COMPARISON OF ENERGY EXPENDITURE ON NORMAL SUBJECTS FOR DIFFERENT FOOTWEAR

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INTRODUCTION

Kinematics would help to understand and analyze human movement pattern. Studies with a combination of human **kinematics** and **kinetics** would give a more useful conclusion.

It would not only help in understanding the gait pattern but it could also prove helpful in assessing different gait parameters and aid in more detailed calculations like the energy consumption. (V T **Inman** et al., 1981).

Previous investigations camed out, demonstrate the usefulness of the force platform and the ground reaction forces in calculating the mechanical work and energy.

(D Gordon et al., 1980 **; Ming** Sun et al., 1993). Studies also indicate the limitation in understanding the human energy balance and expenditure due to the lack of ability for accurate quantification of work performed by human subjects. However, energy expenditure has been calculated with different methodologies by using calorimeters and other **equipments. (Ming** Sun et al., 1993).

The main purpose of the present study is to investigate the possibilities of assessing different types of footwear by calculating the energy expenditure of a set of subjects.

The study would help in comfort and performance assessment of different types of footwear for various individuals. These energy studies with a combination of the person's physiological data and the footwear **material/** construction data would help in performance enhancement of individuals.

EXPERIMENTAL METHODS

A Vicon Movement Analysis Laboratory with **AMTI Force** Platform was employed to collect the **kinematic** and **kinetic** data. The data collection process was camed out on a two dimensional saggital plane. Reflective markers were kept on four anatomical landmarks. (Viz. metatarso phalangeal joint,

lateral malleolus, lateral femoral condyle and on the pelvic bones just above the greater trochanter). A raised walkway with an inlaid force platform was used for movement data collection of the subjects. Eight normal males with an average height of 173.37 **cms,** an average weight of 58 kgs and an average age of 23 were used as subjects for the trials.

The subjects were allowed to walk several times over the walkway to become accustomed to the **environment** and to have a close to normal gait pattern. The subjects were told to walk bare footed and with two different types of footwear. Both the footwear were used as sports appliances and were of English size, 8 designed and manufactured by an internationally reputed company, for different sport activities. Both were made of polyurethane soles and the upper was made of a combination of PUCF and leather. Both the shoes had cellular foam padding at different portions of the shoe. Type 2 shoe had a peculiar tunnel system on the sole which facilitated air flow and thereby had a better shock absorption capability. The subjects were asked for an oral protocol of footwear fitting and all of them replied for a comfortable and proper fit. Collected data were analyzed with the AMASS software supplied by the manufacturers of VICON system.

The mechanical work can be defined as the ground reaction force exerted on the body times the displacement of the centre of mass of the person's body along the direction of the force. This was calculated for each instant of data collection. Each instant had a time difference of 0.02 secs. This force is equal in magnitude to the force exerted by the body on the ground but opposite in direction. The mechanical work estimated with this force is termed as external mechanical work. The internal mechanical work can be explained as the work done by the acceleration of limbs and body segments.

Mechanical power can be defined as the force times the instantaneous velocity of the centre of mass of the body. Energy for a given time was calculated as the sum of the instantaneous power values. The data thus collected and the values of the energy calculations are tabulated for a comparative study. Energy required to perform one unit work, that is the amount of power in watts to perform 1 joule of work was calculated to find the work efficiency.

RESULTS

Several trials for each subject were performed. The data collection was carried out after the subject got accustomed to the laboratory conditions. Trials chosen for final analysis had a similar cadence and velocity values for each subject. The power and energy values calculated are tabulated in Tables 1 and 2. The comparative results of energy expenditure and work are shown in Figures 1 and 2.The work efficiency was calculated and tabulated as shown in Table 3.The values are illustrated in Figure 3.

Table 1 Work calculations (in joules)

Subiects	Bare foot	Shoe 1	Shoe 2
S1	8313	8659	8671
S2	6575	7240	7370
S3	9083	9551	10309
S4	7573	7990	9157
S5	7772	8101	8098
S6	12453	12562	12797
S7	7776	7968	8589
S8	6237	6840	6901

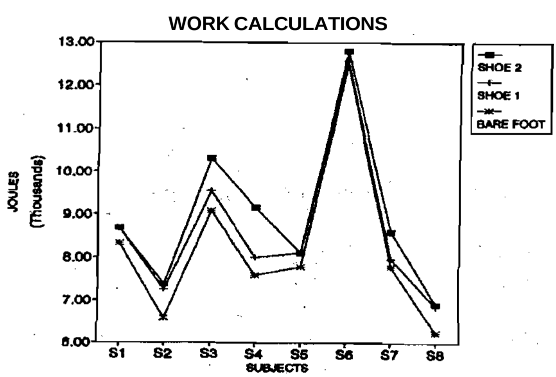

FIGURE 1

Table 2 Energy calculations (in joules/sec)

Subjects	Bare foot	Shoe 1	Shoe 2
S1	1961	2037	2563
S2	1567	1465	1704
S3	3502	3510	3569
S4	2153	2081	2785
S5	3523	3593	3917
S6	2486	2944	2615
S7	2023	2482	2041
S8	1472	1532	1610

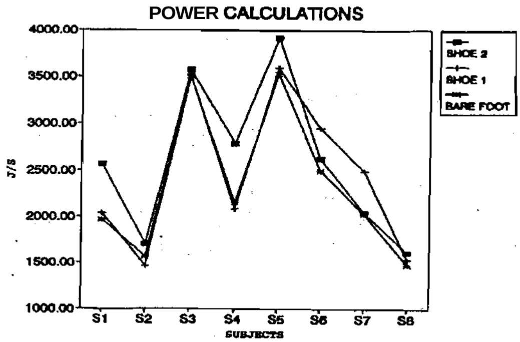

FIGURE 2

Table 3 Work efficiency calculations (injoulesS)

Subjects	Bare foot	Shoe 1	Shoe 2
S1	4.2	4.3	3.4
S2	4.2	4.9	4.3
S3	2.6	2.7	2.9
S4	3.3	3.5	3.8
S5	2.2	2.3	2.1
S6	5.0	4.3	4.9
S7	3.8	3.2	4.2
S8	4.2	4.5	4.3

Table 4 Energy comparisons
(Loss of energy by body with different footwear during foot contact phase)
(Figs. in %age)

Subjects	Bare foot	Shoe 1	Shoe 2
S1	62.0	58.5	55.0
S2	57.0	51.5	58.0
S3	57.0	58.0	64.0
S4	60.5	51.5	62.0
S5	46.0	44.0	53.0
S6	42.0	49.5	54.0
S7	45.0	42.0	54.5
S8	55.5	47.5	53.0

DISCUSSION

The reported values of work done and related energy expenditure is based on instantaneous measurement of force and displacement. The force platform properties and minute measurement system errors could have caused some erroneous values which are not beihg accounted in the present study. It would be necessary to validate this approach with more detailed analysis. The results indicate that all the subjects did more work by wearing both types of footwear when compared to bare foot walking.

On comparing the energy expended for bare foot walking and walking with footwear, all the subjects had to spend more energy with type 2 footwear. However, with type 1 footwear 6 subjects spent more energy and 2 of them spent lesser energy.When a comparison between type 1 and type 2 footwear was made 6 subjects spent more energy with type 2 footwear and the rest spent lesser amount of energy (Figure 2)

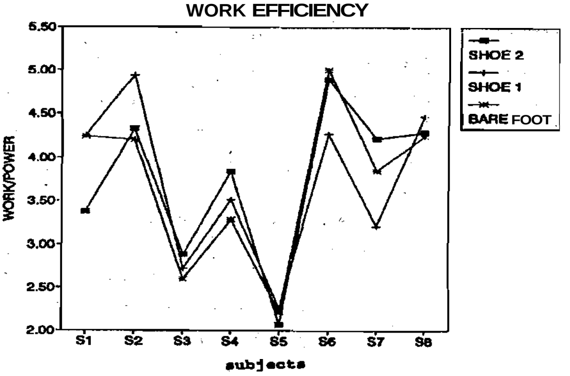

FIGURE 3

As shown in Figure 3, the work efficiency calculations shows that with type 2 footwear 6 subjects had a better efficiency when compared to bare foot walking. 5 subjects with type 1 footwear recorded a better efficiency when compared to bare foot walking. However, only 4 subjects had a general agreement of better efficiency with any type of footwear. When energy was calculated for the negative velocities and tabulated as shown in table 4, 5 subjects had a lower percentage with type 1 footwear. With type 2 footwear the percentage was lower only for 2 subjects and it was higher for 6 subjects. The energy calculation from negative velocities indicates the period in which the subjects would transfer the energy to the adjoining bodies. The general agreement on this observation between the subjects was found less.The number of subjects taken for trials is small to conclude on any particular result. However, M h e r studies are being carried out to consolidate and to improve the findings. The footwear with more cushioning system required more work from the subjects and the subjects needed to spend comparatively more energy. However, in some cases the subjects spent lesser-energy. This indicates that the sole design and material would have a considerable impact on the work and energy of individuals. The energy studies carried out on the lines of the work reported could help in a better sole design and would help in material selection.

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