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THE INCREASE IN ENERGY COST OF WALKING WITH AN IMMOBILIZED KNEE OR AN UNSTABLE ANKLE

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ABSTRACT. The effect of an immobilized knee joint or of an unstable ankle joint on the walking capacity has been assessed with 50 walking tests in ten healthy subjects. The knee joint was immobilized in extension with a standard splint and an unstable ankle joint was simulated by a modified shoe. A significant decrease in convenient walking speed was found. The energy cost of walking as assessed by oxygen cost at a convenient speed was significantly increased both with an immobilized knee (23%) and with an unstable ankle (10%), compared to the normal condition of the subjects. Implications for the management of patients with similar joint disorders are discussed.

Key words: efficiency, immobilization, instability, oxygen consumption, shoes, speed, splint.

The characteristics of normal gait have been extensively studied from a biomechanical point of view (6, 10). Recent physiological studies of walking have shown that walking speed and energy cost are valuable parameters in the assessment of walking capacity, both in normal subjects and in patients with walking disabilities (4, 5, 6, 11).

To our knowledge there is only one previous report on the effect of joint immobilization on walking efficiency (6). Based on a very small series without data on the walking speed, walking with immobilized knee or ankle joint was reported to increase oxygen uptake by 18 and 6% respectively.

Oxygen cost during walking has also been studied in patients with neurologic diseases, in patients following total hip replacement and lower extremity amputations (1, 2, 3, 7, 9), but so far not in patients with lower limb instability.

In an earlier publication (8) we have described a method of determining walking efficiency with great accuracy.

The aim of this study was to analyze to what extent immobilization of the knee or instability of the leg influences walking capacity by measuring walking speed and corresponding energy cost.

SUBJECTS AND METHODS

Ten subjects, 3 men and 7 women, volunteered to participate in this study. None of them suffered from heart or lung diseases and none had any musculoskeletal symptoms. The mean age of the subjects was 39.5 ± 7 years (mean ± SD), mean weight 62.5 ± 10.5 kilograms and mean height 172 ± 9 centimetres.

The walking test

Five different walking tests were performed on each subject on each occasion. The subjects walked along a 70 meter long corridor. The heart rate was registered with a pulsometer (Sport Tester TM PE-3000). To ensure physiological steady state conditions the subjects walked for a minimum of 4 min, with an unchanged heart rate during the latter part.

Walking speed was determined by a speedometer mounted on a small cart, which was pushed alongside the patient. Mean walking speed was also calculated as the ratio between distance and time. The subjects were asked to select the walking speed that was most convenient.

In the first walking test, used as a reference test, the subjects wore a pair of normal Swedish clogs. In the second walking test the right shoe was exchanged to a similar wooden clog but with a convex sole making the foot as well as the leg unstable. In the third walking test the subjects walked with normal Swedish clogs but with the right knee immobilized in extension in a splint.

The fourth and fifth walking tests were performed with the normal wooden clogs at the speeds which were determined in previous tests with unstable leg and immobilized knee. To achieve these predetermined walking speeds the subjects were guided by a testleader who walked alongside, pushing the speedometer cart.

Energy cost

During the walking tests the subjects wore a light-weight box (3.5 kilograms, volume 10 litres) on their back. They also wore a nose clip and breathed through a mouth piece, connected to the mixing box by a flexible low-resistance hose. Argon gas with a constant well-defined flow was added at the inlet of the box for determination of ventilation. A sample of the gas mixture, contained in the box at the end of the walking test, was aspired with a glass-syringe and was subsequently analysed by a respiratory mass spectrometer (Centronics MGA 200). Ventilation and gas exchange were calculated as earlier described (8). Collection of expired gas and determination of oxygen cost was performed after each test.

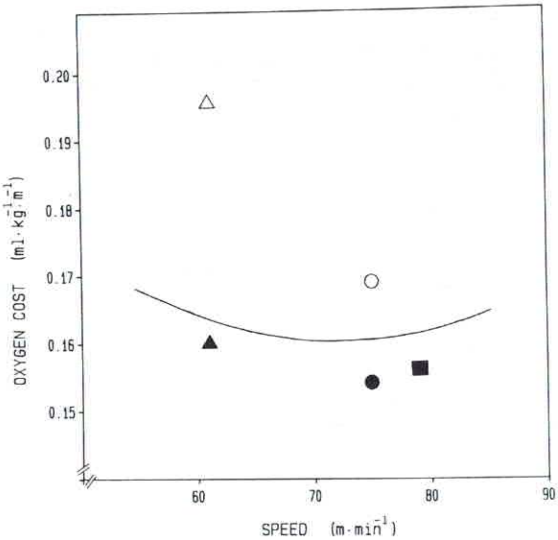

Fig. 1. Mean values of oxygen cost in $ml \times kg^{-1} \times m^{-1}$. in relation to walking speed in $m \times min^{-1}$ ■, convenient walking speed with normal clogs; ○, convenient walking speed, unstable leg; △, convenient walking speed, immobilized knee; ●, predetermined speed (=unstable leg), normal clogs; ▲, predetermined speed (=immobilized knee), normal clogs; —, oxygen cost at different walking speeds for normal subjects, according to Inman et al. (6).

Statistical methods

Standard statistical methods were used to test means and standard deviations (SD). Student's *t*-test and Wilcoxon's non-parametric test were used to test individual differences in speed and oxygen cost.

RESULTS

Walking speed

The average value for the convenient walking speed in normal shoes was 78.7 ± 6.7 $m \times min^{-1}$. With an unstable ankle the convenient speed decreased to 75.4 ± 7.9 $m \times min^{-1}$, $p<0.01$ (Fig. 1). With an immobilized knee the convenient walking speed decreased to 60.6 ± 9.6 $m \times min^{-1}$, $p<0.001$ (Fig. 1).

Oxygen cost

The oxygen cost at different walking speeds from all five walking tests are presented in Fig. 1. The average value for oxygen uptake at convenient speed using normal shoes was 0.156 ± 0.013 $ml \times kg^{-1} \times m^{-1}$. The relationship between oxygen cost and walking speed in normal subjects, according to Inman et al. (6), is presented graphically in Fig. 1.

With an unstable ankle joint the average oxygen uptake was 0.169 ± 0.022 $ml \times kg^{-1} \times m^{-1}$. The energy cost increased 10%. With normal shoes at the same speed the oxygen uptake was significantly decreased to 0.154 ± 0.016 $ml \times kg^{-1} \times m^{-1}$, $p<0.01$.

With an immobilized knee the average oxygen uptake was 0.196 ± 0.027 $ml \times kg^{-1} \times m^{-1}$. The energy cost increased 23%. With normal shoes at the same speed the oxygen uptake significantly decreased to 0.160 ± 0.015 $ml \times kg^{-1} \times m^{-1}$, $p<0.001$.

DISCUSSION

The self-selected, convenient walking speed and corresponding oxygen cost have previously been found to be valuable parameters for assessment of walking ability (6, 8, 11).

For each subject three walking tests with normal shoes were performed to obtain results permitting comparison to the test conditions of walking with an unstable shoe and an immobilized knee. The convenient walking speeds chosen by our subjects using normal shoes were in accordance to those given as normals by Ralston (11) and furthermore there was very little difference between our estimates of oxygen cost in the three tests at predetermined speeds and those given as normals by Inman et al. (6)

Our findings from tests at a self-selected, convenient speed are similar with Inman's studies (6). Both studies demonstrate that immobilization of the knee joint gives significantly increased energy cost compared to both normal conditions and instability. In patients, muscle hypotrophy in the disabled leg and a lower physical fitness might give even larger increases in oxygen cost during walking with an immobilized or unstable joint. Consequently, before suggesting treatment with joint immobilization, the individual's ability to improve their oxygen capacity to compensate for the increased oxygen cost resulting from such treatment should be considered. Studies on walking capacity in patients with various musculoskeletal disorders are needed to allow any further conclusions to be made on optimal managements, especially in the elderly. From a physiological point of view especially for patients with muscle hypotrophy or elderly stabilizing splints allowing some flexion might be advocated when possible.

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