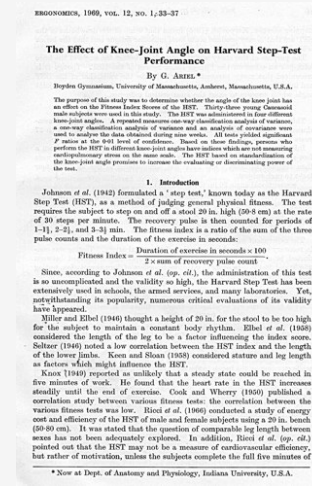




The Effect of Knee-Joint Angle on Harvard Step-Test

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The Effect of Knee-Joint Angle on Harvard Step-Test Performance

This 1969 study by G. Ariel at the University of Massachusetts aimed to determine if the angle of the knee joint affects the Fitness Index Scores of the Harvard Step Test (HST). The study involved 33 young male subjects and administered the HST at four different knee-joint angles.

The data was analyzed using a repeated measures one-way classification analysis of variance, a one-way classification analysis of variance, and an analysis of covariance. All tests yielded significant F ratios at the 0.01 level of confidence, indicating that the knee-joint angle does affect the HST scores.

The study concluded that individuals who perform the HST at different knee-joint angles have indices that do not measure cardiopulmonary stress on the same scale. The findings suggest that standardizing the knee-joint angle could increase the evaluating or discriminating power of the test.

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Below find a reprint of the 5 relevant pages of the article "The Effect of Knee-Joint Angle on Harvard Step-Test" in "Ergonomics":

The Effect of Knee-Joint Angle on Harvard Step-Test Performance

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The purpose of this study was to determine whether the angle of the knee joint has an effect on the Fitness Index Scores of the HST. Thirty-three young Caucasian male subjects were used in this study. The HST was administered in four different knee-joint angles. A repeated measures one-way classification analysis of variance, a one-way classification analysis of variance and an analysis of covariance were used to analyse the data obtained during nine weeks. All tests yielded significant F ratios at the 0.01 level of confidence. Based on these findings, persons who perform the HST in different knee-joint angles have indices which are not measuring cardiopulmonary stress on the same scale. The HST based on standardization of the knee-joint angle promises to increase the evaluating or discriminating power of the test.

1. Introduction

Johnson *et al.* (1942) formulated a 'step test,' known today as the Harvard Step Test (HST), as a method of judging general physical fitness. The test requires the subject to step on and off a stool 20 in. high (50.8 cm) at the rate of 30 steps per minute. The recovery pulse is then counted for periods of 1-1½, 2-2½, and 3-3½ min. The fitness index is a ratio of the sum of the three pulse counts and the duration of the exercise in seconds:

$$\text{Fitness Index} = \frac{\text{Duration of exercise in seconds} \times 100}{2 \times \text{sum of recovery pulse count}}$$

Since, according to Johnson *et al.* (*op. cit.*), the administration of this test is so uncomplicated and the validity so high, the Harvard Step Test has been extensively used in schools, the armed services, and many laboratories. Yet, notwithstanding its popularity, numerous critical evaluations of its validity have appeared.

Miller and Elbel (1946) thought a height of 20 in. for the stool to be too high for the subject to maintain a constant body rhythm. Elbel *et al.* (1958) considered the length of the leg to be a factor influencing the index score. Seltzer (1946) noted a low correlation between the HST index and the length of the lower limbs. Keen and Sloan (1958) considered stature and leg length as factors which might influence the HST.

Knox (1949) reported as unlikely that a steady state could be reached in five minutes of work. He found that the heart rate in the HST increases steadily until the end of exercise. Cook and Wherry (1950) published a correlation study between various fitness tests: the correlation between the various fitness tests was low. Ricci *et al.* (1966) conducted a study of energy cost and efficiency of the HST of male and female subjects using a 20 in. bench (50.8 cm). It was stated that the question of comparable leg length between sexes has not been adequately explored. In addition, Ricci *et al.* (*op. cit.*) pointed out that the HST may not be a measure of cardiovascular efficiency, but rather of motivation, unless the subjects complete the full five minutes of

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stepping exercise. Karpovich (1965) found that some of the drawbacks of the HST are that it may produce acute local muscular fatigue and that the bench is too high.

The purpose of this study was to determine whether the angle of the knee joint has an effect on the Fitness Index Scores of the HST. Though it is recognized that many parameters may influence the validation of the HST and introduce error of measurement, this study dealt only with the knee-joint angle which appears to exert the most critical influence.

2. Method

Thirty-three male Caucasian students enrolled at the University of Massachusetts served as subjects in this study. Their ages ranged from 18 to 27 years (see Table 1).

Initially, conventional angles, i.e. angle reflected at the knee joint from a foot-atop-bench position, were measured for each subject. The subjects were then assigned to tasks. The HST was administered in the following four tasks to each subject:

- conventional angle 20 in. (50.8 cm) (N),
- conventional angle + 10 degrees (N + 10),
- conventional angle - 10 degrees (N - 10),
- mean of all conventional angles (\bar{N} = 103°).

Subjects performed each task in randomized sequence. An easily adjustable bench facilitated the changing of bench heights.

The experiment was conducted during a nine-week period. Pulse frequency in recovery was obtained by palpation of the radial artery. Testing was conducted in a room in which the ambient temperature fluctuated between 25.3°C and 26.4°C. In order to minimize the effect of diurnal variation, testing was conducted between 2 p.m. and 4 p.m.

Table 1. Physical characteristics of the subjects (33)

	Age (years)	Weight (kg)	Height (cm)	Length of femur (cm)	Length of tibia (cm)
Mean	20.63	77.60	177.27	44.36	38.65
Standard deviation	2.080	9.397	6.979	4.538	4.244
Range	18-27	67.6-107.1	168-195	39.5-53.4	30.6-58.6

3. Results and Discussion

In attempting to find whether or not the angle of the knee joint, created while stepping on the bench in the HST, had a significant effect on the Fitness Index Scores, three separate statistical measures were applied: repeated measures one-way classification analysis of variance, a one-way classification analysis of variance, and an analysis of covariance.

In Table 2 are presented the means of the Fitness Index Scores attained within the different treatments.

Table 2. Means of the Fitness Index Scores attained within the different treatments (N = 33)

	Normal angle	Normal angle + 10°	Normal angle - 10°	Mean angle
Mean score	76.988	73.190	82.922	78.887
Standard deviation	7.432	6.782	9.926	10.311
Standard error	0.914	0.834	1.221	1.269

From Table 2, it appears that the lowest scores were obtained in the $N+10^\circ$ angle. Stated another way, when the subject had to bend his knee to the largest extent, his scores dropped. Exactly the opposite result was obtained when the angle of the knee joint was decreased to $N-10^\circ$.

In Table 3 are presented the findings according to a repeated measures, one-way classification analysis of variance.

Table 3. Repeated measures one-way classification analysis of variance to test the significance of the differences between the means of the HST

Source of Variation	Sum of squares	df	Variance	F
Between subjects	8976-111	32		
Within subjects	2721-269	99		
Treatment	1598-740	3	532-913	48-1433*
Residual	1122-529	96	11-693	
Total	11699-3798	131		

* F ratio needed for significance at the 0-01 level of confidence = 4-01.

From the statistical results observed in Table 3 it is obvious that the differences between the different means of the HST scores are significant beyond the 0-01 level of confidence and that the results obtained are not due to chance alone but there were cause and effect factors present in the study.

The findings according to a one-way classification analysis of variance appear in Table 4.

Table 4. One-way classification analysis of variance to test the significance of the differences between the means of the HST scores obtained at the different knee-joint angles

Source of Variation	Sum of squares	df	Variance	F
Between subjects	1598-7172	3	532-9057	6-7532*
Within subjects	10100-6316	128	78-91111	
Total	11699-3488	131		

* F ratio needed for significance at the 0-01 level of confidence = 3-93.

It is evident from Table 4 that the differences between the means of the HST scores obtained at the different knee-joint angles are significant beyond the 0-01 level of confidence.

In both statistical methods, the *F* ratios were significant, but it is interesting to note that the *F* ratio obtained by one-way analysis of variance is much smaller than the *F* ratio of the repeated measures one-way classification analysis of variance. The reason might be that the interaction factor was not considered in the one-way classification analysis of variance and was considered in the repeated measures one-way classification analysis of variance. This resulted in a different error term which, in consequence, increased the *F* ratio value for the repeated measures method.

Table 5 presents the findings according to the analysis of covariance with weight as the covariate.

The analysis of covariance was employed in order to determine whether or not the weight of the subjects exerted any influence on the scores when compared to one-way classification analysis of variance. The *F* ratio of 7-009 in the analysis of covariance when compared to *F* ratio of 6-7532 in the one-way classification analysis of variance, revealed that removing the covariate (the weight of the individual) refined to a greater extent the differences which were more angle dependent.

Table 5. Analysis of covariance to remove the bias introduced by differences in initial level of body weight and differences between the scores obtained at the different knee-joint angles

	Variation Between	Variation Within	Total
Sum of squares X	1598-72	10100-63	11699-35
Sum of squares Y	1-321	11659-789	11661-110
Sum of products	0-276	2276-064	2276-340
Degrees of freedom	3	127	130
Adjusted sum of squares	1598-878	9656-221	11255-099
Variance estimates	532-959	76-033	

$F = 7-009^*$

* F ratio needed for significance at the 0-01 level of confidence = 3-93.

Since the *F* ratios were calculated to be 48-1433 for the repeated measures one-way classification analysis of variance; 6-7532 for the one-way classification analysis of variance; and 7-009 for the analysis of covariance, it was revealed that there was a significant difference at the 0-01 level of confidence between the various HST index scores obtained in the different angles.

A Newman-Keuls multiple comparison test disclosed that in the repeated measures one-way classification analysis of variance, all angles except between N and N angles were significantly different at the 0-01 level of confidence. In the one-way classification analysis of variance, only the difference between the extreme angles, $N-10^\circ$ and $N+10^\circ$, reached significance at 0-01 level of confidence. The difference between the $N+10^\circ$ and N , and the N and $N-10^\circ$ angles was significant at the 0-05 level of confidence.

These data support the view that HST scores are not comparable for persons who flexed their legs at differing angles. It appeared that the larger the angle (fully extended leg = 0 degrees knee-joint angle), the more difficult the performance as reflected in lower HST scores. The *F* ratio of 7-009 in the analysis of covariance when compared to *F* ratio of 6-7532 in the one-way classification analysis of variance, revealed that removing the covariate (the weight of the individual) refined to a greater extent the differences which were more angle dependent. Hence, the weight of the individual might also affect the scores.

In the present study, all subjects performed all treatments, rather than selecting subjects for each particular treatment. This methodology was utilized in order to compare results of the same subjects relative to the performance of the HST at different angles.

Based on the findings of this study, persons who perform the HST in different knee-joint angles have indices which are not measuring cardiopulmonary or physical fitness on the same scale if, in fact, the HST measures either. The larger the angle, the more difficult will be the performance. It could be said that any test of similar nature which is performed on a bench or a stool has the same disadvantage.

The standard deviation of the Mean Angle (\bar{N}) contained the largest value (see Table 2). This is interpreted as a better test score when compared with the variation of the scores obtained from the conventional administration of the HST. Obviously, it is more practical to standardize an object to a subject; however, greater validity is assured by standardizing a subject to an object.

By equating this variable, i.e. the knee-joint angle, the evaluating and comparing power of the HST may be increased.

In the present study, the standardized angle was 103° which was equal to the mean of the normal angles of all subjects; however, it is possible that other angles might suit the purpose better. It appears from this study that the knee-joint angle or the height of the bench are not linear with regard to the cardiopulmonary stress.

The author wishes to acknowledge the acceptance of constructive criticism and guidance provided by Dr. Benjamin Ricci.

Le but de cette étude était de déterminer si l'angle de l'articulation du genou avait une influence sur la valeur de l'indice d'aptitude physique obtenu à partir du Harvard Step Test (H.S.T.). Trente-trois jeunes sujets masculins ont été utilisés pour cette étude. Le H.S.T. a été administré avec quatre angles différents de l'articulation du genou.

Des techniques d'analyse de la variance et d'analyse de la covariance ont été utilisées pour analyser les résultats obtenus au cours des neuf semaines d'expérimentation. Tous les tests statistiques se sont avérés significatifs à .01. Se fondant sur ces constatations, il s'avère que des personnes qui effectuent le H.S.T. avec des angles différents de l'articulation du genou ont des indices qui ne mesurent pas le stress cardiopulmonaire sur une même échelle. Un H.S.T. basé sur une standardisation des angles de l'articulation du genou permettrait d'augmenter les pouvoirs d'estimation et de discrimination du test.

Das Ziel dieser Untersuchung war es, zu bestimmen, ob der Winkel des Kniegelenks den Indexwert des Harvard Step-Tests (HST) beeinflusst. 33 junge kaukasische männliche Personen wurden verwendet. Der HST wurde mit vier verschiedenen Kniegelenkwinkeln durchgeführt. Eine Ein-Weg-Klassifikations-Varianzanalyse wiederholter Messungen, eine Ein-Weg-Klassifikations-Varianzanalyse und eine Analyse der Kovarianz wurden verwendet, um die während 9 Wochen erhaltenen Daten zu analysieren. Alle Tests ergaben signifikante F-Verhältnisse auf dem 0.01 Niveau der Zuverlässigkeit. Aufgrund dieser Befunde haben Personen, die den HST mit verschiedenen Kniegelenkwinkeln ausführen, Indizes, welche die kardiopulmonale Anstrengung nicht mit der gleichen Skala messen. Der HST würde bei Standardisierung des Kniegelenkwinkels einen grösseren Aussagewert und eine bessere Vergleichbarkeit erhalten.

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