Improvement in running economy may be explained by the changing in muscle synergy

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Summary

The present study aimed to determine if changes in muscle synergy induced by the different shoe cushioning property could explain the improvements in running economy (RE). Nine healthy active males performed six 5-min runs at 12 km/h on the instrumented treadmill while wearing three different running shoes. Oxygen consumption ($\dot{V}O_2$) was measured, and the condition with the lowest $\dot{V}O_2$ was defined as "High-Performance Shoes (HPS)", and the condition with the highest $\dot{V}O_2$ was defined as "Low-Performance Shoes (LPS)", respectively. Six muscle synergies were identified and statistical differences were observed in the weightings of muscle synergy during the early stance phase. These findings that suggest that changes in the weightings of muscle synergy in the triceps surae muscles during the early stance phase may explain the improvement in RE.

Introduction

Although it is well known that running shoes with appropriate mechanical properties improve RE [e.g. 1], the underlying biomechanical and physiological mechanisms remain unclear. Since skilled running movement has been explained by the plasticity of muscle synergy in the lower limb muscle groups [2], it is possible that the improvement in running economy due to shoe characteristics could be explained by an improvement in the coordinated movement of the lower limb muscle groups via muscle synergy. Therefore, the purpose of this study was to determine whether changes in muscle synergy between the shoe conditions could explain the improvements in RE

Methods

Nine healthy active males participated in the present study. All subjects performed a 5-min run at 12 km/h on the instrumented treadmill with three different compression stiffness of running shoes (control, hard, and soft). Subjects completed six 5-min trials in mirrored order (e.g., A-B-C-C-B-A). $\dot{V}O_2$ was measured during 5 min of running using the breath-by-breath methods, and the average values of the $\dot{V}O_2$ during 4-5 min was calculated. Surface electromyography (EMG) activity was recorded bilaterally from the following 12 muscles: tibialis anterior (TA), gastrocnemius medialis (GM), soleus (Sol), vastus lateralis (VL), rectus femoris (RF), biceps femoris (BF), gluteus medius (Gmed), gluteus maximus (Gmax), rectus abdominis; superior portion (RAS), erector spinae (ES), latissimus dorsi (LD), deltoideus; anterior portions (DELTA). Non-negative matrix factorization was used to extract muscle synergies from EMG data with 30 strides in each trial [3]. A threshold of 95% for the total variance accounted for (tVAF) was chosen to quantify the required synergies for each trial. The condition with the lowest $\dot{V}O_2$ was defined as HPS, whereas the condition with the highest $\dot{V}O_2$ was defined as LPS among the three types of running shoes tested. Statistical differences in $\dot{V}O_2$ and muscle activation weightings were calculated using paired t-test between HPS and LPS. The significance of the differences was set at $p < 0.05$. Data are presented as mean ± standard deviation.

Results and Discussion

$\dot{V}O_2$ was significantly lower in the HPS (41.1±2.3 mL/kg/min) than in the LPS (42.3±2.4 mL/kg/min) ($p<0.01$). Based on tVAF, six synergies were found to be common among all subjects. The weightings of the left RAS and left VL in Synergy3 (swing phase) was significantly smaller in HPS condition ($P<0.05$). However, the contributions of these muscles to the RE might be small due to small weightings. On the other hand, the weightings of the left GM and left Sol in HPS condition were significantly smaller than in the LPS condition in Synergy4 ($P<0.05$; left foot stance phase). These findings suggest that the smaller weightings of GM and Sol in Synergy4 may be associated with a reduction of energy generation of the muscles to attenuate the loading impact, possibly contributing to better RE.

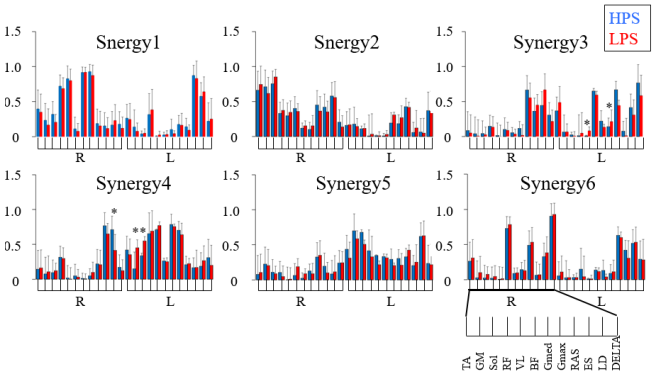

Figure 1: Weight of muscle synergy between HPS and LPS. *<0.05

Conclusions

$\dot{V}O_2$ was lower in the HPS condition than in the LPS condition along with lowering the weights of muscle synergy. The results of this study suggest that changes in the weightings of muscle synergy in the triceps surae muscles during the early stance phase may explain the improvement in RE.

References

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[3] Hagio et al. (2017) *PLos ONE*, **12(2)**: e0171535