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SEQUENCE OF MAXIMUM ANKLE MUSCLE FORCE CONTRIBUTION DURING GAIT

[1]Michalina Błażkiewicz and [1,2]Andrzej Wit
[1]Jozef Pilsudski University of Physical Education in Warsaw, Poland
[2]ALMAMER in Warsaw, Poland; email: michalinablazkiewicz@gmail.com, web: www.awf.edu.pl

SUMMARY
The purpose of this study was to determinate the sequence of activation of maximum muscle force contribution in ankle joint during gait cycle. Three-dimensional kinematics, ground reaction forces was measured during walking trial of ten healthy subjects. Our results indicate that the profile of contribution of ankle muscle force is not the same in all subjects. In all 10 individuals we observed that muscle soleus generate the greatest strength both in dynamic and isometric conditions, after that in the hierarchy is muscle gastrocnemius - medial head just in dynamic conditions. For another muscles the sequence looks different.

INTRODUCTION
Methods such as kinematic analysis, combined with the registration of GRF and EMG signals become customary for a comprehensive analysis of gait. However, the analysis of muscle forces distribution, the analysis of acceleration caused by the muscles as well as the perturbations are currently one of the major issues raised in biomechanics, requiring the use of sophisticated optimization models. The aim of this study was to find the sequence of maximum peaks of ankle muscle force contribution during gait.

METHODS
To quantify the contributions of the individual muscles during gait ten male healthy subjects (x=24.5±6.6years, h=181±8.7cm, m=75.9±7.3kg) participated in this study. Kinematic data were collected at 100Hz using eight Vicon System cameras. Reflective markers were placed using the full body 'Plug-in-Gait' marker set. Ground reaction force data were measured at 1000Hz using two Kistler force plates. The simulation was generated using OpenSim 2.4.0 [1]. A generic musculoskeletal model with 19 degrees of freedom and 92 Hill-type muscle-tendon actuators was scaled to match the anthropometry of the subjects. By solving an inverse kinematics problem, the joint angles of the musculoskeletal model that best reproduce the experimental kinematics of the subject were calculated. Inverse dynamics task was solved to determinate net moments at each of the joints. To reduce dynamic inconsistencies between the kinematics model and the measured ground reaction forces, a residual reduction algorithm (RRA) was used. Following RRA muscle forces were computed using the computed muscle control (CMC) tool. For each of the subjects, the maximum value for each of the 12 muscles acting around the ankle joint during gait cycle was calculated. In addition, the values were compared with values obtained in the isometric conditions [2].

RESULTS AND DISCUSSION
On the figure below is presented the sequence of the maximum forces value for each of 12 muscle acting on ankle joint in the study group during gait cycle. The profile of contribution of ankle muscle force is not the same in all subjects.

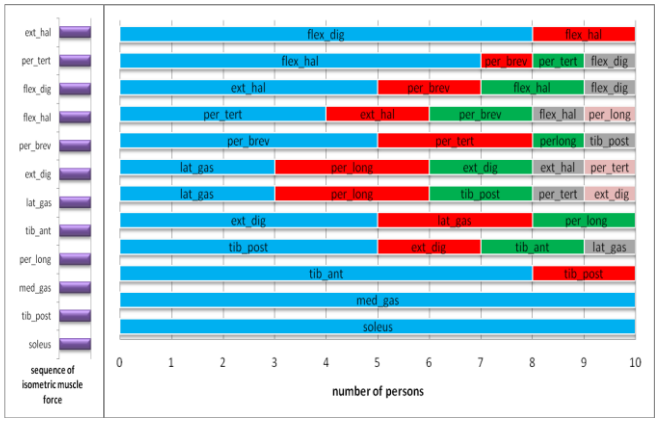

Figure 1: Profile of maximum muscle forces in ankle joint compared with sequence of isometric muscle force.

We found that in all group of 10 individuals the strongest muscle is soleus both in dynamic and isometric conditions. Immediately after is muscle gastrocnemius - medial head. Third in terms of maximum strength in dynamic condition is muscle tibialis anterior – eight persons and muscle tibialis posterior – two persons. The lowest value of maximum forces we observed for muscle flexor digitorum (8 persons) and muscle flexor hallucis (2 persons). For another muscles the sequence of ankle muscle force look different.

muscle	average difference [N]	muscle	average difference [N]
1) m. soleus	1792.9	7) m. flex_dig	247.8
2) m. tib_post	1094.9	8) m. flex_hal	247.0
3) m. perlong	632.9	9) m. tib_ant	174.2
4) m. med_gas	425.4	10) m. ext_dig	100.5
5) m. lat_gas	317.4	11) m. ext_hal	41.7
6) m. per_brev	280.8	12) m. per_tert	40.2

In group of 10 persons, the average difference between the maximum values of muscle forces during gait cycle and those obtained in the isometric condition arranged as in the table above.

CONCLUSIONS

The sequences of maximum muscle force acting on ankle joint in dynamic and isometric conditions are different. The difference of sequence of maximum muscle force acting on ankle joint was observed also within group in dynamic condition. Some of the reason of these differences is diverse body weight, sex and age of the individuals, but also the use - or not use the effect of contraction-extension cycle, which has an impact on the strength and speed of movement during the investigation.

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REFERENCES

1. Delp SL, et al. OpenSim: open-source software to create and analyze dynamic simulations of movement. *IEEE transactions on biomedical engineering 54 (11):* 1940-1950, 2007.
2. Wickiewicz TL, et al. Muscle architectuie of the human lower limb. CORR 179: 275-283, 1983.