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**TITLE**

DIFFERENCE IN ENERGY COST BETWEEN ROAD AND TREADMILL WALKING

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by

A.C. Custance

DREO REPORT NO. 603



PROJECT NO.
D52-20-80-10

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## ABSTRACT

Using two subjects walking at 3.5 mph on a treadmill indoors, and over a circular course out-of-doors, with and without a 28 lb. load, and under similar ambient temperatures, it was found that the energy cost was 23% greater out-of-doors than on the treadmill with the load, and 15% greater without it.

## RÉSUMÉ

Utilisant deux sujets marchant sur un tapis roulant à une vitesse de 3.5 milles à l'heure dans le laboratoire et sur une piste circulaire à l'exterieur, avec et sans un poids de vingt-huit livres, et dans les memes conditions de température ambiante, on a trouvé que la dépense d'énergie était 23 pourcent de plus à l'extérieur que sur le tapis roulant avec le poids, et 15 pourcent de plus sans le poids.

# DIFFERENCE IN ENERGY COST BETWEEN ROAD AND TREADMILL WALKING

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The use of a treadmill for measuring the energy cost of performing exercise under well-controlled conditions is a practice of long standing. One of the earliest studies was that of Benedict and Murschhauser (1) made in 1915, and similar studies have been repeated many times since then. A most comprehensive review of such experiments is that of Passmore and Durnin (2). Campbell (3) was one of the first to compare the energy cost of running on a treadmill as opposed to running on a level road, and from experiments with one subject only he concluded that the two forms of exercise were not essentially different. Similarly, Noltie (4) more recently reported that he could find no significant difference in $O_2$ consumption of a trained athlete runnning at 7.5 mph on a cinder track and on a treadmill.

However, a number of workers have observed that exercise on a treadmill does not provide a safe guide to the energy required to perform a similar exercise out-of-doors, for the mechanics of walking in the two situations is different. Smith (5) reported that the energy cost was greater in the latter on this account. Several factors contribute: there is the resistance of the air to the forward movement of the body, a factor virtually absent on the treadmill except for leg movement; and there is the forward thrust required in order to sustain progression.

As Daniels _et al._ (6) observed, it is possible to learn to walk on a treadmill in such a way as to "ride" it with the expenditure of very little energy. Even the energy required to lift the body at each step can be derived from the treadmill itself by merely swinging the leg forward and then holding the knee more or less rigid while the body is maintained against a backward translation by holding the handrail.

A large part of the walking results from lifting the body at each step. We have found this rise per step to be between 3/4" and 1-1/4" for most subjects, though men with an ungainly gait may exceed 1-3/4" per step. This agrees essentially with the findings reported by Noltie (7). Thus the total lift per minute in ft. lbs. can readily be determined and a theoretical calculation made of this component in the overall energy cost picture. But most subjects learn to minimize this "lift" on the treadmill, especially in in long runs where they may resort to reading as they walk and for this purpose develop a smoother gait. The weight of the subject, a factor which in the out-of-doors situation becomes of prime importance in terms of energy cost and which, according to Malhotra et al. (8), is more important than height, age, or sex, thus becomes of somewhat less importance on the treadmill. As a consequence, certain kinds of equipment, load carrying systems for example, cannot be properly evaluated on the treadmill.

Even the structure of the treadmill platform itself has a bearing on the energy cost of walking on it. Experience in these laboratories with a motor-driven treadmill in which the belt was conveyed over rollers has shown that the energy required to walk was greater than with the belt conveyed over a smooth low-friction platform. The difference in work load seems to be partly because of the discomfort caused to the feet by the "kneading" action of the rollers , and partly because the maintenance of balance is more difficult until the subject becomes accustomed to it. Conditioning takes several days and sometimes more than a week.

When Erickson et al. (9) found unexpectedly that treadmill walking required more energy than walking on a level paved road, they attributed it to these factors. However, now that treadmills are available with a very smooth belt action, it has become increasingly apparent that the effort of walking is less on a treadmill than out-of-doors provided that the enviromental and other conditions are essentially similar. Daniels et al. (10) found that it required 9 to 10% more energy to walk with a load of 46 lb. at 3.5 mph on a paved road than on a level treadmill. Differences between subjects were considerable, but all the data pointed in the same direction.

We have recently had occasion to confirm Daniels' findings during the testing of two load-carrying systems involving a total weight of 28 lb. made up of a 21 lb pack plus 7 lb of clothing and boots. Two subjects only were used, a moderately tall well-built man (5'-10", 175 lb) and a short rather slight man (5'-6", 137 lb) chosen in order to determine, if possible, whether the centre of gravity of the two pack systems made a significant difference with respect to subject build. The first series of exercises consisted of 1 hour at 3.5 mph on a level treadmill, preceded or followed (alternately) by 10 minutes at the same speed but without the load. A second series of exercises was conducted out-of-doors, around a 10 minute circular course with slight grades; 40% was paved and the balance was a well packed gravel surface, the course being traversed 6 times at 3.5 mph., with one further traverse either before or after without the load.

Energy cost was determined from a 2 minute sample of expired air taken every 15 minutes on the treadmill and obtained in a Douglas bag every 20 minutes out-of-doors. Each sample was measured for residual $O_2$ with a Beckman paramagnetic analyser, and Weir's formula (11) was used to calculate the energy cost in Cal/hr/kg body weight. The walking speed was accurately maintained by an observer who accompanied each subject pushing a wheel type speedometer calibrated against a treadmill.

In Table I are shown the calculated energy costs of walking on the treadmill and out-of-doors with the two pack systems. No significant difference between the two packs could be observed either indoors or out-of-doors, and the data from both systems have therefore been combined.

It will be seen from this Table that for the two subjects taken together, the mean energy cost was 4.82 Cal/hr/kg indoors as opposed to 5.93 Cal/hr/kg outside, and that marching on a level road required 23% more energy than marching on the treadmill.

From Table II it will be seen that with the subjects carrying no pack whatever, energy cost indoors (as a mean for two subjects) was 4.67 Cal/hr/kg, as opposed to 5.39 Cal/hr/kg out-of-doors, and that the outside exercise therefore required 15% more energy.

It will also be noted that for the shorter man, the pack load was sufficient to add significantly ($P = .001$) by 29% to the energy cost of walking for one hour on the treadmill at this speed. For the taller subject, however, while the energy cost was increased 17%, the increase was not statistically significant due to the range. The number of subjects and the time allowed for these experiments did not permit this aspect of the study to be explored further.

Conclusion: Walking out-of-doors requires more energy than walking on a treadmill under otherwise similar enviromental conditions, the mean increase being 15% without the pack, and 23% with a pack of 28 lb.

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## TABLE I

## ENERGY COST OF WALKING WITH PACK

| Subject A (79.5 kg., 1.96 m) | | Subject B (61.5 kg., 1.70 m) | |
|---|---|---|---|
| Energy Cost: Cal/hr | | Energy Cost: Cal/hr | |
| Treadmill | Out-of-doors | Treadmill | Out-of-doors |
| 378 | 437 | 277 | 328 |
| 400 | 437 | 286 | 394 |
| 303 | 484 | 284 | 343 |
| 365 | 478 | 267 | 408 |
| 398 | 480 | 311 | 430 |
| 414 | 482 | 299 | 410 |
| 404 | 463 | 286 | 386 |
| 427 | 494 | 286 | 328 |
| 384 | 449 | 286 | 351 |
| 406 | 566 | 291 | 394 |
| 384 | 426 | 264 | 362 |
| 406 | 390 | 277 | 427 |
| 380 | 443 | 294 | 388 |
| 357 | 437 | 287 | 401 |
| 351 | 470 | 294 | 403 |
| 370 | 504 | 303 | 337 |
| 394 | 459 | 313 | 389 |
| 390 | 445 | 332 | 377 |
| 378 | 577 | 291 | 360 |
| 365 | 392 | 306 | 337 |
| 396 | 349 | 304 | 275 |
| 388 | 478 | 292 | 372 |
| 398 | 390 | 291 | 386 |
| 414 | Mean = 455 Cal/hr | 291 | 410 |
| 376 | = 5.72 Cal/hr/kg | 277 | |
| 380 | = 17% increase | 291 | Mean = 376 Cal/hr |
| 384 | | 303 | = 6.13 Cal/hr/kg |
| 398 | | 298 | = 29% increase |
| Mean = 389 Cal/hr<br>= 4.88 Cal/hr/kg | | Mean = 292 Cal/hr<br>= 4.76 Cal/hr/kg | |

TABLE II

ENERGY COST OF WALKING WITHOUT PACK

| Subject A (79.5 kg., 1.96 m) | | Subject B (61.5 kg., 1.70 m) | |
|---|---|---|---|
| Energy Cost: Cal/hr | | Energy Cost: Cal/hr | |
| Treadmill | Out-of-doors | Treadmill | Out-of-doors |
| 394 | 347 | 298 | 326 |
| 386 | 327 | 279 | 422 |
| 382 | 412 | 286 | 372 |
| 314 | 357 | 279 | 340 |
| 321 | 406 | 299 | 372 |
| 382 | 431 | 315 | 381 |
| 355 | 488 | | 332 |
| | 384 | Mean = 293 Cal/hr | 304 |
| | 431 | = 4.78 Cal/hr/kg | 362 |
| | 404 | | 303 |
| | 355 | | 410 |
| Mean = 362 Cal/hr<br>= 4.55 Cal/hr/kg | Mean = 395 Cal/hr<br>= 4.97 Cal/hr/kg<br>= 9% increase | | Mean = 357 Cal/hr<br>= 5.82 Cal/hr/kg<br>= 22% increase |

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