To the Graduate Council:

I am submitting herewith a thesis written by Rex Todd Holmes entitled "The Effect of Walking Incline on the Accuracy of a Pedometer." I recommend that it be accepted in partial fulfillment for the degree of Master of Science, with a major in Physical Education.

Henry J. Montoye, Major Professor

We have read this thesis
and recommend its acceptance:

Edward T. Howley

B. Don Franks

Accepted for the Council

Vice Chancellor for
Graduate Studies and Research

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THE EFFECT OF WALKING INCLINE ON THE ACCURACY OF A PEDOMETER

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Rex Todd Holmes

August 1977

1328547

ACKNOWLEDGMENTS

The author wishes to express his appreciation to those who served as subjects in this study, namely Dr. Henry J. Montoye, Ray Brown, Mark Noble, Annie Maude Davis, Steve Shipley, Rick Dowswell, Lauri Holmes, Ginger Sprague, John Richards, Elizabeth Jackson, Becky Wheeler, Fred Wheeler and Leslie Furlong for their cooperation in supplying the basic data.

Recognition is extended to Ms. Jeaneane Payne, who put this work in its final form.

The author is extremely grateful to Dr. Henry Montoye, who gave generously of his time and thoughts throughout the study, serving as major professor, advisor and subject.

ABSTRACT

Seven male and six female subjects completed eight separate one mile walks. Two walks were performed at each of the following grades: 0%, 5%, 10% and 15%, with all tests given at 3 mph. One pedometer was placed on the right hip of each subject during the walk. The study attempted to determine the effect of percent grade on the accuracy of pedometers.

Statistical analysis indicated that some subjects had consistently higher or lower pedometer readings. Also, it was shown that stride length between subjects varied significantly and percent grade caused a change in stride length. However, not all subjects adjusted their strides uniformly with grade changes; hence, the interaction of subjects and stride length at various grades was statistically significant.

Stride length, body weight, height and leg length showed no correlation with mean pedometer readings.

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CHAPTER I

INTRODUCTION

A pedometer is "an instrument usually in watch form that records the distance a walker covers by responding to his body motion at each step" (5). The instrument is worn belt high on either hip. As an individual walks, the pedometer records the distance covered and produces a reading on its dial.

The value of a pedometer depends on its accuracy. According to one author, the use of a commercial pedometer for research purposes proved unsatisfactory owing to its inconsistency (4). However, no data were reported in this study. In fact, except for the study by Gayle, discussed later, a review of the literature showed that no data were available on the accuracy of commercial pedometers.

By studying the accuracy of pedometers, the researcher will be able to determine whether pedometers could be used to measure energy expenditure of individuals in situations inappropriate for time motion studies, and be confident that his results are accurate.

Walking is a popular form of exercise which helps maintain fitness. It is of particular interest to study pedometers because walking is often an integral part of an individual's daily routine, which requires no special clothing or facilities. Many overweight individuals who are advised to lose weight through increased energy expenditure could use a pedometer to determine the amount of energy used during their daily routine. The usefulness of pedometers in a particular exercise program will depend on their accuracy.

CHAPTER II

REVIEW OF LITERATURE

Surprisingly, scientific reports on the accuracy of pedometers have not been published in the literature. A pilot study done at The University of Tennessee by Richard Gayle in 1975 has been conducted, and the results are now in the process of being published (3).

It is generally thought that pedometers work on the pendulum principle; however, upon investigation, it was found they operate on impact. A small hammer is connected to a gear system and upon impact the hammer moves up then down, causing the gears to move which gives a reading on the dial face. Knowing that pedometers operate on impact supports the evidence that different readings were found when pedometers were worn on the right and left sides of the body. This is explained by the fact that most individuals do not walk in such a way that the right and left foot strike the ground with equal force.

The method which is prescribed by the manufacturers for calibrating the pedometer for an individual is to adjust the stride length screw. The method Gayle used proved more accurate (3). He made the calibration after a test run. The subjects were required to walk several times at 0% grade for exactly one mile. The pedometer did not read exactly one mile. The actual pedometer reading was used as a correction factor. All pedometer readings were divided by this correction factor. Gayle found stature, body weight and leg length to be unrelated to the pedometer recording.

Gayle tested the New Haven 100 Mile Pedometer and the Edge Mark Digi Meter, the latter being significantly more accurate.

CHAPTER III

METHODS

Seven male and six female subjects took part in this study. Subjects unfamiliar with a motor driven treadmill were familiarized with walking at 3 mph at 0% grade. All tests were administered identically, with each subject walking exactly one mile.

One commercial pedometer was tested. The Aristo Manpo-Meter (shown in Figure 1) is the brand pedometer used. This is the same as the Digimeter used by Gayle. The stride adjustment screw remained constant, with the stride length set at approximately twenty four inches for all subjects.



Figure 1. Aristo Manpo-Meter, shown in the position in which it hangs from the waist during correct use.

The same pedometer was worn by the same individual throughout the study. It should be noted that all tests were given at 3 mph with the pedometer worn belt high on the right hip of the subject. Figure 2 shows the pedometer placement. The subjects were tested twice at each of the following grades: 0%, 5%, 10% and 15%.

Random selection was used to determine the order in which the walks would be conducted. Eight equal size slips of paper were placed in a jar and drawn out one at a time. This procedure was used for each

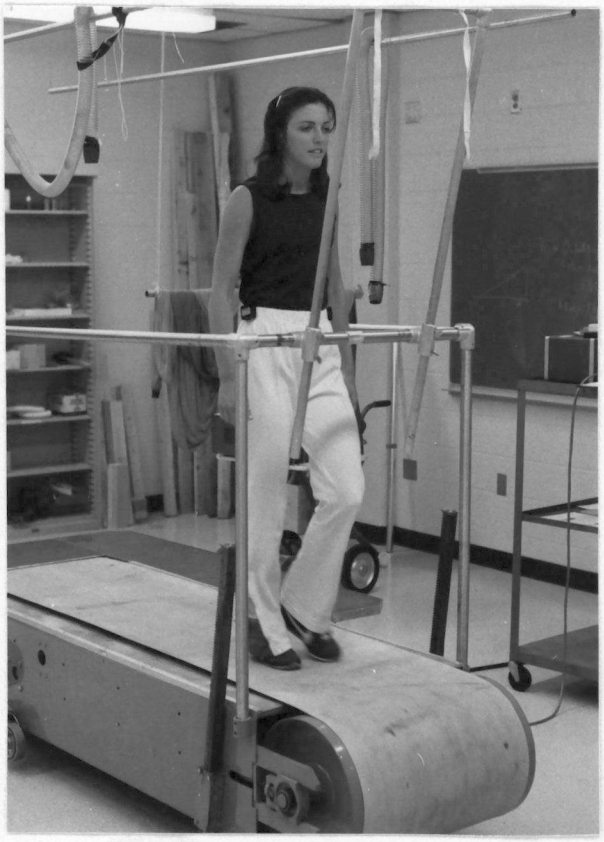


Figure 2. Subject walking on the treadmill with pedometer positioned above right hip.

subject. Each percent grade was represented by two slips of paper. Table 1 illustrates the order of all walks for each subject. Body weight, height, stride frequency (strides/min.) and leg length were recorded to determine their effect on pedometer readings. Each subject was weighed on a calibrated scale. Leg length was determined by two measurements: First, stature was measured in the usual way by having the subject stand erect with weight evenly distributed on both feet against a meter stick attached to a wall. The second measurement consisted of the individual sitting on the floor, with his or her back flush against the meter stick attached to the wall. By subtracting the second measurement from the first, the leg length was computed. The

Table 1. Order of Graded Walks

Subject	Walk 1	2	3	4	5	6	7	8
1	10%	0%	10%	0%	15%	5%	15%	5%
2	15%	15%	0%	10%	5%	10%	0%	5%
3	15%	15%	0%	0%	5%	10%	10%	5%
4	10%	0%	10%	15%	5%	15%	0%	5%
5	10%	5%	15%	0%	10%	0%	5%	15%
6	10%	5%	0%	5%	15%	10%	0%	15%
7	5%	0%	10%	5%	10%	15%	0%	15%
8	5%	0%	15%	10%	5%	15%	0%	10%
9	10%	15%	0%	15%	10%	5%	5%	0%
10	10%	15%	0%	5%	10%	0%	15%	5%
11	5%	5%	10%	0%	0%	15%	15%	10%

number of strides/min. were calculated by counting the strides during the eighth through tenth minute of each walk. Only one time period was chosen because it has been proven that the stride length does not change during a twenty minute walk (3).

The reproducibility of pedometer readings was examined by using both the percent error and a reliability coefficient. The mean and standard deviation for height, weight, leg length and strides/min. were computed for both male and female subjects. An analysis of variance design was used to determine the effect, if any, of grade on pedometer readings and stride length.

The average error in measurement at all grades for the Aristo Manpo-Meter was calculated by taking the difference between the two walks at each grade, adding these differences together and dividing by 52 times the number of grades.

This study was approved by the Human Subjects Committee at The University of Tennessee. A consent form is shown in Figure 3.

The University of Tennessee, Knoxville

Division of Physical Education

Consent Form for Participation in Pedometer Study

The undersigned hereby consents to his/her participation in the study of the accuracy of pedometers. The only physical activity involved will be walking at various speeds, not exceeding four miles per hour, and at various grades, not exceeding 15%. At no time will I be required to walk more than one mile without resting. The exercise will represent at most what is considered moderate work (about 50% of maximum).

The project has been explained to me and I have had an opportunity to have my questions answered. I understand that I am free to withdraw my consent and to discontinue participation on the project at any time.

Date _____ Participant _____

Witness _____

Figure 3. Consent form for participation in pedometer study.

CHAPTER IV

RESULTS

In this study, there were several trials with the same subject at different treadmill grades. An analysis of variance design was used to determine if any significant differences existed among the pedometer readings at the different treadmill grades.

The mean and standard deviations of height, weight, leg length and strides/min. as shown in Table 2 provides additional information about the subjects.

The results of the analysis of variance, Table 3, showed a significant difference between subjects ($F=7.33$; df 12/52; $p<.005$). This means that the pedometer reading was consistently higher for some subjects. Differences between pedometer readings at the different grade levels proved insignificant ($F=2.78$). It should be noted that this F

Table 2. Mean and Standard Deviation of Height, Weight, Leg Length, Strides/Min.

		Ht (cm)	Wt (kg)	Leg Length (cm)	Strides/min.
	M	180.4 cm	81.4 kg	89.7 cm	108.3
Males	SD	7.2 cm	7.3 kg	6.8 cm	4.04
	N	7	7	7	7
	M	166.8 cm	59.1 kg	79.8 cm	116.6
Females	SD	6.3 cm	8.1 kg	5.0 cm	6.3

Table 3. Summary of Analysis of Variance - Subject-vs-Grade

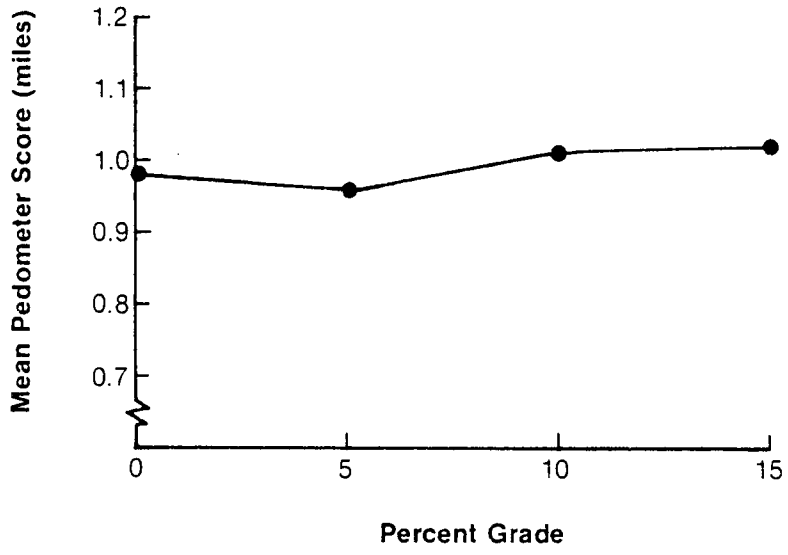
Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Subjects	.7658	12	.0638	7.33****
Treatment	.0727	3	.0242	2.78
Interaction	.3746	36	.0104	1.20
Residual	.4520	52	.0087	1.00
Total	1.6651	103	1.071	

****p<.005

value was .01 away from being significant at the (p<.05). However, as can be seen in Figure 4, there was no apparent pattern to the relationship of grade to pedometer readings.

The relationship between subjects and strides/min. (Table 4) show a significant main effect of subjects (F=33.51; df=12/52; p<.005), grade (F=3.36; df=3/52; p<.025) and the interaction between subjects and strides/min. at different grades (F=2.04; df=36/52; p<.025). This means that some subjects have significantly longer strides than others. The effect of grade on strides/min. can be seen in Figure 4. The significance of interaction between subject and strides/min. suggests that not all subjects adjust their stride length uniformly with increased grade.

Figure 5, Graph A, illustrates the relationship between strides/ mean pedometer score for all subjects. It is also of interest to note the effect of each grade level on the mean strides/min. for



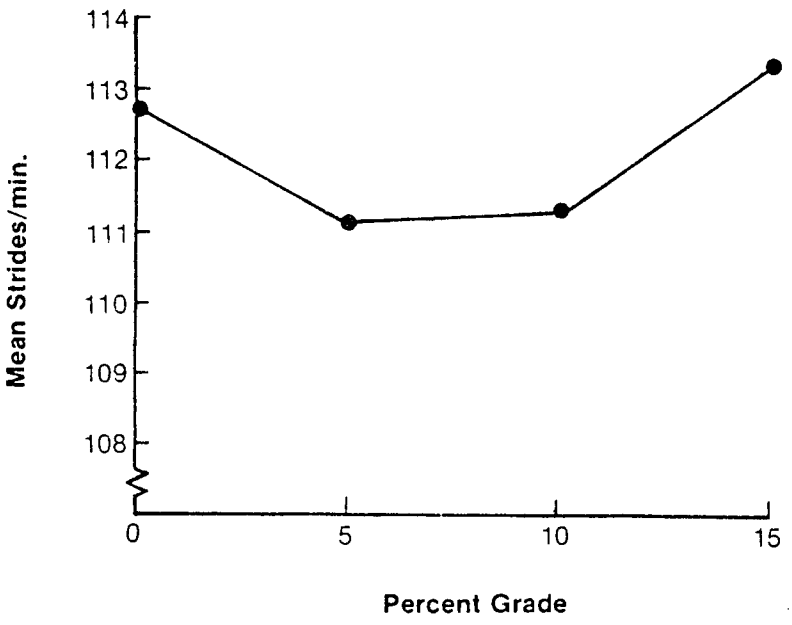


Figure 4. Percent grade plotted against mean pedometer score for all test observations and percent grade plotted against mean strides/min. for all test observations.

Figure 5

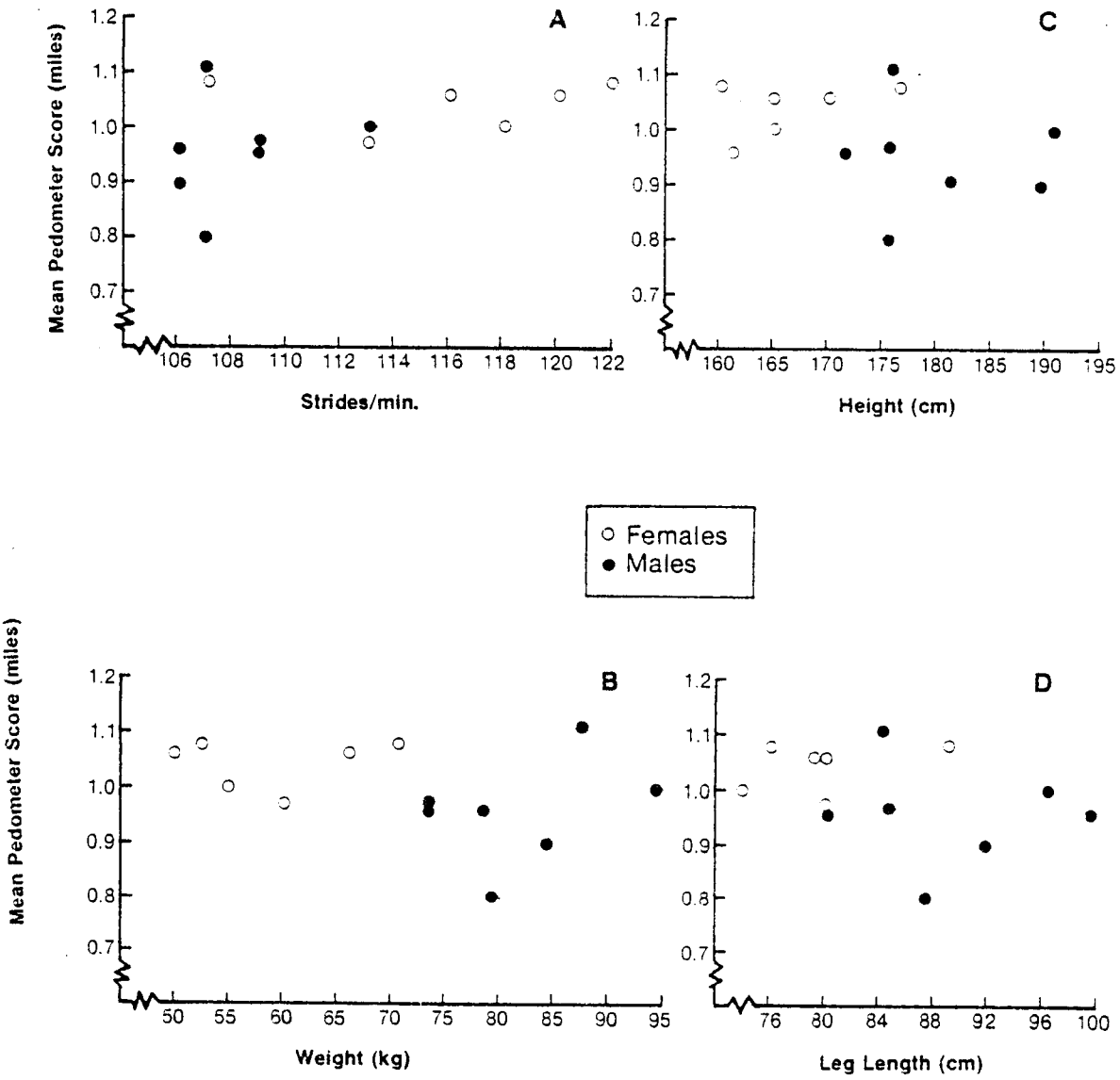


Figure 5. Strides/min., body weight, height and leg length plotted against mean pedometer score for all test observations for each subject.

each subject (Figure 6). Since the manufacturer suggests to adjust the stride length setting to make a pedometer accurate for that individual, the absence of any pattern is surprising.

Body weight, height and leg length were plotted against mean pedometer score to determine if any pattern would develop; however, as seen in (Figure 5, Graphs B, C and D) no apparent correlation exists.

The reproducibility of pedometer readings was evaluated by calculating a reliability coefficient. The reliability between the two pedometer readings proved the pedometer became more consistent at the higher grades, with the variability between individuals greatest at 5% grade (Table 5).

The average error in measurement was 6.5% for the Aristo Manpo-Meter compared to 5.9% for the Digi-Meter used in Richard Gayle's pilot study.

Figure 6

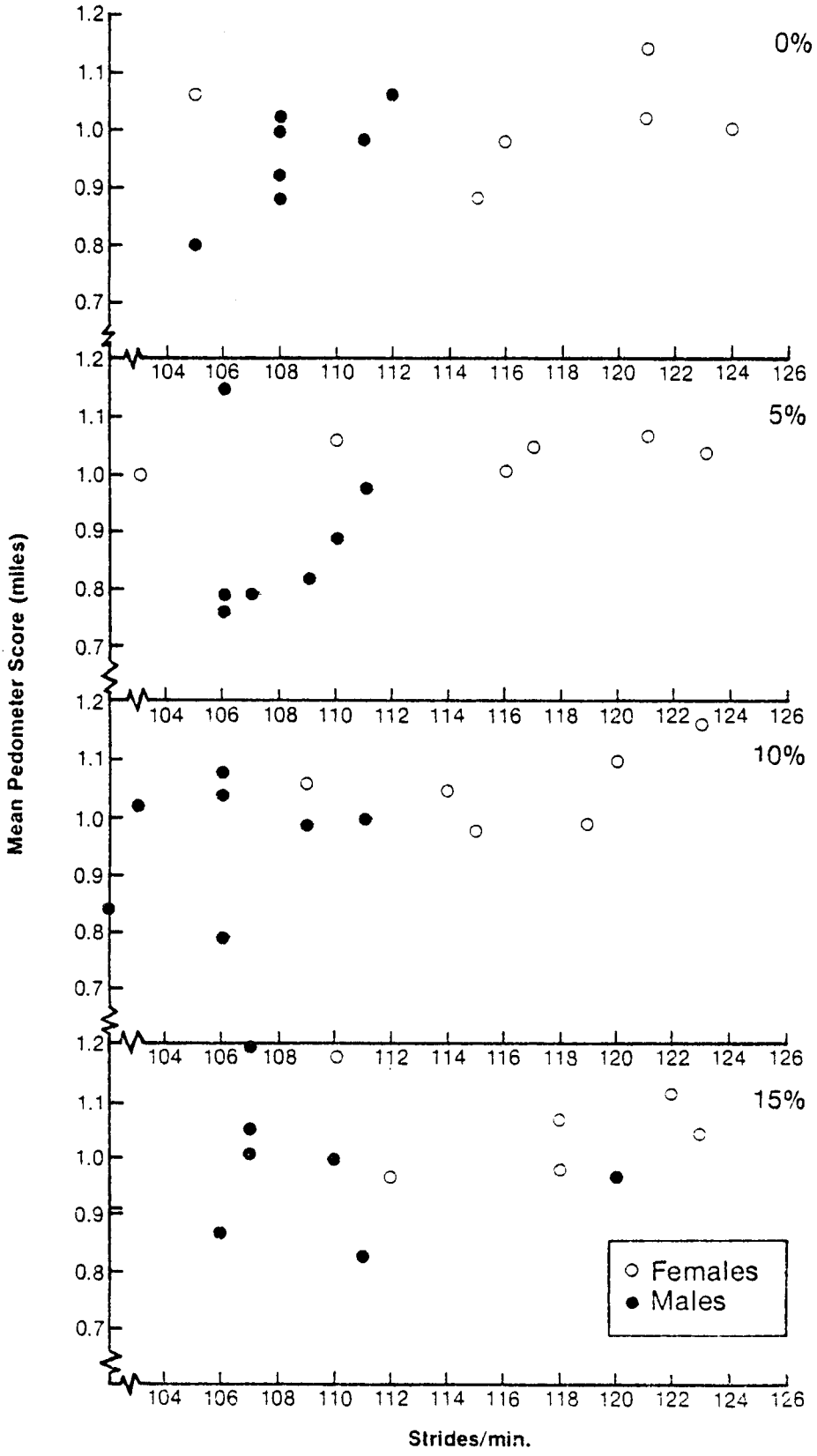


Figure 6. Mean strides/min. for each subject plotted against mean pedometer score at each percent grade.

Table 5. Reproducibility of Pedometer Readings (N=13)

	Grade			
	0%	5%	10%	15%
Reliability Coefficient	.60	.68	.69	.70
$\bar{X}$ (Mean)	.98	.96	1.01	1.03
Standard Error	.025	.036	.028	.032
Percent Error from Mean	2.5%	3.7%	2.8%	3.0%

CHAPTER V

DISCUSSION

The purpose of this study was to determine the effect of percent grade on the accuracy of pedometer readings. Accuracy in a pedometer depends on its ability to yield consistent, though not precise, readings under varied walking conditions (0, 5, 10 and 15% grade) while having speed and pedometer placement constant.

It was shown that the main effects of subjects were highly significant (Table 3, p. 11), proving that some individuals had a consistently higher or lower pedometer reading. This may be attributed to the fact that some subjects exert more or less force against the ground with each stride.

The effect of grade on pedometer reading proved insignificant, although the F value was only .01 away from being significant at the $p<.05$ level. After constructing a graph in which percent grade was plotted against mean pedometer score, it was clear that the effect of grade was very slight (see Figure 4, p. 12).

It would be expected that pedometer reliability would be most consistent at 0%; however, it was just the opposite. Also, surprisingly, the most variability between individuals was at 5%.

It was expected that when looking at strides/min-vs-grade that the main effect of subjects would be significant. It is very apparent that not all individuals walk with the same stride length. It was also not surprising that strides/min. changed with grade. When examining

subjects and strides/min. some individuals adjusted their stride length more or less than did other subjects.

The manufacturers suggest tnat the stride length adjustment be used to calibrate a pedometer to an individual. The relationship illustrated in Figure 5, Graph A suggests that to measure stride length and make the adjustments is an exercise in futility. An individual's stride length has little influence on a pedometer. A better method is to calibrate the pedometer for a particular individual by using a pretest and using the actual pedometer reading as a calibrating figure. This process entails more work, because a preliminary one mile walk must be repeated and all readings adjusted for this correction factor.

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary and Conclusions

Seven male and six female subjects completed eight separate one mile walks. Two walks were performed at each of the following grades: 0%, 5%, 10% and 15%, with all tests given at 3 mph. One pedometer was placed on the right hip of each subject during the walk. The study attempted to determine the effect of percent grade on the accuracy of pedometers.

Statistical analysis indicated that some subjects had consistently higher or lower pedometer readings and stride length between subjects varied significantly. Also, percent grade caused a change in stride length. However, not all subjects adjusted their strides uniformly with grade changes; hence, the interaction of subjects and stride length at various grades was statistically significant. The consistency of pedometer readings increased as percent grade increased, with the most variability between individuals at 5% grade.

Stride length, body weight, height and leg length showed no correlation with mean pedometer readings.

Recommendations

Since this study was conducted in an area in which little work has been done, experimentation in this area should be encouraged. Studies conducted to determine the effect of force with which the foot strikes the ground would be of interest to manufacturers, which might encourage redesigning pedometers.

An investigation should be designed to keep variables constant. The individuals should wear the same shoes throughout the study. The pedometer should be placed on a belt, instead of placing the pedometer on the subject's clothing.

It would be of interest to determine the effect of different walking speeds on pedometer readings. Finally, studies must be designed to determine the accuracy of pedometers during normal walking conditions.

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APPENDIX

Table 6. Raw Data: Pedometer Readings (miles) for Individual One-Mile Walks

Subject	Leg	Percent Grade							
		0%	0%	5%	5%	10%	10%	15%	15%
1	Right	1.05	1.0	0.80	0.79	0.85	0.84	1.04	0.98
2	R	0.81	0.80	0.74	0.79	0.79	0.80	0.81	0.85
3	R	1.10	1.03	1.00	0.95	0.99	1.00	1.03	0.91
4	R	1.12	1.01	1.10	0.90	1.18	0.95	1.30	1.10
5	R	0.90	0.87	0.89	0.70	1.15	0.90	0.95	0.80
6	R	1.10	0.90	1.30	1.00	1.17	0.99	1.31	1.15
7	R	0.92	1.05	1.12	0.90	1.09	0.90	1.08	1.00
8	R	1.02	1.03	1.15	1.00	1.10	1.10	1.15	0.99
9	R	0.95	1.02	0.80	0.85	1.10	0.99	1.00	1.00
10	R	1.0	1.0	1.08	1.00	1.25	1.10	1.18	1.06
11	R	0.89	0.87	1.10	1.02	1.05	0.92	0.90	1.00
12	R	1.00	0.85	0.89	0.89	1.00	1.00	1.01	1.10
13	R	1.14	1.14	1.23	0.88	1.10	1.00	0.96	0.99

VITA

Rex Todd Holmes was born in Wakarusa, Indiana on July 2, 1954. He attended elementary school in that city and was graduated from NorthWood High School in May 1972. The following September he entered Tri-State University, and in May 1976 he received a Bachelor of Science degree in Physical Education. In the fall of 1976 he accepted a teaching assistantship at The University of Tennessee and began study toward a Master's degree in Physical Education. This degree was awarded in August 1977.