# EFFECT OF PLANTAR FLEXOR FATIGUE ON JOINT WORK IN VERTICAL SQUAT JUMPING

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## INTRODUCTION

It has been hypothesized [1] that maximum performance in vertical jumping requires a balanced increase of segmental angular velocities, in order to prevent the shortening velocity of some muscles to become disproportionally high and their work output disproportionally small. The purpose of the present study was to test this hypothesis. For this purpose, we had human subjects perform maximum height squat jumps in two conditions: before and after the plantarflexors of their right leg had been fatigued.

## METHODS

Six physically active subjects (4 male and 2 female, age 26±8 yr, height 1.73±0.08 m, body mass 68.5±5.9 kg) performed three maximum height squat jumps (control condition C). They then executed a series of isometric voluntary plantar flexions until fatigue and, while fatigue was maintained with an inflated cuff around the right lower leg, again performed three maximum height squat jumps (fatigued condition F). During jumping, ground reaction forces of the individual legs were measured with a Kistler force platform and sampled at 200 Hz, simultaneously with bilateral sagittal-plane positional data of anatomical landmarks (Optotrak 3020, Northern Digital). Inverse dynamics was used to determine net joint moments and work. EMG was recorded bilaterally from soleus, gastrocnemius, vastus lateralis, rectus femoris, gluteus maximus and biceps femoris. EMG signals were amplified and sampled at 1000 Hz (Porti-17t, Twente Medical Systems). Off-line, signals were high-pass filtered at 7 Hz, full-wave rectified, and smoothed using a bidirectional digital low-pass Butterworth filter with a 7-Hz cutoff frequency, to yield smoothed rectified EMG (SREMG). For each SREMG signal, onset and peak amplitude were determined as described elsewhere [2]. Repeated-measures ANOVA was used to test for possible differences between F and C.

## RESULTS AND DISCUSSION

No differences occurred in initial position or in take-off height of the center of mass between F and C (Fig. 1), but jump height was reduced by 6.4 ± 4.1 cm on average ($p<0.05$) in F, the condition in which the plantarflexors of the right leg were fatigued (the isometric contractions caused a reduction in isometric plantar flexion moment in the right leg by 70% on average). Total work in the left, unfatigued leg was on average 25 J greater in F than in C, primarily because the joints extended at lower angular velocities and therefore the hip extensor muscles were hampered less by their force-velocity relationship. Total work in the right leg, however, was on average 72 J less in F than in C. Most of the reduction in total work or the right leg was due to a reduction in ankle joint work, but work at the hip joint of the right leg was also reduced by 24 J on average (Table 1). No differences were found between C and F in SREMG onsets.

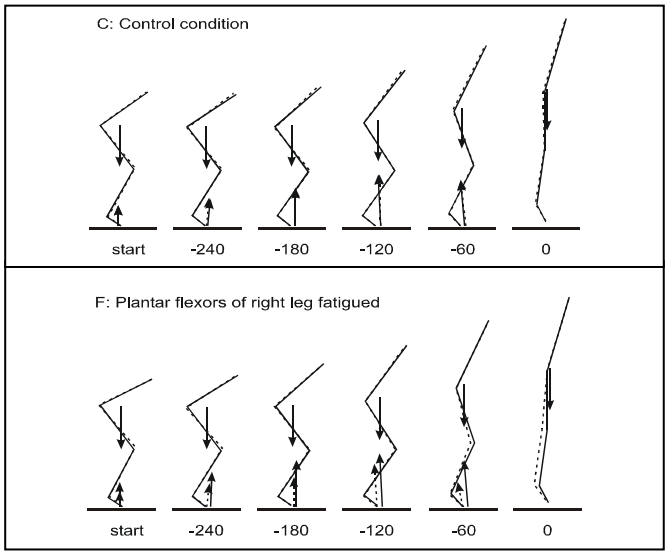


**Figure 1**. Average stick diagrams at indicated times (ms). Arrows pointing upward represent ground reaction force vectors of individual legs; arrows pointing downward represent force of gravity. Solid: left leg, dashed: right leg.

Peak SREMG amplitude of soleus and gastrocnemius of the right leg was reduced by more than 30% in F compared to C, presumably due to failure of neuromuscular transmission and inhibitory reflexes. However, no differences were found between F and C in SREMG peak amplitude in any of the other muscles, suggesting that the reduction in work output at the hip joint of the right leg was primarily due to mechanical factors. Indeed, the hip extension velocity of the right leg increased earlier in F than in C, as can be seen in Fig. 1 from the premature increase in hip joint angle in F.

**Table 1**: Total work and joint work of right and left leg in conditions C and F (n=6).

| | Left leg | | Right leg | |
|---|---|---|---|---|
| | C | F | C | F |
| Total work [J] | 197 ± 23 | 222* ± 35 | 192 ± 26 | 120* ± 26 |
| Hip work [J] | 64 ± 20 | 86* ± 26 | 58 ± 30 | 34* ± 30 |
| Knee work [J] | 64 ± 10 | 61 ± 11 | 62 ± 17 | 66 ± 11 |
| Ankle work [J] | 70 ± 15 | 75 ± 19 | 72 ± 20 | 20* ± 9 |

*Significant difference between C and F ($P<0.05$).

## CONCLUSIONS

The findings of the present study support the hypothesis that maximum performance in vertical jumping requires a balanced contribution of segmental angular velocities.

## REFERENCES

1. Bobbert MF and van Soest AJ. *Exerc Sport Sci Rev* **29**: 95-102, 2001.
2. Bobbert et al. *J Appl Physiol* **105**: 1428-1440, 2008.