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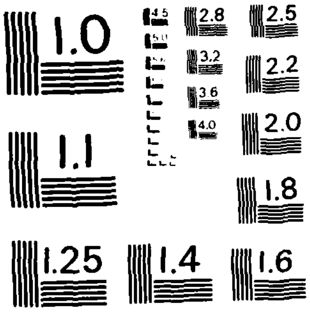
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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

To determine the difference in the energy cost of walking and running in a lightweight athletic shoe and a heavier boot, fourteen male subjects (6 trained and 8 untrained) had their oxygen uptake (VO_2) measured while walking and running on a treadmill. They wore each type of footwear, athletic shoes of the subjects' choice (average weight per pair = 616g), and leather military boots (average weight per pair = 1776g) at 3 walking speeds (4.0, 5.6 and 7.3 km $\cdot h^{-1}$) and 3 running speeds (8.9 10.5 and 12.1 km $\cdot h^{-1}$). The trials for running were

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repeated at the same three speeds with the subjects wearing shoes and these shoes plus lead weights. The weight of the shoes plus the lead weights was equal to the weight of the subjects' boots. The VO_2 values with boots were significantly (p .05) higher (5.9 to 10.2 percent) at all speeds, except the slowest walk, $4.0\ km \cdot h^{-1}$. Also, VO_2 with shoes plus lead weights were significantly ($p < .05$) higher than shoes alone. Weight alone appeared to account for 48-70% of the added energy cost of wearing boots. The relative energy cost (VO_2, $ml \cdot min^{-1}$) of trained and untrained subjects were the same at all speeds, but heart rates for the untrained were significantly higher ($p < .05$) in both shoes and boots except at the slowest walking speed ($4.0\ km \cdot h^{-1}$). These data indicate that energy expenditure is increased by wearing boots. A large portion of this increase may be attributed to weight of footwear. In addition, the increased energy cost of locomotion with boots appears to place a limiting stress on untrained subjects.

The Energy Cost and Heart Rate Response of Trained and Untrained Subjects Walking and Running in Shoes and Boots

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Energy Cost of Walking and Running in Shoes and Boots

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HUMAN RESEARCH

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

SUMMARY

To determine the difference in the energy cost of walking and running in a lightweight athletic shoe and a heavier boot, fourteen male subjects (6 trained and 8 untrained) had their oxygen uptake ($\dot{V}O_2$) measured while walking and running on a treadmill. They wore each type of footwear, athletic shoes of the subjects' choice (average weight per pair = 616g), and leather military boots (average weight per pair = 1776g) at 3 walking speeds (4.0, 5.6 and 7.3 $km \cdot h^{-1}$) and 3 running speeds (8.9 10.5 and 12.1 $km \cdot h^{-1}$). The trials for running were repeated at the same three speeds with the subjects wearing shoes and these shoes plus lead weights. The weight of the shoes plus the lead weights was equal to the weight of the subjects' boots. The $\dot{V}O_2$ values with boots were significantly ($p < .05$) higher (5.9 to 10.2 percent) at all speeds, except the slowest walk, 4.0 $km \cdot h^{-1}$. Also, $\dot{V}O_2$ with shoes plus lead weights were significantly ($p < .05$) higher than shoes alone. Weight alone appeared to account for 48-70% of the added energy cost of wearing boots. The relative energy cost ($\dot{V}O_2$, $ml \cdot kg^{-1} \cdot min^{-1}$) of trained and untrained subjects were the same at all speeds, but heart rates for the untrained were significantly higher ($p < .05$) in both shoes and boots except at the slowest walking speed (4.0 $km \cdot h^{-1}$). These data indicate that energy expenditure is increased by wearing boots. A large portion of this increase may be attributed to weight of footwear. In addition, the increased energy cost of locomotion with boots appears to place a limiting stress on untrained subjects.

Key words: energy cost, oxygen uptake, footwear

Several studies have examined the energy cost of walking (Bobbert 1960, Fellingham et al. 1978, Menier and Pugh 1968) and running (Bransford and Howley 1977, Fellingham et al. 1978, Hagan et al. 1980, Knuttgen 1961, Margaria et al. 1963, Menier and Pugh 1968), but few give any account of the weight or type of footwear worn by subjects. Comparison between studies suggest that as velocity increases energy cost increases in a curvilinear fashion with walking and in a relatively linear fashion with running below maximal levels. However, some small discrepancies between studies are evident and may be due to differences in the weight of footwear worn. It has been shown that a 0.35 kilogram difference in the weight of a pair of shoes can contribute to a significant (3.3 percent) rise in energy cost (Catlin and Dressendorfer 1979). Furthermore, the energy cost of walking with a given load on the feet is approximately 5 times more costly than the same weight on the torso (Soule and Goldman 1969). Thus, it might be expected that even small increments of weight carried on the feet may have significant effects on the energy cost of both walking and running.

Several professional occupations such as firefighting, forestry, mining and the military presently employ the use of heavy footwear and require work tasks of a locomotive nature. However, no studies have examined the energy cost of wearing different weights of footwear, over a wide range of locomotive speeds. Therefore, it was our purpose to compare the energy cost of several walking and running speeds in footwear of different weights.

METHODS

Fourteen male subjects, six trained and eight untrained, volunteered for this study after being informed of the nature and risks of the investigation. Trained subjects ran three or more times per week. Weekly mileage for these subjects averaged 26.8 ± 14.9 miles per week (range 10-50 miles per week). Untrained subjects ran sporadically, if at all, and not more than 10 miles per week. The physical characteristics of these subjects are summarized in Table 1. Height and weight were measured with subjects in shorts and barefooted. Percent body fat was estimated from 4 skin folds sites using well established age and gender corrected equations (Durnin and Womersley 1974). Lean body mass was calculated from percent body fat and weight. Table 1

The study consisted of 3 phases: 1) measurement of maximal oxygen uptake; 2) comparative energy cost of walking and running in shoes and boots; 3) comparative energy cost of running in shoes and shoes plus weights.

Maximum oxygen uptake ($\dot{V}O_2$ max, ml • kg^{-1} • min^{-1}) was measured using a protocol similar to that described by Mitchell et al. (1957) for running on a treadmill (Quinton, model 18-60). After a warmup of 5-6 minutes of walking on a treadmill at 5.6 km • h^{-1} at 0 percent grade, each subject ran at a constant speed (either 10.5 or 12.1 km • h^{-1}). Exercise intensity was progressively increased by raising the slope of the treadmill by 2.5% increments until a subject's oxygen uptake ($\dot{V}O_2$) leveled off or decreased between successive work loads. Subjects ran for 4 minutes at each intensity and were given a 5 min rest prior to the next exercise bout. For the $\dot{V}O_2$ max testing, subjects wore their athletic shoes and shorts.

Expired air was collected in Douglas bags for the last two 30 sec intervals of each exercise intensity, of the $\dot{V}O_2$ max test. Expired air was analyzed for O_2 and CO_2 content using an Applied Electrochemistry S-3A O_2 analyzer and a Beckman LB-2, CO_2 analyzer, respectively. Samples were measured for volume with a Tissot Spirometer. Heart rate (HR) was recorded on a Hewlett Packard 1511B electrcardiograph simultaneously with air sample collection at the end of each exercise intensity. Maximal heart rate (HR max) was the highest HR achieved by a subject during $\dot{V}O_2$ max testing.

For the comparative energy cost evaluations, footwear consisted of athletic shoes (usually a running shoe), and standard leather military boots. The average pair of shoes weighed 616 ± 125 g, and the average pair of boots 1776 ± 113 g.

Each type of footwear was evaluated at 3 walking speeds, 4.0, 5.6, 7.3 km h^{-1} (2.5, 3.5, and 4.5 mi • h^{-1}) and 3 running speeds, 8.7, 10.5, and 12.1 km • h^{-1} (5.5, 6.5 and 7.5 mi • h^{-1}). The treadmill speed was calibrated (± 0.61 m • min^{-1}) before each trial. In a counterbalanced design, $\dot{V}O_2$ was measured at each walking speed wearing first one type of footwear, then the other, both on the same day. For the walking trials, subjects exercised at each speed for 6 minutes. $\dot{V}O_2$ measurements and HR were obtained during the last two minutes of exercise. On another day, the above procedure was repeated for each running speed. For the running trials, however, the subjects ran for 4 minutes at each speed, and $\dot{V}O_2$ and HR data were collected over the last minute of exercise. For both walking and running trials, half the subjects wore shoes first and the other half boots first.

On a third occasion, the above protocol was repeated for the 3 running speeds with 8 subjects (4 trained and 4 untrained) wearing athletic shoes and these athletic shoes plus additional weight. When wearing shoes plus weights, the combined weight on the feet was equal to the weight of the subjects' combat boots. The weights were lead pellets placed in plastic bags which were taped to the sides of the subjects' shoes. These trials were run in an attempt to segregate the energy cost of additional weight on the feet from other, perhaps, biomechanical limitations of boots, such as stiff soles and restrictive uppers.

$\dot{V}O_2$ and HR data were analyzed using an analysis of variance (ANOVA) for multiple groups with repeated measures (Hinkle et al. 1979). If significant F-ratios were found, the data were further analyzed using multiple comparison tests - Cichetti's critical difference test (Cichetti 1972), or Tukey's test (Hinkle et al. 1979) - to identify the significantly different groups or factors. A probability of 0.05 was chosen as the level of acceptance for statistical significance.

RESULTS

$\dot{V}O_2$ data demonstrated that the energy cost of wearing boots was significantly greater ($p < .05$) at all treadmill speeds except the slowest walking speed, $4.0\ \mathrm{km} \cdot \mathrm{h}^{-1}$ (Table 2). The percent increment in energy cost ($\dot{V}O_2$) attributable to wearing the boots as compared to shoes ranged from 5.9% to 10.2% (avg 8.0%), while the average increment in weight added by wearing boots was only 1.4% of the subjects' body weight. HR during boot trials were higher than shoe trials at all speeds except the slowest walk, $4.0\ \mathrm{km} \cdot \mathrm{h}^{-1}$, but differences were not significant (Table 3a and b).

Table 2
Table 3a
Table 3b

The percent difference in energy cost between running in shoes and shoes plus weights ranged from 5.0% to 6.3% (Table 4). The $\dot{V}O_2$ for running in shoes plus weights was found to be significantly higher ($p < .05$) at all 3 running speeds. When the increment in energy cost of wearing shoes plus weights was compared to that of wearing boots, weight alone appeared to account for 48, 63 and 70% $(\dot{V}O_2 \text{ with shoes plus weights} - \dot{V}O_2 \text{ with shoes}) \cdot (\dot{V}O_2 \text{ with boots} - \dot{V}O_2 \text{ with shoes})^{-1} \cdot 100$ of the differences between shoes and boots at running speeds of 8.9, 10.5 and $12.1\ \mathrm{km} \cdot \mathrm{h}^{-1}$, respectively.

Table 4

Comparison of the $\dot{V}O_2$ data for trained and untrained subjects revealed no significant differences in the relative energy cost ($\mathrm{ml} \cdot \mathrm{kg}^{-1} \cdot \mathrm{min}^{-1}$) between the groups for walking or running in boots or shoes. However, HR were significantly higher ($p < .05$) for the untrained subjects at all speeds except the slowest walking speed ($4.0\mathrm{km} \cdot \mathrm{h}^{-1}$) (Table 3a and b).

DISCUSSION

The $\dot{V}O_2$ data collected in this study agree well with previous data reported by others for walking and running in shoes (Margaria et al. 1963, Menier and Pugh 1968) and walking in boots (Soule and Goldman 1969). Also, these data support the calculations of Soule and Goldman (1969) which demonstrated that an equivalent weight carried on feet as opposed to the torso costs 4.7 to 6.3 times as much energy depending on the speed of ambulation. The data from this study indicate that for an increment of weight equal to 1.4% of body weight carried on the feet the average energy cost increased 8% or 5.7 times what one would have expected for the same weight carried on the torso (Soule and Goldman 1969).

Most importantly, the energy cost is significantly increased by wearing boots rather than shoes for walking and running at speeds above 4.0 km $\cdot$ h^{-1}. This is in contrast to Strydom et al. (1968) who stated that increasing the weight of boots from 1.85 kg to 2.95 kg per pair had no significant effect on their energy cost of walking. Hettinger and Muller (1953) suggest that for subjects walking at moderate speeds, increasing the weight of footwear should not effect energy expenditure significantly. The failure of these studies to demonstrate a significant difference between walking in footwear of different weights is not surprising, however, since neither study sampled enough subjects to generate meaningful statistics. Strydom et al. (1968) studied only 2 subjects and Hettinger and Muller (1953) only 1. Also, both these studies demonstrated trends toward increasing energy costs for subjects walking (3.9 km $\cdot$ h^{-1} or more) in footwear of increasing weight. Therefore, it is likely that had the sample sizes of these studies been larger the results would have been statistically significant.

In regard to our data on shoes compared with shoes plus additional weight, it appears that a large proportion of the increased energy cost of wearing heavy footwear may be attributed to weight alone. When the change in energy cost of wearing boots or shoes plus weights is compared, weight alone accounts for 48 to 70% of the change, at the 3 running speeds. The average percent accounted for by weight alone was 60%. This may well be slightly higher since the data at 8.9 km • h^{-1} was effected by the performance of one subject whose energy cost at this running speed decreased when weight was added to his shoes. All other $\dot{V}O_2$ were higher with weights for all subjects, including the anomalous one. Even if we assume the average energy cost of wearing boots due to weight to be as high as 65 to 70% this still leaves 30 to 35% of the increased energy cost unexplained. Some of this unexplained portion of the energy cost of wearing boots may be due to biomechanical limtations such as stiff soles and restrictive uppers.

Looking at data from our study comparing the relative energy cost of trained and untrained subjects was interesting. While the absolute $\dot{V}O_2$ (ml • min^{-1}) for trained subjects was lower at any given exercise intensity, the relative $\dot{V}O_2$ (ml • kg^{-1} • min^{-1}) which is scaled to body weight was the same. These findings can be explained by the lower body weights of the trained subjects. They suggest that within relatively narrow limits energy cost of transporting a kg of body weight is the same for trained and untrained subjects. Because the absolute energy cost of walking or running was lower for the trained subjects, coupled with their higher maximal oxygen uptakes, they were functioning at lower percents of their $\dot{V}O_2$ max. The heart rate data reflected the greater physiologic stress of the untrained subjects. HR for the untrained subjects was significantly higher than the trained subjects at all speeds except the slowest running speed (4.0 km • h^{-1}).

While HR increased when subjects changed from shoes to boots in all cases, these increases were not statistically significant. This may be explained partially by the large variation between subjects' HR compared to the relatively small differences observed on changing footwear.

The $\dot{V}O_2$ and HR data from this study have implications for both aerobic training methods and also, the design and choice of footwear. Pandolf and Goldman (1975) produced a training effect in sedentary middle aged men by having them wear 1.5 kg weights on each ankle for 3 weeks and then 2.25 kg for 3 more weeks. These ankle weights were worn for normal walking activities with no other changes in their daily activities or exercise. Their findings suggest that use of ankle weights might be a good way to achieve aerobic conditioning of elderly individuals and to rehabilitate orthopedic patients for whom it is desirable to minimize musculo-skeletal trauma. Although we did not look at the question of training effects, our data suggest that just wearing boots (1.7 g per pair, about 1/2 the weight used by Pandolf) will increase the energy cost of walking at 5.6 and 7.3 $km \cdot h^{-1}$ substantially.

While the addition of weight to the lower leg may be an effective means of achieving a training effect with otherwise low intensity exercise in sedentary individuals, we question the wisdom of using leg weights or heavy footwear for running, especially for untrained individuals. The untrained subjects we studied were already functioning at relatively high exercise intensities (76% of $\dot{V}O_2$ max, and 83% HR max) when they ran 8.9 $km \cdot h^{-1}$ (11 $min \cdot mi^{-1}$) in boots. Since recommended training levels are between 50 to 80% $\dot{V}O_2$ max (American College of Sports Medicine 1978) or 70-85% HR max (McArdle et al. 1981), untrained subjects would be limited to running at very slow speeds if they wore boots (or weights) weighing 1.7 kg per pair or more. Our subjects, trained and untrained, felt that running at 8.9 $km \cdot h^{-1}$ was uncomfortably slow. At the next running speed 10.5 $km \cdot h^{-1}$ (9 $min \cdot mi^{-1}$), untrained subjects ran at 83 and 90% of $\dot{V}O_2$ max and HR max, respectively. It has been found that if exercise intensity is regulated at 80% of maximal HR rather than 90%, individuals complain of fewer musculoskeletal problems and tolerated the training program better (Pollock 1978). If this is so, it is another reason for untrained or sedentary subjects not to run in heavy footwear or with ankle weights.

The implications of this study for the design and manufacture of footwear would also seem to be clear. By decreasing the weight of footwear the energy cost for individuals wearing them can be reduced. Until recently, the only manufactures interested in making lighter footwear were those producing running shoes. The technology from the running shoe industry, however, is now being applied to the manufacture of lightweight boots for hiking and mountain climbing. It would seem that the rapidly developing technology for producing lightweight but rugged materials could be applied to the manufacture of not only athletic and recreational footwear, but also professional work boots, provided supportive and protective features could be maintained.

In summary, the salient findings of this study indicate that for trained and untrained subjects walking or running in boots significantly increases the energy cost compared to the same activity in athletic shoes. Furthermore, while the relative energy cost per kg body weight is the same for trained and untrained, the physiological stress (HR and % $\dot{V}O_2$ max) is significantly greater for the untrained.

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REFERENCES

American College of Sports Medicine (1978) The Recommended Quantity and Quality of Exercise for Developing and Maintaining Fitness in Healthy Adults. Sports Med. Bull. 13(3):1-4

Bobbert AC (1960) Energy exenditure in level and grade walking. J. Appl. Physiol. 15:1015-1021

Bransford DR, Howley ET (1977) Oxygen cost of running in trained and untrained men and women. Med. Sci. Sports 9:41-44

Catlin MJ, Dressendorfer RH (1979) The effect of shoe weight on the energy cost of running. (abstract) Med. Sci. Sports 11(1):80

Durnin JBGA, Wormersley J (1974) Body fat assessment from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. Br. J. Nutr. 32:77-79

Cichetti, DV (1972) Extension of multiple range tests of interaction tables in the analysis of variance. Psych. Bull. 77:405-408

Fellingham GW, Roundy ES, Fisher AG, Bryce GR (1978) Caloric cost of walking and running. Med. Sci. Sports 10:132-136

Hagan RD, Strathman T, Strathman L, Gettman LR (1980) Oxygen uptake and energy expenditure during horizontal treadmill running. J. Appl. Physiol 49:571-575

Hettinger T, Muller EA (1953) Der einflub des schuhgewichtes auf den energieumsatz beim gehen and lastentragen. Int. Z. Angew. Physiol. einschl. Arbeitsphysiol. 15:1015-1021

Hinkle, DE, Wiersma W, Jurs SG (1979) Applied Statistics for the Behavioral Sciences. Houghton Mifflin Company, Boston, MA

Knuttgen, HG (1961) Oxygen uptake and pulse rate while running with underdetermined and determined stride lengths at different speeds. Acta Physiol. Scand. 52:366-371

Margaria R, Cerretelli P. Aghemo P, Sassi G (1963) Energy cost of running. J. Appl. Physiol. 18:367-370

McArdle WD, Katch FI, Katch VL (1981) Exercise Physiology: Energy, Nutrition, and Human Performance. Lea and Febiger, Philadelphia

Menier DR, Pugh L (1968) The relation of oxygen intake and velocity of walking and running in competition walkers. J. Physiol 197:717-721

Mitchell JH, Sproule BJ, Chapman CB (1958) The physiological meaning of the maximal oxygen intake test. J. Clin. Invest. 37:538-547

Pandolf KB, Goldman RF (1975) Physical conditioning of less fit adults by use of leg weight loading. Arch. Phys. Med. Rehabil. 56:255-261

Pollock ML (1978) How much exercise is enough? Physician and Sports Med. 6:50

Soule RG, Goldman RF (1969) Energy cost of loads carried on the head, hands or feet. J. Appl. Physiol. 27:687-690

Strydom NB, van Graan CH, Morrison JF, Viljoen JH, Heyns AJ (1968) The influence of boot weight on the energy expenditure of men walking on a treadmill and climbing stairs. Int. Z. Angew. Physiol. einschl. Arbeitphysiol. 25:191-197

TABLE 1. Description of Subjects

		Age (years)	Height (cm)	Weight (kg)	Body Fat (%)	Lean Body Mass (kg)	$\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$)	HR max ($b \cdot min^{-1}$)
Trained	$\bar{X}$	30.5	174.6	68.2	14.5	59.9	62.0	189.7
	S.D.	4.3	5.9	8.9	3.4	5.2	4.2	8.2
	n	6	6	6	5	5	6	6
Untrained	$\bar{X}$	30.4	174.4	80.2	21.9	62.5	46.1	194.3
	S.D.	3.5	6.1	7.1	3.9	5.1	3.71	5.6
	n	8	8	8	8	8	8	8
Combined	$\bar{X}$	30.4	174.5	75.1	19.1	61.5	52.92	192.3
	S.D.	3.7	5.8	9.8	5.1	5.3	9.0	7.0
	n	14	14	14	13	13	14	14

TABLE 2. Average $\dot{V}O_2$ (ml • kg^{-1} • min^{-1}) of subjects walking and running on a treadmill in different types of footwear

		WALKING			RUNNING		
Speed (km • h^{-1})		4.0	5.6	7.3	8.9	10.5	12.1
	$\bar{X}$	10.5	14.2	21.7	30.4	35.2	39.6
Shoes	S.D.	1.1	[illegible].3	2.6	1.4	2.0	2.3
	n	14	14	14	14	14	14
	$\bar{X}$	11.1	15.4	23.4	33.6	38.2	42.8
Boots	S.D.	1.4	1.1	2.1	1.9	1.9	2.1
	n	14	14	14	14	14	14
$\Delta \dot{V}O_2$		0.6	1.2	1.7	3.1	3.0	3.2
% $\Delta \dot{V}O_2$		5.9	8.4	7.9	10.2	8.5	8.0
p*		n.s.	.05	.05	.05	.05	.05

*p = level of significance for multiple comparison test of shoes vs. boots

TABLE 3a. Average heart rate (HR, b • min^{-1}) of trained (T) and untrained (UT) subjects walking on a treadmill in different types of footwear.

Walking Speed (km • h^{-1})		4.0		5.6		7.3	
		Shoes	Boots	Shoes	Boots	Shoes	Boots
T	$\bar{X}$	78.0	79.7	88.8	90.0	102.2	108.7
	S.D.	7.2	6.2	7.1	7.9	12.8	9.4
	n	6.0	6.0	5.0	6.0	6.0	6.0
UT	$\bar{X}$	91.5	90.6	105.6	107.9	133.0	136.6
	S.D.	9.8	7.3	10.6	7.2	14.8	12.0
	n	8.0	5.0	7.0	7.0	7.0	8.0
Δ HR		13.5	10.9	16.8	17.9	30.8	27.9
% Δ HR		17.3	13.6	18.9	19.9	30.1	25.7
p*		n.s.	n.s.	0.05	0.05	0.05	0.05

*p = level of significance for multiple comparison test for T vs. UT

TABLE 3b. Average heart rate (HR, $b \cdot min^{-1}$) of trained (T) and untrained (UT) subjects running on a treadmill in different types of footwear.

Running Speed ($km \cdot h^{-1}$)		8.9		10.5		12.1	
		Shoes	Boots	Shoes	Boots	Shoes	Boots
T	$\bar{X}$	122.8	126.2	134.6	166.8	144.6	177.2
	S.D.	12.5	10.7	17.2	8.5	20.9	7.4
	n	5.0	5.0	5.0	6.0	5.0	5.0
UT	$\bar{X}$	149.3	160.4	138.4	174.0	151.6	184.6
	S.D.	9.6	10.9	15.3	7.5	19.1	3.7
	n	6.0	7.0	5.0	7.0	5.0	5.0
Δ HR		26.5	34.2	32.2	35.6	32.6	33.0
% Δ HR		21.5	27.1	23.9	21.1	22.5	18.6
p*		0.05	0.05	0.05	0.05	0.05	0.05

*p = level of significance for multiple comparison test for T vs. UT

TABLE 4. Average $\dot{V}O_2$ (ml • kg^{-1} • min^{-1}) of subjects running on a treadmill in shoes and shoes plus weight (WT)*

		RUNNING		
SPEED (km • h^{-1})		8.9	10.5	12.1
SHOES	$\bar{X}$	30.1	33.9	38.2
	S.D.	1.8	2.4	2.6
	n	8	8	8
SHOES PLUS WT*	$\bar{X}$	31.6	36.0	40.2
	S.D.	2.2	1.7	2.0
	n	8	8	8
$\Delta \dot{V}O_2$		1.5	2.1	2.0
$\% \Delta \dot{V}O_2$		5.0	6.3	5.2
p**		< 0.05	< 0.05	< 0.05

*Weight of subjects shoes plus weight (lead shot) equals weight of boots

**p = level significance on multiple comparison test

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