



Scientific contribution/Reflection

Special Biomechanics at the 7th Socratic Lectures

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Abstract: 7th Socratic lectures featured plenary lecture of osteotomies for hip dysplasia, by prof. Duško Spasovski from Belgrade, Serbia and honorary lectures of Andreas Leithner, Graz, Austria and Marija Ipavec, Ljubljana, Slovenia. This was the final event for the students of the 1st year of Orthotics and Prosthetics at the Faculty of Health Sciences, University of Ljubljana, who during the curriculum of the subject Special biomechanics analyzed a series of X-ray images of hips before and after the operation that was supported by Erasmus student Honza Pluhar. In this way the students were actively participating in a multicenter research connecting four institutions (from Denmark, Serbia, Czech Republic and Slovenia). In the final event, the students provided their experiences with the HIPSTRESS method. Here we report on the teaching activities and the students' experiences.

Keywords: Teaching biomechanics; HIPSTRESS; Online teaching; Online examination; Open book examination

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1. Curriculum

In the academic year 2021/2022, the subject Special biomechanics took part of the spring semester. The lectures were organized in March and April and they were accompanied by analysis of the biomechanical parameters of hips. Socratic Lectures presented the final lectures with the examination. As the use of the computer is necessary and with availability of new technological tools to teach online, the curriculum was performed online (Bambič et al., 2021). Furthermore, we had a visitor student Honza Pluhar, who came for the Erasmus mobility and stayed 4 months in Ljubljana. Mr Pluhar analyzed series of about 150 hips and created tools for support of the learning the method HIPSTRESS (instructions, video). Students downloaded demo version of the program Corel to acquire the geometrical parameters of hips and pelvis that are needed for determination of biomechanical parameters. Biomechanical parameters were determined by using previously published mathematical model (Ursic et al., 2021). Each student analyzed 8 – 12 X ray images. During the lectures, all participants simultaneously analyzed the same X ray image and inserted the measurements as well as calculations in a common google drive Excel document.

2. Examination

The examination questions were sent to the students before the Symposium started. All students were to listen to the plenary lecture, then, they were distributed evenly to scientific sections. All tools and social networks were allowed to be used for answering the questions (Bambič et al., 2021). The plenary lecture was given by prof. Duško Spasovski, an orthopaedic surgeon from Belgrade, Serbia, on hip osteotomies. The honorary lectures was given by Marija Ipavec who besides being the first author of the HIPSTRESS model for hip stress (Ipavec et al., 1999) has a decades long experience of having an above-knee prosthesis. The scientific sections covered the fields of medicine, veterinary medicine, materials, ecology and small cellular particles. Students were encouraged to ask the lecturers to help them with the answers and to invite them to contribute to a Google drive document, however, this opportunity did not take place as the lecturers were delayed in lectures and the students did not get the chance to better organize the support. After the end of the scientific section the students have assembled the answers into one MS Word document and have submitted it to an official mail of the Socratic Lectures within the limited time. Below are the questions and students' answers. The first group of questions addressed analysis of the operation due to hip dysplasia, as shown below.

Q: What is hip dysplasia? What causes it and what can happen if left untreated? Explain it from a clinical point of view.

A: According to (Anon A, 2022), hip dysplasia is an abnormality in which the pelvis and the femur (thigh bone) do not fit together as they should. Symptoms include pain in the hip, limping and unequal leg lengths and we treat it with braces for babies, physical therapy and surgery. It is thought that most people were born with hip dysplasia. The reason is either because of the position of the baby in the womb where there is too much pressure on the hips or it's a genetic problem, where the issue is passed down in the family. If the hip dysplasia is not treated it can cause a lot of long-term problems such as hip labral tear, osteoarthritis, dislocated joint and unstable joint. According to the lecturer Borut Kovačič hip dysplasia from a clinical viewpoint means that the acetabulum can not contain the femoral joint head. It's referred to as the shallow acetabulum socket.

Q: The method HIPSTRESS enables quantitative assessment of hip dysplasia. What are the biomechanical parameters that can be obtained from this method?

A: In his presentation Honza Pluhar stated that the biomechanical parameters that can be obtained from HIPSTRESS method are peak stress on the weight bearing area p_{max} that can be given in dimensionless form $p_{max} r^2 / WB$, where r is the radius of the hip articular sphere and WB is the body weight, the position of the stress pole given by the inclination angle Θ , the hip stress gradient index G_p given in its dimensionless form $G_p r^3 / WB$ and functional angle of the load bearing φ .

Q: What are the surgeon's criteria leading to the decision that the operation will be performed?

A: The plenary lecturer Dusko Sapsovski stated that the gradient index to be positive/negative is an indication for any kind of hip surgery. There are other radiological criteria and clinical criteria for arthritis. If people do not have any complaints or not have significant complaints, the gradient index seems the main prognostic tool.

Q: What is the goal of the operative treatment of hip dysplasia?

A: The goal is to change the orientation of the socket so it can better cover the ball of the hip joint.



Q: There are different osteotomies that change the unfavorable geometry of the hip and pelvis. Why does the surgeon decide to choose the periacetabular osteotomy?

A: A periacetabular osteotomy (PAO) is a surgical treatment for hip dysplasia that is caused by a deformity in the acetabulum, the curved portion of the pelvis that forms the socket of the hip joint. This procedure is in comparison with other procedures much simpler.

Q: What happens to the patient during a periacetabular osteotomy (PAO)? How would you describe the process/changes from a medical and biomechanical perspective? Try to link the answers together.

A: PAO is a surgery used to correct a condition called hip dysplasia or acetabular dysplasia. Hip dysplasia is when there is insufficient coverage of the femoral head (ball) by an excessively shallow acetabulum (hip socket). During a PAO, the acetabulum is repositioned to cover more of the femoral head in order to improve the stability of the hip joint. The PAO surgery improves hip function, decreases hip pain, and stops the damage occurring inside of the joint that can lead to hip arthritis over time. After the surgery the patients have reduced pain, improved hip function and increased activity level scores in short-term. The 10-year outcomes for the PAO procedure show that 80-90% of patients are free of end-stage osteoarthritis (Anon B, 2022).

Q: You have performed biomechanical analysis of hips before and after periacetabular osteotomy by using HIPSTRESS mathematical models. Please give your experience. When you have already learned how to do the task, how long did it take to analyze one hip? Did you have difficulties measuring the center-edge angle? If so, please describe them and how you solved the problem. Were there any other decisions that you had to make that were not straightforward? Please describe them. Were the instructions that you have received (the lectures, the literature, the written instructions, the video) helpful to perform the task? Did you need help from each other by exchanging experience or you could perform the task alone with the suggested aids? Did you have problems with software? If so, how did you solve them? Please include the answers of all the students. The opinions are expected to be different.

A: The answers of individual students are given below.

Student 1: When I first saw our assignment (analysis of hips) I panicked. It was something I had no knowledge about and I thought that it would be impossible for me to complete my work. Then I said to myself that I need to try my best. We all know that the first step is the hardest one and that it usually takes the most of the time. Analyzing the first hip was the slowest - around 1 hour - because I really took time and did things rather slowly, step by step. At the same time I was listening and watching Honza Pluhar's tutorial on how to perform biomechanical analysis of hips before and after periacetabular osteotomy by using HIPSTRESS mathematical models, which was very helpful. I was able to learn so much from him. He explained every step in detail and guided us through all assignments. Because of his excellent guidance I started to enjoy doing my work, one of the main reasons was that I saw big improvement in understanding of what I am actually doing and also time improvement (from 1 hour to around 20 minutes for one hip). I had no difficulties measuring the center-edge angle and my decisions were quite straightforward (well not at the first but with time I was less scared and became more confident in what I was doing). I also did not have troubles with software or Corel in general (it is beginner friendly). I am thankful for all of the support and guidance I had through work, and also for the knowledge I will be able to use in my future career.

Student 2: The first hip I analyzed together with Veronika Kralj Igljč and Honza Pluhar who were explaining it in one of our lectures. It was a long process but after two lectures of them explaining how to use the HIPSTRESS method I finally understood. It took me around 15 to 20 minutes per X-ray. I did not have any additional issues with performing measurements. The software (Corel) was easy to use and very specific, which made it easier to gather the measurements for Excel. I had the most issues with the »Solve« function in Excel but after some help from one of my colleagues I had it covered.

Student 3:- At first I was scared, the work from Honza Pluhar looked complicated. Then I tried it myself. The first patient's analysis took me a while, but by the end I became better at the techniques and procedures to the point where I spent about 10 minutes on each picture. The video was a great help, as I was able to see how something was drawn or measured, and also how the measurements were put into the table. I had no problems with measuring, but it was a bit more difficult to draw accurate circles and points, as the images were a bit foggy. The most difficult part for me was defining the boundaries, so I had to make difficult decisions about where to end which line. I found it difficult to know which measurements to put in which column of the table, so I asked my classmates to help me. The software Corel seemed difficult at the beginning, but once I found out how to use it, it was quite easy.

Student 4. At first I was scared because the program Corel did not work. Then with help from Honza Pluhar and Veronika Kralj Igljč I finally succeeded in uploading the Corel program. Honza Pluhar's instruction and explanation was so helpful. He showed the procedure step by step and it was easy to understand. The first measurement took me one hour, then it was going faster. I had a little bit of a problem with Excel table, but then I watched the video explanation from Honza Pluhar and it was helpful. It was interesting and fun to learn something new.



Student 5. My experience with using HIPSTRESS mathematical models was quite interesting. At first, I was a little bit confused about how to use the program Corel as it was new to me. After listening to the lecture of Honza Pluhar on how to use this program I understood what to do. During the lecture I took notes and after that I helped other colleagues, so I refreshed my knowledge on how to analyze hips. On average it took me 10 minutes to measure one hip. Filling the data in Excel took me most of the time. Overall, I had fun during analysis of hips.

Student 6. The first time using the application, I stumbled upon many difficulties and problems, mainly because I had no prior experience on such work. Thanks to Honza Pluhar who showed us the basic functions of the program and how to analyze hips I managed to find a way to complete all the tasks. After adapting to the program, every hip analysis went faster, therefore it took about 45 minutes at first and later about 25 minutes. I had no problems with measuring the center-edge angle, after repeating the process a few times. The whole process was fairly straightforward after thoroughly watching the instruction video, which was very helpful and was a key part of understanding the software and completing the task. Of course, the task would be nearly impossible without the extra literature and lectures that we received. I sought no help from my colleagues, as I managed to finish everything by myself. The software is very useful and easy to use, the only difficulty I stumbled upon was downloading it without paying a subscription, as it only has a 15 day free period. The issue was solved by using a different computer.

Student 7. In my case the instructions for the HIPSTRESS method were not introduced to me by a professor or a lecturer but by my fellow colleague who has been present at the first lesson of Veronika Kralj Igljč and Honza Pluhar. She then gave me very clear instructions which I grasped pretty much immediately. I had no problem understanding the concept and no problems when using the program Corel. I found the program really easy to use despite never using it before. The X-rays were also pretty clear and fairly easy to read from so I had no problems by placing the points of measurement. It took only 5 to 10 minutes per image. The Excel program was also very useful and well prepared, the equations were pre prepared by Honza Pluhar so all you had to do was enter the measurements. Overall I found the experience very positive.

Student 8. At first I was a bit worried, because it was my first time using a program Corel. Veronika Kralj Igljč and Honza Pluhar did an amazing job explaining the whole process. I had no problems with the measurements, because the X-ray pictures were quite clear so it only took me about 10 minutes per image. The program in general was very easy and fun to use. The Excel table was well prepared, with clear instructions of where to insert each measurement. I also helped my colleagues with their measurements because they did not attend the classes. In the end I found the making of the HIPSTRESS models quite fun.

Student 9. My experience with Corel was quite nice. I did not have any problems with software, the only disadvantage of the program is that the free trial lasts only 14 days. I think Honza Pluhar and Veronika Kralj Igljč made a very clear explanation on how to draw lines and measure certain parts of the hip. The video where Honza Pluhar explains every single step was quite helpful, especially for those who couldn't attend every lecture of biomechanics. I did not have any difficulties with measuring the center-edge angle, however I had some problems determining the extreme point of each femoral head. The first hip took me around 20 minutes to analyze, because I was not used to working with Corel program. Overall it took me 2.5 hours to complete the task, including watching the video of Honza Pluhar and inserting the data into the Excel table. When it comes to the Excel table, this is where I had the most difficulties. I did not know how to calculate the angle theta H. This part was a bit time consuming, but with help of my colleagues I managed to do it.

Student 10. My experiences with using HIPSTRESS mathematical models are positive. I was not present at the lectures and did not know the guidelines on how to use Corel or how to make the measurements. Luckily one of my colleagues was at the lectures and I asked her for help. She explained the procedures of using the program clearly and after doing one X-ray with her support I grasped the concept. After that I knew how to do the X-rays by myself. Most of the X-rays were clean but some of them were not and because of that it was a bit hard to do some parts of the measurements on them. It took me about 5 – 15 min per hip. In the Excel table prepared by Honza Pluhar, we had to write the measurements and then the Excel would calculate everything by itself. This type of taking measurements and drawing by using a program were new to me. Overall, it was fun and enjoyable.

Student 11. At first, the task seemed difficult to me, but while listening to the lectures, I realized that it's not. It took me around 40 minutes to complete the analysis of the first hip, but for the other analyses I only needed 20 minutes. At the beginning it was hard to start because I did not know how and I had some problems. But when I understood what I was doing it was easier. I didn't have any problems with Corel or with Excel tables. I think Honza Pluhar and Veronika Kralj Igljč gave us very clear instructions on how to draw and use the program Corel. Also the video of Honza Pluhar was very helpful. It was a great experience.

Student 12 - When I started, I was a little bit scared, because I did not know how to use the Corel program. The whole thing was new to me. I watched the video that Honza Pluhar sent to us. For the first picture I needed more time, because I was not sure if I was doing it right. I asked some classmates for advices and they helped me. I learned very quickly how to do it and at the end it was very



easy. For one picture I needed about 15 minutes. So all this didn't take me much of time. Actually it was fun. It was easy, because the X-ray pictures were really nice and clear. At the end I also had some problems with the excel table, but I learned how to do it right.

Student 13. My first impression of the assignment was that it looked very interesting, because the records were made for the first time. Help was available for both, X-ray pictures and analysis. With the help I was given it took me about 40 minutes to analyze the first couple of X-rays. For the next few it took me about 20 minutes. At first I was trying to figure out how to do things and when I understood, it took less time. In my opinion this type of lectures were very interesting and useful for the future because not many times do we get the chance to do something practical and to use technology (the program Corel). This can not be avoided in the modern world. So I am certain that the skills I have acquired will most certainly be useful in the future when we get to actually do something and take a better look into our field of profession. With the use of the program Corel I had no particular problems because it was easily downloaded and it proved beginner friendly. I missed a few of the lectures in the beginning where Honza Pluhar explained how we were supposed to do biomechanical analysis of the hips before and after periacetabular osteotomy by using HIP-STRESS mathematical models, so I had to ask for help from my fellow students. Also I used the video by Honza Pluhar.

Q: What is your opinion on the results of the biomechanical analysis of the operation?

A: Honza Pluhar stated that 50% of the hips on the contralateral side to the operation in the study got worse as regards biomechanical status. The plenary lecturer Dusko Sapovski agreed with that percentage. The overall opinion on the biomechanical analysis was that it is very important to identify changes in hips that were operated on, and to have accurate measurements of hips that will undergo surgery.

The second group of questions addressed the contents of the scientific sections.

Section 1, Medicine: Q: What is the value of population studies for treatment of a single patient?

A: Population studies are important because they provide the medical doctors and researchers with extensive data that helps them determine the reasons for different diseases and ways to treat them. The more information they have the easier it is for them to connect a specific type of disease to the single patient they are treating. The value of the population studies is immense when it comes to research data and result compilation.

Section 1, Medicine: Q: What are biomechanical features of carpal tunnel syndrome?

A: Previously presented evidence indicates that carpal tunnel syndrome is related to compression of the median nerve inside the carpal tunnel. Biomechanical arguments in which the extrinsic finger flexor tendons inside the carpal tunnel are characterized as a frictionless pulley-belt mechanism are useful to show quantitatively how the wrist size and position and the hand position affect forces on the tendons and their adjacent structures (Armstrong and Chaffin, 1979).

Section 1, Medicine: Q: Which biomechanical features are important in acquisition of platelet and extracellular vesicles-rich plasma? How can knowledge of physics help in optimization of the preparations from blood?

A: In centrifugation of blood, the time was calculated individually on the basis of patient's erythrocyte sedimentation rate (ESR) according to the mathematical model where two options were considered: The "high platelet and extracellular vesicle" protocol aimed at yielding plasma with the highest possible platelet and extracellular vesicle concentration that can be obtained by a single spin preparation without pelleting platelets and extracellular vesicles and the "half volume" protocol aiming to determine the time needed for the upper border of erythrocytes to arrive down to one half of the length of the blood sample (Božič et al., 2021).

Q: Honorary lecture by Andreas Leitzhner: Briefly describe the novelties in technology recently introduced in orthopedics and traumatology.

A: The new technologies discussed in the symposium are deep learning machines that recognise patterns, next generation sequencing, particle therapy, robotics, virtual reality simulations, digitalisation e.g. speech recognition and hybrid operation theaters.

Q: Honorary lecture by Marija Ipavec: In your opinion, how can an engineer of orthotics and prosthetics best support a patient that needs an artificial limb?

A: The engineer of orthotics and prosthetics must listen to the patient, anticipate errors from experience. However, cooperation with others, for example physiotherapists, is also required. The engineer must envisage what is wrong with the prosthesis by observing the patient. When the patient starts walking the engineer must know how to select the prosthesis that will be comfortable for the patient.

Q: Please describe briefly (about half a page) the contents of the lectures of each of the sections of Socratic lectures.

A: Section 1: Medicine. The first presentation by Borut Kovačič, Klemen Stražar and Lenart Zore entitled Pelvic osteotomies: experience of University Medical Centre Ljubljana was mostly about pelvic osteotomies. An osteotomy is any surgery that cuts and reshapes your bones. The next topic was Biomechanical analysis of periacetabular osteotomy by Honza Pluhar where we learned that the aim of biomechanics is to create a simple model, based on which it can be decided whether the hip is dysplastic and needs to undergo a



surgery. We discussed the HIPSTRESS model that we also used on our individual X-ray assignments, what is the meaning of the parameters (peak stress, hip stress gradient) and how the results are useful to a surgeon.

Blaž Mavčič in his presentation The role of hip arthroplasty registries and cohort studies in orthopedic surgery explained the historical perspective and additional factors of arthroplasty. Nejc Steiner presented a lecture entitled Surface-based total blood volume calculation for platelet and extracellular vesicle-rich gel preparation, Domen Vozel presented a similar subject: Use of platelet and small cellular particles rich plasma for closure of skull base and Sara Bitenc Zore presented another lecture on plasma preparation: Facial nerve reconstructive surgery in otorhinolaryngology and its enhancement by platelet-rich plasma therapy. In these subjects, the main concept is the use of plasma that can be obtained from individual patients to treat their injuries and wounds. Platelet and extracellular vesicles rich plasma can be made into a platelet and extracellular vesicles rich gel that can later be applied on external or internal wounds and help them heal better and faster. We discussed which factors are important and how they differ, so that they can contribute to give us the optimal results. Some of the factors are patient preparation, blood withdrawal, blood centrifugation, plasma activation and total blood volume calculations. Domen Vozel described the basics of plasma and gel preparation. There are different autologous and heterologous preparations and plasma-based or buffy-coat-based protocols. He also explained the process of application and cryopreservation of preparations. It is believed that in the future these preparations will have more versatile use, mainly in the field of otorhinolaryngology. The presenters showed us a few videos and pictures of how the gel was used in skull-base surgery and how the plasma therapy works/enhances healing after a facial reconstructive surgery.

Section 2, Veterinary medicine: Pšenica Kovačič explained the activities to take care of stray cats and provide the behavior consulting and education of cat welfare. She presented evolution of cats and their changes throughout history and some of her cat clients with health problems (e.g. with low urine output and small ureter volume). Some breeds have more health problems than the others (Persian cats have more health issues than for example F1 savannah cats).

Section 4, Materials: The subjects of the section were the impact of corundum ceramic, TiO₂ and hydroxyapatite nanoparticles on cell line in vitro, fabrication of TiO₂ microflowers and their antibacterial effect against Escherichia coli, additive manufacturing in orthotics and prosthetics and transmission electron microscopy of biomaterials used in total hip arthroplasty. In failed hip prostheses the wear debris particles were successfully extracted from the tissue and were found to be of different composite, mainly Al₂O₃, Ti-Al-V alloy and additional elements such as Ca, Fe and P. Nanostructured Poly(D,L-lactide-co-glycolide)/titania composites may possess the ability to simulate surface and chemical properties of bone and cartilage, respectively, to allow for alternatives in the design of prostheses with greater efficacy. Pure TiO₂ has a high antibacterial effect on pathogenic samples of Escherichia coli from clinical isolates, which is further increased with the addition of increasing concentrations of silver (Mantravadi, 2017). The most interesting topic for many of students was additive manufacturing technology, which in comparison to the traditional one has many advantages that can solve problems such as material wasting and time consumption. On the other hand it also permits customization for special applications or consideration of individual characteristics, which are both very important when it comes to treatment and rehabilitation of patient.

Section 5, Small cellular particles: Nowadays there are improved methods of seeing cells, such as scanning electron microscopy - SEM and transmission electron microscopy - TEM. These methods are appropriate to observe also apoptotic bodies - small cellular particles that contain substances and information from cells that are undergoing programmed death, and other types of small cellular particles. To isolate small cellular particles that are shed into cell exterior, they should be separated from cells. Centrifugation is one of the methods for this purpose. However, at higher centripeta acceleration of the centrifuge rotor, the cells change shape or become destroyed, which is also one of the mechanisms to yield small cellular particles in the isolates.

SEM gives us the best records of three dimensional shape of small cellular particles. Also, this technique allows for observation of a large number of individual particles. However, the preparation of the sample is quite invasive and it can destroy or transform small cellular particles. In cryogenic TEM however, the sample is vitrified in ice of the thickness of around 100 nm. The preparation of the sample for imaging is less aggressive than in SEM, however, particles larger than about 500 nm are not appropriate to observe by cryogenic TEM because they could not be contained in thin ice. This imposes constraints in isolation of particles.

3. Discussion

It is evident from the answers of the students that they have entered a discussion with the speakers. Also, they have used internet to arrive to the answers to the questions. Their most exhaustive answers were on their experience with determination of the biomechanical parameters, which is most valuable. Almost all the students described that they were able to learn the HIPSTRESS method with the help that was provided by a teacher and a peer student Honza Pluhar. The students of orthotics and prosthetics were of the first year while Honza Pluhar is completing his masters in Prague. He is skilled with mathematics, physics and computer science. He performed the analysis of the majority of hips, checked the quality of the determination of geometrical parameters of the students, provided

tutorials and also presented the results in lectures to the students and to the colleagues in Socratic lectures symposium. As our aim was to analyze a great number of hips, the input of the students was important to be able to accomplish this aim.

In designing the students' activities during the symposia, it was our wish to introduce new possibilities into teaching; as it is now possible to share documents, more persons can write the document at the same time, so this document started to form at the symposium. Within Section 1 (Medicine) a 15 minutes interval was reserved to students to discuss their questions and it was suggested that the students can ask the presenters to help them improve the document. Unfortunately, this event could not take place because some presenters took more time than expected and the participants were then late for the joint section presenting honorary lectures. It is our wish that important aspect of reviewing the answers on spot would be taken into account. For example, the students' answer to the question: Why does the surgeon decide to choose the periacetabular osteotomy? was that this procedure is in comparison with other procedures much simpler. As great skills of the surgeon are necessary to perform this operation, an opinion of the surgeon that has ever performed this operation would be of much value.

4. Conclusions

The students have proved that they collaborated well to formulate the answers. They used the English language to communicate with the participants of the international symposium. They helped each other to complete the task on assessment of biomechanical parameters. One of the students wrote: »So I am certain that the skills I have acquired will most certainly be useful in the future when we get to actually do something«, not being aware that they already actually entered research with their interest in the subjects, providing the data for the biomechanical analysis and supporting the participants of the symposium.

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