Are the 1600 years old hiking shoes still working?

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Summary

Inspired by a commonly known poem of Tang Dynasty, this project investigated the underlying mechanisms of Xie Gong's clogs (Xie Lingyun, 385-433AD), a type of clogs with removable pegs that were widely used in ancient China around 1600 years ago. Samples of shoes were made according to unearthed clogs from Nanjing in 2009. The energy cost and lower limb muscle activity were determined across several walking conditions. The experiment results proved the ancient clogs can save energy and reduce some muscles' amplitude during hill walking on one peg shoes. Based on it, modern hiking shoes could be developed to minimize energy and assist with walking on hilly terrain.

Introduction

In the widely known Tang Dynasty poem by Li Bai 'T'ien-mu Mountain ascended in a dream', there are words describing the clogs of Xie Gong's clogs 'I wear his pegged boots; Up a ladder of blue cloud' [1]. This has inspired our research to explore the mechanical difference between two pegs and one peg shoes walking. Antonellis explored the metabolic cost of walking with modular footwear that offsets downhill or uphill grades. They found shoes that partially offset treadmill grade minimized metabolism and shoe inclination influenced soleus muscle activity [2]. A study using eight subjects and comparing the oxygen consumption and heart rate indicated that physiological cost of stairs is always less than a ramp of equal slope [3]. By Xie Gong's clogs study, we aim to reveal the possibility of using shoes or outsoles to alter our gait pattern for the purpose of energy saving on different terrains.

Methods

Currently 7 healthy participants (5 male, 2 female, age 35.5±6 years, mass 75±13 kg, height 170±6.5 cm; mean ± std) have completed the study. We developed a wooden clog with inclination of 15° according to the unearthed ancient clogs dimension from Nanjing [4], see Figure 1. We tested 2 types of shoes on 7 different treadmill grades (downhill -25%, -20%, -15%, level 0%, uphill 10%, 15%, and 20%). Front peg was removed when walking uphill and rear peg was removed when walking downhill. Uphill treadmill speed was set at 3km/h, and downhill treadmill 2.5km/h. Each grade walking lasted 5 minutes. We recorded oxygen consumption and carbon dioxide production using a Metalyzer (Cortex, Germany) during each walking. We also recorded soleus, vastus lateralis and 6 other lower limb muscles' activation using a wireless electromyography (EMG) system (Trigno TM, Delsys, USA; 2000Hz).

Results and Discussion

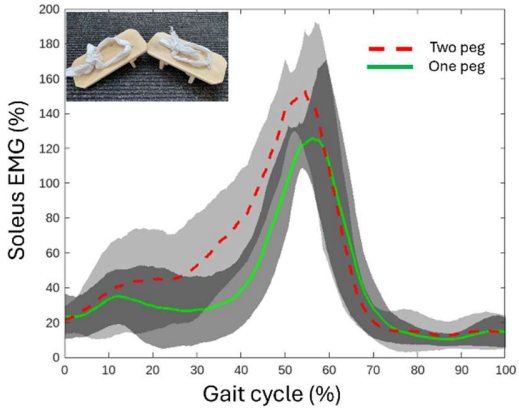

Figure 1: Soleus muscle activity and Xie Gong's clogs

Current results show that the metabolic rate of one peg shoes is lower than two peg shoes for large treadmill grades on both uphill and downhill conditions (20% uphill and -25% downhill, see Table 1). For smaller treadmill grades on uphill (10% and 15%), the difference is less apparent. But one peg shoe reduces the metabolic rate for downhill walking despite small grades. Below knee muscles such as soleus muscles show reduced amplitude (see Figure 1) for one peg comparing to two peg shoes during uphill walking which infers a difference in walking gait pattern between the conditions.

Conclusions

Inspired by an ancient poem, Xie Gong's clogs are developed and tested in our motion lab. The research findings support the poem words and possible design of future hiking shoes.

Acknowledgments

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References

[1] Three Hundred Poems of The T'ong Dynasty.
[2] Antonellis P. et al (2019), *R. Soc. open sci.* **7**: 191527
[3] Corlett E.N. et al (1972), *Appl. Ergon.* **3.4**: 195-201
[4] Zhigao W. et al (2012), *Chi. Cult. Relics*, **3**:41-58

Table 1: Metabolic rate data (Wkg^{-1})

	One up (10%, 15%, 20%)			Two up (10%, 15%, 20%)			One down (15%, 20%, 25%)			Two down (15%, 20%, 25%)			Level
Average	5.760	6.823	8.426	5.716	6.833	8.575	2.604	2.578	2.871	2.732	3.014	3.353	3.459
std	0.428	0.304	0.515	0.511	0.851	0.293	0.165	0.415	0.528	0.157	0.309	0.330	0.430