How Does Disuse of Plantarflexors Affect Upper Knee Kinetic?

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Abstract— This study aims to perform analysis simulation study on healthy-subject gait cycle by zeroing the major plantar flexor (PF) muscles strength in order to perceive the effects on knee and hip muscles/joints. The results showed high compensation from knee and hip joint forces/moments. In addition, a two-sample t-test showed a significant difference in the knee force and moment in some regions of the stance phase.

I. INTRODUCTION

Abnormalities in gait could be caused by irregularities in one or several muscle parameters. Strength is one of these important properties which plays a crucial role in a proper execution of gait cycle. The reduction in strength could lead to failure in performing any of the activities of daily living. Krogt et al. [1] investigated the degrees that muscle weakness can be tolerated before walking is impaired using OpenSim. However, to the best of authors' knowledge, there have not been any studies investigating the effects of below knee muscles loss on the knee and hip muscle joints. For this reason, inverse dynamic simulations of human walking has been performed in AnyBody™ (v6.0, AnyBody Technology A/S, Aalborg, Denmark) using a full-body model. We aimed to investigate the difference between healthy (full strength) and diseased shank muscles (zero strength) on upper knee joints. We hypothesized that disuse of plantarflexor (PF) muscles would have significant impact on knee and hip forces and moments in different planes. This information will be useful to develop rehabilitation therapies for population with neuromuscular disease and below knee amputees.

II. PROCEDURE

One healthy subject (age: 26; weight: 83 kg; height: 183cm) was participated in this experiment. The subject was free of any neuromuscular pathology, any skin condition or lower limb injury. The subject performed walking in a lab equipped with 13 ProReflex MCU1000 cameras (Qualisys, Gothenburg, Sweden). The experimental procedures involving human subject described in this study were approved by the Institutional Ethical Review Board.

A standard model (AnyBody AMMR 1.6.2, MoCap Model) was used in this study. The model consists of 55 muscles and seven degrees of freedom per each leg. Based on the marker position, the model was scaled to anthropometry of the subject. In order to calculate muscle and joint forces, inverse dynamics was performed on Hill type muscle tendon model with a third order polynomial muscle recruitment criterion. Ground reaction force prediction algorithm was used for analyses. After the full strength analysis was performed, the strength of the major PF muscles was set to zero including gastrocnemius medialis and lateralis, soleus medialis and lateralis, flexor hallucis and digitorium and a second inverse dynamics was performed.

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III. RESULTS AND DISCUSSIONS

In order to investigate the compensation that occurs when major PF muscles strengths have been zeroed, average difference in maximum peak of muscle and joint force as well as joint moment between affected muscles and their healthy counter parts were calculated. Table. I shows the compensated muscles and joints in order of the highest to lowest average maximum difference, when PF is disused.

Table I. Average maximum difference between healthy and diseased cases. The muscles and joints which had the highest impact were presented.

Muscle group	Average Maximum Difference		
	Muscle Force	Joint force	Joint Moment
PF	SEMIM, SEM, SAR PD, GMIN & GMED AP , RF, BFCB	Hip PD, Hip ML, Knee AP, Knee PD, Knee ML	Hip PD, Knee AP, Hip ML, Knee PD, Knee ML

Abbreviation: semimembranosus (SEMIM), semitendinosus (SEM), sartorius (SAR), gluteus minimus (GMIN), gluteus medius (GMED), biceps femoris caput breve (BFCB), rectus femoris (RF), medial/lateral (ML), proximal/distal (PD), anterior/posterior (AP).

In addition, the mean difference between the knee and hip forces and moments of healthy and diseased conditions were investigated using a two-sample one dimensional statistical parameter mapping with a significance level set to ($\alpha = 0.05$). The results indicated that the knee force ML and PD in the early stance and knee moment AP in mid-terminal stance were statistically significantly different.

IV. CONCLUSIONS

The simulation study showed higher muscle force compensation from quadriceps and hamstring muscles when PF strength was zeroed. Moreover, the results showed a high significant average maximum difference in the knee and hip joint forces and moments. These results may have importance in strength training and rehabilitation programs for people with low/no strength of major PF muscles.

REFERENCES

[1] M. M. van der Krogt, S. L. Delp, and M. H. Schwartz, "How robust is human gait to muscle weakness?," Gait & posture, vol. 36, pp. 113-119, 2012.