DESIGN OF SUSPENDED LOAD BACKPACKS FOR YOUNG URBAN PROFESSIONALS

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INTRODUCTION

According to the United Nations [1], as of 2008, a majority of the population lives in cities for the first time in history.[1] Mobility is an increasing problem for these city dwellers especially as they use public transportation and carry belongings with them on their backs throughout their day. Additionally, many urban professionals, particularly those under age 40, rely on electronics such as smartphones (0.028 kg), tablet PCs (0.45 kg), and laptops (1.36 kg and up). As young, urban professionals travel for work and school, they bring these electronics with them every day. An ergonomic bag aims to protect a human's back from injury and fatigue. As technology develops enabling reduction of the vertical force of loads on the carrier, bags can enable higher loads to be carried with less injury [2].

This population's load carrying behavior has not been well studied. Most load carrying studies tend to focus on military loads of approximately 27 kg [2], schoolchildren's loads of approximately 9 kg, or other profession-specific loads such as apple pickers. Studies of traditional "locked" backpacks test compression, distribution of pressure and padding, and strap placement. These locked backpacks, as Larry Rome explained [2], impose large peak forces on the wearer as the loaded backpack is accelerated with vertical motion of the pelvis during each step. Larry Rome proved that suspending the load could reduce vertical movement of the system's center of mass, force on the carrier, and the metabolic cost of carrying loads. However, this suspended-load energy harvesting backpack was developed for heavy, military loads, and with six pounds for the frame alone, would not be appropriate for daily urban use.

This study intended to test loads of a different magnitude. The goal of this initial feasibility study was to determine if a spring mounted suspended load carrying system was a viable option for reducing fatigue experienced by young urban professionals during every day load carrying scenarios.

METHODS

The bags of 80 subjects (48 women, 32 men) were weighed with a Pelouze heavy duty temperature compensated scale. Most subjects were young professionals and computer science graduate students, age 25-35, who carry laptops and smart phones with them on a daily basis, in a single bag, either backpack (both shoulders), tote (one shoulder), or messenger (diagonal across body) shape.

Previous studies determined that vertical center of mass (COM) excursion ranges from 0.027 to 0.048 m during walking for this age group [3]. [3] The mean of that range, was used for initial testing.

The spring constant necessary to suspend the load was calculated through Hooke's Law ($F = kx$) from the average bag weight and COM excursion.

One subject (1.6256 m, 511.5 newtons, female) was recruited for initial prototype testing. Extension springs with the proper spring constant were used in a spring-loaded mass prototype, including a Dyneema lightweight and strong bag with an appropriate load inside. The spring-loaded mass was attached to a frame and its movement was observed relative to a subject's hips while a subject walked at a self selected pace. To trace the COM of the subject versus the COM of the spring loaded mass, lights were attached to both COMs. A long

exposure photograph was taken to show the motion via a light path coming from separate light marker on the subject's hip and on the bouncing mass.

RESULTS

The lightweight frame constructed for testing is shown in Figure 1.

Figure 1: Initial prototype of lightweight frame system.

The average daily load of young urban professionals in New York City was calculated to be approximately 5 kg. The average weight of subjects' bags was 50 N. The mean COM excursion was determined from literature to be 0.035 m. The spring constant k was determined to be 1442 N/m**.**

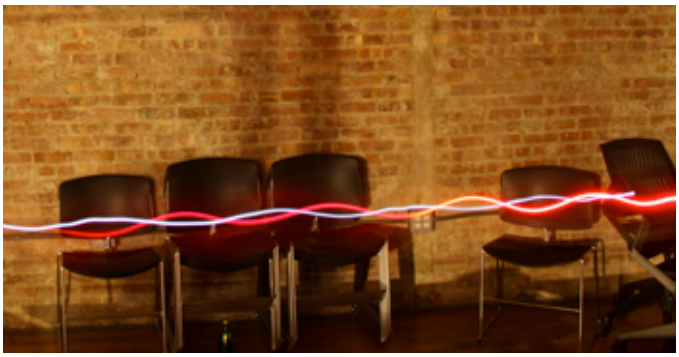

Figure 2: Long exposure photograph indicating out of phase movement of the COMs of the load and the subject. The white light is on the subject, red light is on the bag.

In this feasibility test, the lights showed the mass was moving out of phase with the carrier's gait as expected (Figure 2).

DISCUSSION

The preliminary results indicate that this spring and frame system can in fact uncouple the vertical excursion of the load from the COM excursion of the subject at a load commonly carried by a young, urban professional. This study is part of a larger ongoing study examining the relationship between walking biomechanics, load carrying, and bag design. To date, several early bag prototypes have been developed. Future work will include optimizing the spring constants to improve the loads' ability to move out of phase with the subject. Additionally, a more ergonomic physical prototype will be created, featuring an improved minimal frame as pictured in Figure 1.

This next version of the prototype will involve attaching the spring setup to a frame to allow it to be used for longer periods of time comfortably. The frame will be updated to make it as minimal and lightweight as possible. Though initially this study has characterized the kinematics of how the suspended load travels in relation to the body, future studies will also measure kinetics. This research represents a first step in developing a daily use urban load suspension system.

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