21	6,265
	Min	1,58	56,0	22,5	95,0	62,0	47	4,1
	Max	1,79	92,2	30,4	153,0	93,0	97	11,4
	% of N	14,7%	13,9%	11,4%	15,5%	15,5%	15,5%	15,5%
60-90	Mean	1,5523	60,746	25,244	131,231	71,462	71,00	6,159
	Min	1,42	37,5	17,0	83,0	56,0	47	3,5
	Max	1,71	77,6	33,0	203,0	87,0	92	10,8
	% of N	23,9%	24,1%	24,8%	23,6%	23,6%	23,6%	23,6%
>90	Mean	1,4983	63,192	28,200	143,000	71,917	74,25	6,929
	Min	1,36	47,6	19,8	110,0	35,0	57	4,0
	Max	1,61	83,7	37,2	178,0	111,0	98	12,3
	% of N	11,0%	11,1%	11,4%	10,9%	10,9%	10,9%	10,9%
Total	Mean	1,6450	66,189	24,486	125,523	72,050	69,95	5,570
	Min	1,36	37,5	17,0	83,0	35,0	47	2,5
	Max	1,87	110,0	37,2	203,0	111,0	99	14,1
	% of N	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

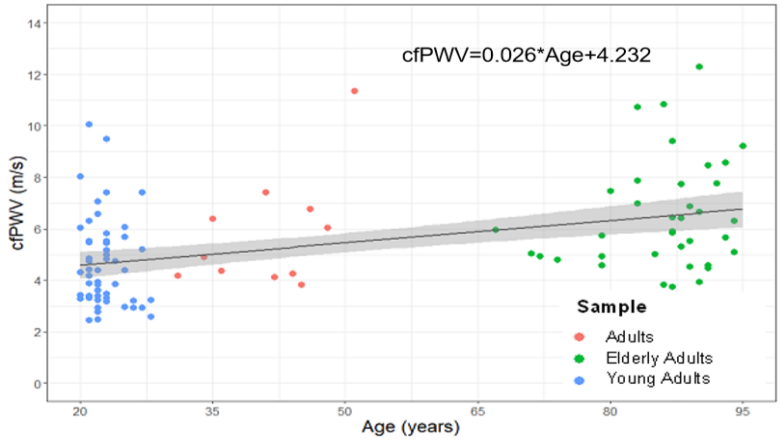

Fig. 1. Linear regression model for age and cfPWV. The shaded area represents the confidence interval for the regression line.

Table 2. Mean values of cfPWV, in m/s, for men and women with or without hypertension, dyslipidemia and diabetes mellitus type II diagnosed.

Risk Factor		cfPWV (m/s)	
		Male	Female
Hypertension	No	4,9	5,1
	Yes	8,0	6,0
Dyslipidemia	No	5,1	5,4
	Yes	9,5	5,4
Diabetes	No	5,4	5,4
	Yes	6,9	5,7

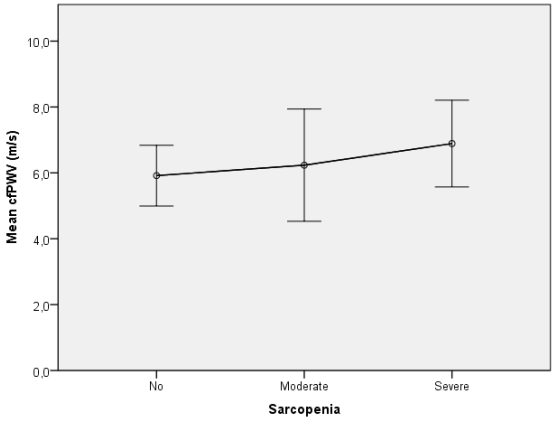

Fig. 2. Mean cfPWV according to sarcopenia existence and type.

Values of CAP were recorded in a sample of 220 subjects (116 male and 104 female) in different age ranges (see table 3). Figure 3 represents the linear regression model for age as the independent variable and CAP as the dependent one, where it is possible to see that CAP increases with ageing.

Table 3. Sample description for CAP record and analysis.

CAP Analysis

Age Range		Height (cm)	Weight (kg)	BMI (kg/m2)	SP (mmHg)	DP (mmHg)	HR (bpm)	CAP (mmHg)
<30	Mean	170,5168	68,419	23,382	119,35	73,21	71,06	95,085
	Min	151,00	48,0	17,1	94	57	47	76,0
	Max	191,00	133,0	42,9	153	94	157	132,3
	% of N	54,1%	54,3%	54,1%	54,1%	54,1%	75,0%	18,7%
30-60	Mean	167,9597	70,710	24,570	121,48	81,02	65,57	105,898
	Min	150,00	44,0	,0	63	62	45	76,1
	Max	186,00	108,0	35,2	172	115	89	153,0
	% of N	28,2%	27,9%	28,2%	28,2%	28,2%	20,4%	46,7%
>60	Mean	163,4872	72,718	27,118	131,90	80,24	68,29	112,970
	Min	147,00	54,0	22,3	98	68	50	76,0
	Max	179,00	101,0	35,4	174	97	92	142,7
	% of N	17,7%	17,8%	17,7%	17,7%	17,7%	4,6%	34,6%
Total	Mean	168,5500	69,823	24,379	122,18	76,66	69,81	106,322
	Min	147,00	44,0	,0	63	57	45	76,0
	Max	191,00	133,0	42,9	174	115	157	153,0
	% of N	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

4 Conclusions and Further Work

The age-related increase in aortic stiffness of the selected Portuguese cohort was confirmed. Our data shows a positive correlation for cfPWV with the sarcopenia severity

degree, which represents an increasing arterial stiffness and might be explained by the fact that the loss of muscle mass is often associated with chronic inflammation [14].

Central Arteria Pressure was correctly and easily measured with VasoCheck in all age ranges population. It was possible to conclude that CAP increases with ageing, and in future work it is pretended to demonstrate that is a good marker of CV risk in this cohort.

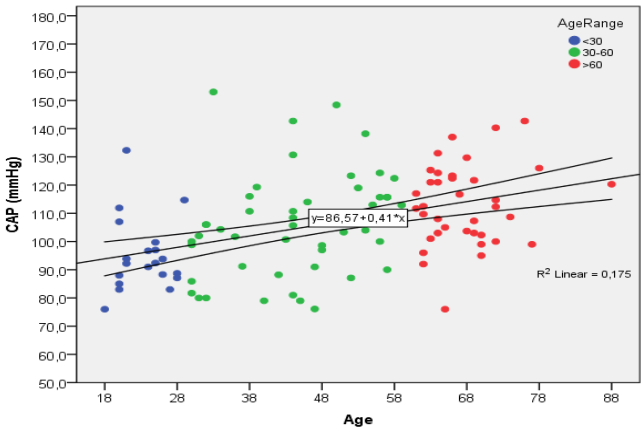

Fig. 3. Linear regression model for age and CAP. The lines over and above the regression line represent the area of the confidence interval.

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