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KINEMATICS AND KINETICS OF HEALTHY AND OSTEOARTHRIC KNEE DURING WALKING STAIRS

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Abstract: *This paper presents the results obtained for healthy subjects and osteoarthritic patients during climbing and descending stairs. The variations and the maximum flexion-extension angles and maximum reaction force values are presented. The climbing and descending tests demonstrated that the maximum values of flexion-extension angle are smaller for osteoarthritic knees than for healthy knees. The angle values are higher on descending than on climbing for all participants. For climbing stairs the values are (1.25-1.4) body weight and for descending stairs the values are (1.4-1.6) body weight.*

Key words: *climbing stairs, descending stairs, reaction forces, electro goniometers, platform forces, knee joint, osteoarthritic knee*

1. Introduction

Climbing and descending stairs is a daily activity of people, healthy but, also, suffering of different diseases, including musculoskeletal diseases. Compared to the over-ground normal gait, this activity is a much more demanding activity, especially in people with diseases [2-8]. Biomechanical analysis of stairs walking using force platforms and goniometers helps researchers to improve knowledge of human locomotion, being useful in gait rehabilitation or in the design of humanoid robots [3]. In [5-8] the biomechanical analysis of flexion-extension leg joints during climbing or descending stairs are presented. In gait analysis, the measurement of ground reaction forces is well-known, but in the case of climbing or descending stairs only a few studies have been conducted to determine the reaction forces [2-4, 6, 8]. Force platforms and a video system for measuring motion were used in [6] to identify parameters of the legs while climbing stairs.

The objective of this study is to measure the force reactions and the variation of knee flexion-extension angles of human knee during climbing and descending stairs.

2. Description of the experimental tests

The experimental tests for osteoarthritic patients were performed in the Department of Orthopaedic and Traumatology of Emergency County Hospital of Craiova and consisted of three trials climbing and descending at 12 stairs. Data collection was performed in the day before the knee prosthetic surgery. For healthy subjects (HS) the measurements were performed in the Biomechanics Laboratory at INCESA Research Centre of University of Craiova.

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2.1. Equipment

In the performed experiments a Biometrics Ltd data acquisition system based on electrogonimeters, which are wearable sensors successfully used in biomechanics [9-14].

DataLog MWX8 is a portable device used for collecting and monitoring data in real-time, simultaneous on 8-channels, and it is used in human gait analysis, medical research, and robotics.

To simultaneously collect data during experimental tests, six flexible electrogoniometres (SG 100 and SG 150 types) for the six joints of both lower limbs of each subject were used (Figure 3) [14].
Also, to measure the ground reaction forces variation, six FP4 Biometrics force platforms were used [13, 14]. For data acquisition two 8-channel DataLOGs at a frequency of 500 Hz (MWX 8 Biometrics Ltd) were used [14]. One DataLOG was connected with the six platforms and the other one was connected with six electrogoniometers (three for left leg joints and three for right leg joints). The data transfer from the DataLOGs to computer was conducted in real time via Bluetooth. In Fig. 1 the schema-block of data acquisition system mounted on the subject is shown. For each joint, the system allows data acquisition for flexion-extension movement and for lateral movement. For this paper we are interested to use the data files obtained for both knee of every participant in the experimental tests.

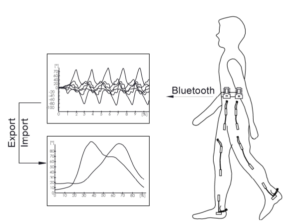


Fig. 1. *Block-schema for collecting and processing data using Biometrics system.*

Fig. 2. *Biometrics flexible electrogonio-meters and DataLog.*

2.2 Subjects

Data acquisition was performed on a sample consisting of 3 patients, a man and two women aged between 56 and 68 years, all three suffering by osteoarthritis of the right knee, and on a sample of four healthy subjects, two men and two women ages close. The healthy subjects donĉt suffer from joint pain, no symptoms of an arthritic diseases and no surgery of the lower limbs. For all healthy subjects and patients, the anthropometric data were collected before the beginning of the tests. Table 1 and 2 present the mean and standard deviation for the anthropometric data of patients and healthy subjects.

Table 1

Patients	Average	St. Dev.
Age [years]	61	6.24
Weight [kg]	71.3	11.02
Height [cm]	165.4	1.53
Leg length [cm]	80.7	3.06
Hipï knee length [cm]	39	3.61
Kneeï ankle length [cm]	42	0.6

Table 2

Subject	Average	St. Dev.
Age [years]	27.7	2.52
Weight [kg]	72.6	10.26
Height [cm]	172.7	6.4
Leg length [cm]	75	7
Hipï knee length [cm]	37.4	4.9
Kneeï ankle length [cm]	37.6	2.1

The experimental protocol was presented to each participant and they performed more repetitions before the start of final tests.

Fig. 3. *Fixation of the electro-goniometers on the lower limbs.*

3. Results

Data were collected using Biometrics system.
The results were exported in .txt format, and then imported in software SimiMotion [15]. The imported data in SimiMotion were divided into cycles and phases walking and, using application "Calculated envelopeò, the diagrams of medium cycle were obtained.

The variations of the flexion extension and adduction-abduction angles for hip, knee and ankle joints of the right lower limb for the patient No. 1 are shown in Figure 4. In figure 5 are shown comparative diagrams of flexion-extension medium cycles for descending stairs test for right and left knee joint.

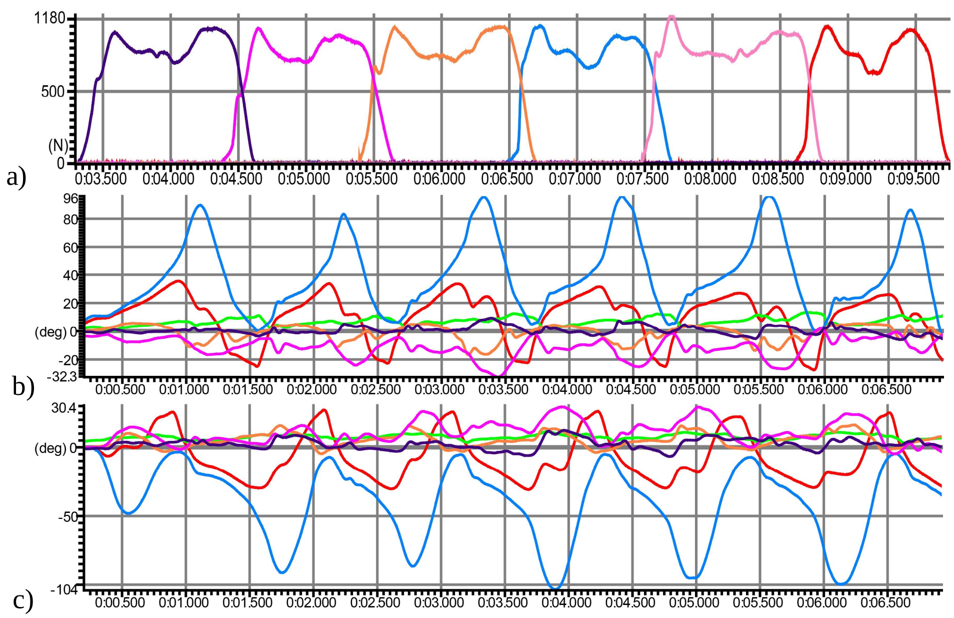
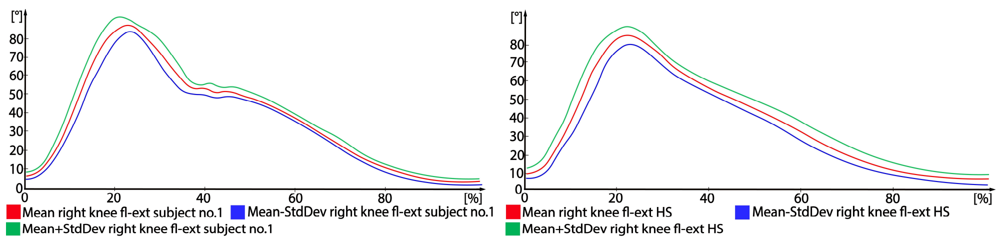


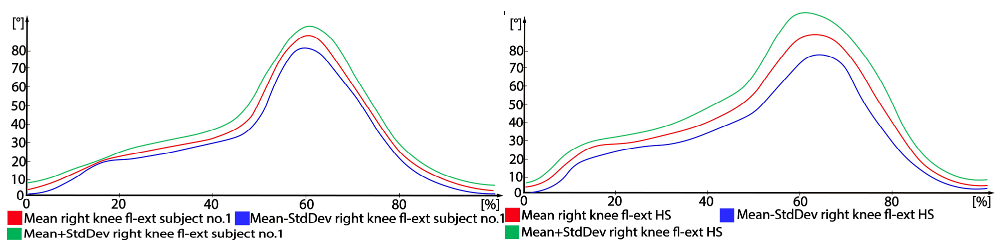
Fig. 4. *The diagrams obtained by Biometrics System for healthy subjects*: *a) Reaction forces variation on the six force platforms for descending stairs test*; *Variation of the angle of flexion extension and adduction abduction angles for right; b) and, respectively, for left c) ankle, knee and hip joints in descending stairs test.*

The flexion-extension cycles and the mean flexion-extension cycles for the right knee joints from healthy subject no.1 is presented in figure 6.



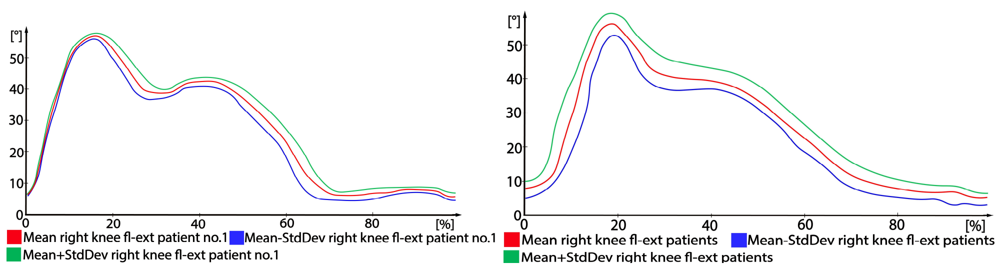
a) b)

Fig. 5. *Flexion extension medium cycles for right knee on climbing stairs: a) for subject no. 1, b) for entire sample of healthy subjects*



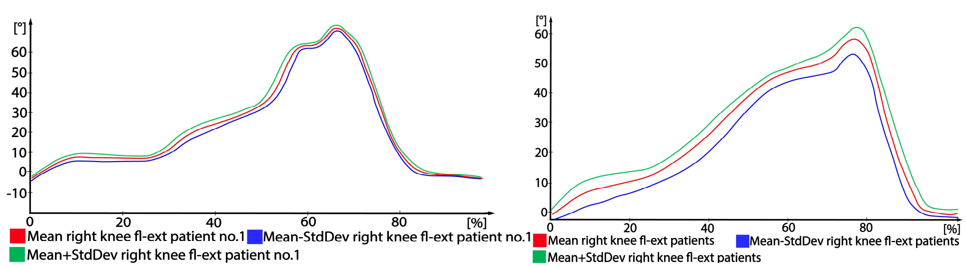
a) b)

Fig. 6. *Flexion extension medium cycles for right knee on descending stairs: a) for subject no. 1, b) for entire sample of healthy subjects.*



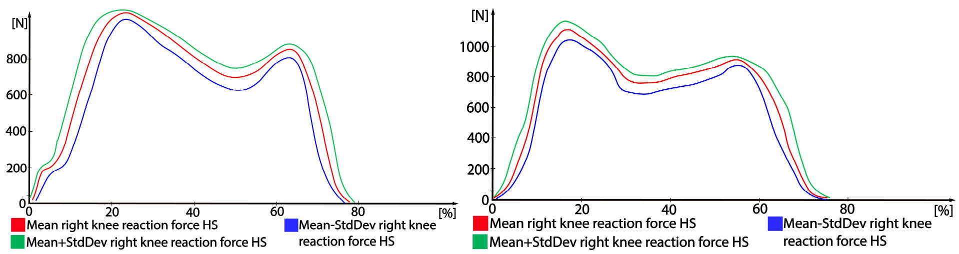
a) b)

Fig. 7. *Flexion extension medium cycles for right knee on climbing stairs: a) for patient no. 1, b) for entire sample of patients.*



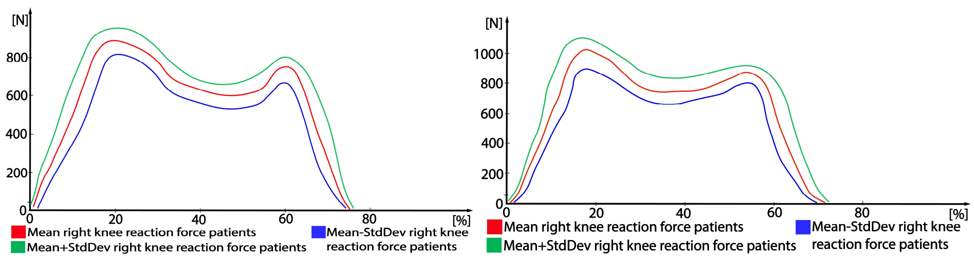
a) b)

Fig. 8. *Flexion extension medium cycles for right knee on descending stairs: a) for patient no. 1, b) for entire sample of patients.*



a) b)

Fig. 9. *Medium* Reaction *force for healthy subjects: a) climbing stair, b) descending stairs*



a) b)

Fig. 10. *Medium Reaction force for patients: a) climbing stairs; b) descending stairs*

In tables 3 and 4 the maximum flexion-extension angles and maximum reaction force values for the healthy subjects and for patients are presented.

Table 3

Patients	**Descending**		**Climbing**	
	Max. angle [deg]	Max. reaction force [N]	Max. angle [deg]	Max. reaction force [N]
1	68	1082	57	940
2	61	1044	56	910
3	66	860	58	765
Medium Cycle	65	1007	57	874

Table 4

Subject	**Descending**		**Climbing**	
	Max. angle [deg]	Max. reaction force [N]	Max. angle [deg]	Max. reaction force [N]
1	89	1180	88	1045
2	95	1082	91	962
3	95	1146	88	914
4	85	1144	84	1006
Medium Cycle	89	1163	86	983

In table 5 are presented the average and standard deviation for time and frequency of walking stairs for all tests.

Table 5

Healthy subjects	**Descending**		**Climbing**	
	Average	St. Dev.	Average	St. Dev.
Time [s]	10.7	1.81	11.25	0.24
Frequency	0.89	0.15	0.94	0.24
Patients				
Time [s]	11.85	0.21	12.47	0.49
Frequency	0.99	0.02	1.04	0.02

4. Discussions and conclusions

The experimental tests demonstrated that the maximum values of flexion-extension angle are smaller with about 20 degrees for osteoarthritic knees than for healthy knees for both kinds of tests: climbing and descending. The variation curves have similar allures for patients and for healthy subjects. Also, the flexion-extension angles values are higher on descending than on climbing for all participants in the experimental tests: healthy subjects or patients.

The study demonstrated that ground reaction force from the beginning of the stance phase is higher than at the end of the stance phase. In normal walking the ground reaction force values are 1.1-1.15 weight [1], in contrast with the case of climbing stairs when the values are comprised in the interval (1.25-1.4) body weight and, respectively, (1.4-1.6) body weight in descending stairs. These results are similar with the results obtained in [1, 2, 6]. In the case of osteoarthritic patients, for similar body weights, the reaction forces values are smaller than in the case of healthy subjects.

5. References

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