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INSERTIONAL ACHILLES TENDINOPATHY IN PATIENTS WITH HAGLUND'S SYNDROME: RESULTS OF COMPUTER MODELING AND BIOMECHANICAL RESEARCH

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Abstract

In this study, a biomechanical relationship was found between the pathological process in Haglund syndrome and secondary tendinopathy of the Achilles tendon. We have developed the calculation diagram, created computer models and determined the values of the stress-strain state of the rear foot structures in the normal and with Haglund syndrome. It was found

that the maximum stress values are concentrated on the Achilles tendon, but in pathological model the stress values were significantly higher than normal in the whole range of motion of the foot. Normally, maximal stress on the calcaneus is localized on its posterior surface - on the anterior surface of the retrocalcaneal recess. In Haglund syndrome, maximum stress was recorded on the upper surface of the posterior sections of the calcaneus. Haglund syndrome is marked by overloading of the calf muscle. The results of this study explain the development of degenerative changes in the AT in patients with Haglund syndrome. It was also found that the enlarged posterior-upper part of the calcaneus is a factor in the development of insertional Achilles tendinopathy, which should also be considered when choosing further treatment.

Keywords: Achilles tendinopathy; Haglund syndrome.

Introduction

Posterior heel pain syndrome is a common entity that frequently involves the Achilles tendon (AT). There are 2 categories of Achilles tendinopathy: insertional and noninsertional. Insertional Achilles tendinopathy accounts for 20-24% of all Achilles pathology [2, 8]. There are a myriad of diagnoses that can present with symptoms reflective of insertional Achilles tendinopathy, such as Haglund syndrome, retrocalcaneal bursitis, retrocalcaneal exostosis, and Achilles tendinosis. Most of these conditions often coexist and can confound the primary diagnosis of insertional Achilles tendinopathy.

Insertional Achilles tendinitis was first described by Clain and Baxter [3], as an overuse phenomenon causing inflammation and degeneration of the Achilles tendon insertion. Retrocalcaneal bursitis is an inflammatory disease that occurs as a result of mechanical impingement of the retrocalcaneal (deep) synovial bursa located between the AT and the posterior-superior part of the calcaneus. Haglund syndrome was described by Swedish orthopedic surgeon Patrik Haglund in 1928 [4] and included the bursitis, but caused by the impingement of the synovial bursa between the AT and the enlarged posterior-superior part of the calcaneus - "Haglund deformation" [9].

Some authors note a hypothetical relationship between pathological changes in the calcaneus, retrocalcaneal bursa and AT. Haglund deformity, may theoretically compress against the Achilles tendon and the retrocalcaneal bursa, which can contribute insertional Achilles tendinopathy symptoms [7, 11].

Schepsis and Leach [10], in their study of long-distance runners, noted the association of Haglund's deformity and retrocalcaneal bursitis with Achilles tendinitis. Karjalainen, P. T., Soila, K., et al. in the study of 118 symptomatic tendons an enlarged retrocalcaneal bursa was

diagnosed in 19% of cases. It was also found that in 15 of 18 cases of insertional tendinopathy RB was detected [6]. Todd A. Irwin in his study [5] also points to the link between inflammatory processes in the synovial bursa and the degenerative changes of the tendon itself - between RB and tendinopathy. In the course of a retrospective study [1] 176 patients with insertional tendinopathy AT Håkan Alfredson and Christoph Spang found that 74% of patients were also diagnosed with superficial/retrocalcaneal bursitis and Haglund syndrome. Therefore, based on previous research, we can say that the relationship between RB or Haglund syndrome and tendinopathy is very likely and needs further study.

We believe that the study of biomechanical relationships between the structures of the normal and pathology rear foot allows you to look more broadly at the of the pathophysiology process, as well as identify key factors of pathogenesis, which can improve the effectiveness of treatment.

Modern computer simulation technologies allow us to calculate with great precision the various necessary parameters without resorting to a long, costly and difficult experiment.

Methodology of biomechanical research

The aim of this study was to determine the relationship between Haglund syndrome and the development of secondary AT tendinopathy. Mathematical calculations and computer simulations have investigated the stress-strain state (SSS) of the rear foot structures in the act of walking and standing in Haglund syndrome compared with intact foot. A scientific search in the literature did not reveal any studies of the SSS structures of the rear foot structures (AT, deep synovial bursa, calcaneus) in Haglund syndrome.

Initially, for all further biomechanical calculations, a simulated 3-D solid foot model was created using the “SolidWorks” software package (Dassault Systèmes SolidWorks Corporation, Canada). The model in the neutral position in the ankle is presented in Figure 1.

To determine the force of the calf muscle and AT in standing and walking we developed a calculation diagram (Fig. 1). The assumption is made that the value of CB_1 does not change with the rotation of the foot around C, then from the equilibrium condition:

$$\sum M_c = 0: F \cdot \sin \alpha \cdot CB_1 - P \cdot CA_1 = 0;$$

α – the angle of inclination of the AT relative to the vertical axis;

P – body weight 750 N (75 kg);

F – Achilles tendon tension force.

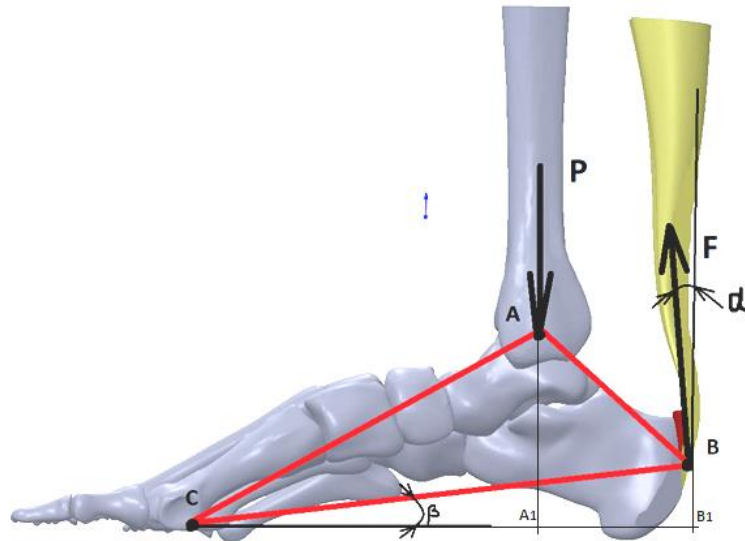


Figure 1. 3D model in the neutral position in the ankle.

$$F = \frac{P \cdot CA_1}{\sin \alpha \cdot CB_1} = 458 \text{ H};$$

- the force of the calf muscle to maintain the vertical position of the body in standing.

To determine the force of tension of the AT in walking, consider 2 positions – heel strike phase of gait, on the onset of the heel of the front foot (plantar flexion -10°) and toe-off phase of gait, when tearing off the heel of the back foot during repulsion from the ground (dorsal flexion $+10^\circ$). To achieve a plantar flexion of -10° , the center of mass is shifted back to the distance AB as shown in Figure 2. Therefore, this distance must be taken into account for calculations of the AT tension.

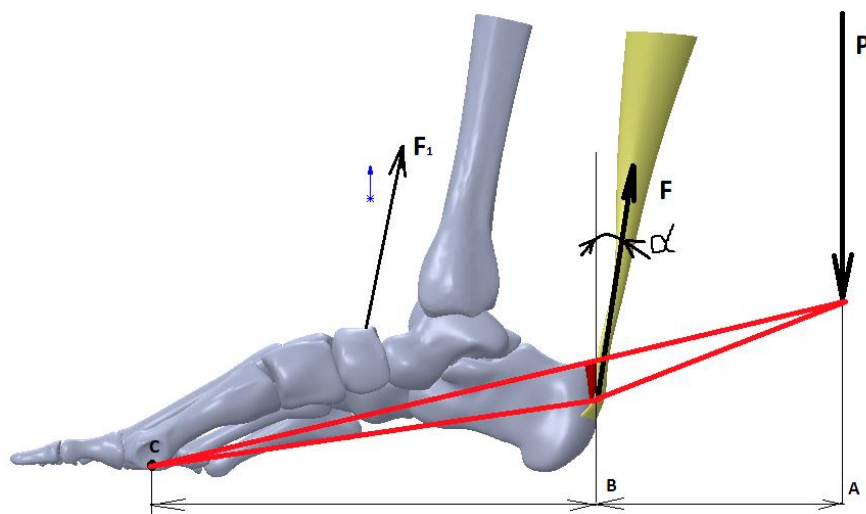


Figure 2. Estimated 3D model at the position of the plantar flexion -10° .

$$\sum M_c = 0: F \cdot \sin \alpha \cdot CB - P \cdot CA = 0;$$

α – the angle of inclination of the AT relative to the vertical axis;

P – body weight 750 N (75 kg);

F – Achilles tendon tension force.

$$F = \frac{P \cdot CA}{\sin \alpha \cdot CB} = 459 \text{ H};$$

- the force required to maintain the vertical position of the body in plantar flexion -10° of the foot.

But the value of force is divided into two components: the tension of the AT 65% (277 H) and the stabilizing force of the anterior muscle group 35% (182 H).

To achieve a back flexion of $+10^\circ$, the center of mass of the body is shifted forward by the distance of the AC as shown in Figure 3. Therefore, to calculate the AT tension, this distance must be taken into account.

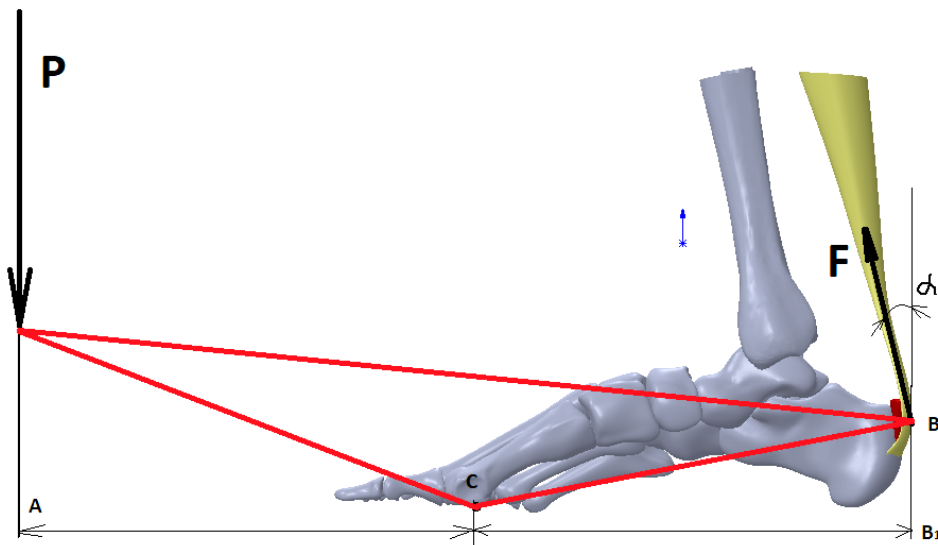


Fig. 3. 3D model in the position of the dorsal flexion $+10^\circ$ in the ankle

$$\sum M_c = 0: F \cdot \sin \alpha \cdot CB_1 - P \cdot CA = 0;$$

α – the angle of inclination of the AT relative to the vertical axis;

P – body weight 750 N (75 kg);

F – Achilles tendon tension force.

$$F = \frac{P \cdot CA}{\sin \alpha \cdot CB_1} = 1028 \text{ H};$$

- the force required to hold the vertical position of the body when pushing the hind leg away from the ground (dorsal flexion + 10°).

Considering all of the above, we will use the following values of the AT loads to determine the SSS:

- for keeping the body in a standing position develops AT efforts in 458 H;
- to support the foot when approaching the ground (heel strike), the AT develops an effort of 277 H (65% of standing force) and 182 H (35%) develops the front group of the lower leg muscles as stabilizers;
- to detach the foot from the ground (toe-off) and lift it to 10° AT develops an effort of 1028 H.

Further calculations performed by finite element analysis (FEA), which allows to explore the evolution of the deformation process simulation model elements - bone, bursa and the tendon, with large nonlinear geometric and physical properties of materials and time variables external influences. For the purpose of calculating the SSS by the FEA, the simulation models were imported into the “ANSYS” (ANSYS, Inc., USA). The calculations used the following physical properties of biological tissues (Table 1).

Table 1

Properties of model materials

Material	Young's module, Pa	Poisson's ratio
Cortical bone	17,6e9	0,3
Bursa	5e7	0,45
Tendon	4e8	0,45

Two models were studied for each variant of the calculation - an intact model and a model with Haglund syndrome for three positions in the ankle (Fig. 5).

In semiautomatic mode, finite element (FE) models were generated, which averaged 332 906 nodes and 191 538 elements (Fig. 6). To increase the accuracy of FEA, the mesh is compacted in the contact areas of the bursa and tendon elements. The FE grid is represented mainly by tetrahedral elements, the size of which on the basic model does not exceed 1 mm, at the points of concentration of 0.1 - 0.5 mm.

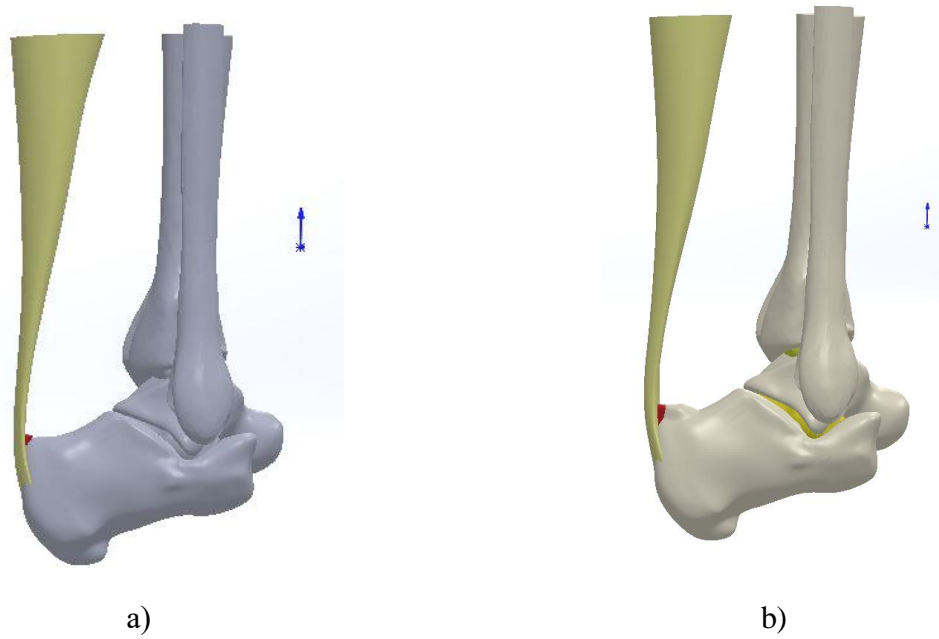


Fig. 5. Simulation 3D models: intact model (a) and model with Haglund syndrome (b)

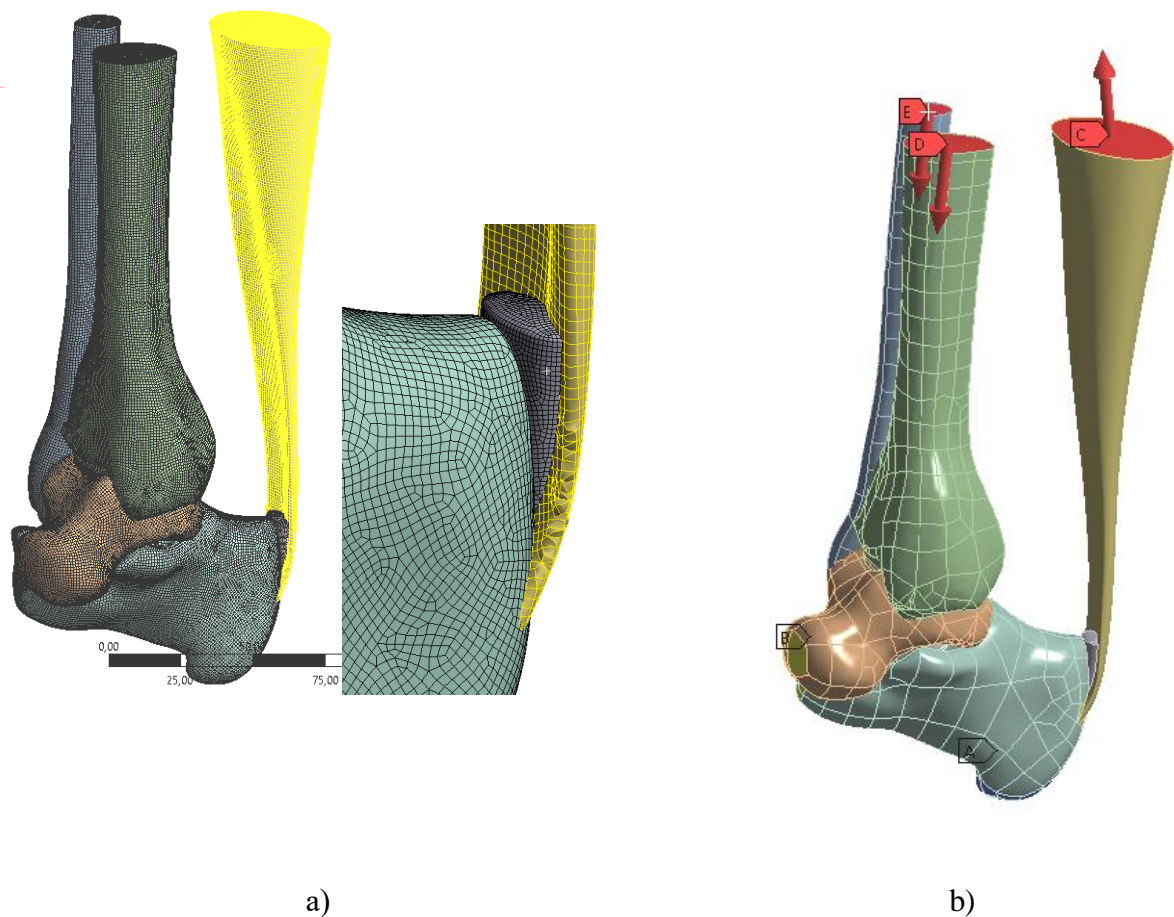


Figure 6. FE mesh (a) and boundary conditions (b), where A - rigid fixation of the plantar area of the calcanea, B - restriction of movement on the axes with the possibility of rotation (to simulate a solid foot), C - tension force of the AT, D and E - body weight is applied to the tibia (90%) and fibula (10%).

The key parameters for comparative analysis are the data obtained by calculating the stress (Mises) and strain intensity, as well as the total deformations, which were determined on all elements of the model.

Results and analysis

SSS parameters of models in the neutral ankle position for each variant of the calculations - an intact model and a model with Haglund syndrome are presented in Fig. 7, Fig. 8, Fig. 9 and Table 2.

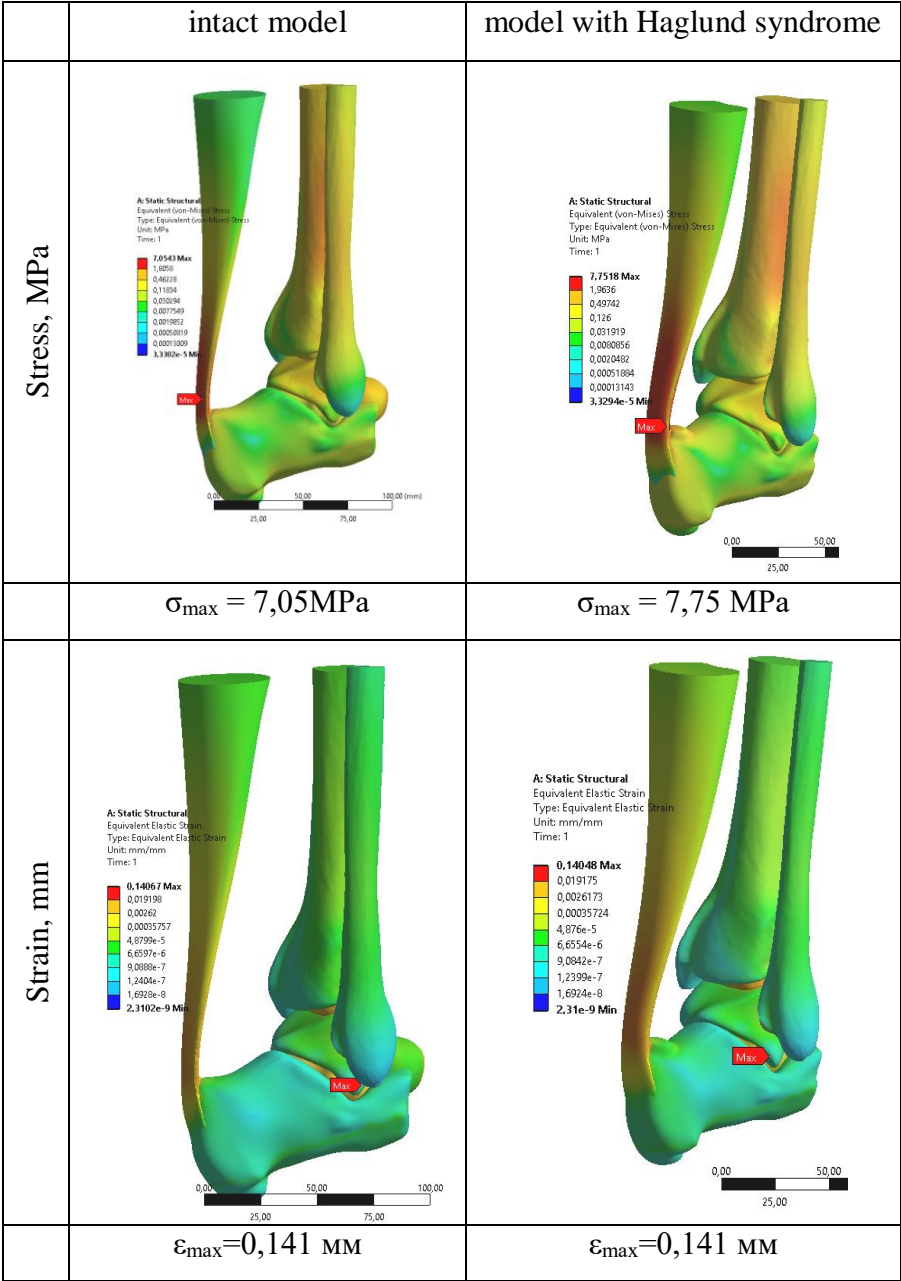


Fig. 7. SSS parameters of models in the neutral ankle position for each variant of the calculations - an intact model and a model with Haglund syndrome.

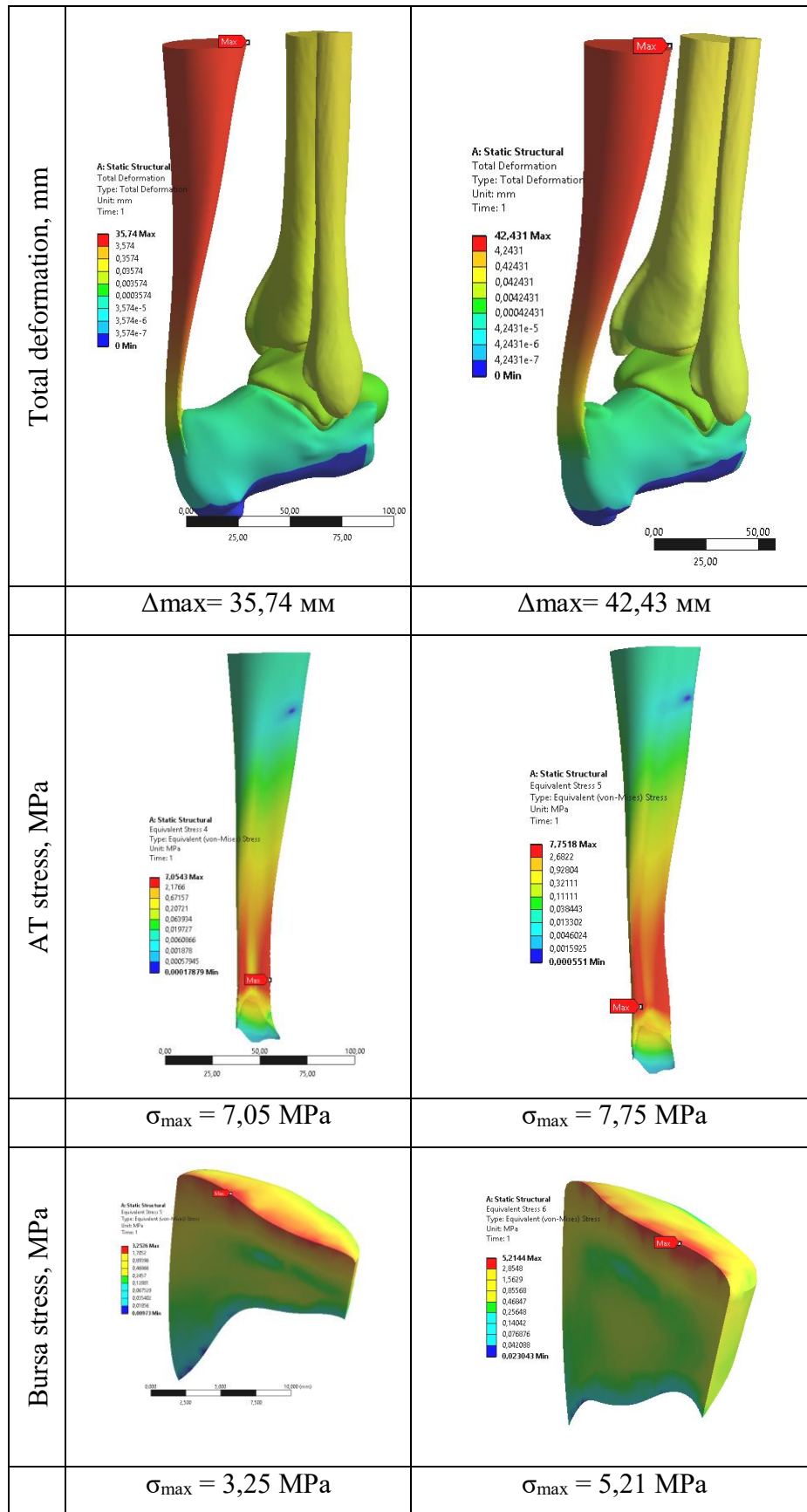


Fig. 8. SSS parameters of models in the neutral ankle position for each variant of the calculations - an intact model and a model with Haglund syndrome.

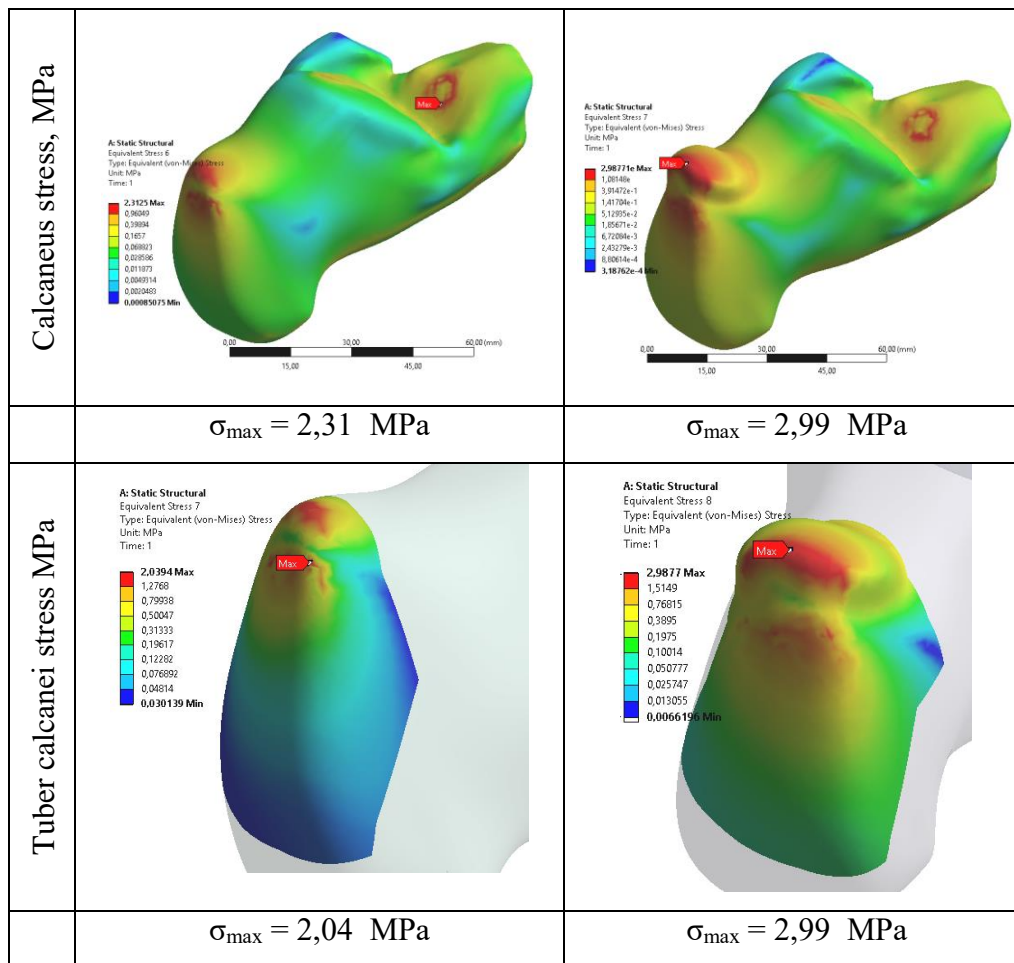


Fig. 9. SSS parameters of models in the neutral ankle position for each variant of the calculations - an intact model and a model with Haglund syndrome.

Table 2

Values of the SSS parameters for models in the neutral ankle position for each calculation option

	Intact model	Model with Haglund syndrome
Stress, MPa	7,05	7,75
Strain, mm	0,141	0,141
Total deformation, mm	35,74	42,43
AT stress, MPa	7,05	7,75
Bursa stress, MPa	3,25	5,21
Calcaneus stress, MPa	2,31	2,99
Tuber calcanei stress, MPa	2,04	2,99

It was determined that the stress values of the whole model in the intact model and the model with Haglund syndrome were different - 7.05 MPa and 7.75 MPa respectively. However, these parameter was higher by 10.0% in the model with Haglund syndrome. Strain

of the model did not differ in both models and amounted to 0.14 mm. The maximum values of total deformations were expected on the calf muscle and in the intact model were amount to 35.74 mm, in the model with Haglund syndrome - 42.43 mm. In relation to the intact model, this value in the model with Haglund syndrome was more by 18.7%. To fix the body in a standing position, the calf muscle has to contract more in Haglund syndrome. We believe this is an additional factor leading to an overload of the AT-calf muscle.

We also investigated the maximum stress values for rear foot structures: AT, retrocalcaneal bursa and the calcaneus.

The maximum value of AT stress was determined in the model with Haglund syndrome - 7.75MPa, which is 10.0% higher than in the intact model (7.05MPa). It should be noted that in the intact model and the model with Haglund syndrome, the maximum stress were registered at the AT.

Investigating the value of bursa stress we obtained the expected results. Thus, the parameter was higher by 60.3% (5.21 MPa) in the model with Haglund syndrome compared to the intact model (3.25 MPa). It is proved that the increase of the retrocalcaneal bursa is the important pathogenetic factor of this disease.

The calcaneus stress values were 29.4% higher in the Haglund syndrome model and were 2.99MPa versus 2.04MPa intact model. It should be noted that, unlike the intact model, maximal stresses on the calcaneus in pathologic model were concentrated on the tuber calcanei. The stress on the tuber calcanei are 46.5% higher in the model with Haglund syndrome than in the intact model. In our opinion, this indicates the unity of the system "AC-calcaneus" and the inability of the pathological process in the retrocalcaneal bursa without the absence of adaptive changes in other surrounding structures.

Summing up all the above results, it can be argued that, compared to the intact model, model with Haglund syndrome is characterized by higher SSS values, which explains the development of secondary changes in AT and calcaneus.

A comparative analysis of the results of the SSS calculations for the models in the neutral ankle position for each variant of the study is presented in the diagram (Fig. 10).

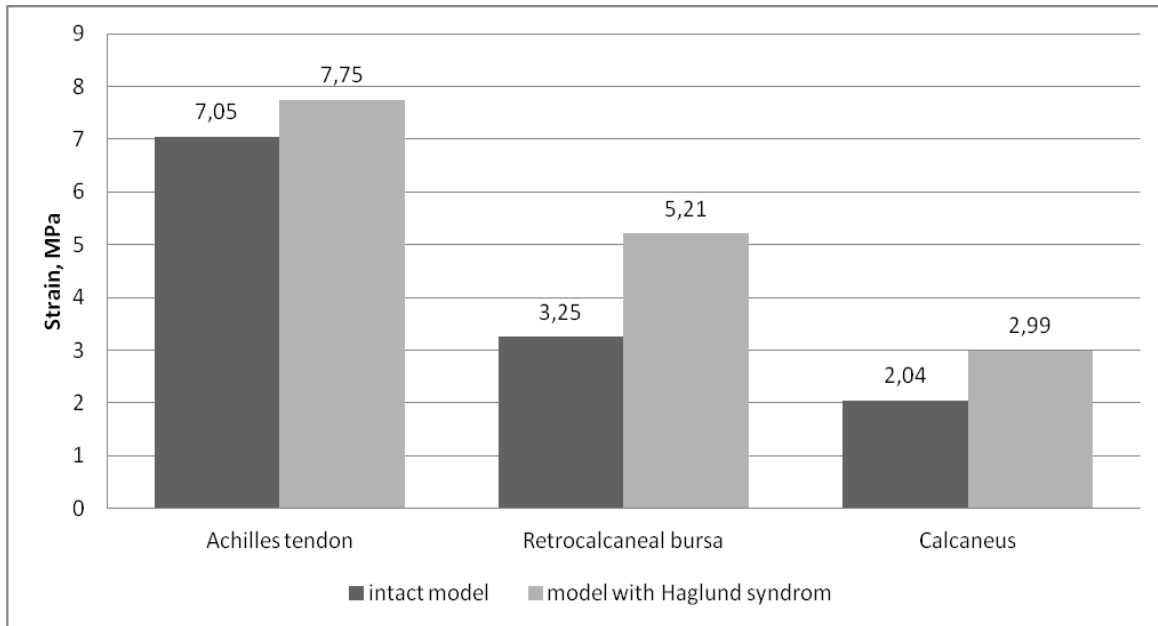
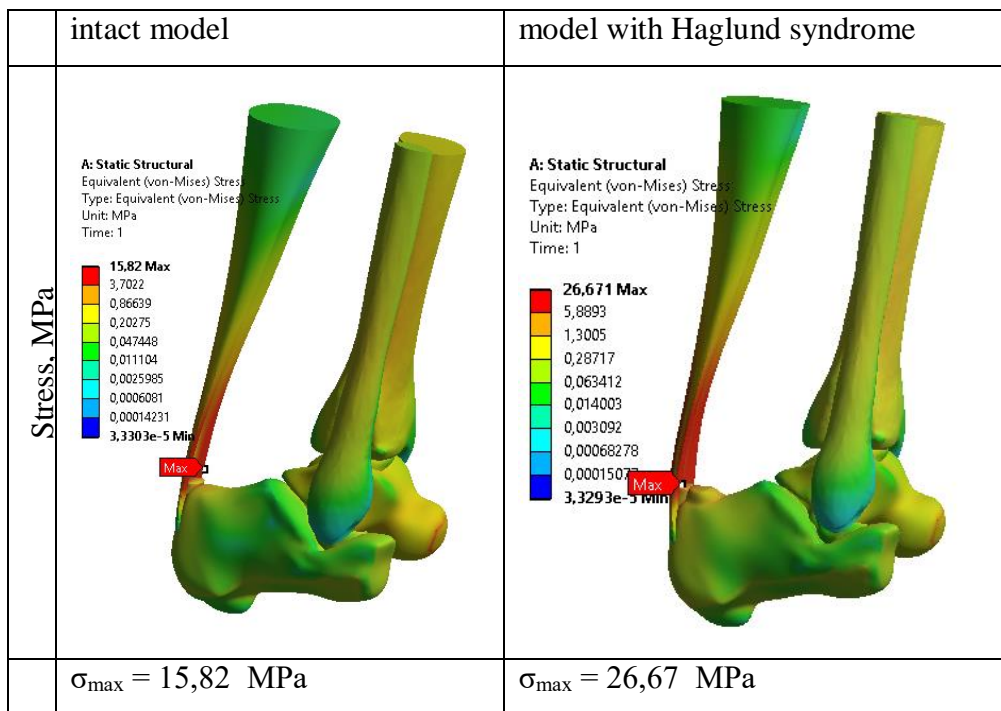


Figure 10. Comparative analysis of the SSS values for models in the neutral ankle position.

The results of the SSS models in dorsal flexion of the foot for each variant of the calculation - an intact model and a model with Haglund syndrome are presented on Fig. 11, Fig. 12, Fig. 13 and Table 3.



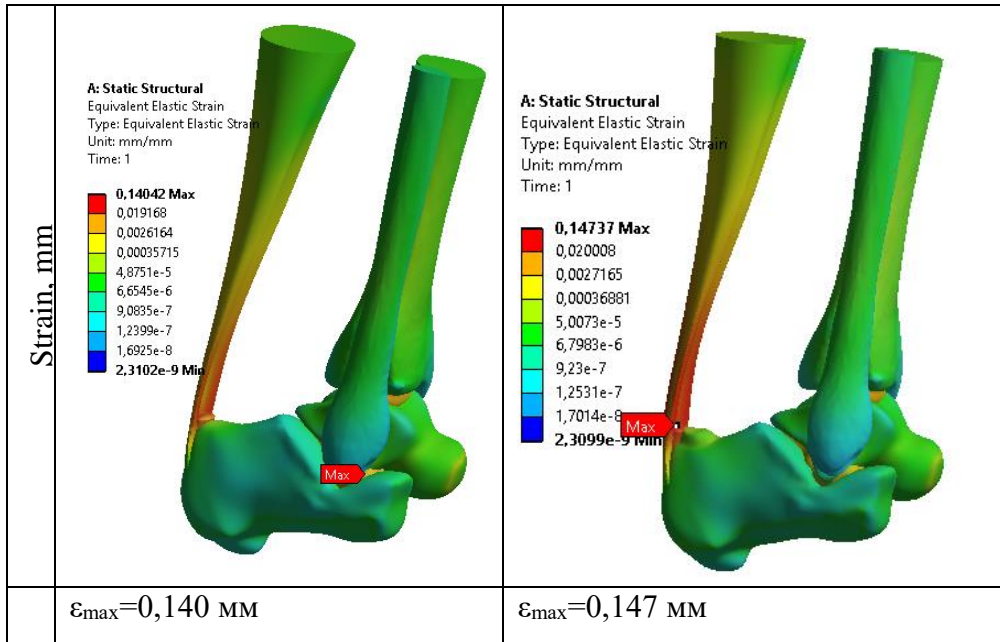
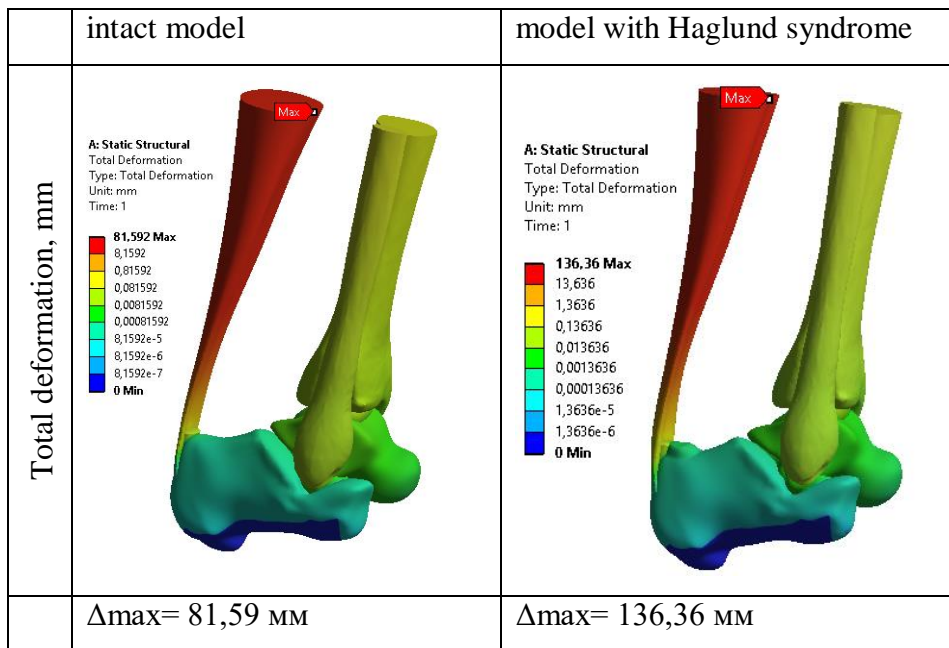


Fig. 11. SSS parameters of models in dorsal flexion of the ankle for each calculation option - an intact model and a model with Haglund syndrome



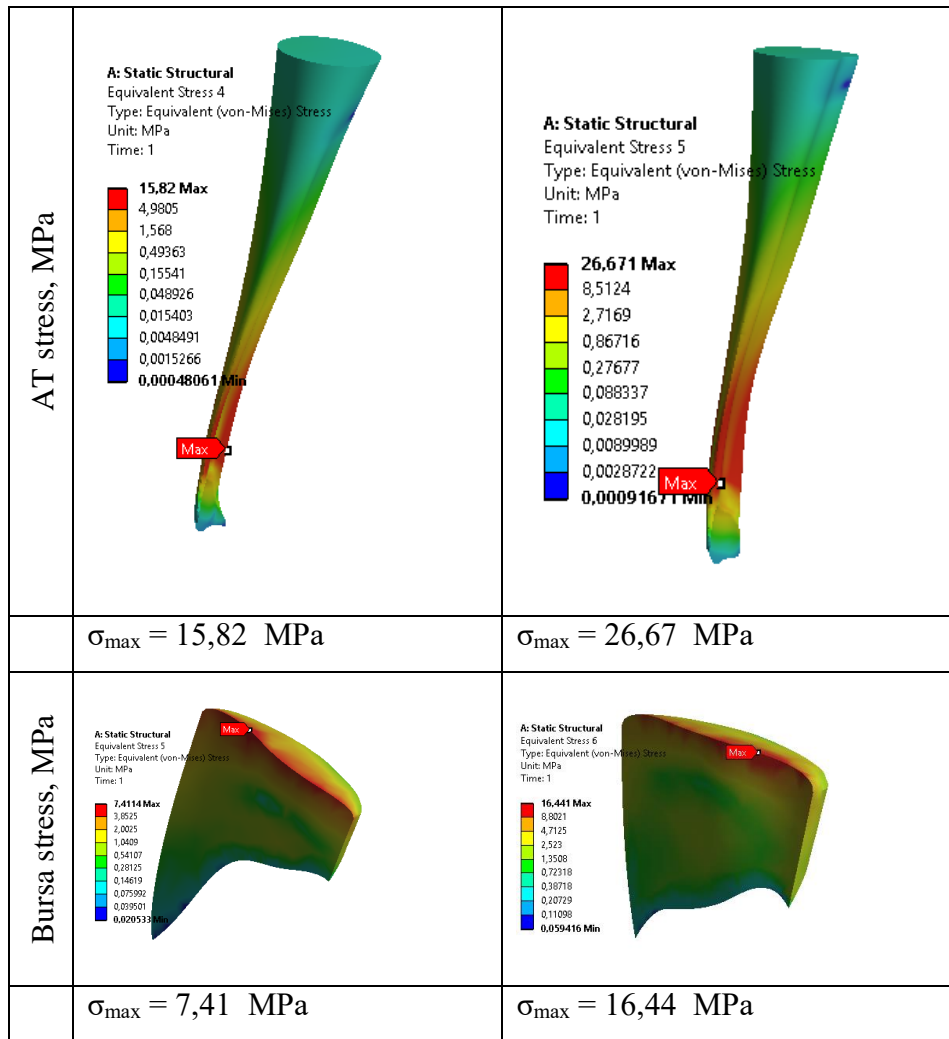
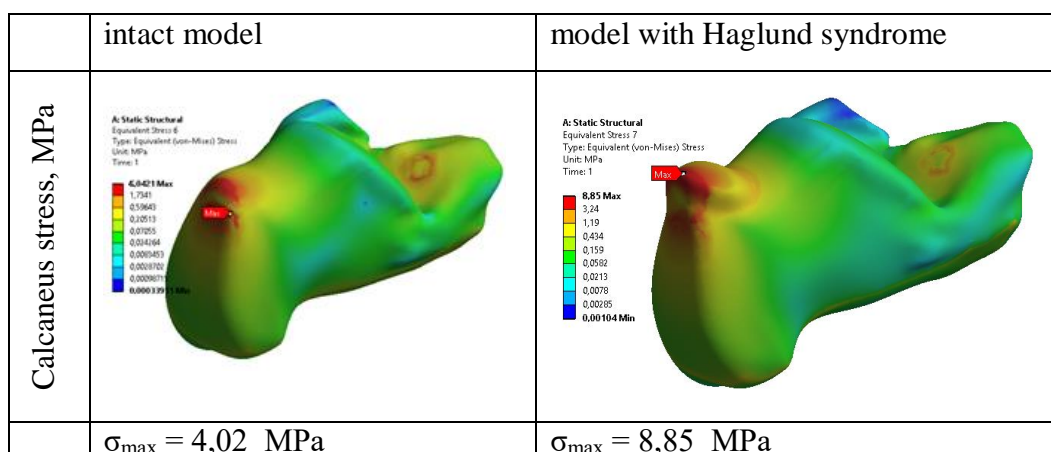


Fig. 12. SSS parameters of models in dorsal flexion of the ankle for each calculation option - an intact model and a model with Haglund syndrome



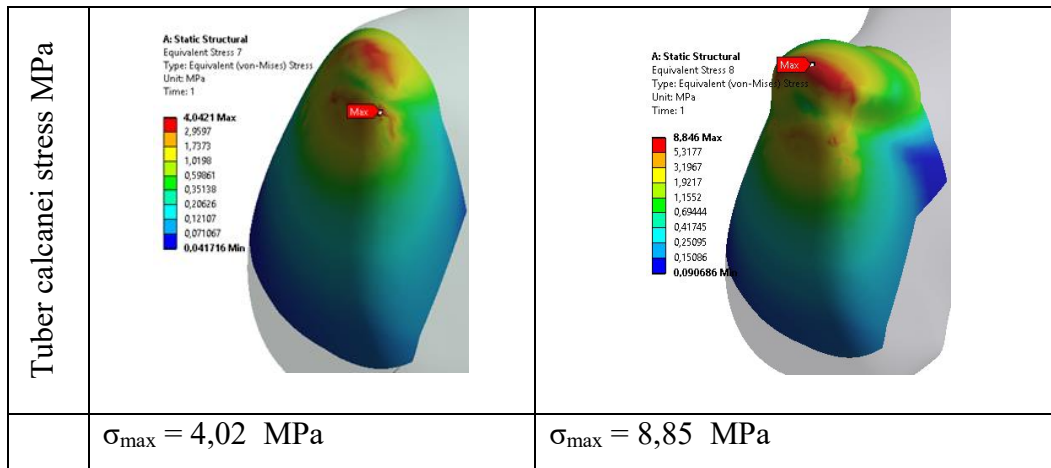


Fig. 13. SSS parameters of models in dorsal flexion of the ankle for each calculation option - an intact model and a model with Haglund syndrome.

Table 3

Values of the SSS parameters for models in the dorsal flexion for each calculation option

	Intact model	Model with Haglund syndrome
Stress, MPa	15,82	26,67
Strain, mm	0,14	0,147
Total deformation, mm	81,59	136,36
AT stress, MPa	15,82	26,67
Bursa stress, MPa	7,41	16,44
Calcaneus stress, MPa	4,02	8,85
Tuber calcanei stress, MPa	4,02	8,85

In dorsal flexion, as we expected, on all anatomical structures of the models were the maximum values of SSS. So the highest stress values were localized on the AT. The intact model stress was 15.82MPa and in the Haglund syndrome model, it was 26.67MPa, which is 68.6% higher. We believe that the concentration of maximum stresses on the AT in this disease is the etiopathogenetic factor of concomitant secondary tendon diseases.

The strain values of the models were not significantly different in both studied models and amounted to 0.14mm for the intact model and 0.147mm for the model with Haglund syndrome.

The study found that the maximum values of total deformations were localized on the calf muscle and amounted to 81.59 mm for the intact model and 136.36 mm for the model with Haglund syndrome, which was more 67.1% compared to the intact model. It was found that in pathological models, to maintain the dorsal flexion of the foot, the calf muscle should be significantly reduced and carry additional load, which also plays a role in the development of secondary changes.

Also, in dorsal flexion, when AT inclination angle decreases, a significant increase in the stress on the enlarged bursa was observed. If in the intact model this parameter were 7.41MPa, then in the model with Haglund syndrome - 16.44MPa (+ 121.8%). In our opinion, such overloads cause further degenerative changes of the synovial membrane - its thickening and compaction, which in turn will affect the surrounding structures, such as the AT and the posterior upper parts of the calcaneus.

The highest stress values studied on the tuber calcanei were concentrated on its posterior-upper parts. In the model with Haglund syndrome the stress value was significantly higher - 8.85MPa, which is 120.1% more than in the intact model (4.02MPa). However, in addition to the significant increase in tension in these part, it should be noted that in intact models, the maximum stress is localized more on the posterior surface of the tuber calcanei, on the anterior surface of the retrocalcaneal recess, whereas in pathological model the maximum stress was recorded on the upper surface of the posterior part. We believe that the formation of "Haglund deformity" is possible as a adaptive reaction of the body to the local overload of this anatomic area by an enlarged retrocalcaneal bursa. Normally, reactive reparative processes proceed as adaptive with normal physiological reactions. However, with pathological changes, they will reach the level of adaptive processes with structural changes.

Comparative analysis of SSS parameters for models in dorsal flexion of the ankle for each calculations option is presented in the diagram (Fig. 14)

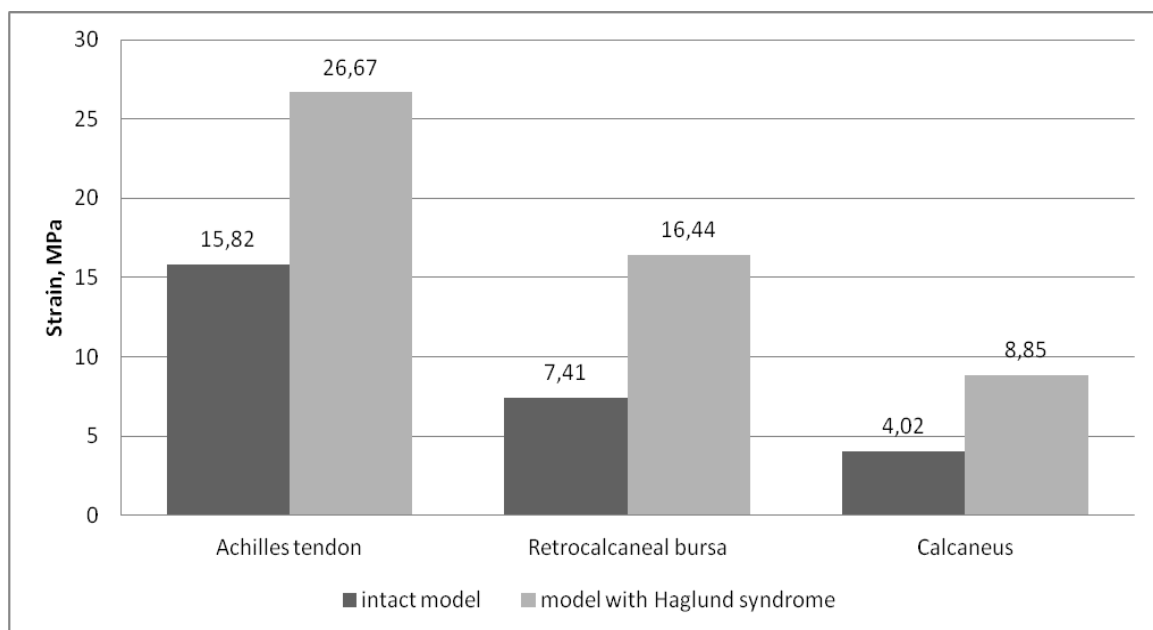


Fig. 14. Comparative analysis SSS parameters for models in the dorsal flexion of the ankle for each calculations option

The values of the stress-strain state parameters of models in plantar flexion -10° - intact model and model with Haglund syndrome are presented in Fig. 15, Fig.16, Fig.17 and Table 4.

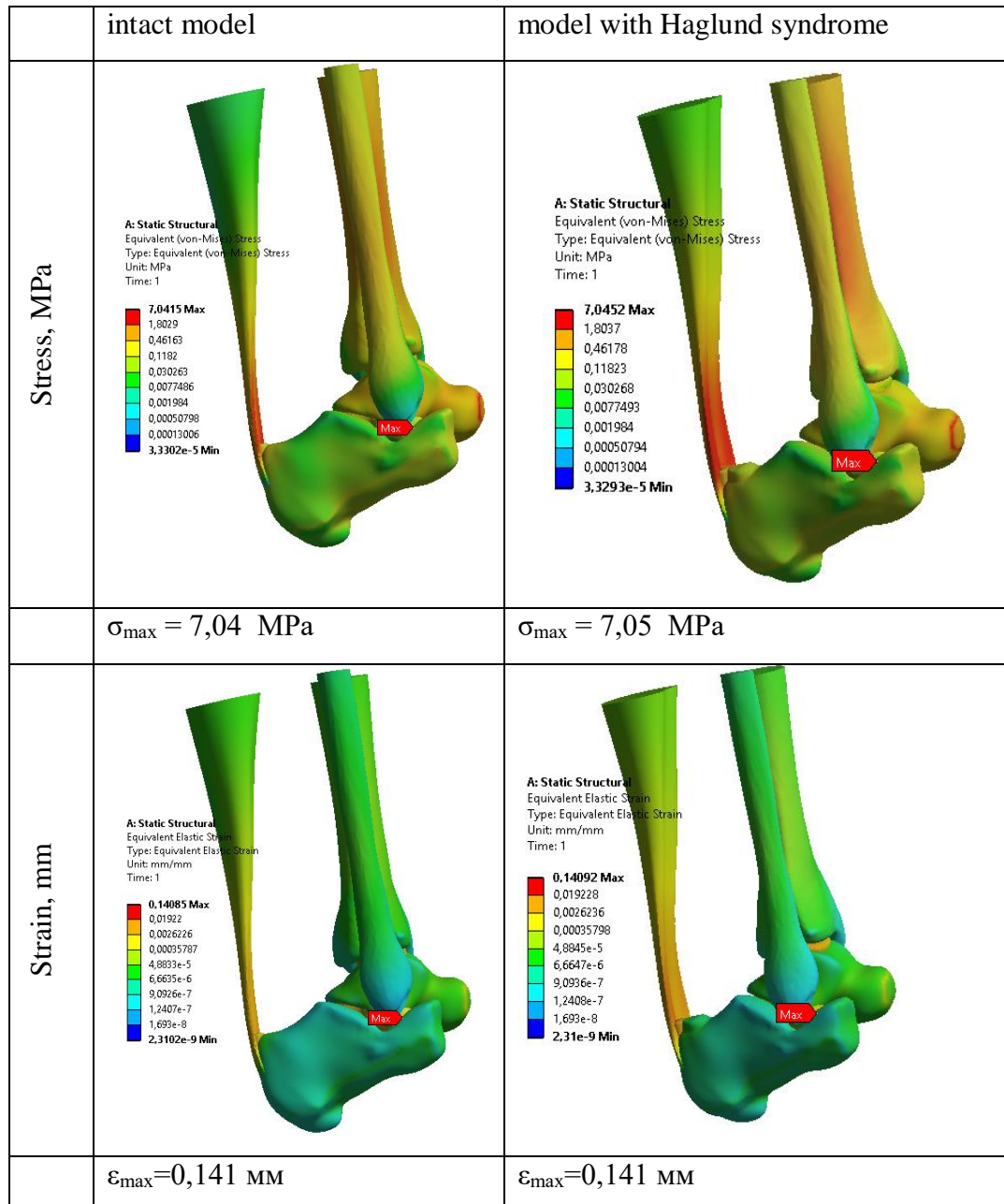


Fig. 15. SSS parameters of the studied models in the plantar flexion of the foot

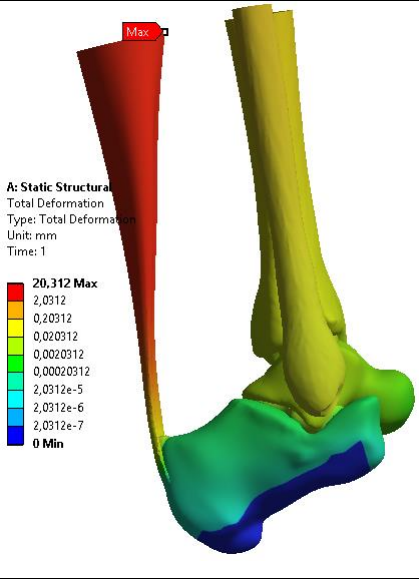
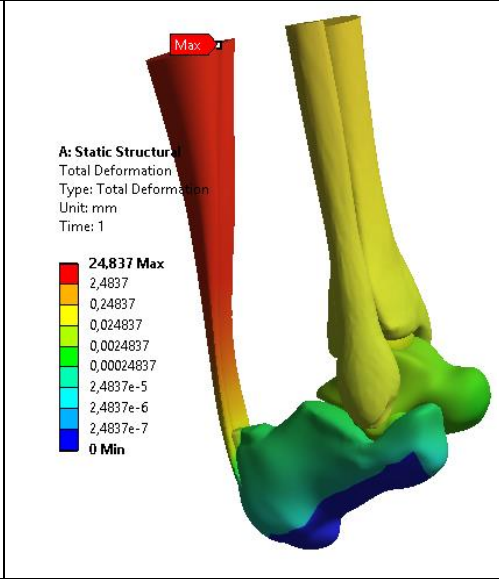
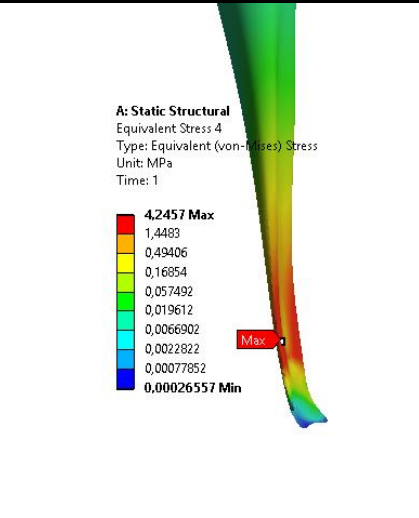
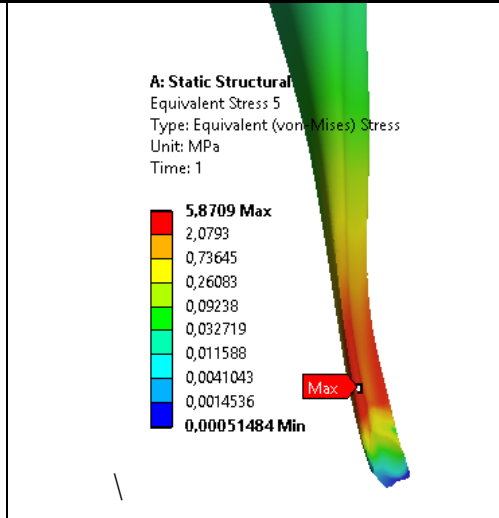
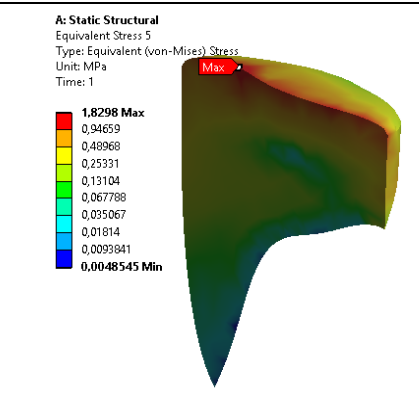
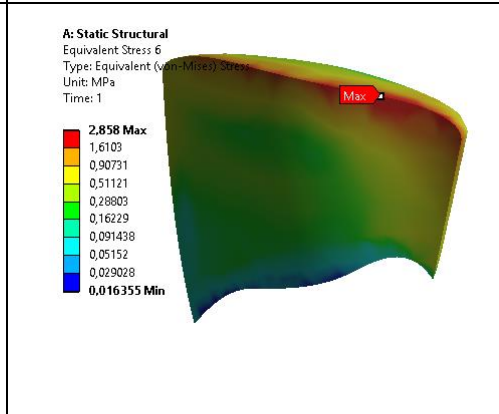
	intact model	model with Haglund syndrome
Total deformation, mm	 <p>A: Static Structural Total Deformation Type: Total Deformation Unit: mm Time: 1</p> <p>20,312 Max 2,0312 0,20312 0,020312 0,0020312 0,00020312 2,0312e-5 2,0312e-6 2,0312e-7 0 Min</p>	 <p>A: Static Structural Total Deformation Type: Total Deformation Unit: mm Time: 1</p> <p>24,837 Max 2,4837 0,24837 0,024837 0,0024837 0,00024837 2,4837e-5 2,4837e-6 2,4837e-7 0 Min</p>
	$\Delta_{max} = 20,31 \text{ mm}$	$\Delta_{max} = 24,84 \text{ mm}$
AT stress, MPa	 <p>A: Static Structural Equivalent Stress 4 Type: Equivalent (von-Mises) Stress Unit: MPa Time: 1</p> <p>4,2457 Max 1,4483 0,49406 0,16054 0,057492 0,019612 0,0066902 0,0022822 0,00077852 0,00026557 Min</p>	 <p>A: Static Structural Equivalent Stress 5 Type: Equivalent (von-Mises) Stress Unit: MPa Time: 1</p> <p>5,8709 Max 2,0793 0,73645 0,26083 0,09238 0,032719 0,011588 0,0041043 0,0014536 0,00051484 Min</p>
	$\sigma_{max} = 4,25 \text{ MPa}$	$\sigma_{max} = 5,87 \text{ MPa}$
Bursa stress, MPa	 <p>A: Static Structural Equivalent Stress 5 Type: Equivalent (von-Mises) Stress Unit: MPa Time: 1</p> <p>1,8298 Max 0,94659 0,48968 0,25331 0,13104 0,067788 0,035067 0,01814 0,0093841 0,0048545 Min</p>	 <p>A: Static Structural Equivalent Stress 6 Type: Equivalent (von-Mises) Stress Unit: MPa Time: 1</p> <p>2,858 Max 1,6103 0,90731 0,51121 0,28803 0,16229 0,091438 0,05152 0,029028 0,016355 Min</p>
	$\sigma_{max} = 1,83 \text{ MPa}$	$\sigma_{max} = 2,86 \text{ MPa}$

Fig. 16. SSS parameters of the studied models in the plantar flexion of the foot..

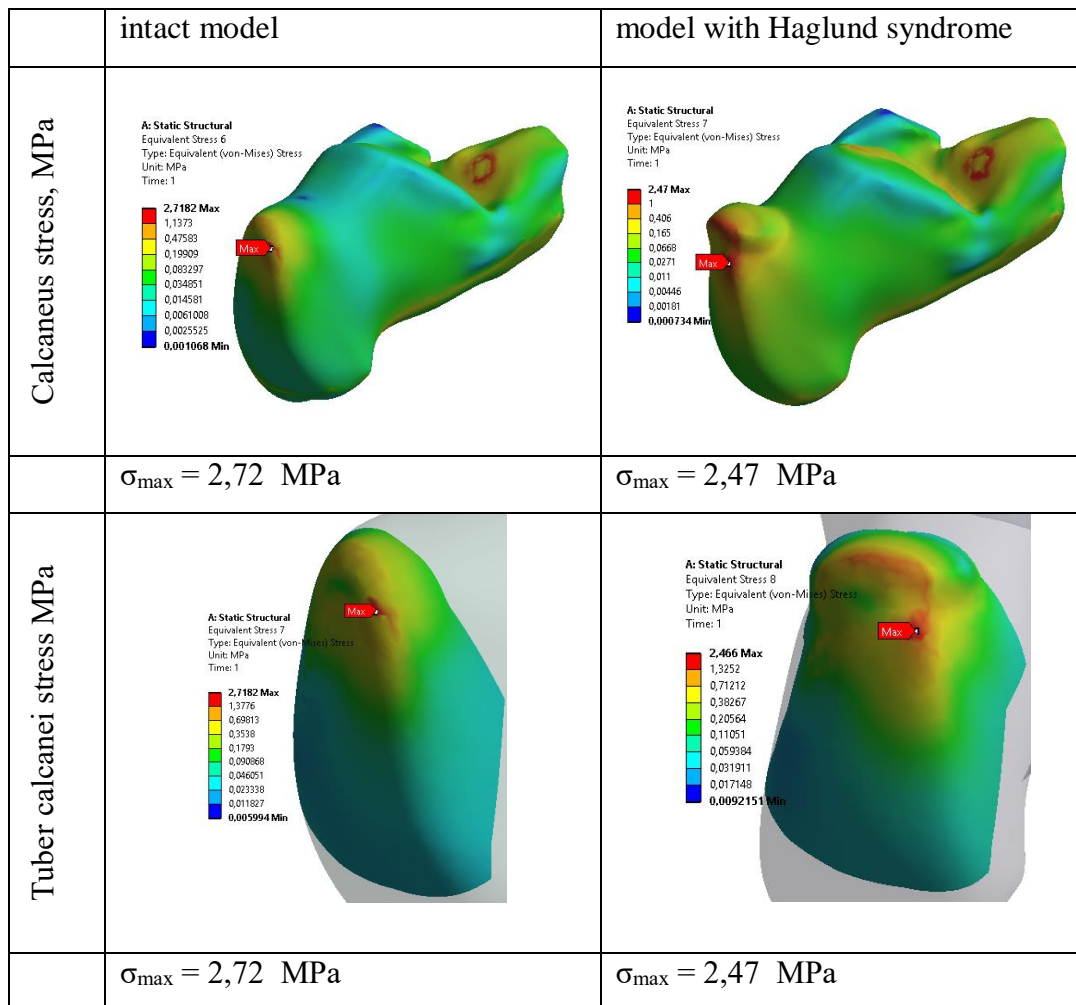


Fig. 17. SSS parameters of the studied models in the plantar flexion of the foot.

Table 4.

Values of the SSS parameters for models in the position of plantar flexion of the ankle for each calculation option

	Intact model	Model with Haglund syndrome
Stress, MPa	7,04	7,05
Strain, mm	0,141	0,141
Total deformation, mm	20,31	24,84
AT stress, MPa	4,25	5,87
Bursa stress, MPa	1,83	2,86
Calcaneus stress, MPa	2,72	2,47
Tuber calcanei stress, MPa	2,72	2,47

In plantar flexion, the SSS of the rear foot structures in the studied models were lower than those in the neutral position or in dorsal flexion of the foot. This is due to both a decrease

in the tensile strength of the AT and an increase in the size of the retrocalcaneal recess, the introduction of the Kager fat pad, and the lack of the retrocalcaneal bursa impingement.

Thus, the stress values of the whole model in both tested models were equal 7.04 MPa. It should be noted that this stress was recorded on the ankle bone structures and not on the rear foot structures.

Strain values of the models did not differ for both studied models and amounted to 0.141 mm.

The maximum values of total deformations were recorded on the calf muscle and were 20.31 mm for the intact model and 24.84 mm (+22.3%) for the model with Haglund syndrome.

Similar results were obtained at the AT. Thus, the tendon stress in the intact model was 4.25 MPa and in the model with Haglund syndrome - 5.87 MPa (+ 38.1%).

It is found that the stress values on the bursa they were 56.3% higher (2.86MPa) in the model with Haglund syndrome compared to the intact model (1.83MPa).

The study calculated the stresses on the tuber calcani. In contrast to the previous values of this parameter in other positions of the foot on pathological models of tension was lower compared to the intact model. Thus, in the model with Haglund syndrome, the strain value was 2.47MPa, which is 9.2% less than in the intact model (2.72MPa). In our opinion, the reduction of stress in pathological models is associated with a larger contact surface and a more uniform stress distribution on the calcaneus surface and the AT.

Comparative analysis values SSS parameters for models in plantar flexion of the ankle for each calculation option is presented in the diagram (Fig. 18).

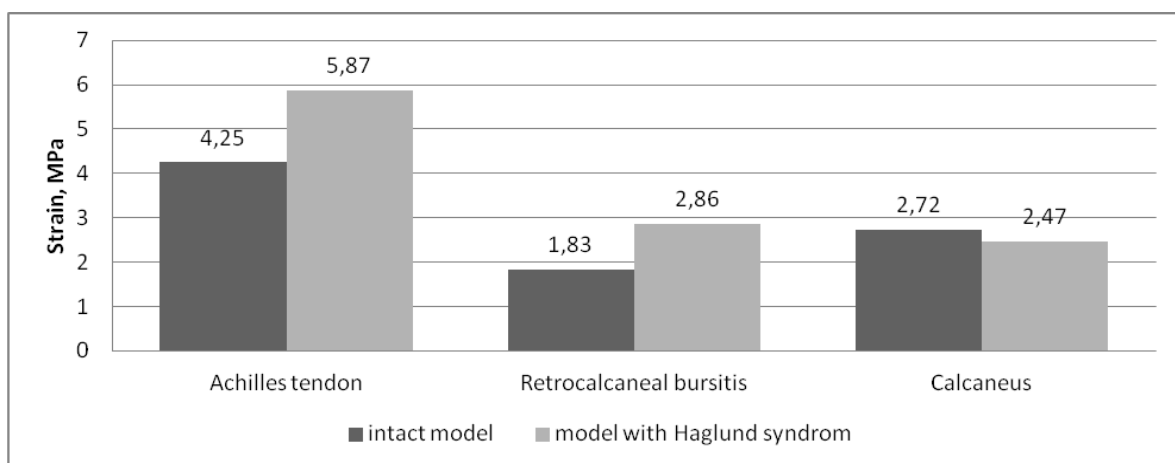


Fig. 18. Comparative analysis values SSS parameters for models in plantar flexion of the ankle for each calculation option

In the study, we also analyzed the SSS values of the rear foot structures: AT, the retrocalcaneal bursa, the calcaneus and the calf muscle. In our opinion, these anatomical structures form a single biomechanical system, so its further study is key to understanding of the relationship between the components in normal and disease. The values and dynamics of strain at the AT are presented in Fig. 19

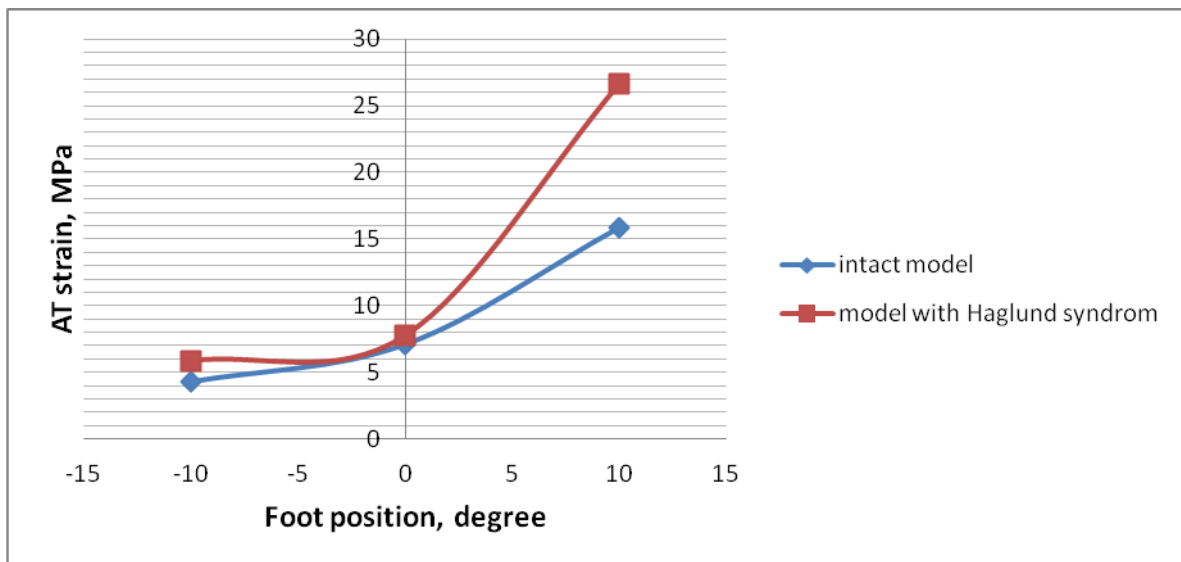


Fig. 19. Dynamics of strain values on the AT depending on the position of the foot for the all models

Analyzing the dynamics of AT stress values for the studied models, higher values are observed in the model with Haglund syndrome. The stress gain was 244.1%. The same parameter in intact models - 124,4%.

The data obtained indicate the overload of the AT in patient with Haglund syndrome. It should be noted that in the transition from the neutral position to the position of the dorsal flexion, the tension increases geometrically. Unlike pathological intact model shows a more linear increase.

The values and dynamics of the strain on the retrocalcaneal bursa are presented in Fig. 20.

Analyzing the dynamics of the bursa stress values, higher values on pathological model are noted. Thus, in the transition from the neutral position to the dorsal flexion position (+10⁰), the stress increase was 215.5% for the model with Haglund syndrome. For the intact model, the increase of this parameter was only 128.0%.

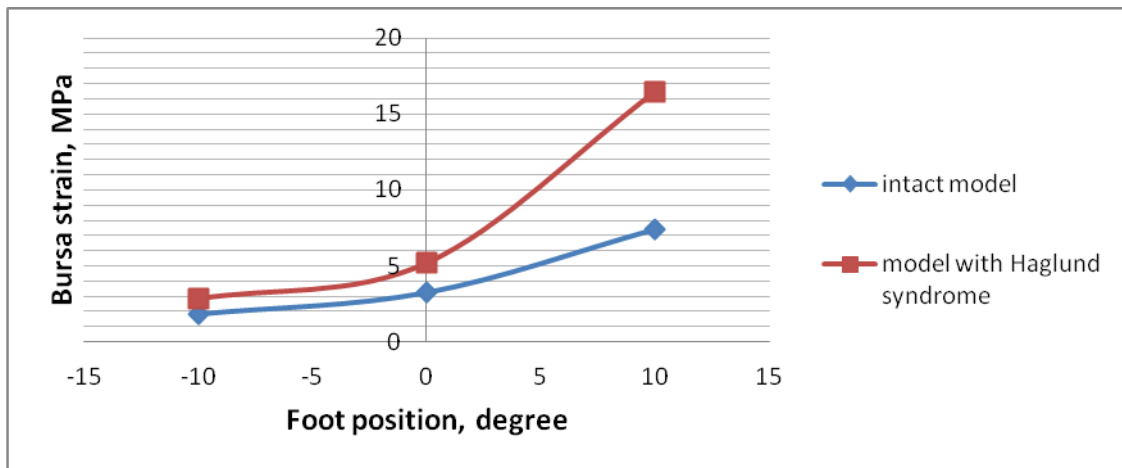


Fig. 20. Dynamics of stress values on the retrocalcaneal bursa, depending on the position of the foot for the studied models

The data obtained indicate a significant overload of the synovial bursa. In our opinion, this can lead to degenerative changes in the synovial membrane - its thickening and compaction. In the clinical case, thickening synovial membrane of the bursa will have an impact not only on the disease course and on the effectiveness of treatment.

During the study, we investigated the maximum values of the SSS parameters at the AT insertion. This anatomic area directly contacts the retrocalcaneal bursa, which, in our opinion, can affect the pathogenesis of the disease.

The values and dynamics of strain on the tuber calcanei are presented on Fig. 21.

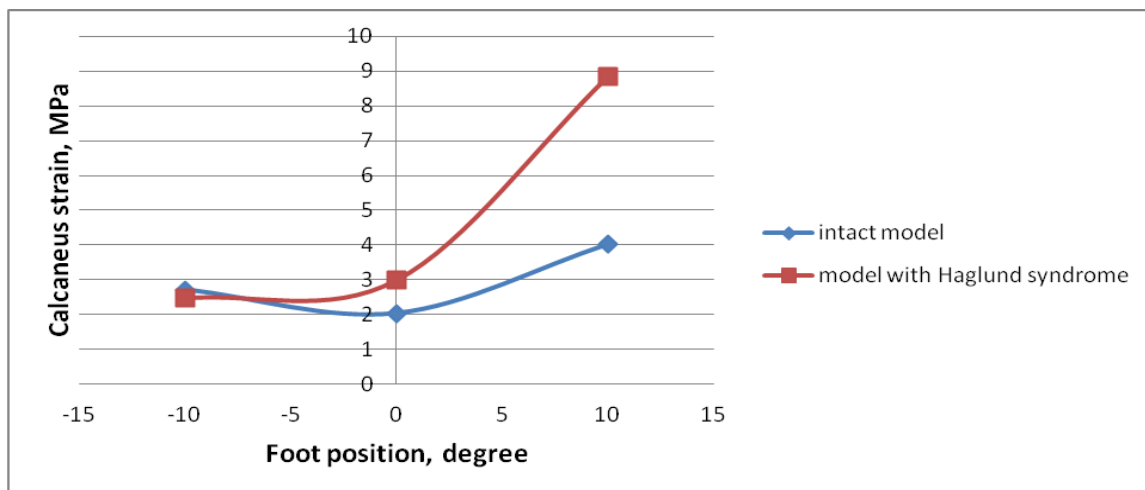


Fig. 21. Dynamics of stresses on the calcaneus depending on foot for the studied models

The study found that in the position of plantar flexion stress on the tuber calcanei in models with Haglund syndrome was lower by 17.4%, compared to the intact model. This is

explained by the increase in the contact surface of the enlarged bursa with the calcaneus. However, already in the neutral position of the foot strain in pathological models was recorded more than in the intact model. When moving from the neutral position to the dorsal flexion, the stress on the calcaneus increased. Thus, in the model with Haglund syndrome the increase in stress was - 196.0%, in the intact model was 97.0%.

Maximum values of total deformations among all structures of the model were recorded on the calf muscle. The values and dynamics of total deformations are presented on Fig. 22.

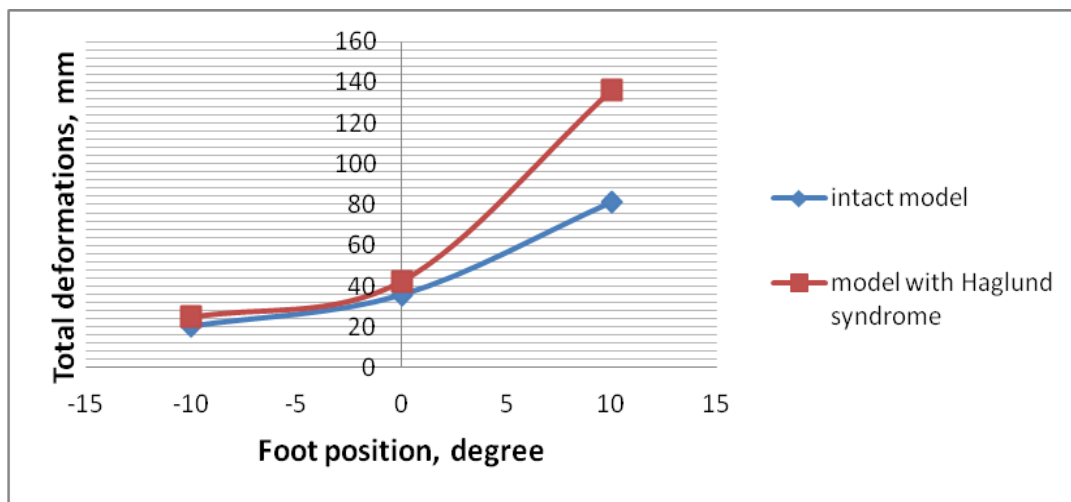


Fig. 22. Dynamics of values of total deformations depending on the position of the foot for the studied models

The values of the total deformations in plantar flexion in a both models were lower compared to the similar results in the neutral position and in the dorsal flexion. However, in the model with Haglund syndrome, compared to the intact model, this parameter was 22.3% higher (24.84 mm and 20.31 mm respectively) in the flexion position, 18.7% higher in the neutral position (42.43 mm and 35.74 mm respectively) and 67.1% higher (136.36 mm and 81.59 mm respectively) in the dorsal flexion of the foot.

In our opinion, an increase total deformations values indicates an overload of the calf muscle. The analysis of the results showed that in the model with Haglund syndrome, the load on the calf muscle is greater than in the intact model in the whole range of motion of the ankle.

Conclusions

All structures of the rear foot (AT, retrocalcaneal bursa, calcaneus) make up a single biomechanical system. Changes in the SSS of one part of the system lead to adaptive changes others and the whole system.

It is proved that the maximum stress concentrates on the AT; however, in the cases of Haglund syndrome, the stress values were significantly higher than the normal values.

The damping function of the enlarged retrocalcaneal bursa has been proved by increasing the surface of contact with surrounding structures.

In our study were also identified features redistribution of stress on the tuber calcanei. Normally, maximum stresses are localized on the posterior surface of the calcaneus - the anterior wall of the retrocalcaneal recess. And if in the case of Haglund syndrome this is explained by the enlargement of these parts of the calcaneus.

It has been established that overload is localized not only in the area of the heel hump, but also in the calf muscle, which expands the complexity of disorders in patient with Haglund syndrome.

The results of this study explain the development of degenerative changes in the AT in patients with Haglund syndrome. It was also found that the enlarged posterior-upper part of the calcaneus is a factor in the development of insertional tendinopathy of the AT, which should also be considered when choosing further treatment.

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