A Passive Assistive Exoskeleton to Increase Running Efficiency

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Abstract

A Valparaiso University engineering senior design team is developing a lower-body exoskeleton prototype to increase the user’s running efficiency by 2%. The device is passive, which means that all elements of the system are powered by the user’s motion and impact with the ground. This is done via elastic fabric elements and spring steel actuators that are attached at the user’s hip, knee, and ankle. The effect of the device on the runners is to increase running efficiency.

Introduction

This project is a continuation of a project started in 2017 by myself and two other undergraduate research students under the guidance of Professor Craig Goehner. A first prototype was built and then presented on at the 2018 American Society of Biomechanics Conference. The original project attempted to develop an ankle-based exoskeletal device “that will improve the efficiency associated with moderate physical locomotion activities and lessen the strain on involved joints”. However, it was believed by the group to have been ultimately unsuccessful as initially testing indicated that it made running 40% less efficient. The new project expands on the original by building a passive exoskeleton for the whole lower body, not just the ankles as the researchers believe there is untapped efficiency potential by incorporating other joints.

The new iteration of the project is being done by a Senior Design team, under the guidance of Professor Reva Johnson, with the goal to develop a passive assistive exoskeleton to increase the efficiency of moderate running by 2%. Both iterations were designed to be tested using a VO2-max test which calculates how much energy a runner is expending at a given instant based on their oxygen consumption.

Testing

The setup for the VO2-max test requires the runner to run on a treadmill while wearing a mask that measures the intake and expulsion of oxygen. The runner is initially guided through a series of speed and elevation changes ranging from 0 to 5.0 mph and from a 0 to 18% gradient over a 20-minute testing interval. The runner then does the same protocol with the device (image to left). The variables recorded during the test are the subject’s heart rate, total Kcals used, the speed of the treadmill and the elevation of the treadmill. In 2018, two baseline tests were done and were compared to a single test with the device.

Analysis

As the VO2-max test output the total Kcals used during the test, it didn’t display the change in Kcals at a given point during the test (i.e., the energy consumption for a given instant). The group believed that the efficiency of the device might vary throughout the test, so a new variable was developed using the time-stamp and total Kcals used for each data point to calculate the Kcals consumed at a given moment. This new variable Kcal/min was then used in the efficiency calculations and other comparisons between the device and baseline tests.

Results

Using the created Kcal/min variable, the percent difference in efficiency between the exoskeleton device and the baseline was calculated at each point throughout the test. A two-sample t-test was used to determine if the results were statistically significant (points were not matched due to the differing lengths and inconsistent time points of the trials). The pipeline also produces the percent differences in efficiency for each 5-minute interval so the researchers can examine a specific interval easier.

Conclusion

An analysis pipeline was built in Python that is able to take raw VO2-max testing data and output useful graphs and statistical analysis. Importantly, the results show how efficiency changes over time, speed and elevation to give researchers further insight into the strengths and limitations of their design. When testing of the latest prototype resumes, the researchers will be able to use this pipeline to quickly determine how their design has altered the runner’s energy consumption.

Future developments of this pipeline would be to expand it to automatically average the results of several baseline and exoskeleton test results so a larger sample size can be examined. The testing procedure could be altered to have the subject move over a wider variety of speeds and elevations to further examine the effect on energy consumption.

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