LEG SPRING MODEL PROPERTIES OF CHILDREN

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INTRODUCTION

Investigators have examined the dynamics of running by applying a center of mass-based, leg spring model developed by McMahon and colleagues (Ferris et al., 1999; He et al., 1991; McMahon & Cheng, 1990). In this model, the leg and body are represented as a simple linear spring and a point mass, respectively (Fig. 1).

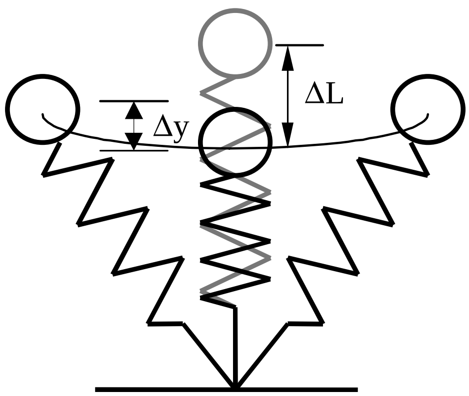

Fig 1: Leg spring model (adapted from McMahon & Cheng, 1990).

Leg spring stiffness (k_{leg}), the ratio of maximum vertical force during foot contact to ΔL, remains constant as humans run faster (He et al., 1991) and as various species of animals trot and hop faster (Farley et al., 1993). In addition, Farley and colleagues found k_{leg} and the effective vertical stiffness of the leg spring (k_{vert}) to increase with body mass when considering animals ranging from a 0.1 kg rat to 140 kg horse.

Human running and hopping are usually examined with adult samples. The invariance of k_{leg} across running speeds and the symmetry between legs, for example, were shown in samples of university students (Bachman et al., 1999) and adult amputee runners (Heise et al., 1999). Changes in body mass and leg length that accompany physical maturation are influences that have not been examined from the perspective of the leg spring model.

The purpose of the present study was to examine the properties of the leg spring model (k_{leg}, k_{vert}) in a sample of children. Specifically, the relationships of spring coefficients to running speed and body mass were investigated. The findings of the present investigation may have implications in the design and prescription of prosthetic limbs for children.

METHODS

Ten healthy children (4 girls, 6 boys) between the ages of 5 and 10 yr participated in the study (mean ± SE: age = 8.0 ± 0.6 yr; body mass = 27.5 ± 2.9 kg; leg length = 56.9 ± 2.5 cm). None of the subjects exhibited asymmetrical leg length discrepancies. Each subject attended one test session. At first, they practiced striking a force plate in the middle of a 20 m gymnasium during a 15-min warm-up. Subjects were then instructed to run at a slow or fast speed, however, speed was not imposed or controlled. Attempts were made to collect data for 8 trials (2 slow, 2 fast for each leg). Good trials were selected based on foot contact with the force plate and no apparent aberrations in running gait. Vertical ground reaction force data were collected and 2 camcorders recorded sagittal plane motion (one for forward velocity calculations and one for leg length at foot contact). For each satisfactory trial, k_{leg} and k_{vert} were calculated using the approach of McMahon and Cheng (1990) and normalized by multiplying them by the ratio of leg length to body weight (K_{leg}, K_{vert}).

RESULTS AND DISCUSSION

Data are presented from right foot contacts only. Left foot contacts resulted in similar leg spring measures. Stiffness coefficient values (mean k_{leg} = 3.88 kN/m; see Fig. 2 for K_{leg}, K_{vert}) were much lower than adult data reported previously (Bachman et al., 1999; He et al., 1991; Heise et al., 1999).

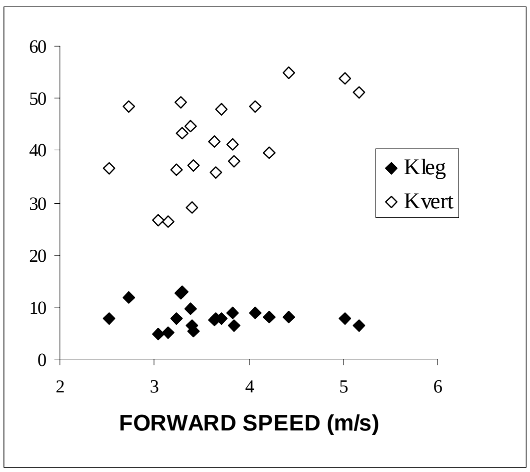

Fig 2: Normalized stiffness coefficients for 10 subjects (2 speeds each).

As expected, K_{leg} was independent of running speed ($r = -.17$), whereas K_{vert} showed a significant positive relationship with forward speed ($r = .56$, $p < .02$).

A regression analysis (Fig. 3) showed that body mass (M) significantly influenced k_{leg}:

$k_{leg} = .1065(M) + .95$, $R^2 = .57$, $p < .001$

It is difficult to compare this relationship with the work of Farley et al. (1993) because their subjects were mostly animals and the range of body mass in their work greatly exceeded that of the present study.

He et al. (1991) suggested a constant k_{leg} across running speeds may simplify the fabrication of prosthetic legs. However, the results from the present investigation show that body mass influences leg spring stiffness in children when running and the fit of prosthetic legs may not be as simple as suggested.

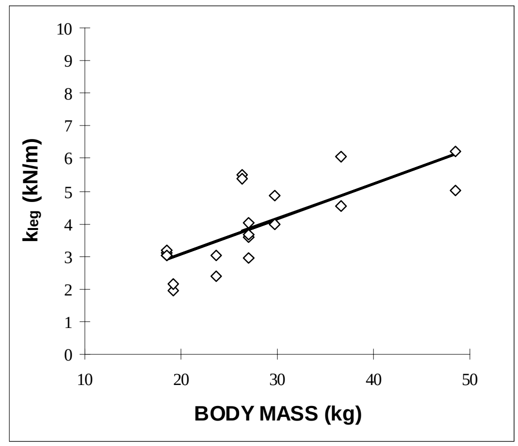

Fig 3: Leg spring stiffness as a function of body mass in 10 subjects (2 speeds each). Solid line is regression (see text for equation).

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