



# The Research of Correlation Between Blood Pressure and Nailfold Capillary Parameters in Exercising and Non-Exercising Pregnant Women

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## Abstract

**Background/Aim:** With an increase in cardiac output, blood pressure values in pregnancy increase. The aim of the study was to examine the effect of prenatal exercises on the circulatory parameters and the correlation between blood pressure and nailfold capillary parameters in healthy pregnant women.

**Methods:** The blood pressure shape and length of nailfold capillary were assessed in 35 non-exercising pregnant women and 35 pregnant women who exercised, at the beginning of the study (between 20 and 32 gestational week) and the end of the study (28 – 40 gestational week).

**Results:** The elevation in blood pressure was significantly lower in pregnant women who exercised in relation to non-exercising pregnant women. After eight weeks, the length of the capillary loops was increased by 30  $\mu\text{m}$  and the number of pregnant women with pronounced shape changes of capillary loops increased, with no difference between the groups. Non-exercisers had a correlation between the change in diastolic pressure and the increase in capillary length ( $r = 0.53$ ,  $p = 0.001$ ). In the experimental group, the correlation between the change in blood pressure and the increase in the length of capillary loops was not determined.

**Conclusion:** Prenatal physical activity had a beneficial impact on the circulation of pregnant women. In pregnant women in the third trimester, after eight weeks of follow-up, the length of the nailfold capillary loops and the presence of pronounced shape changes of capillary loops were increased, without difference between exercisers and non-exercisers. In non-exercising pregnant women, the capillary length was increased with the elevation of diastolic blood pressure, while the correlation was not found in pregnant women who exercised.

**Key words:** Prenatal exercises; Pregnancy; Blood pressure; Nailfold capillary; Computer-assisted image analysis.

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## Introduction

In pregnancy, the circulatory system is adapted to adequately meet the demands of the mother and fetus. With an increase in cardiac output, blood pressure values in pregnancy are increased, systemic vasodilation leads to a decrease in total

peripheral resistance of blood vessels and blood pressure remains within the normal range.<sup>1-5</sup> Pregnancy-induced hypertension (PIH) is one of the main causes of morbidity (up to 10 %) and mortality in pregnant women (up to 14 %).<sup>6-8</sup> In

hypertension, there is a disturbance of the balance of vasomotor influences that leads to vasoconstriction and possible closure of vessels in the microcirculation.

In pregnancy, with the development of hypertension, there is a rarefaction of nailfold capillaries.<sup>3,9</sup> This is in line with the findings in adults with borderline and hypertensive values who have a rarefaction of the skin capillaries and morphological changes (dilatation, tortuosity, crossover, avascular fields, microhaemorrhage), which generally reflects changes in most capillary beds of the organism.<sup>10</sup> Adults who do regular physical activity have lower blood pressure values. Haakstad et al found that blood pressure values in normotensive pregnant women who exercised regularly were lower.<sup>11</sup> In the prenatal period, exercise intervention reduces the number of pregnancy complications by 40 %.<sup>12-14</sup>

Data on the influence of prenatal exercises on blood pressure values and microcirculatory characteristics in pregnant women with a normal pregnancy are rare. Nailfold capillaroscopy is a non-invasive method that provides insight into microcirculatory changes and provides an opportunity to assess the effect of treatment.

The aim of the study was to examine the effect of prenatal exercises on the circulatory parameters and the correlation between blood pressure and nailfold capillary parameters in healthy pregnant women, in order to apply moderate physical activity in the prevention of hypertension in pregnant women.

## Methods

The study included seventy pregnant women and was conducted at the Faculty of Medicine, University of Banja Luka, Bosnia and Herzegovina and at the Health Centre "Sveti Vračevi Čelinac". On the Clinicaltrials.gov database, the trial was registered and the identifier was NCT05001906. During prenatal appointments with the gynaecologists, healthy nulliparous pregnant women, inactive with no previous regular structured exercises, were recruited to the prenatal program. After the gynaecological examination and confirmation of healthy pregnancy, pregnant women were included in the program. The respondents joined the program during the second and third

trimester, ie from 20th to 32nd week of gestation at the earliest. One cycle of psychophysical preparation for childbirth lasted for 8 weeks. The respondents received oral and written information about the study. The study was approved by the Ethics Committee of the Faculty of Medicine Banja Luka (decision No 18/4.3.25/20). The criteria for inclusion were: age of pregnant women from 20 to 40, a normal pregnancy confirmed by a gynaecologist, duration of pregnancy from 20th to 32nd gestational week and single pregnancy. Exclusion criteria were: pregnancy-induced hypertension, bleeding, rupture of the amniotic sac, premature birth, intrauterine growth restriction, anaemia, not being regular in the physical exercise program and at the participant's own request.

The respondents were divided into control and experimental group. The control group consisted of 35 pregnant women who attended theoretical classes on childbirth and did not exercise. The sedentary participants continued their regular daily activities and life habits. The experimental group consisted of 35 pregnant women who attended theoretical classes and prenatal exercises for 45 min, three times a week, in the program of psychophysical preparation for childbirth. The prenatal exercise program was prepared according to the recommendations of the American College of Obstetricians and Gynaecologists (ACOG recommendations).<sup>15</sup> The exercise program was presented with: muscle stretching exercises, exercises to strengthen the abdominal wall, exercises to increase pelvic mobility, pelvic floor muscle training and breathing and relaxation techniques. The exercise included moderate walking for about 5 minutes, followed by exercises for 30 minutes. During exercises, ten to twelve repetitions were conducted in two to three series. The exertion of pregnant women was monitored on the basis of the subjective feeling of exertion. Exercising was stopped when the subjective feeling was "moderately difficult". Exercises of medium intensity were performed, using the Borg scale as a reference.

The blood pressure of pregnant women was measured with a standard mercury manometer. The blood pressure, the shape and length of nailfold capillary loops were assessed at the beginning of the study, between 20 and 32 weeks of gestation (time point 1) and at the end of the study, after eight weeks of theoretical classes in the control group and eight weeks of prenatal exercises

in the experimental group, between 28 and 40 weeks of gestation (time point 2). Nailfold capillaroscopy images were obtained with stereo microscope Leica EZ4 and digital video camera with adapter LM-Scope. During nailfold capillaroscopy, the pregnant woman was sitting with an outstretched hand, laid on a table at the level of the heart. In order to improve the transparency of the keratin layer of the nailfold of the fourth digit of the left hand, a drop of immersion oil was placed on the nailfold.<sup>16</sup> Capillary morphometry was performed by analysis of digital images of capillaries using Image Y software. The normal shape of capillaries is a hairpin or inverted letter U.<sup>16-18</sup> Tortuous capillaries were registered separately. Deviation from these forms was registered as pronounced shape changes and expressed as the number of capillaries with pronounced shape changes per 1 mm of distal row capillary in nailfold.<sup>18</sup> The capillary length was determined as the distance between the top of the capillary loop and the place where the capillary loop is no longer visible.

Statistical analysis of the obtained data was performed using the licensed software version SPSS 20.0. Data were analysed using descriptive statistical methods, t-test, Chi-square ( $\chi^2$ ) test, McNemar test and Pearson correlation test.

## Results

The control and experimental groups were equal with respect to age and gestational age at the time of joining the study. In the control group, the age of pregnant women was  $29.72 \pm 3.24$  and gestational age was  $28.97 \pm 3.38$ . In the experimental group, the age of pregnant women was  $30.12 \pm 3.31$  and gestational age was  $29.35 \pm 3.56$  weeks of gestation.

Hypertension was developed by four non-exercising pregnant women in the control group. The systolic blood pressure was increased by 15.56 mm Hg, from  $111.67 \pm 9.41$  mm Hg (at the beginning of attending classes on childbirth) to  $127.22 \pm 13.44$  mm Hg (at the end of theoretical classes on childbirth) in the control group. The lowest change in systolic blood pressure was -10 mm Hg, ie there was a decrease in blood pressure by 10 mm Hg and the highest was 30 mm Hg. Also, the diastolic blood pressure was increased by 16.08 mm Hg, from  $71.11 \pm 7.85$  mm Hg to  $87.19 \pm 17.97$

mm Hg. The lowest change in diastolic blood pressure was 0 mm Hg, ie there was no decrease in blood pressure and the highest was 30 mm Hg.

In the experimental group, the mean systolic blood pressure was significantly changed by 2.5 mm Hg from  $108.68 \pm 9.79$  mm Hg to  $111.18 \pm 9.77$  mm Hg. The lowest change in systolic blood pressure was -10 mm Hg and the highest was 30 mm Hg. The mean diastolic blood pressure was not changed. Before intervention diastolic pressure was  $68.38 \pm 9.43$  mm Hg and after  $68.24 \pm 8.25$  mm Hg. The lowest change in diastolic blood pressure was -10 mm Hg and the highest change was 20 mm Hg.

In pregnant women who performed prenatal exercises the elevation of systolic blood pressure and the change of diastolic blood pressure was significantly less compared to the elevation of systolic and diastolic blood pressure in non-exercising pregnant women ( $t = -5.892$ ,  $p < 0.001$ ).

Capillary loops that were aligned in rows were differentiated in the nailfold skin with nailfold capillaroscopy. In the proximal rows, the capillary loops were perpendicular to the skin surface and only the tips of the capillary loops were visible, while in the distal rows the capillary loops were parallel to the skin surface of the nailfold and were more accessible for analysis. The arms of the capillary loop were clearly visualised and the entire capillary loop had the normal shape of a hairpin or inverted letter U (Figure 1A).

At the beginning of the study in the control group, the tortuosity of nailfold capillary loops (with the preserved shape of a hairpin), was found in 10 pregnant women (28.57 %) and nailfold capillary loops with pronounced shape changes (with loss of a hairpin shape) were found in 1 pregnant woman (2.86 %) (Table 1 and Figure 1B).

In the experimental group, the tortuosity of nailfold capillary loops was found in 9 pregnant women (25.71 %) and nailfold capillary loops with pronounced shape changes were found in 1 pregnant woman (2.86 %).

After eight weeks of the prenatal program in pregnant women who did not exercise, tortuosity of nailfold capillary loops were found in 8 pregnant women (22.86 %) and nailfold capillary loops with pronounced shape changes in 11 pregnant women (31.43 %) (Figure 1C and 1D). In the experimental group of pregnant women who exercised, tortuosity of nailfold capillary loops was found in 7 pregnant women (20.00 %) and

nailfold capillary loops with pronounced shape changes were found in 6 pregnant women (17.14 %) (Table 1). The average number of capillary loops with pronounced shape changes in the control group was 2.67 capillary/mm and in the experimental group was 2.50 capillary/mm.

en with pronounced shape changes of capillary loops increased significantly in the control group (McNemar = 15,000, df = 3, p = 0.002) and the experimental group (McNemar = 8,000, df = 2, p = 0.018), while there was no significant differences between groups ( $\chi^2 = 2.485$ , df = 2, p = 0.289).

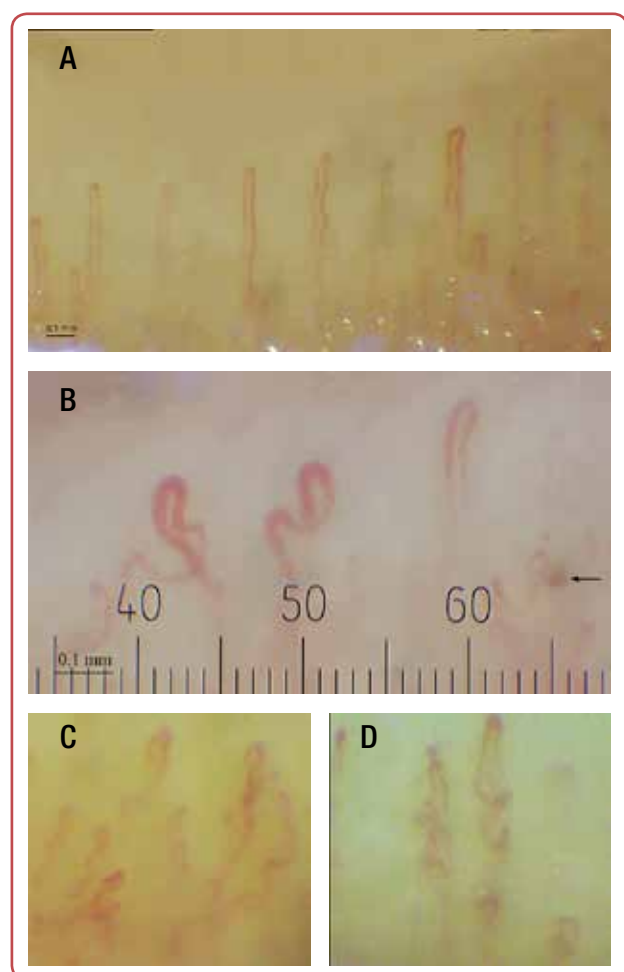
After eight weeks, the number of pregnant wom-

At the beginning of the study the average value of

**Table 1:** Shape and length of nailfold capillary in pregnant women at the beginning and end of the intervention

The shape of nailfold capillary		Normal shape N (%)	Tortuous capillary N (%)	Pronounced shape changes N (%)	Number of the capillary with pronounced shape changes (capillary/mm of the distal row)
Control group	Pre-intervention	24 (68.57 %)	10 (28.57 %)	1 (2.86 %)	1
	Post-intervention	16 (45.71 %)	8 (22.86 %)	11 (31.43 %)	2.67
	p-value*			p = 0.002	
Experimental group	Pre-intervention	25 (71.43 %)	9 (25.71 %)	1 (2.86 %)	1
	Post-intervention	22 (62.86 %)	7 (20.00 %)	6 (17.14 %)	2.50
	p-value*			p = 0.0018	
Between groups				p-value**	p = 0.289

*P-value\** refers to the difference in pronounced shape changes before the intervention and after the intervention in the group; data were analysed with the McNemar test.  
*P-value\*\** refers to the difference in pronounced shape changes after the intervention between the control group and the experimental group; data were analysed with  $\chi^2$  test.



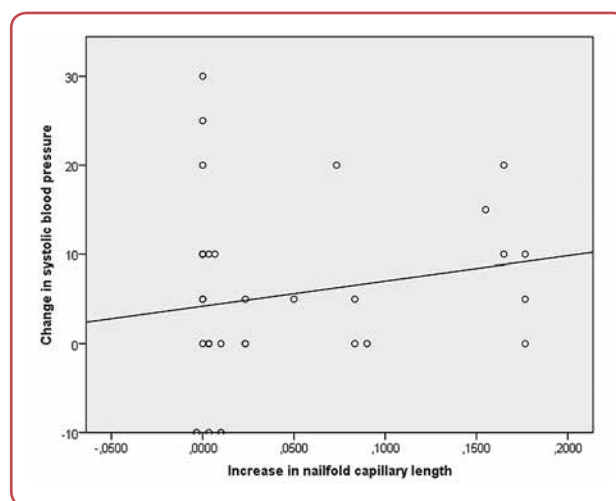
**Figure 1:** Nailfold capillary loops of pregnant women: A) Hairpin shape of capillary loops, B) Pronounced bending of the arms of capillary loops and haemorrhage (arrow), C) and D) Tortuosity and multiply crossings of capillary arms

**Table 2:** The length of nailfold capillary loops in non-exercising pregnant women and pregnant women who exercised, at the beginning and end of the prenatal program

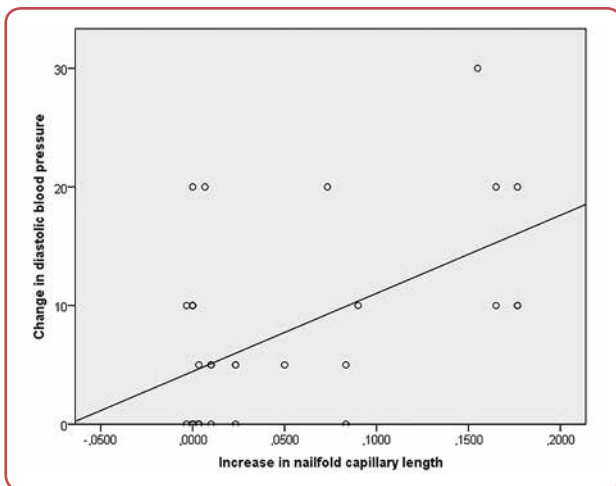
The length of nailfold capillary loops (µm)	Non-exercising pregnant women	Pregnant women who exercised
Pre-intervention	169 ± 56	172 ± 81
Post-intervention	199 ± 72	202 ± 96
p-value*	0.03	0.05

The results are presented as mean values ± standard deviation. Data were analysed with the t-test.

*P-value* refers to the difference in the length of nailfold capillary loops before the intervention and after the intervention in the group.



**Figure 2:** Relationship between change in systolic blood pressure and increase in nailfold capillary length



**Figure 3:** Relationship between change in diastolic blood pressure and increase in nailfold capillary length

capillary loop length in non-exercising pregnant women was  $169 \pm 56 \mu\text{m}$  and in pregnant women who exercised was  $172 \pm 81 \mu\text{m}$  (Table 2). At the end of the study capillary loop length in non-exercising pregnant women was  $199 \pm 72 \mu\text{m}$  and in pregnant women who exercised was  $202 \pm 96 \mu\text{m}$ . The mean increase in length was  $30 \mu\text{m}$  in both groups. A significant difference in capillary length was found between the first measurement time and the second measurement time in the control group ( $t = -2.352$ ,  $p = 0.03$ ) and the experimental group ( $t = -2.060$ ,  $p = 0.05$ ).

The values of the change in systolic blood pressure after the intervention were compared with the values of the increase in the capillary length and the values of the change in diastolic blood pressure after the intervention were compared with the values of the increase in the capillary length. In the control group, no positive correlation was found between the value of the change in systolic blood pressure and the value of the increase in the capillary length ( $r = 0.18$ ,  $p = 0.299$ ) (Figure 2). A positive correlation was found between the value of the change in diastolic blood pressure and the value of the increase in the length of capillary in pregnant women who did not exercise ( $r = 0.53$ ,  $p = 0.001$ ) (Figure 3).

In the experimental group, no connection was found between the value of systolic blood pressure change and the value of capillary length increase ( $r = 0.05$ ,  $p = 0.761$ ). Also, no connection was found between the value of diastolic blood pressure change and the value of capillary loop length increase ( $r = 0.16$ ,  $p = 0.343$ ).

## Discussion

Early studies in the area of prenatal exercise have shown concerns about the potential risks of exercise to new-born health. Concerns about the safety of exercise in pregnancy appear to persist.<sup>6</sup> In this study, the increase in blood pressure was significantly lower in pregnant women who performed prenatal exercises for eight weeks. Moderate physical activity had a beneficial impact on blood pressure in pregnant women. The development of hypertension in pregnancy was accompanied by vasoconstriction, which is present in all capillaries and also affects the vascularisation of the placenta and foetal nutrition.<sup>8, 19</sup> With the maintenance of blood pressure values in the normal range, the vascularisation of the placenta is better and thus the nutrition and development of the foetus.

Haakstad et al analysed the effect of a 12-week aerobic exercise (60 min 2 x/week) on the blood pressure of pregnant women who joined the exercise program between 12 and 24 gestational weeks. It was found that after the intervention, in 36-38 gestation weeks, systolic and diastolic blood pressure in resting was significantly lower in pregnant women who exercised.<sup>11</sup>

Rodríguez-Díaz and co-authors investigated the effectiveness of physical activity based on the Pilates method. After the exercise program of 8 weeks, there was a decrease in systolic blood pressure of 4 mm Hg in pregnant women who exercised, while in the control group, systolic pressure increased by 8 mm Hg. Diastolic blood pressure in the experimental group decreased by 4 mm after exercise and in the control group increased by 6 mm Hg.<sup>20</sup>

De Castro et al, using a meta-analysis of randomised studies, found that intervention of prenatal exercise was associated with a reduction of systolic and diastolic blood pressure compared with non-exercising pregnant women.<sup>12</sup>

Arterial hypertension causes lesions of variable intensity to the circulatory system.<sup>21</sup> Nailfold capillaroscopy revealed rarefaction of functional capillaries in the nailfold skin of pregnant women with PIH.<sup>17</sup> Microcirculation of the nailfold skin and retina is available for examination and analysis. Decreased capillary density and shape changes of nailfold were associated with reduced reti-

nal vessel density.<sup>21</sup> Changes in microcirculation in these capillary beds indicate that changes are present in other capillary beds in the body. Basically, PIH is generalised vasoconstriction. Recent works on the aetiology of PIH indicate increased oxidative stress at the level of the placenta and damage to the endothelium of placental capillaries. Damage to the endothelium of capillaries results in inadequate secretion of vasoactive substances that are vasodilators, resulting in vaso-spasm.

Normal forms of nailfold capillary loops include normal-hairpin capillary loops, normal-tortuous capillary loops while retaining the shape of the hairpin (the limbs bend but do not cross) and normal-crossing capillary loops with retaining the shape of the hairpin (the limbs cross once or twice).<sup>1,16</sup> Tortuous capillaries in addition to hairpin-shaped capillaries were specially set aside in this study. The appearance of tortuosity of microcirculatory blood vessels indicates initial changes in microcirculation in hypertensive angiopathy. All pregnant women who had a capillary with pronounced shape changes at the end of the intervention had capillary tortuosity at the beginning of the study. After 8 weeks in both groups, the number of pregnant women with pronounced shape changes of capillary and the length of capillary loops increased. No differences between groups were found.

Data on the microcirculation of nailfold in pregnancy are rare in the literature. The finding of the increased number of pregnant women with pronounced shape changes after eight weeks of follow-up is in line with the finding of a study by Pacini and co-workers. Pacini and co-workers have found with capillaroscopy significant physiological variations of nailfold microcirculation during gestation and a progressive increase of neoangiogenesis during normal pregnancy.<sup>22</sup> Neoangiogenesis in capillaroscopy has also been described as abnormal shapes of nailfold capillary.<sup>23</sup>

In a previous study Bojanić and al found that in non-exercising pregnant women, who had an increase in blood pressure, the density of nailfold capillaries did not change after eight weeks of follow-up. Also, in pregnant women who exercised and who had systolic blood pressure increase with no change in diastolic blood pressure, no change in capillary density was found. It was concluded that the increase in blood pressure maybe

has a greater effect on the other morphological characteristics of nailfold capillaries, such as the shape or length of capillaries.<sup>24</sup> Thevisen et al stated that it can be assumed that during normal pregnancy the diameters of the capillary become larger.<sup>1</sup>

In this study, in non-exercising pregnant women, a positive correlation was found between the value of change in diastolic blood pressure and the increase in capillary loop length. No correlation was found between the value of the change in systolic blood pressure and the increase in the length of the capillary loop. In pregnant women who exercised, no connection was found between the change in systolic and diastolic blood pressure and the increase in capillary loop length.

So far, studies have not analysed the relationship between changes in blood pressure and the diameter of capillary loops in pregnant women. In a study in normotensive patients, there was a connection between the value of blood pressure and the density of skin capillaries in which the increase in the value of blood pressure decreases the density of nailfold capillaries.<sup>3</sup>

## Conclusion

Prenatal physical activity had a beneficial impact on the circulation of pregnant women. Pregnant women who exercised during pregnancy had a smaller elevation of blood pressure. In pregnant women in the third trimester, after eight weeks of follow-up, the nailfold capillary loops were longer and the number of pregnant women with pronounced shape changes of nailfold capillary was increased, without a difference between exercisers and non-exercisers. In non-exercising pregnant women, the capillary length increases with the elevation of diastolic blood pressure. The correlation between systolic blood pressure and capillary length was not found in non-exercising pregnant women. In pregnant women who exercised, no correlation was found between the increase in blood pressure and the length of capillary loops.

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## Conflict of interest

None.

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