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ORIGINAL RESEARCH ARTICLE

Associations between arterial health and sexual function in women aged 60–64 years

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Abstract

Introduction: Female sexual dysfunction is very common, but its determinants remain under-investigated. Vasculogenic impairments are suggested to be related to female sexual dysfunction, but previous literature regarding the association is scarce. This study aims to study the association between arterial health and female sexual function in women in their 60s.

Material and methods: The sample for this cross-sectional study comprised 117 women (aged 60–64 years) who participated in the Finnish Retirement and Aging study. Arterial health was measured according to the participants' pulse wave velocity, ankle–brachial index, blood pressure, and pulse pressure. Sexual function was measured using the Female Sexual Function Index, which resulted in a total score and six sub-scores. Associations were examined using multivariable regression analyses, which were adjusted for age, relationship happiness, systemic menopausal hormone therapy and/or local estrogen, smoking, alcohol risk use, body mass index, and depressive symptoms.

Results: Higher diastolic blood pressure was associated with a higher total Female Sexual Function Index score (β=0.24, 95% confidence interval [CI] 0.07–0.41) and with higher desire (β=0.02, 95% CI 0.01–0.04), arousal (β=0.04, 95% CI 0.01–0.08), lubrication (β=0.04, 95% CI 0.002–0.08), satisfaction (β=0.03, 95% CI 0.003–0.05), and pain (β=0.06, 95% CI 0.02–0.10) sub-scores. Also, higher ankle–brachial index was associated with higher satisfaction sub-score (β=2.10, 95% CI 0.44–3.73) and lower pulse pressure was associated with higher orgasm sub-score (β=0.03, 95% CI 0.0002–0.06). Other associations between ankle–brachial index and Female Sexual Function Index scores were statistically insignificant, but considering the magnitude the findings may imply clinical significance. Systolic blood pressure and pulse wave velocity were not associated with sexual function.

Abbreviations: ABI, ankle–brachial index; BDI, Beck Depression Index; BMI, body mass index; CVD, cardiovascular disease; FIREA, Finnish Retirement and Aging Study; FSD, female sexual function; FSFI, Female Sexual Function Index; MHT, menopausal hormone therapy; PWV, pulse wave velocity.

Conclusions: This study suggested a plausible association between higher diastolic blood pressure and female sexual function, but considering clinical significance our findings suggest an association between higher ankle–brachial index and good sexual function in women in their 60s.

KEYWORDS
ankle–brachial index, arterial health, blood pressure, late middle-aged women, sexual dysfunction, sexual health, woman

1 | INTRODUCTION

Female sexual dysfunction (FSD) includes disorders related to sexual desire, arousal, orgasm, and pain.[1] There is a lack of overall prevalence estimates for FSD in postmenopausal women. According to a published meta-analysis, up to 40.9% of premenopausal women suffer from FSD during their lifetimes.[2] Of the different aspects of FSD, hypoactive sexual desire disorder and female orgasmic disorder have been shown to be most frequent.[2] As age is an important risk factor for FSD, the prevalence of FSD in postmenopausal women is thought to be higher.[3] Despite the high prevalence of FSD, the etiology and contributory factors are poorly understood but may relate to impaired arterial health. Although the role of arterial health in the development of FSD has attracted increasing interest in recent years,[4] it remains under-investigated.

Pathophysiological mechanisms of FSD are not completely understood, but some of the proposed explanations are changes in hormonal balance, mainly in estrogen and in testosterone, and vasculogenic impairments in the genitals.[5] Both estrogen and testosterone are suggested to be important in maintaining the normal structure and function of the vagina and clitoris.[6] Use of systemic and local estrogen has been shown to be associated with better sexual function, especially concerning lubrication, pain, and satisfaction.[7] The role of testosterone is more debated. Although there is evidence to support testosterone as an effective treatment for FSD in postmenopausal women, less is known about the long-term effects of testosterone treatment for FSD.[8]

According to current knowledge, the peripheral sexual response is dependent on genital blood flow that is regulated by vascular and non-vascular smooth muscle. The exact signaling pathways that mediate the sexual response are unknown, but preclinical studies suggest nitric oxide and cyclic guanosine monophosphate to be at the center.[5] Impairments to endothelium in genital blood vessels—as a result of, for example, atherosclerosis, hypertension, aging, or smoking—may weaken vascular dependent relaxation and lead to decrease in relaxing factors such as nitric oxide.[9,10] Other pathways have also been suggested, but most studies have been made with animal models and evidence in humans is scarce.[5]

Previous studies on the association between arterial health and FSD have concentrated mainly on hypertension as an arterial health indicator. According to earlier studies, FSD is more prevalent in hypertensive women than in normotensive women.[11–13] Furthermore, some,[12] but not all,[13] studies have suggested that FSD improves with antihypertensive treatment. In contrast, however, beta-blockers have been shown to worsen sexual function in women.[14]

Key message

Despite the high prevalence of female sexual dysfunction, its relationship with arterial health is poorly understood. Our population-based study suggested a plausible association between higher diastolic blood pressure and higher ankle–brachial index and good female sexual function in women in their 60s.

Only a few studies have examined the relationship between atherosclerosis and FSD. Atherosclerosis is a lipid-driven chronic inflammatory process that leads to plaque build-up inside arteries, reducing arterial blood flow.[15] As a systemic disease, atherosclerosis manifests in various diseases, such as coronary artery disease, acute stroke, and peripheral artery disease. Though all the clinical manifestations have their own characteristics, the pathophysiology of atherosclerotic processes are mainly similar in different arterial territories.[16] In one case–control study, women with coronary artery disease experienced FSD and reduced sexual function more often than healthy controls.[17] Another case–control study examined the relationship between pulse wave velocity (PWV), a marker for arterial stiffness and atherosclerosis, and FSD in patients undergoing hemodialysis.[18] Arterial stiffness was greater among women with FSD than among women without FSD. In addition, the same study found that a deteriorated ankle–brachial index (ABI), a marker for peripheral artery disease, was more prevalent among women with FSD.[18] These studies were limited by their small heterogeneous populations. Both studies examined FSD in women with vascular disease, coronary artery disease or chronic kidney disease, but the authors did not discuss the relationship between arterial health and FSD in otherwise healthy women.[17,18] Both studies diagnosed FSD based on the Female Sexual Function Index (FSFI), but the latter study did not investigate the connections between PWV, ABI, and FSFI sub-scores,[18] which reflect different aspects of sexual function.

To address the gaps in the literature, we aimed to study the associations between different indicators of arterial health and FSD among women in their 60s with controlled systemic illnesses in a cross-sectional study design. We hypothesized that women with markers for deteriorating arterial health would have decreased sexual function.

2 | MATERIAL AND METHODS

2.1 | Participants

The study population consisted of women who participated in the Finnish Retirement and Aging Study (FIREA) (Figure 1).[19,20] The eligible population included all public-sector employees with expected retirement dates between 2014 and 2019. In 2012, they all worked in Southwest Finland in nine selected cities. Altogether, 6679 participants, both women (n=5490) and men (n=1189), responded to at least one of the FIREA questionnaires. The Finnish-speaking participants with expected retirement dates between 2017 and 2019 and who were still employed were invited to participate in a clinical sub-study (n=773 total, n=647 women, and n=126 men). Of these, 241 women participated, 157 returned questionnaires regarding sexual function, and 137 answered at least one of the FSFI questions. In total, 117 women reported being in a relationship and were included in the analyses.

2.2 | Measurements of arterial health

2.2.1 | Arterial stiffness (pulse wave velocity)

Arterial stiffness was assessed with on carotid–femoral pulse wave velocity (PWV) measurements using a SphygmoCor PVx system with an MM3 electronics module and a Millar tonometer.[21] The women were asked to avoid heavy meals, caffeine, and tobacco for 3 h and alcohol for 24 h before the assessments. They also rested in a supine position for 5–10 min before examination. Three electrodes were attached to the body to record the timing of cardiac R-waves (times of pulse wave departures from the heart). The pulse waves were measured at the right femoral arteries and right common carotid arteries (times of pulse wave arrivals at the distal arteries). The distance between the manubrium sternum and the registration points was measured to provide a straight distance between the registration points. Transit time referred to the time delay between the bases of the two waveforms and the R-wave of the simultaneously recorded electrocardiogram. Subsequently, PWV was calculated by dividing the distance by the transit time (m/s). PWV measurements were performed twice and averaged for statistical analysis. A reasonable cut-off score for increased carotid–femoral PWV is >10 m/s for the general population.[22] Higher PWV values indicate arterial stiffening, which is a risk factor for future cardiovascular disease.[22]

2.2.2 | Ankle–brachial index, blood pressure, and pulse pressure

Ankle–brachial index, blood pressure, and pulse pressure were measured with a Microlife Watch BP Office Central device. The women were asked not to eat or drink for 10 h before examination, and to avoid tobacco for 4 h, alcohol for 24 h, and heavy exercise during the preceding day before examination. Each woman sat on a chair and rested for 5 min before the examination. First, blood

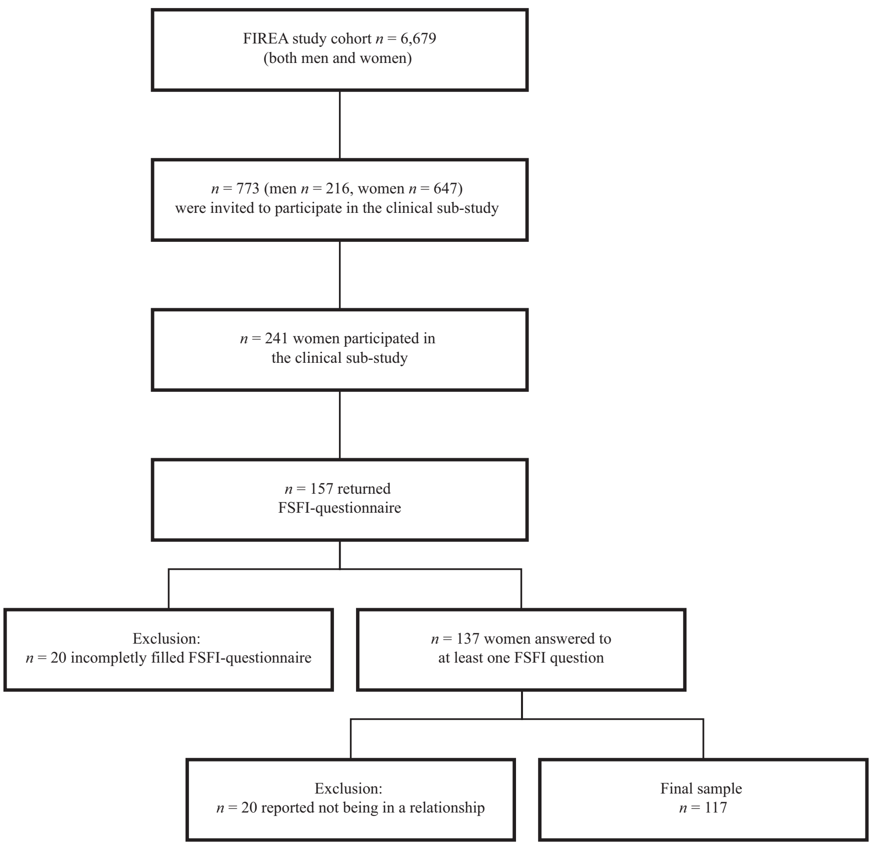

FIGURE 1 Flowchart of the study. FIREA, Finnish Retirement and Aging Study. FSFI, Female Sexual Function Index.

pressure was measured twice in both arms as a screening measure, and central blood pressure was measured from the arm that produced higher blood pressure values. Thereafter, the ABI measurement was performed in the supine position, first on the right arm and ankle concurrently, and then on the left side. The ABI was calculated by dividing the ankle blood pressure by the brachial blood pressure. In addition, pulse pressure was calculated as the difference between systolic and diastolic blood pressures. Left-side ABI, blood pressure, and pulse pressure were used for the analyses in this study. A high ABI value indicated good peripheral arterial function, and an ABI value below 0.90 was considered a marker for peripheral arterial disease.[23] In Finland, the suggested upper limits for normal blood pressure are 140 mmHg for systolic pressure and 90 mmHg for diastolic pressure;[24] 60 mmHg is considered the upper limit of normal pulse pressure.[25]

2.3 | Evaluation of sexual function

Sexual function was assessed using the FSFI questionnaire, which is suitable for use with both sexually active and non-active women.[26] The questionnaire evaluates sexual function over the preceding 4 weeks and includes 19 questions across 6 subdomains: desire (two questions), arousal (four questions), lubrication (four questions), orgasm (three questions), satisfaction (three questions), and pain (three questions). Sexual function is evaluated based on the FSFI sub-scores and total scores. Desire has a minimum score of 1.2, indicating "low desire". Minimum score for satisfaction is 0.8 indicating "dissatisfaction". Arousal, lubrication, orgasm, and pain have a minimum score of 0, indicating "no sexual activity." Six is the maximum sub-score for each subdomain. Higher sub-scores each indicate better function in the concerning subdomain. For pain, higher sub-score indicates less experienced pain. The total scores range from 2 to 36, with a higher score indicating better sexual function. A total score ≤26 is considered the cut-off for FSD.[26,27]

2.4 | Confounding factors

The selected confounders are shown to be associated both with sexual function and cardiovascular health.[3,7,28–35] Age was reported in years. Relationship happiness was evaluated with the question "How do you consider your current relationship?" and with answer options "very happy", "fairly happy", "neither happy nor unhappy", "fairly unhappy", and "very unhappy" and dichotomized as happy/unhappy. Those who reported being "neither happy nor unhappy" were classified as "unhappy". The use of systemic menopausal hormone therapy (MHT) (yes/no) and/or local estrogen (yes/no) was assessed in the questionnaire and combined for the analyses. Smoking (nonsmokers [never or former]/current smokers) and alcohol consumption (beer, wine, and/or spirits, with risk use defined as >16 drinks per week)[36] were self-reported. Body mass index (BMI, kg/m^2) was calculated from the measured weight and height. Depressive symptoms were evaluated using the Beck Depression Inventory (BDI).[37] Women self-reported any chronic diseases or symptoms (hypertension, myocardial infarct, stroke, claudication, etc.) previously diagnosed by a physician and their current medication.

2.5 | Statistical analyses

The characteristics of the study participants are presented as means and standard deviations for the continuous variables and as percentages (number, *n*) for the categorical variables. Because of the skewed distributions, the FSFI totals, and sub-scores are reported as medians and lower (Q1) and upper (Q3) quartiles. The characteristics are shown for the study population and also stratified by FSD. To compare the characteristics between women with and without FSD, a two-sample *t* test was performed for continuous variables assuming equal variances. Regarding age, the mean values were compared using the same method but assuming unequal variances. A Levene test was used to evaluate assumption of equality of variances. Comparisons for categorical variables were made with chi-squared test.

The FSFI sub-score was calculated for each domain that had at least one question answered. Altogether 22 women had one or more missing values in the FSFI questionnaire; missing values were substituted with the mean value for that question across all participants. The total scores were calculated for all questionnaires that had at least three subdomain questions partly or completely answered.

The associations between PWV, ABI, blood pressure, pulse pressure, and FSFI total as well as FSFI sub-scores were evaluated with separate multivariable linear regression models. Age, relationship happiness, systemic MHT use and/or local estrogen use, smoking, alcohol risk use, BMI, and BDI score were used as confounding factors in the analyses. Age, FSFI score, PWV, ABI, blood pressure, pulse pressure, BDI score, and BMI were included in the models as continuous variables, whereas the rest of the confounding factors (relationship happiness, systemic MHT use and/or local estrogen use, smoking, and alcohol risk use) were included as categorical variables.

To examine selection bias, the basic characteristics and self-reported cardiovascular diseases and symptoms of the current study population ($n=117$) were compared with the FIREA clinical sub-study population ($n=241$) and female survey participants ($n=5263$). An additional analysis of multivariable linear regression models was used to evaluate the associations between PWV, ABI, blood pressure, pulse pressure, and FSFI total as well as FSFI sub-scores in study participants who did not self-report hypertension. The same confounding factors (age, relationship happiness, systemic MHT use and/or local estrogen use, smoking, alcohol risk use, BMI, and BDI score) were used in the analyses. Furthermore, the associations between PWV, ABI, blood pressure, pulse pressure, and FSFI total and FSFI sub-scores were investigated in all the 137 women who answered the FSFI questionnaire, including those without a reported relationship. In this analysis, relationship happiness was left out as

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a confounding factor, but other confounding factors (age, systemic MHT use and/or local estrogen use, smoking, alcohol risk use, BMI, and BDI score) were used as in the preliminary analyses. The statistical analyses were conducted using JMP® Pro for Mac version 17.0.0 (SAS Institute, Cary, NC, USA).

3 | RESULTS

The characteristics of the study population are shown in Table 1. The mean age was 62.3 ± 1.0 years, and 82.9% reported being in a "fairly happy" or "very happy" relationship. Of the participants, 17.4% self-reported having diagnosed hypertension and of those, 94.3% used antihypertensive medication. Only 4.7% self-reported having cardiovascular disease, 5.7% had diabetes, and 24.5% had hypercholesterolemia. All women, except one, with self-reported diabetes used antidiabetic medication and 41.7% of women with reported hypercholesterolemia used statins. Characteristics of the study participants did not differ between women with and without FSD, except for diastolic blood pressure. Compared with the FIREA survey and clinical sub-study female participants, the current study participants less often reported having hypertension, they were more often married or cohabiting, and had higher occupational positions (Table S1).

Table 2 shows the FSFI totals and sub-scores. The median total score was 25.9 points (interquartile range [IQR] 19.4–30.7). Based on a cut-off threshold of ≤26 for FSD, 50.4% of the participants had FSD. Regarding the FSFI sub-scores, the lowest median score was 2.4 (IQR 1.8–3.0) for desire, followed by 4.1 (IQR 2.4–5.0) for arousal. The highest median score, 5.6 (IQR 3.6–6.0), was for pain, meaning that only a few women experienced pain during sexual activity.

The mean PWV was 7.97 ± 1.41 m/s. Of all the women, 89.0% had normal (<10 m/s) PWV. Table 3 shows the results of the multivariable regression analyses. No association was found between PWV and FSFI totals or sub-scores.

The mean ABI was 1.23 ± 0.13. ABI values were normal (ABI >0.9) in 96.4% of women. A higher ABI was associated with a higher satisfaction sub-score (β = 2.10, 95% CI 0.44–3.73). Other associations between FSFI scores and ABI were not statistically significant, but the magnitude of these associations could imply clinical significance. There was a tendency that higher ABI was associated with higher arousal (β = 1.69, 95% CI −1.05 to 4.42), lubrication (β = 2.31,

TABLE 1 Basic characteristics (n = 117).

	All			No FSD (n = 57)			FSD (n = 58)			*p* for group differences[a]
	n	Mean (SD)	%	*n*	Mean (SD)	%	*n*	Mean (SD)	%	
Age (years)	115	62.3 (1.0)		56	62.3 (1.1)		57	62.4 (1.1)		0.601
Happy relationship	117		82.9	57		87.7	58		79.3	0.225
Systemic MTH user	116		29.3	56		37.5	58		22.4	0.078
Local estrogen user	116		48.3	57		49.1	57		47.4	0.851
Local lubricant user	116		21.6	57		22.8	57		21.0	0.821
Smoking	112		4.5	56		3.6	54		3.7	0.970
Alcohol risk use	115		9.6	56		8.9	57		8.8	0.977
BMI (kg/m^2)	112	25.7 (3.6)		55	26.0 (3.6)		56	25.5 (3.6)		0.522
BDI score	115	5.6 (4.6)		56	5.0 (4.9)		57	6.0 (4.2)		0.257
Hypertension	109		17.4	54		16.7	53		18.9	0.766
CVD	107		4.7	53		3.8	52		5.8	0.662
Diabetes	107		3.7	53		5.7	52		1.9	0.317
Hypercholesterolemia	106		22.6	53		24.5	51		21.6	0.720
PWV (m/s)	109	7.97 (1.41)		54	8.0 (1.46)		53	7.9 (1.21)		0.675
ABI	112	1.23 (0.13)		56	1.25 (0.12)		55	1.21 (0.14)		0.142
Systolic blood pressure (mm Hg)	113	137.6 (19.1)		56	138.3 (17.9)		55	136.7 (19.8)		0.671
Diastolic blood pressure (mm Hg)	113	82.5 (10.4)		56	84.7 (10.5)		55	80.5 (9.7)		0.032
Pulse pressure (mm Hg)	113	55.0 (13.7)		56	53.6 (12.3)		55	56.3 (12.8)		0.303
FSD[b]	115		50.4							

Note: Hypertension, CVD, diabetes and hypercholesterolemia were self-reported.

Abbreviations: ABI, Ankle–brachial index; BDI, Beck Depression Inventory score; BMI, body mass index; CVD, cardiovascular disease; FSD, Female Sexual Dysfunction; MTH, menopausal hormone therapy; PWV, pulse wave velocity; SD, standard deviation.

[a]Assessed with two-sample *t* test for continuous variables and with chi-squared test for categorical variables.

[b]22 women had one or more missing values in the FSFI questionnaire and data for those were imputed for 21 questionnaires.

95% CI −0.61 to 5.23), pain scores (β=2.08, 95% CI −1.20 to 5.37), and total score (β=9.44, 95% CI −3.87 to 22.75).

The mean systolic blood pressure was 137.6±19.1 mm Hg, and the mean diastolic blood pressure was 82.5±10.4 mm Hg. Of all the women, 26.5% had both elevated systolic blood pressure (≥140 mm Hg) and elevated diastolic blood pressure (≥90 mm Hg). Fifteen percent of women had only elevated systolic blood pressure and 1.8% had only elevated diastolic blood pressure. Mean diastolic blood pressure for women without FSD was 84.7±10.5 mm Hg, which was higher than in women with FSD (p=0.032), whose diastolic blood pressure mean was 80.5±9.7 mm Hg (Table 1). Higher diastolic blood pressure was associated with higher desire (β=0.02, 95% CI 0.01–0.04), arousal (β=0.04, 95% CI 0.01–0.08), lubrication (β=0.04, 95% CI 0.002 to 0.08), satisfaction (β=0.03, 95% CI 0.003–0.05), and pain (β=0.06, 95% CI 0.02–0.10) sub-scores and with a higher total score (β=0.24, 95% CI 0.07–0.41). Furthermore, a borderline association was found between higher diastolic pressure and a higher orgasm sub-score (β=0.04, 95% CI −0.002 to 0.08). No association was observed between systolic blood pressure and FSFI totals or sub-scores.

TABLE 2 FSFI scores in the study population (n=117).

FSFI score	*n*	Median (IQR)
Desire	116	2.4 (1.8–3.0)
Arousal	116	4.1 (2.4–5.0)
Lubrication	116	4.8 (3.3–5.7)
Orgasm	116	4.4 (2.4–5.6)
Satisfaction	111	4.8 (4.0–6.0)
Pain	115	5.6 (3.6–6.0)
Total	115	25.9 (19.4–30.7)

Note: Twenty-two women had one or more missing values in the FSFI questionnaire and data for those were imputed for 21 questionnaires.
Abbreviations: FSFI, Female Sexual Function Index; IQR, interquartile range.

The mean pulse pressure was 55 mm Hg (13.7), and 26.5% of the women had increased pulse pressure (>60 mm Hg). In the study population, lower pulse pressure was associated with a higher orgasm score (β=0.03, 95% CI 0.0002–0.06).

Table S2 shows associations between arterial health and sexual function in women without self-reported hypertension. In this group, higher diastolic blood pressure had a tendency for higher pain score indicating less experienced pain. Also, higher ABI had a tendency for higher arousal, lubrication, satisfaction sub-scores, and higher total score. Other associations were not detected. Furthermore, higher diastolic blood pressure was associated with higher desire, arousal, pain, and satisfaction sub-scores and higher total score in all the women who participated in the study (Table S3). A tendency between higher diastolic blood pressure and higher lubrication score was also found.

4 | DISCUSSION

In this study, we aimed to examine the associations between arterial health and sexual function in women in their 60s. We found that women with higher diastolic blood pressure had better sexual function, as well as higher desire, better arousal, greater satisfaction, and less experienced pain. These findings suggest an association between diastolic blood pressure and female sexual function. We also found association between higher ABI and greater sexual satisfaction. Moreover, higher ABI tended to be associated with better arousal, easier lubrication, and less pain, as well as with better sexual function, but due to the small sample size the associations did not reach statistical significance.

Our finding that higher diastolic blood pressure was associated with better sexual function was a novel one. Of the FSFI sub-scores, higher diastolic blood pressure was associated with higher desire, better arousal, greater satisfaction, as well as less pain and easier lubrication during sexual activity. Previous literature has focused on exploring the associations between hypertension and FSD,[13] but has

TABLE 3 Associations between arterial health and sexual function (n=117).

	PWV				ABI				Systolic blood pressure			
	n	*β*	95% CI	*p*	*n*	*β*	95% CI	*p*	*n*	*β*	95% CI	*p*
Desire	102	0.06	−0.06 to 0.18	0.337	106	0.71	−0.45 to 1.87	0.229	106	0.006	−0.001 to 0.02	0.159
Arousal	102	0.18	−0.11 to 0.46	0.232	106	1.69	−1.05 to 4.42	0.223	106	0.001	−0.02 to 0.03	0.912
Lubrication	103	0.04	−0.26 to 0.34	0.793	106	2.31	−0.61 to 5.23	0.120	107	−0.001	−0.02 to 0.02	0.952
Orgasm	103	0.13	−0.17 to 0.43	0.383	106	0.91	−2.11 to 3.94	0.551	107	−0.006	−0.03 to 0.02	0.572
Satisfaction	99	0.06	−0.14 to 0.25	0.571	103	2.10	0.44 to 3.73	0.014	103	0.006	−0.01 to 0.02	0.377
Pain	102	0.04	−0.32 to 0.39	0.829	106	2.08	−1.20 to 5.37	0.211	106	0.008	−0.01 to 0.04	0.526
Total score	102	0.71	−0.73 to 2.14	0.330	106	9.44	−3.87 to 22.75	0.161	106	0.019	−0.07 to 0.14	0.709

Note: Associations were evaluated with separate multivariable linear regression models and adjusted with age, relationship happiness, systemic MHT use and/or local estrogen use, smoking, alcohol risk use, BMI, and depressive symptoms. Due to missing data on arterial health parameters and missing values in the FSFI questionnaire *n* values differ across the comparisons.
Abbreviations: ABI, ankle–brachial index; BMI, body mass index; CI, confidence interval; MHT, menopausal hormone therapy; PWV, pulse wave velocity.

not investigated the association between diastolic blood pressure and FSD. The mechanism behind this connection is unknown, but age-related decrease in diastolic blood pressure could offer an explanation. Beyond 50–60 years of age, diastolic pressure starts to decrease, despite systolic blood pressure continuing to increase, due to stiffening of the larger arteries.[38] A decrease in diastolic pressure may deteriorate peripheral tissue perfusion and lead to tissue hypoxia.[39] Vaginal engorgement and clitoral erection are thought to depend on genital blood flow.[40,41] Hence, deteriorating tissue perfusion could negatively affect sexual function and explain the positive association between higher diastolic pressure and sexual function. Even though diastolic blood pressure was associated with almost all FSFI sub-scores and total score, the magnitude of these associations remained marginal. According to our findings, a 10 mm Hg rise in diastolic blood pressure would result in 2.4 points higher FSFI total score. The association was weaker in women without reported hypertension, in whom a 10 mm Hg rise in diastolic blood pressure would result in 1.7 points higher total score. Due to the small number of participants, we could not investigate if the associations persisted in women with self-reported hypertension.

In contrast to diastolic blood pressure, we found no association between systolic blood pressure and FSD. To the best of our knowledge only two studies have considered systolic blood pressure and FSD. In a cross-sectional study conducted in the USA with 635 postmenopausal women with hypertension, systolic blood pressure was not associated with FSFI total scores.[42] However, only 28.8% of the women in that study were sexually active. Another study was a Greek case–cohort study involving 417 young and middle-aged hypertensive (>140/90 mm Hg) and normotensive women, which found that higher systolic blood pressure strongly correlated with worse sexual function based on FSFI scores.[12] The different results of the Greek study and our study may be a result of the different study designs and differences in the study samples. The Greek study included 136 women treated for hypertension whose FSFI scores were low compared with those of both untreated hypertensive and normotensive women. Furthermore, the women using antihypertensive medication had the highest mean systolic blood pressure among the three groups. The authors suggested that inadequate control of hypertension and the use of beta-blockers were major determinants of FSD. In our study, instead, most of the women were normotensive according to both the self-report and the actual blood pressure measurements.

The present study is the first to investigate the relationship between pulse pressure and FSD. Lower pulse pressure was associated with better ability to reach an orgasm during sexual activity. As discussed previously, systolic blood pressure continues to increase with age, but diastolic blood pressure decreases and pulse pressure increases.[38] Therefore, pulse pressure is considered a well-known hemodynamic marker for aging.[43] High systolic pressure can lead to endothelial dysfunction, which reduces the bioactivity of nitric oxide[44,45]—an important factor in the regulation of genital tissue blood flow and genital arousal responses.[46] A decrease in diastolic pressure can reduce peripheral tissue perfusion.[39] Even though these mechanisms could explain the association between higher pulse pressure and ability to reach an orgasm, the magnitude for the association was marginal, which leads us to doubt the clinical significance of the finding.

Women with higher ABI values had greater sexual satisfaction. Even though we detected no statistically significant associations between ABI values and other FSFI sub-scores and total score, the effect for arousal, lubrication, pain and total score may suggest clinical significance of the associations. Also, among women without self-reported hypertension the associations between higher ABI values and higher arousal, lubrication, and satisfaction sub-scores and total score persisted as tendencies. Previous literature regarding the relationship between peripheral arterial health and FSD remains limited, but a Croatian case–control study with 92 participants, of which 34 were women, found that patients with FSD had lower ABI values than patients without FSD.[18] In our study population, almost all women had ABI values in the normal range and mean ABI was

Diastolic blood pressure				Pulse pressure			
n	*β*	95% CI	*p*	*n*	*β*	95% CI	*p*
106	0.02	0.01–0.04	0.005	106	−0.0003	−0.01 to 0.01	0.959
106	0.04	0.01–0.08	0.015	106	−0.02	−0.05 to 0.01	0.163
107	0.04	0.002–0.08	0.040	107	−0.02	−0.05 to 0.01	0.142
107	0.04	−0.002 to 0.08	0.051	107	−0.03	−0.06 to −0.0002	0.049
103	0.03	0.003–0.05	0.027	103	−0.005	−0.02 to 0.01	0.614
106	0.06	0.02–0.10	0.007	106	−0.02	−0.05 to 0.02	0.374
106	0.24	0.07–0.41	0.006	106	−0.09	−0.24 to 0.046	0.185

normal in women with and without FSD, whereas in the Croatian study the FSD group had pathological mean ABI values and the non-FSD group had ABI mean values in the normal range. The ceiling effect in our study could explain the weaker association. Nevertheless, our findings imply an association between peripheral arterial function and female sexual function and therefore, it would be warranted to investigate in future studies sexual function in women with pathological ABI or clinical signs of peripheral artery disease.

We could not confirm an association between the central arterial stiffness measured by PWV and FSD. So far only two studies have been published investigating that association. One of them is the previously mentioned Croatian case–control study on patients with end-stage renal disease undergoing chronic hemodialysis.[18] PWV was found to be higher in patients with FSD compared with the non-FSD group.[18] Furthermore, a recently published cross-sectional Greek study showed similar results in postmenopausal women. They found that PWV values correlated negatively with FSFI scores independently of menopausal symptoms.[47] In our study, almost all the women had normal PWV, and only a few reported cardiovascular disease other than hypertension, whereas in the Croatian study, participants had end-stage renal disease, which has an at least partly vascular etiology.[48] In addition, different study designs and population sizes could explain the different results. In the Greek study the PWV values were higher in the women with FSD indicating worse central arterial function, whereas in our study population, women with and without FSD had similar PWV values. Also, almost all participants in our study had PWV values in the normal ranges and variance among study participants was little. These factors could explain differences in the study results between the current study and the Greek study.

The strengths of our study include the use of a valid and widely used sexual function questionnaire.[26,27] This made it easier to compare our study outcomes with previously published data. Moreover, arterial health was measured using a variety of parameters that reflected both central and peripheral arterial health. We considered many confounding factors, such as depression and relationship happiness, in the analyses. For example, depression has shown to decrease sexual function in females.[49] Previous studies in the field have investigated women with detected arterial impairment,[18,47] whereas our study is the first to evaluate the relationship between arterial health and FSD in women in their 60s with relatively good arterial function.

However, our study has some limitations. First, our study sample was quite small, and the study was cross-sectional; therefore, the causality between arterial health and sexual function could not be determined, and future follow-up studies with larger sample size are warranted. Second, most of the women in our study had good arterial function according to PWV and ABI values, which can partly explain why associations found between arterial health parameters and sexual function were limited. There were fewer women with hypertension in the current study population compared with the FIREA survey and clinical sub-study female participants. This demonstrates that women in our study might be healthier regarding arterial function compared with women of the same age in Finland. Third, the response rate to the FSFI questionnaire was fairly low and some participants left sporadic questions unanswered in the questionnaire. Fourth, we did not gather data for the reasons for refusal, but previous literature suggests conservative attitudes, lower level of education status and lower alcohol consumption to be associated with refusal of attending sexuality surveys.[50] The current study participants had higher occupational positions compared with the FIREA survey and clinical sub-study female participants, but differences in alcohol consumption were not detected. Conservative attitudes were not surveyed but it is possible that these factors may also cause selection bias in the current study.

Even though the FSFI questionnaire is a valid tool for assessment of sexual complaints and is widely used in FSD research,[26] it does not consider sexual distress associated with sexual complaints. A recent study published in the *Journal of Sexual Medicine* suggested the use of the Female Sexual Distress Scale in combination with the FSFI questionnaire as the diagnostic tool for FSD in clinical use.[51] Sexual complaints are not by themselves defined as an FSD if not accompanied by distress.[52] Therefore, we could have overestimated the frequency and severity of FSD in our study population by using only the FSFI questionnaire and so may have weakened the found associations. Furthermore, we cannot comment on the differences in sexual function between the current study population compared with the FIREA survey and the clinical sub-study female participants because the data were only gathered from the current study population. Because we assessed relationship happiness and used it as a confounder in the analyses, we excluded women without a reported relationship. Therefore, the study results cannot be reliably applied to the sexually active women with casual relationships. Finally, the age of male partners was not investigated. Risk for sexual dysfunction in men increases with age,[53] and male sexual dysfunctions, especially erectile dysfunction, are known to be associated with FSD in heterosexual partnerships.[54]

5 | CONCLUSION

Despite the high prevalence of FSD, its relationship with arterial health is poorly understood. According to our study results, higher diastolic blood pressure was associated with better sexual function in women in their 60s. Also, considering the clinical significance of our findings, an association between higher ABI and better sexual function may be suggested. However, further prospective studies with larger sample sizes are warranted to confirm these associations.

AUTHOR CONTRIBUTIONS

Viivi Virkkunen is the lead author of the paper. Päivi Polo-Kantola, Sari Stenholm, and Katja Kero are leaders of the study, coinvestigators, and coauthors. Teemu Niiranen and Olli Heinonen are coinvestigators and coauthors. Mari Koivisto was the statistician for the study.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest pertaining to this manuscript.

ETHICS STATEMENT

The FIREA study was conducted in accordance with the Helsinki Declaration and was approved by the Ethics Committee of the Hospital District of Southwest Finland on August 25, 2015 (ETMK: 84/1801/2014). All participants gave their written informed consent.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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