THE RELATIONSHIP BETWEEN A PROGRESSIVE VERSUS SINGLE-STAGE TREADMILL TEST FOR EVALUATION OF CLAUDICATION

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INTRODUCTION
Peripheral arterial disease (PAD) is defined by atherosclerotic plaque buildup and subsequent blockages along the arterial walls of the extremities[1]. The narrowing of the arteries leads to reduced blood flow to the leg musculature upon exertion clinically resulting in complaints of leg pain. This pain, known as claudication, stops once muscular exertion ceases and metabolic demand returns to baseline[2]. Prior to 1991, the most common means to evaluate claudication was a single-stage treadmill walking test. The single-stage treadmill walking test consists of a fixed speed, fixed slope protocol. In 1991, Gardner et al.[1] reported results from a progressive treadmill walking test which consisted of a fixed speed with a progressively increasing slope protocol. The progressive test reduced testing time likely due to increased muscular demand. Due to the discrepant nature of the protocols, there has been no previous attempt to determine a relationship between these protocols. This has led to an inability to compare historical data to more recent data and allow for comparisons among different laboratories as the two protocols continue to be used. Therefore, the purpose of this study was to determine a relationship between the two protocols to allow for increased comparison of results among laboratories and studies. To allow for commonality, it was hypothesized that metabolic work demands of leg muscles are the primary cause of ischemic pain. Thus, a relationship in the mechanical work demands should similarly exist and thus allow for approximation of performance in one walking test based on the other.

METHODS
Thirty-one patients with PAD (age: 65.2±6.71 yrs; ht: 175.6±6.1 cm; mass: 87.5±15.6 kg) were screened and consented for participation. Subjects initially performed a progressive treadmill test followed by a rest period, and then several other biomechanical tests (e.g., overground walking trials and strength testing) as part of the larger study. Following these other tests, subjects rested before completing a single-stage treadmill test. The overall goal, and instructions given for each treadmill test, is to "walk until the pain in your leg forces you to stop". The time is then recorded as the maximum walk time. The single-stage test protocol is a fixed speed and slope at 1.5 mph (0.67 m/s) and 10% grade. The progressive test protocol is a fixed speed of 2.0 mph (0.89 m/s) and the slope starts at a 0% grade, but is then inclined 2% every 2 minutes[1]. Mechanical work for the treadmill tests was modeled as a point mass with work consisting of changes in translational kinetic and potential energy. Due to an overall upright posture during walking, contributions to work from rotational kinetic energy were assumed minimal and thus disregarded. A log transformation was then performed to remove nonlinearities. The calculation for mass-normalized work during the single-stage protocol was calculated as:

\[ W = (V_s^2/2 + V_z^2/2 + V_z^*g)^*t \]  \hspace{1cm} (1)

where \( V_s \) and \( V_z \) are the forward and vertical velocity components, respectively, from treadmill speed and slope and \( t \) is time. This results in values of 0.667 m/s and 0.067 m/s for \( V_s \) and \( V_z \), respectively. The calculation for mass-normalized work during the progressive protocol was similar with the exception that the values for \( V_s \) and \( V_z \) were adjusted every two minutes as the slope of the treadmill was increased. The relationship between performance in the single-stage and progressive protocols was evaluated through Pearson product-
moment correlations with a significance level set at alpha equal to 0.05. We examined mechanical work since the primary cause of reduced walking performance seems to be associated with energy, however time measurements were also correlated.

RESULTS AND DISCUSSION
There was a large range in maximum walking times for the tests for the single-stage (avg: 308.19s ± 290.77, max: 1190s, min:50s) and the progressive protocols (avg: 429.61s ± 343.59; max: 1339s, min: 51s), allowing for a wide spectrum of performance to be included within the analysis. Significant relationships for time (r=0.630, p<0.001) and work (r=0.563, p=0.001) were found (Figure 1). But, this relationship was considerably stronger for work following the log transformation to remove nonlinearities (r=0.835, p<0.001).

Work, however, accounts for both slope and speed and thus makes it more desirable for comparing different studies presented in the literature. Visual inspection of work, however, revealed a similar problem with utilizing any regression equation. Specifically, the problems in the time domain are similarly seen but compressed with less spread, resulting in an even smaller coefficient of determination (R²=0.317). But, when nonlinearities present were removed through a log transformation, the result was a marked relationship with a coefficient of determination that more than doubled (R²=0.697). Thus, the following regression equation is proposed for comparing/translating maximum walking studies utilizing differing protocols:

\[ SS = 0.5486 \cdot PP + 2.4257 \]  

Where \( SS \) is the natural log of the work calculated from a single-stage protocol utilizing eq. 1 above, and \( PP \) is the natural log of the work calculated from a progressive protocol similarly utilizing eq. 1 above but with varying velocity components according to the slope and speed.

CONCLUSIONS
Single point mass approximations of work during a treadmill walking task, following a log transformation, yields a valuable result of the individual's maximum walking performance. The log calculation of the work can then be compared to other individuals' performance in maximum walking tests regardless which protocol was used.

REFERENCES

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