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Motion laws determination, on experimental way, of joints from the human lower limb structure for certain activities imposed to the locomotor apparatus

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Abstract: In this paper it is proposed the kinematics analysis achievement, on experimental way, of the human lower limb joints, for the following activities: walk, go up or down the stair steps, and change over the body stance (setting down on a chair or stand up from a chair).

Based on this experimental kinematics analysis, it is followed to obtain the motion laws generated by each human lower limb joint for the activities mentioned above.

The motion laws will be obtained, on an experimental way, by using special software called SIMI Motion, and these can be useful in the sight of equivalent kinematics model achievement from the human lower limb structure which can be used in the sight of lower limb prosthesis design, for example: ankle prostheses, knee prostheses, hip prostheses.

1. INTRODUCTION

Through this paper it brings to be known the motion laws developed at the level of the main articulations of the human lower limb (hip articulation, knee articulation, ankle and foot articulation).

The novelty element which is brought in this paper frame it represents the determination of these laws on experimental way, but also the implementation method and utilization of a kinematics analysis software called SIMI Motion.

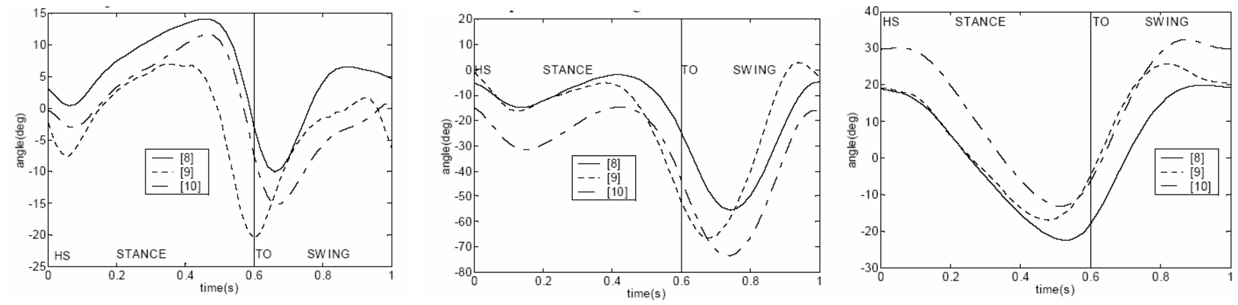
Although the paper represents a application point in the biomechanical domain, and the software can be used in experimental kinematics determinations applied on the other systems, for example the mechanical ones (experimental kinematics analysis of a krank shaft- connecting rhod – piston mechanism from a combustion engine structure).

It is important to retain the fact that the obtaining method of some motion laws in the case of mechanical or biomechanical complex systems is very difficult, especially on analytical way.

The analyzed biomechanical system – human lower limb is a very complex one, totalizing a number of 31 bony elements, connected through 41 joints, which is very difficult to analyze from kinematics viewpoint in the sight of motion laws determination.

Obviously this, in the specialty literature, these motion laws are determined by numerous researchers on different ways and methods, having as main scientific scope, the achievement of this objective. So, it can be made a reference at ROSE J., GAMBLE J researchers from University Center from Baltimore SUA, where in the 1994 year have studied the human walking process, and these motion laws almost existent in the specialty literature as a reference laws, are emphasized in the figure 1, a, b, c, the activity were deployed on a single step.

LINSKELL J., researcher at the DUNDEE Biomechanical Research Center from Scotland had studied the movement activity on experimental way, on 3 human subjects – adult persons which doesn't present locomotion disabilities, the concrete data's are presented on a special dedicated web page to human lower limb gait analysis and the obtained diagrams based to the kinematics analysis results are presented in figure 2 for each joint.



a. *b.* *c.*

Figure 1. The motion laws obtained by the ROSE J., GAMBLE J. for the following joints: a – ankle; b – knee; c – hip. **[3]**

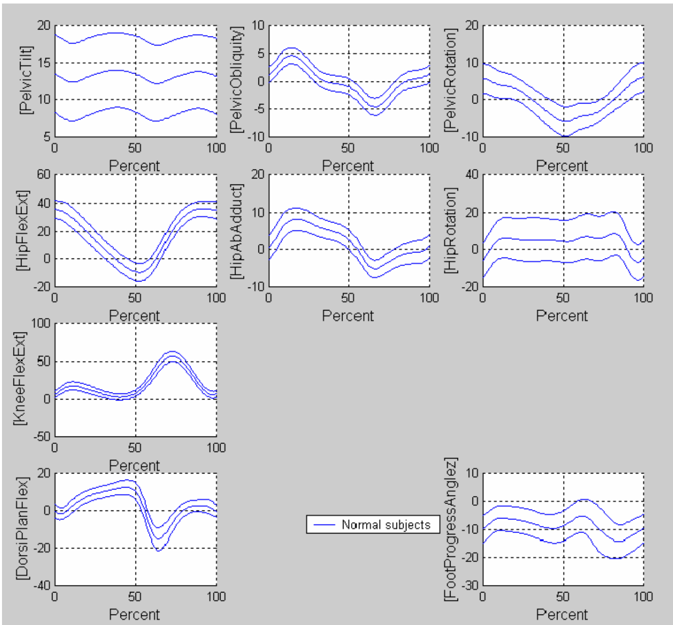


Figure 2. The motion laws obtained by the LINSKELL J., for the following joints: ankle, knee, hip. **[1]**

2. DESCRIPTION OF THE UTILIZED EXPERIMENTAL SYSTEM

The experimental kinematics analysis was performed by using a acquisition and image analysis system, called SIMI Motion (SIMI Reality Motion Systems GmbH - http://www.simi.com) [4], which can be found in the endowment of the Kinetotherapy and Sport Faculty from University of Craiova. The process of obtaining the kinematics data's through image capture and analysis is described in the scheme from figure 3.

The kinematics data's obtaining cycle presupposes the attachment of a markers series onto human lower limb subject (the one which is studied in this paper), by using for attachment of these markers, the anatomical points, which are characterizes the identification at a anatomical level of the interest articulations center positions (figure 4).

The capture and take over phase of an image were performed through a PANASONIC high – rapid video camera which was found in the endowment of the SIMI Motion system, and the image recorder where performed with the ACER notebook aid, the equipment is presented in figure 5.

The final phase of the experimental kinematics data's obtaining process is constituted from the images analysis by data's processing, and the markers position onto human subject where automated identified, with the software options help onto each frame, obtaining the kinematics curves (displacement, speed, accelerations) for each joint from the human lower limb structure (figure 6).

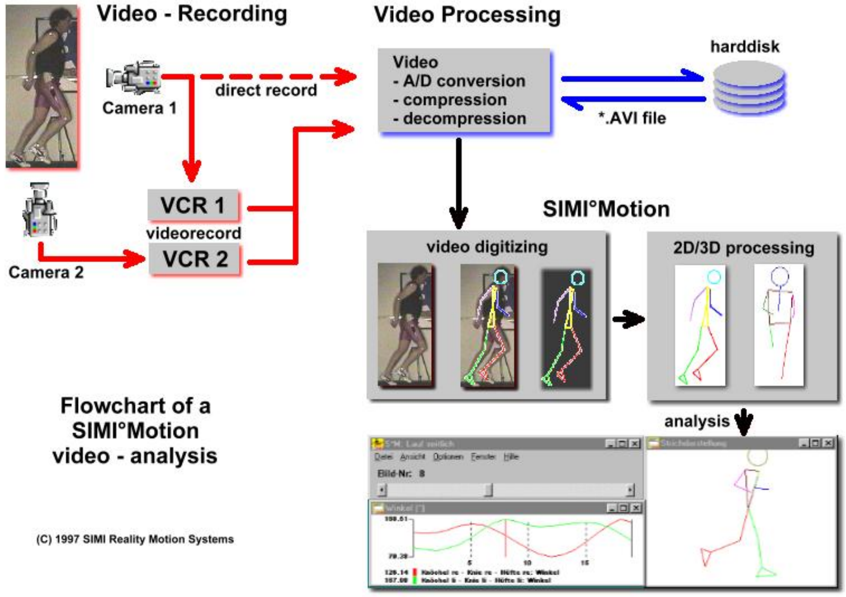


Figure 3. Video – analysis process schematization of the SIMI Motion software.

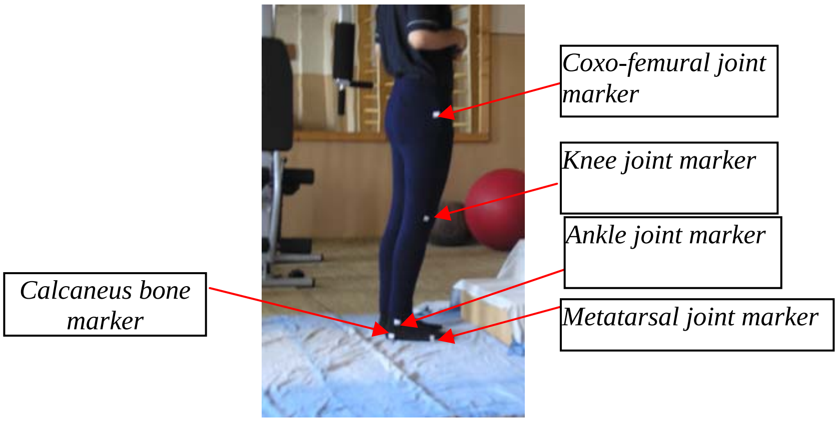


Figure 4. Aspect regarding the marker attachment.

Figure 5. Data acquisition system and the high – rapid video camera.

The experimental analysis deployment in the sight of evidenciating the motion laws which were realized at the level of hip, knee and ankle joints, were performed on a human 26 years old subject with a 65 kg weight, 1,75 height, the elements length were: l_{femur}= 401mm; l_{tibia}=322 mm; l_{foot}= 210 mm; $l_{calcaneus-ankle}$= 66,5 mm; $l_{calcaneus-metatarsal}$= 130 mm, the analysis where constituted the in – vivo determinations of the articulations kinematics for the following activities:

- walking activity (figure 7, a);
- go up or down the stair steps activity (figure 7, b);
- change over the body stance activity (setting down on a chair or stand up from a chair – figure 7, c).

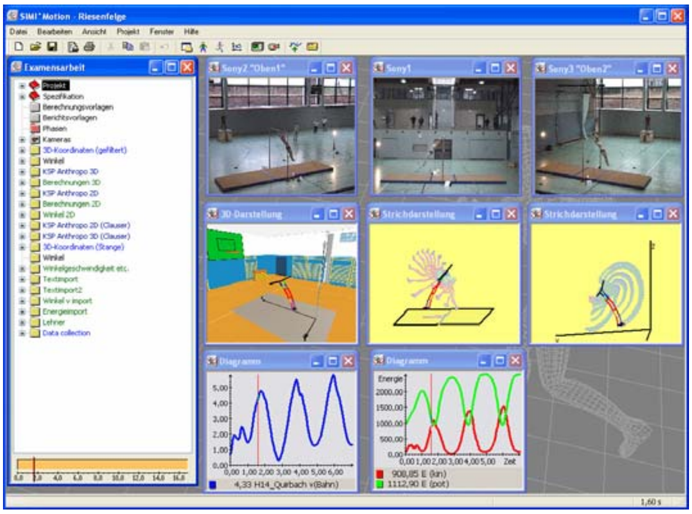


Figure 6. SIMI Motion software interface. **[4]**

a. b. c.

Figure 7. Aspects regarding the deployment of the activities in the experiment frame: a – walking activity; b - go up or down the stair steps activity; c - change over the body stance activity.

4. PRESENTING THE OBTAINED RESULTS

The kinematics experimental analysis was deployed on 3 types of activities, resulting the motion laws of the 3 joints particularized for the activities in cause.

Although for the walking activity, this was deployed in a 2D plane which the subject was moved in X axis direction on a 2,5 m distance, in a 4,2 seconds , deploying a number of 3 steps, such as is presented in figure 8.

Based on the kinematics analysis performed with the software equipment's help, this was generated in automatically mode the kinematics model having on base the markers emplacement mode (figure 9).

The software was permitted to generate the calculus of displacements, speeds and accelerations of interest depending on time, the diagrams were represented in the conventional scheme base from figure 10.

The obtained motion laws through this experimental kinematics analysis are presented summary in figure 11.

In a similar way the procedures of the experimental kinematics analysis were particularized repeated for the other activities.

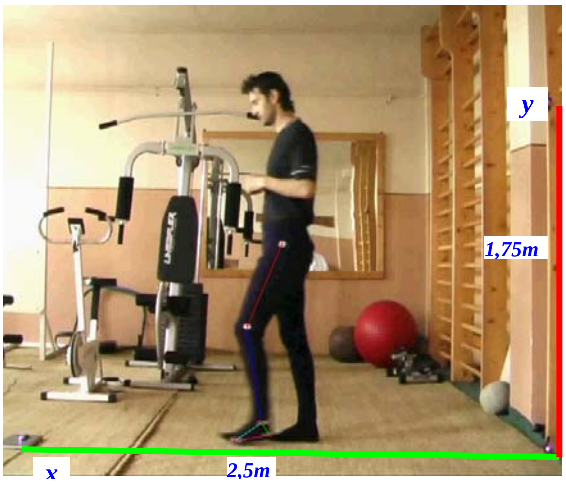


Figure 8. Aspect regarding the deploying activity of walking and equivalent kinematics model creation with the SIMI Motion software's aid.

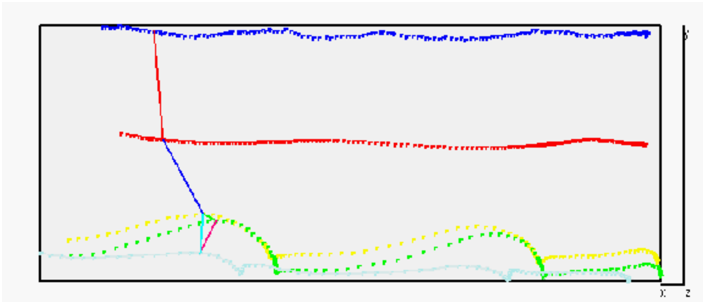


Figure 9. The kinematics model af the human lower limb studied in walking activity case.

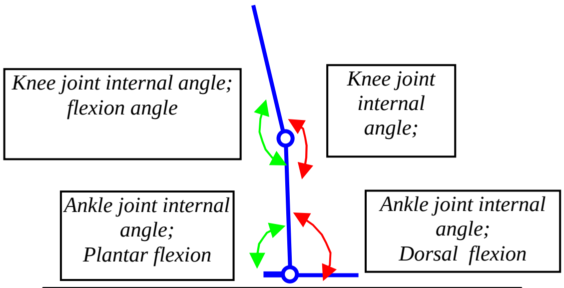
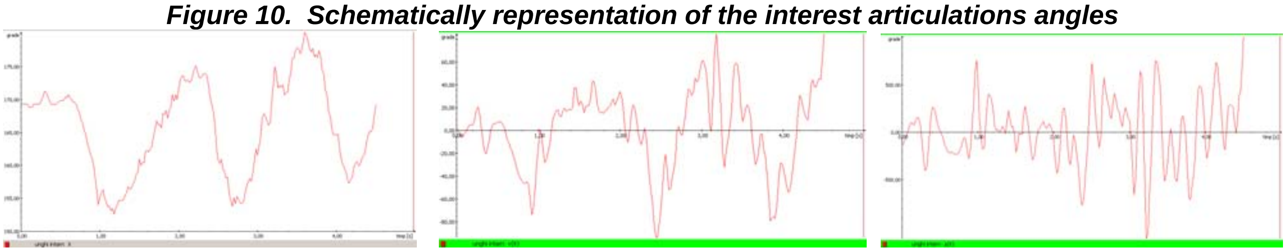
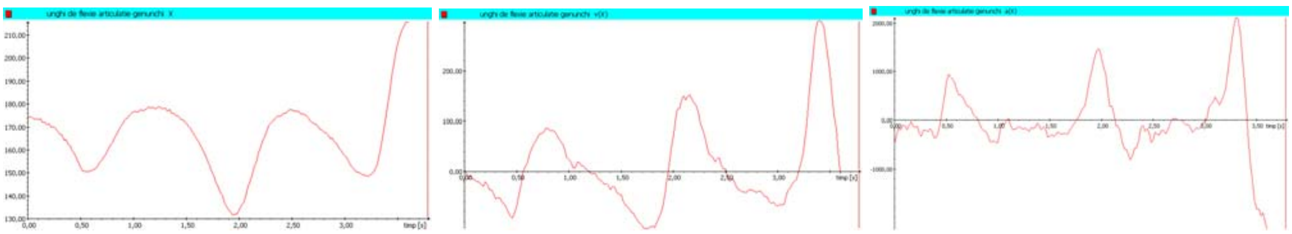


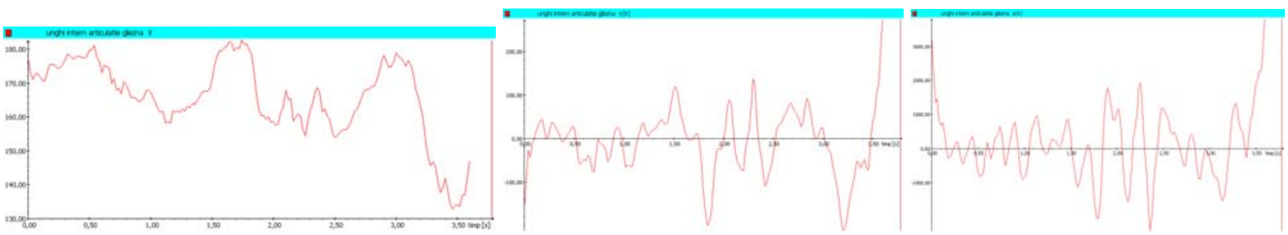
Figure 10. Schematically representation of the interest articulations angles



Angular variations of the hip joint: displacements, speeds, accelerations.



Angular variations of the knee joint: displacements, speeds, accelerations.



Angular variations of the ankle joint: displacements, speeds, accelerations.

Figure11. Angular variations at joints level obtained in the walking activity frame

For the go up or down the stair steps activity, this was deployed in the 2D plane, which the human subject was deployed in XY axes directions, the plane was conceived on 2,5x1,75m dimensions, measuring time was 4 seconds, such as is presented in figure 12.

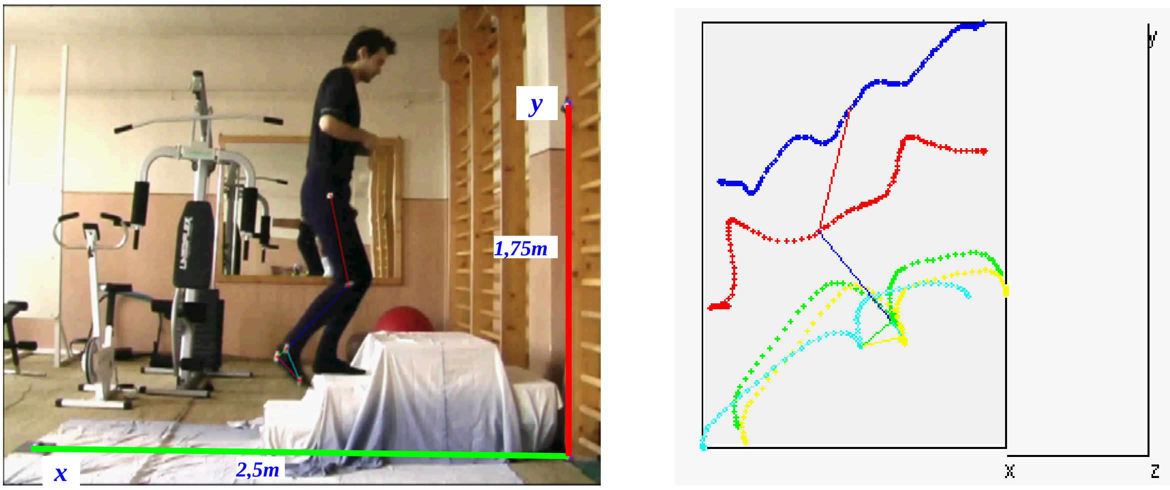
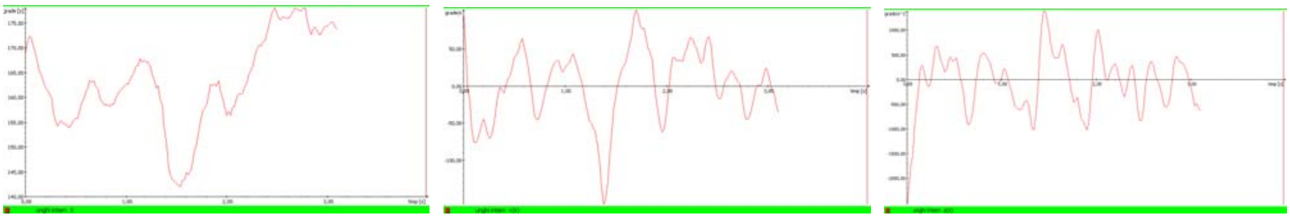


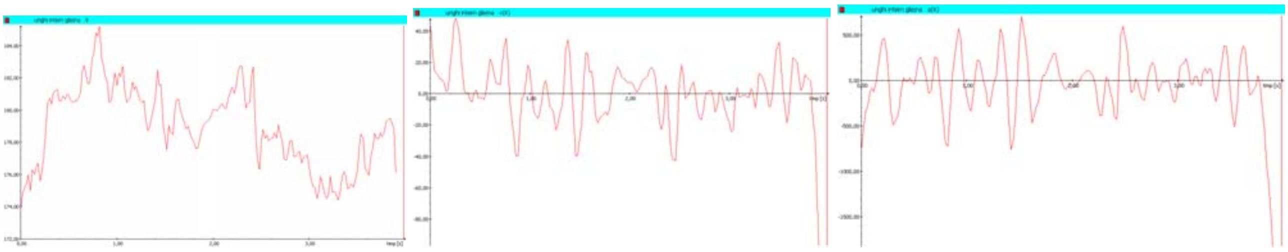
Figure12. Aspects regarding the deploying of the go up or down the stair steps activity and equivalent kinematics model creation with the SIMI Motion software's aid.

The resulted motion laws are emphasized in figure 13, for each joint from the human lower limb structure.



Angular variations of the hip joint: displacements, speeds, accelerations.

Angular variations of the knee joint: displacements, speeds, accelerations.



Angular variations of the ankle joint: displacements, speeds, accelerations.

Figure 13. Angular variations at the articulations level obtained in the go up or down the stair steps activity frame.

For changing over the body stance (setting down on a chair or stand up from a chair), the subject was performed movements in XY – 2D plane with the 2,5x1,75m dimensions, deploying time of the phase was 4,8 seconds such as is presented in figure 14.

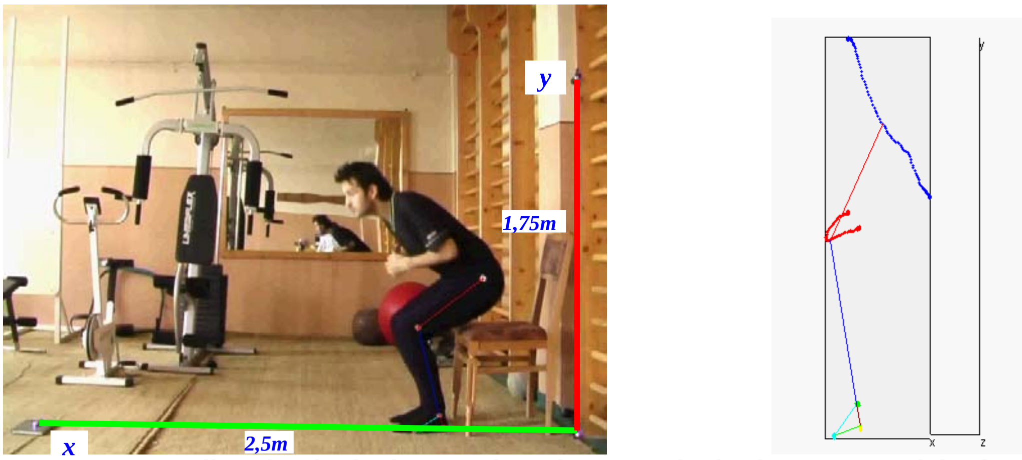
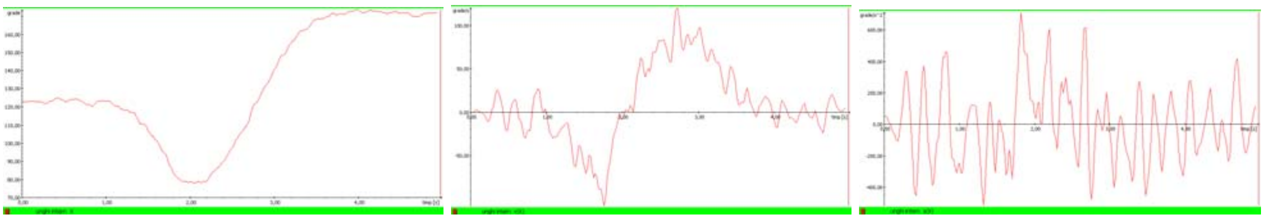
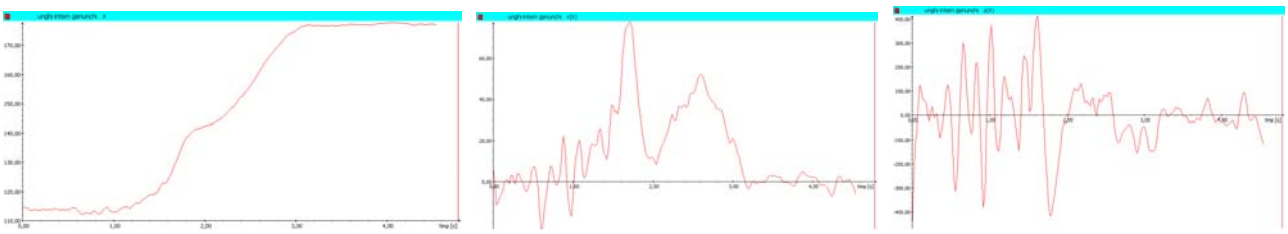


Figure 14. Aspects regarding the deploying of changing over the body stance activity (setting down on a chair or stand up from a chair) and equivalent kinematics model creation with SIMI Motion software's aid.

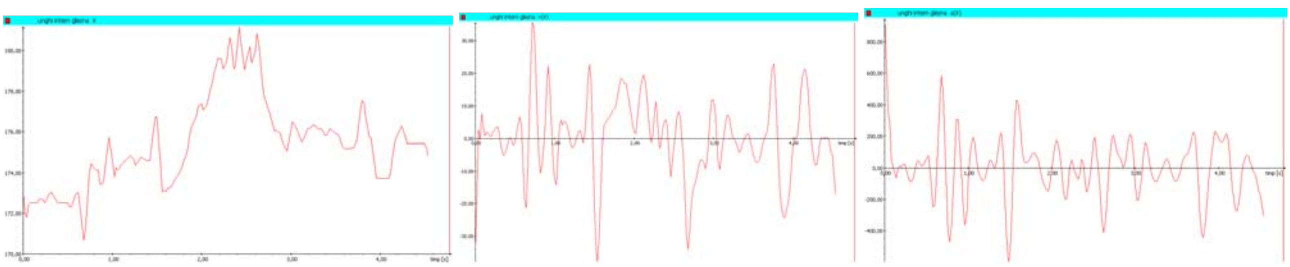
And for this activity the software has permitted the calculus generation of displacements, speeds and accelerations for each articulation of interest in the allocated space, and the resulted motion laws for this activity were presented in figure 15.



Angular variations of the hip joint: displacements, speeds, accelerations.



Angular variations of the knee joint: displacements, speeds, accelerations.



Angular variations of the ankle joint: displacements, speeds, accelerations.

Figure 15. Angular variations at articulations level obtained in the changing over the body stance activity frame (setting down on a chair or stand up from a chair).

5. CONCLUSIONS

The experimental kinematics model obtained through the human subject participation, presupposes a dimensional correlation of the markers position in rapport with the theoretic kinematics model equivalent with the human lower limb (figure 20).

So it was obtained a kinematics data set for the activities mentioned above, which can serve in the sight of designing of a new exo-prosthetic system, therefore in the sight of implants models study with finite elements in the sight of these comportment improvement through geometrical modifications.

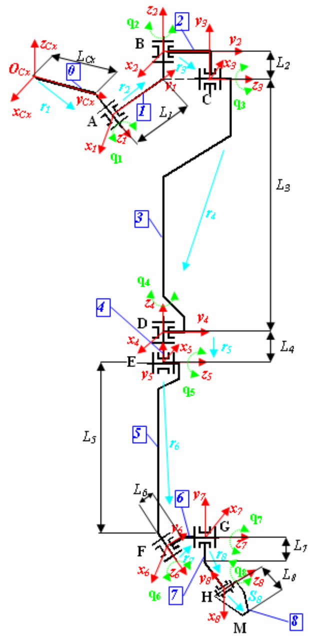


Figure 20. Kinematics scheme of the equivalent human lower limb.

The kinematics data obtained on experimental way can be useful in the sight of dynamic study realization of the theoretical kinematics model equivalent to human lower limb in the sight of forces and reactions determination on analytical way from the kinematics joints through an original method, in the sight of exo-prosthetic and/or endo-prosthetic (implants) systems developing or improvement.

The aim of this paper is to present a experimental kinematics method by using SIMI Motion software, but this method can be applied on diverse mechanical systems from the assemblies or subassemblies structure of machines or aggregates, the method can be particularized for example in an applicative mode for experimental kinematics analysis of the human lower limb which represents a high degree of complexity.

Also the software permit the experimental kinematics analysis realization as much as in plane (2D) or in space (3D), the software can be useful in kinematics analysis of some complex mechanisms.

6. REFERENCES

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