Transilvania University of Brasov
FACULTY OF MECHANICAL ENGINEERING

The 7th International Conference on
Computational Mechanics and Virtual Engineering
COMEC 2017
Brasov, ROMANIA, 16-17 November 2017

A STUDY ON THE CORRELATION BETWEEN STEP LENGTH AND THE FEMUR-TIBIA RATIO

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Abstract: *In this paper we study the correlation between the length of the femur and tibia and the length of the step in order to obtain a useful parameter in various applications in the fields of access control and human identification. A group of 40 subjects were filmed during normal walking and their step length was measured, along with their femur and tibia length, in order to obtain the ratio between the femur and tibia and to see if there is a correlation between that ratio and the length of the step.*
Keywords): *biomechanics, step length, access control, human identification*

1. INTRODUCTION

The scientific interest in studying human walking has existed since ancient times. The main fields of interest related to the study of human walking (gait analysis) are sports, medicine, identification of humans based on walking and access control.
There are multiple ways to analyze human walking. We recall the radio methods in which devices are installed on the body of the subjects, and these communicate using radio waves with a fixed control point, thus positioning the subject at any point in time and measuring the displacement. Also, given that it transmits the position of a point at any moment in time, GPS technology can also be used to analyze human walking. Some of the most popular methods for gait analysis are based on photo-video technologies. These are preferred because they come with a number of advantages: it is not necessary to install heavy equipment on the studied human subject's body parts; it also offers better accuracy than GPS and is usually better suited to studying fast motions, such as those in sports.
For our study, we preferred to use video materials from which we extracted walking coordinates that helped us measure different parameters related to human walking. First of all, we intended to find if the walking pattern of a subject, in normal conditions (normal walking) is consistent over different walking sessions, then we were interested in searching for a correlation between the dimensions of body parts (in our case, the length of the leg's main bones, femur and tibia) and the length of the step - this could be used in human identification based on gait.

2. MEANS AND METHODS

In this paper we used video technologies to record subjects during normal walking, in order to measure their step lengths (Figure 1). A total of 40 subjects had their motions recorded, each along 10 straight-line sessions, on a predetermined, planar trajectory.

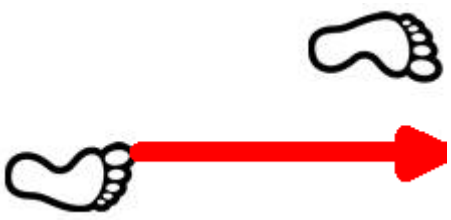

Figure 1: The step length, from the top of one feet to the top of the other feet

A high-speed video camera and different frame rate settings were initially used (60 frames per second, 120 and 500 frames per second were considered). After some initial testing, considering that there are no significant differences between the three settings, for time and storage space reasons, we have chosen shooting at 60 frames per second (Figure 2).

Figure 2: Capturing the step length for different subjects

First of all, the length of the femur and tibia were measured for each subject, using a tailoring meter. A number of two steps were recorded for each subject (ignoring the first step) during each recording session, resulting in the end a number of 20 step lengths for a subject. We defined the parameter *p* as the ratio between the length of the femur *f* and the tibia length *t*:

$$p=f/t$$

3. RESULTS

The results of the experiment described above were recorded in the form of Excel tables, overall resulting 40 tables, one for each subject. We were interested in the consistency of the length of the step for the different walking sessions for each subject taken individually, and also we were looking for an eventual way in which the pair body parts – step length can be compared for the 40 subjects. A summary of the data is presented below in Figure 3.

```
femur =

  Columns 1 through 20

    48    47    53    43    55    49    54    49    46    52    46    50    55    55    49    50    55    50    51    54

  Columns 21 through 40

    49    48    55    49    48    49    49    52    49    48    42    54    46    44    48    47    46    52    54    49


tibia =

  Columns 1 through 20

    46    41    50    39    49    42    48    38    40    45    44    45    45    48    45    47    47    41    48    51

  Columns 21 through 40

    42    43    46    43    43    41    43    43    46    42    38    45    39    41    42    41    42    46    53    44


stepsize =

  Columns 1 through 20

    48    48    61    52    42    60    49    50    45    50    61    49    55    51    59    61    68    54    54    50

  Columns 21 through 40

    61    62    55    57    61    41    49    48    35    50    37    55    50    37    54    38    51    44    53    49
```

Figure 3: The values for the 40 subjects (round values, the step size is taken as an average value)

The first thing which we found was the femur / tibia ratio, which is presented in Figure 4.

```
Femur_Tibia_Ratio_P =

  Columns 1 through 12

    1.0435    1.1463    1.0600    1.1026    1.1224    1.1667    1.1250    1.2895    1.1500    1.1556    1.0455    1.1111

  Columns 13 through 24

    1.2222    1.1458    1.0889    1.0638    1.1702    1.2195    1.0625    1.0588    1.1667    1.1163    1.1957    1.1395

  Columns 25 through 36

    1.1163    1.1951    1.1395    1.2093    1.0652    1.1429    1.1053    1.2000    1.1795    1.0732    1.1429    1.1463

  Columns 37 through 40

    1.0952    1.1304    1.0189    1.1136
```

Figure 4: The femur-tibia ratio for the 40 subjects

In order to find an eventual correlation between the body parts dimensions and the length of the step, we determined the ratio between the femur and the step size, presented below in Figure 5.

```
Femur_vs_Stepsize =

  Columns 1 through 12

    1.0000    0.9792    0.8689    0.8269    1.3095    0.8167    1.1020    0.9800    1.0222    1.0400    0.7541    1.0204

  Columns 13 through 24

    1.0000    1.0784    0.8305    0.8197    0.8088    0.9259    0.9444    1.0800    0.8033    0.7742    1.0000    0.8596

  Columns 25 through 36

    0.7869    1.1951    1.0000    1.0833    1.4000    0.9600    1.1351    0.9818    0.9200    1.1892    0.8889    1.2368

  Columns 37 through 40

    0.9020    1.1818    1.0189    1.0000
```

Figure 5: The femur-step size ratio for the 40 subjects

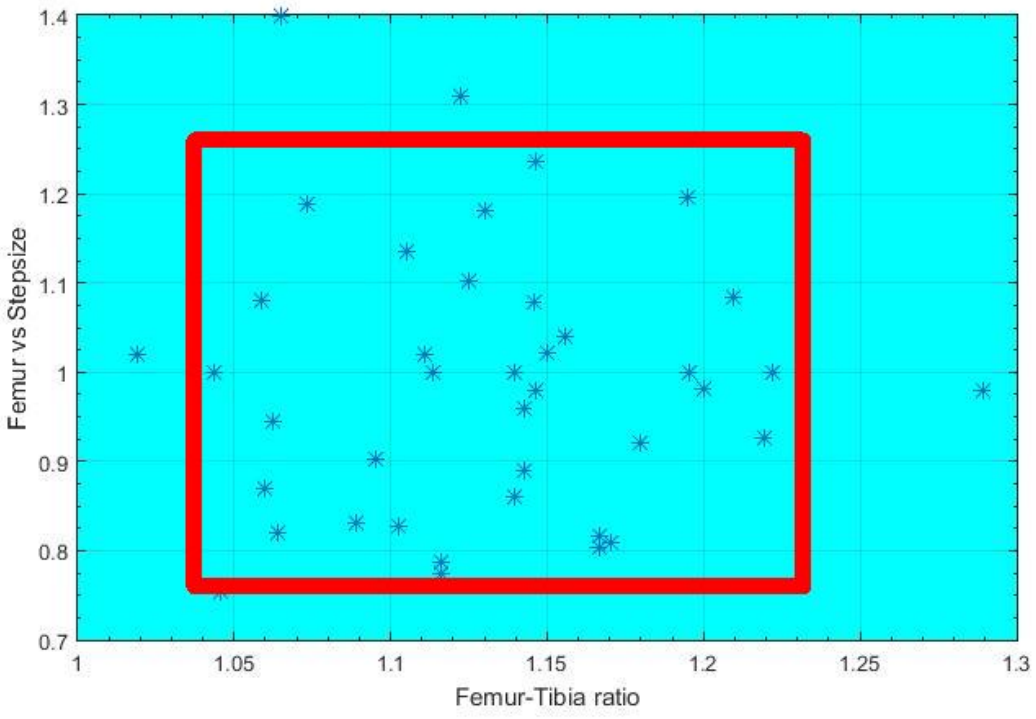

Figure 5: The femur-tibia vs femur-step size ratio for the 40 subjects

We can see that there is no clear universal correlation for all subjects between the body parts and the length of the step. Still, for a vast majority of them, the femur-step size ratio is between 0.75 and 1.25, and, more importantly, the pair femur-tibia and femur-step size seems specific to each subject. Regarding human identification and a large sample size, this cannot serve as a single main method to identify humans based on gait but, once the femur-tibia and femur-step size pairs are known, it can help reduce the number of possible suspects from a large group.

4. CONCLUSION

After analyzing the data which we obtained, we could clearly see two things. First of all, the length of the step tends to be consistent for the same subject during the different walking sessions: we can say that subjects walk (more or less) in the same way from the step length's point of view. Secondly, we could not find a general correlation for all the subjects in regard to body parts ratio *p* versus the length of the step, but still, some conclusions could have been drawn: for a big part of the subjects which had the ratio p between 1.04 and 1.23, (35 out of 38) the length of the step and the length of the femur were close in size but specific to each subject.
There are other aspects when it comes to drawing conclusions. Obviously, the sample of 40 subjects is very small for a study of this kind. Also, some subjects could have been experiencing some form of "stage fright", knowing they are on camera, not being able to walk normally, as they would usually do. Also, we had a number of 6 female subjects and 34 male subjects, all aged between 21 and 24. We decided to include the results of female subjects in the study because they did not seem out of the ordinary compared to the other results which we obtained, but, considering a future study, with a significantly larger number of subjects, we must do a pre-analysis in order to decide if male and female results are consistently different, and also will consider a larger demographic, including people of older age.
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