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Task-specific symptomatology changes resulting from prolonged submaximal bicycle riding

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ABSTRACT. Key Cluster Analysis of 31 selected symptoms in the physical activity questionnaire of Kinsman et al. (9) separated the Fatigue Cluster into two components subsequently labeled General Fatigue and Leg Fatigue. Following prolonged strenuous exercise on a bicycle ergometer at 56% of estimated max$\dot{V}O_2$, these symptom clusters increased significantly relative to initial values; they also had high coefficients of stability and test-retest reliabilities. The heart rate increment from the 5th to the 13th min of effort was correlated —.41 with ride duration, .38 with Leg Fatigue, and .35 with General Fatigue. This suggests that riders of shorter duration have greater heart rate increases and larger scores for the Leg and General Fatigue components than do longer riders.
Personality differences that could account for the wide range of quitting times observed at 56% max$\dot{V}O_2$, and physiological mechanisms underlying the subjective reports of physical fatigue are discussed.

INTRODUCTION

The word Fatigue is commonly used to label different events occurring at diverse levels of biological organization. Fatigue often implies changes in function, from the failure of a muscle to maintain contraction to decrements in the work performance of the whole organism. It also sometimes refers to subjective responses to prolonged mental or physical work. Bartley (3) has suggested labeling the former class of events "impairments," while restricting "fatigue" to the subjective responses to work. However, to define fatigue in this way depends upon an adequate means of measurement.

The measurement of subjective events is necessarily indirect, depending on self-report techniques. Attempts to develop self-report methods measuring subjective responses to physical work have generally used one dimensional scalings of tiredness (5,11,12). While useful, such unidimensional scalings ignore the complexity of subjective responses to strenuous exercise. Recently, we (9) have derived a self-report Physical Activity Questionnaire (PAQ) consisting of three independent sets of scaled adjective items labeled Fatigue, Task Aversion, and Motivation. Although the response to each of these sets of adjectives changed during exercise only one set, Fatigue, appears to describe physical fatigue.

The objective of this paper is to test the hypothesis that within the set of Fatigue items there exists a general and a leg-specific class of subjective reports, and that the latter measures unique aspects of fatigue during bicycle riding.

METHODS

Preliminary medical examination eliminated subjects with physical conditions which precluded safe participation in strenuous exercise. On two occasions, 64 of the screened male volunteers [age (means ± SD) of 22.9 ± 2.2 years; weight of 73.9 ± 9.1 kg; height of 177.3 ± 6.9 cm] rode an electrically-braked bicycle ergometer at a workload approximately 56% of maximal aerobic power. Ride 1 was performed in the afternoon at a room temperature (mean ± SD) of 79 ± 4°F while Ride 2 was performed in the morning two to four days later at 74 ± 4°F.

Max$\dot{V}O_2$, i.e., maximal aerobic power, was estimated according to Åstrand & Rhyming (1). Heart rate was monitored from ECG recordings during both rides. Subjects were instructed to continue riding until they became so discomforted that they felt it necessary to stop. Since the experiment formed part of a larger study to assess personality and performance, the content of instructions required individual interpretation and was not highly motivating.

The 63-item Initial Adjective List (IAL) was given to subjects immediately preceeding and following each ride. For the pre-ride IAL, the subjects were instructed to report how they felt at that moment; however the end-of-ride IAL asked subjects to indicate how they

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felt at the moment they stopped riding. The IAL was constructed in three stages: first, a pool of 83 adjectives or adjective phrases was compiled from (a) the initial fatigue checklists developed by Pearson and Byars (13) and by McNelly (12), (b) the General High Altitude Questionnaire (8), and (c) a list developed by this research team. Second, content evaluation eliminated ambiguous and redundant adjectives, leaving 63 items (Table 1). Finally, each adjective was placed along a dimension of severity by using a 5-point Likert-type scale (1 = absent; 5 = severe). All adjectives were assigned to one of three *a priori* categories (mood, somatic discomfort, and arousal). Based on these categories, items were randomly ordered to minimize a set response to any one category. Half of the items of the six page IAL were scaled from severe (5) to absent (1), while the rest were scaled in reverse order. The order of presentation of the items within the IAL was controlled in part for set response and for differences in time from end-of-ride by randomly assigning one of six page sequences to each subject. Experience prior to the study indicated that after two practice sessions the IAL could be completed comfortably within a two-minute period.

TABLE 1. Items of the Initial Adjective List.[a]

1. Perspiring	33. Bored
2. Sweating	34. Lively
3. Hard to Keep Going	35. Concentration
4. Weak Legs	36. Lazy
5. Working Hard	37. Easy to Think
6. Heavy Legs	38. Happy
7. Out of Gas	39. Test Attention
8. Thirsty	40. Drive
9. Sore from Sitting	41. Vigorous
10. Rather Quit	42. Pleased
11. Drained	43. Head Tightening
12. Physically Tired	44. Determined
13. Shaky Legs	45. Active
14. Weak	46. Drowsy
15. Worn Out	47. Abdominal Cramps
16. Dry Mouth	48. Nauseated
17. Heart Pounding	49. Worried
18. Tired	50. Backache
19. Short of Breath	51. Abdominal Pains
20. Muscle Aches	52. Headache
21. Weary	53. Satisfied
22. Panting	54. Fidgety
23. Leg Aches	55. Angry
24. Refreshed	56. Easily Distracted
25. Comfortable	57. Dizzy
26. Breathing Hard	58. Listless
27. Do Something Else	59. Depressed
28. Numbness	60. Tense
29. Easy Going	61. Irritable
30. Leg Twitching	62. Jumpy
31. Leg Cramps	63. Fed Up
32. Muscle Tremors	

[a] Items were ordered according to decreasing mean pre- to end-of-ride change. With the exception of item 27, Do Something Else, items 1-32 were selected for inclusion in the analyses.

Data analysis was restricted to the 31 items showing the most change from pre- to post-exercise values. Key cluster analyses (17) were performed on this set of items for the end-of-ride data to test the hypothesis that general and leg specific fatigue factors group into unique clusters. The analysis sought to identify non-redundant sets of items, i.e. clusters, with (a) the items defining a cluster having a similar profile of correlation coefficients across all 31 items of the IAL, (b) maximum independence between clusters, and (c) maximum accountability of total variance. In an earlier report, (9) end-of-Ride 2 was judged to have a more independent and conceptionally clear cluster structure than Ride 1. Therefore, present analyses were based on the end-of-Ride 2 data.

RESULTS

Ride durations were in close agreement for both tests. The mean (± SD) was 36 ± 24 min for Ride 1 and 36 ± 22 min for Ride 2, with a range from 1½ min to 98 min for both rides. The correlation between times for Ride 1 and 2 was .80.

The mean heart rate at 5 min was 137 ± 11 (N = 53) and 133 ± 11 (N = 54) for Rides 1 and 2, respectively. From the 5th to 13th min of both rides, the mean heart rate increment (HRI) during each minute was 0.8 ± 0.7 beats, with respective ranges from 0.0 to 2.5 beats and from 0.0 to 2.8 beats for Rides 1 and 2. During Ride 2, HRI was significantly correlated to ride duration ($r = -.41$, $p < .05$). That is, subjects with a longer ride tended to have a smaller HRI early in the ride than those with a ride of shorter duration.

A key-cluster analysis (17) identified 5 symptom clusters labeled CI to CV, each comprised of mutually collinear defining items.[2] Cluster CV was eliminated, since it comprised a meaningless pair of items having a low alpha reliability (.57).[3] Three highly collinear[4] non-defining items (Muscle Tremors, Heavy Legs, and Shaky Legs) were added to the defining items of CII since they improved the reliability and the conceptual content of this cluster. After making these changes, a four-cluster (CI to CIV) *preset* analysis was performed. Results are summarized in Table 2. On a conceptual basis, the clusters were labeled Task Aversion (CI), Leg Fatigue (CII), General Fatigue (CIII), and Thirst (CIV).

The orthogonal and oblique factor coefficients for the defining items are higher within than between clusters.[5] Partial communalities (h^2) for the definers ranged from .94 to .36 for CI, .70 to .60 for CII, .81 to .72 for CIII, and .82 to .57 for CIV. The cluster CII reproduced the largest percentage of the initial correlation matrix, 62%, while CI, CIII, and CIV reproduced 21%, 58%, and 22%, respectively. Of the residual correlations remaining after factoring four clusters, 92% were less than .10, indicating that clusters CI to CIV were able to account for nearly all of the initial correlation matrix. Since thirst (CIV) is a doublet with no collinear non-defining items, it was excluded from subsequent analyses.

TABLE 2. Summary of Preset Key Cluster Analysis for Ride 2.

Variables	Preset Definers	Orthogonal Factor Coefficients & Communalities					Residual Correlations			Oblique Factor Coefficients			
		CI	CII	CIII	CIV	h^2	<.1	<.2	<.3	CI	CII	CIII	CIV
Task Aversion (CI)													
31 Sweating	CI	.96	—.10	—.21	—.06	.94	29	2	0	.96	.25	.25	.20
1 Perspiring	CI	.87	—.15	—.20	—.08	.82	29	2	0	.87	.16	.19	.13
9 Rather Quit	CI	.59	.12	.30	—.11	.52	27	4	0	.59	.34	.58	.24
17 Comfortable	CI	.52	.12	.11	.25	.36	28	3	0	.52	.30	.39	.44
23 Refreshed		.44	.12	.24	.05	.27	26	5	0	.44	.27	.44	.28
Leg Fatigue (CII)													
18 Leg Cramps	CII	.21	.81	.01	—.04	.70	31	0	0	.21	.83	.51	.42
21 Leg Twitching	CII	.23	.78	—.06	—.11	.68	31	0	0	.23	.82	.46	.35
3 Muscle Tremors	CII (New)	.43	.71	—.11	.04	.70	27	4	0	.43	.82	.48	.50
10 Aching Muscles	CII	.35	.74	—.06	.02	.67	30	1	0	.35	.81	.49	.47
6 Legs Aching	CII	.36	.74	—.09	.10	.69	29	2	0	.36	.81	.48	.38
25 Weak Legs		.36	.70	.29	.04	.70	30	1	0	.36	.78	.73	.52
13 Heavy Legs	CII (New)	.17	.75	.17	.13	.63	28	3	0	.17	.76	.58	.53
27 Shaky Legs	CII (New)	.24	.72	.13	.06	.60	28	3	0	.25	.76	.57	.49
2 Short of Breath		.46	.63	.12	.01	.63	27	4	0	.46	.76	.62	.48
30 Panting		.41	.62	.26	—.01	.62	26	4	1	.42	.73	.69	.47
20 Hard to Breathe		.31	.37	.21	.09	.52	26	5	0	.32	.68	.61	.50
22 Heart Pounding		.34	.33	.19	.04	.48	25	3	3	.34	.66	.59	.45
14 Numbness		.21	.19	.00	.06	.24	28	3	0	.21	.48	.32	.32
General Fatigue (CIII)													
15 Worn Out	CIII	.42	.56	.56	.11	.81	31	0	0	.42	.67	.88	.58
24 Tired	CIII	.39	.40	.66	—.04	.75	31	0	0	.39	.51	.86	.40
7 Weary	CIII	.50	.32	.60	—.08	.72	30	1	0	.50	.48	.84	.35
8 Out of Gas	CIII	.34	.43	.65	.01	.72	31	0	0	.34	.52	.84	.43
5 Physically Tired		.58	.35	.44	.12	.67	30	1	0	.58	.54	.77	.52
4 Weak		.58	.38	.37	.03	.61	29	2	0	.58	.56	.73	.52
26 Drained		.47	.45	.32	.14	.54	24	7	0	.47	.59	.68	.53
28 Hard to Keep Going		.58	.29	.32	—.18	.52	22	8	1	.58	.48	.61	.24
19 Working Hard		.23	.36	.27	—.07	.26	28	2	1	.23	.42	.48	.24
Thirst (CIV)													
29 Dry Mouth	CIV	.35	.50	.18	.64	.82	31	0	0	.35	.59	.54	.92
16 Thirsty	CIV	.24	.30	.10	.65	.57	31	0	0	.24	.36	.33	.78
% Reproduction of Initial Correlation Matrix		21	62	58	22								
% of Total Residuals							91.6	7.7	0.7				

In key cluster analysis, the defining items of each cluster are selected on the basis of their collinearity and relative independence from items defining other clusters. Figure 1. Only the first four defining items of each cluster are plotted for visual clarity. Within clusters CII and CIII, the correlation profiles appear very similar indicating high collinearity; however, within cluster CI, the items appear somewhat less collinear. In agreement with the figure, average indices of collinearity, P^2 (where $0 \leq P^2 \leq 1$), were .78, .97, and .92 for clusters CI, CII, and CIII, respectively.

Further demonstration of item clustering is presented in the three-dimensional spherical analysis (SPAN) diagram shown in Figure 2. The points, I, II, and III are the termini of three orthogonal vectors extending from the center to the surface of a sphere which geometrically represents the score space. If Task Aversion (CI), Leg Fatigue (CII), and General Fatigue (CIII) clusters were completely independent of one another, they would group around the termini of the orthogonal vectors. While three relatively tight, collinear clusters appear in the SPAN diagram, they are not highly independent. According to the position on the sphere, Task Aversion is somewhat related to General Fatigue, while Leg Fatigue is much more related to General Fatigue. Leg Fatigue, therefore, appears to be a task-specific component of the PAQ Fatigue Cluster.

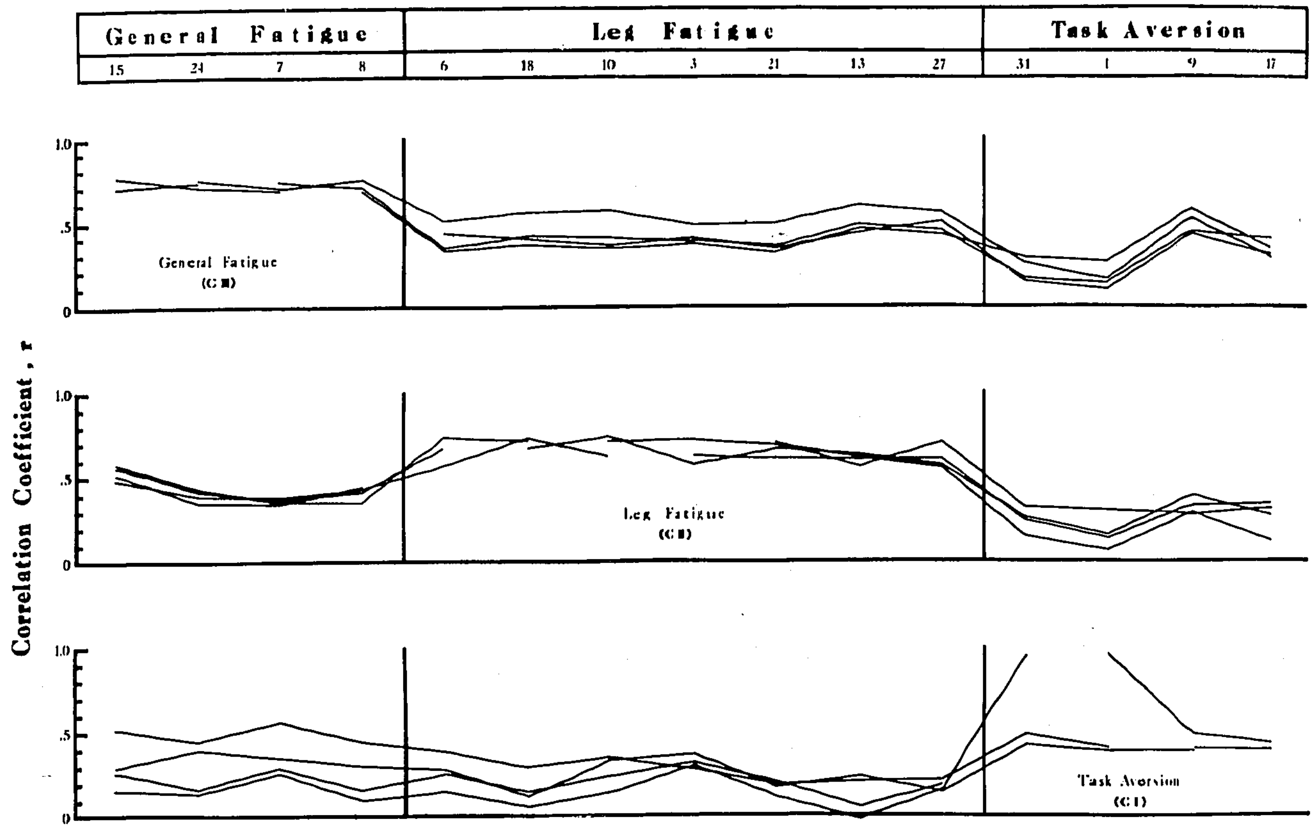

Figure 1 — Collinearity of the three Physical Activity Questionnaire clusters for end-of-Ride 2. Note that only the first four items of each cluster are presented, and the correlation coefficient of the item with itself, being 1.00, was excluded. See Table 2 for the items that comprised each cluster.

Collinearity within clusters implies, but is not the same as, internal consistency. Reliability coefficients and inter-correlations of the raw cluster scores for Rides 1 and 2 are presented in Table 3. For both rides, cluster reliabilities shown on the diagonals of the table are high, ranging from .82 to .92. Leg Fatigue and General Fatigue are highly related for both rides, although less so for Ride 2 ($r = .58$) than for Ride 1 ($r = .72$). Task Aversion, on the other hand, was found to be only moderately related to both Leg Fatigue and General Fatigue.

Replicability of these findings is of primary interest. By performing the identical *preset* key cluster analysis on end-of-Rides 1 and 2, the similarity for both rides may be evaluated directly through *comparative* key-cluster analysis (17). An index of similarity, COS θ (where $0 \leq \text{COS}\ \theta \leq 1$), may be computed to compare the position of any two clusters in three-dimensional space as shown in the SPAN diagram of Figure 2. The COS θ values for end-of-Rides 1 and 2 were .75, .82, and .81 for clusters CI, CII, and CIII, respectively. A more routine index of the replicability of these results may be made by calculating the test-retest reliability for each cluster between end-of-Rides 1 and 2. Test-retest reliabilities for clusters CI, CII, and CIII were .75, .84, and .74, respectively. Thus, the symptom clusters show excellent agreement for both rides.

Cluster score validity can be determined in part by comparing cluster score changes from pre- to end-of-ride (Table 4). Paired *t*-tests for both rides indicate that the end-of-ride scores increased significantly for each cluster (all p's $\leq .001$). These increases were, respectively, 69%, 91% and 57% for clusters CI, CII, and CIII during Ride 1, and 92%, 87% and 66% during Ride 2.

Results of the preset key cluster analysis (Table 2) identified 7 defining and 6 non-defining, highly collinear items within the Leg Fatigue cluster. Since the item Numbness appears to be unique, it was not considered further. Conceptually, these items can be divided into leg and cardiopulmonary symptoms. Within the leg symptoms, three groups of items are identifiable on the basis of mean end-of-ride values (Table 5): (a) Leg Cramps, Leg Twitching, and Muscle Tremors with a mean of 1.96; (b) Aching Muscles and Leg Aches with a mean of 2.42; and (c) Weak Legs, Heavy Legs, and Shaky Legs with a mean of 2.93.

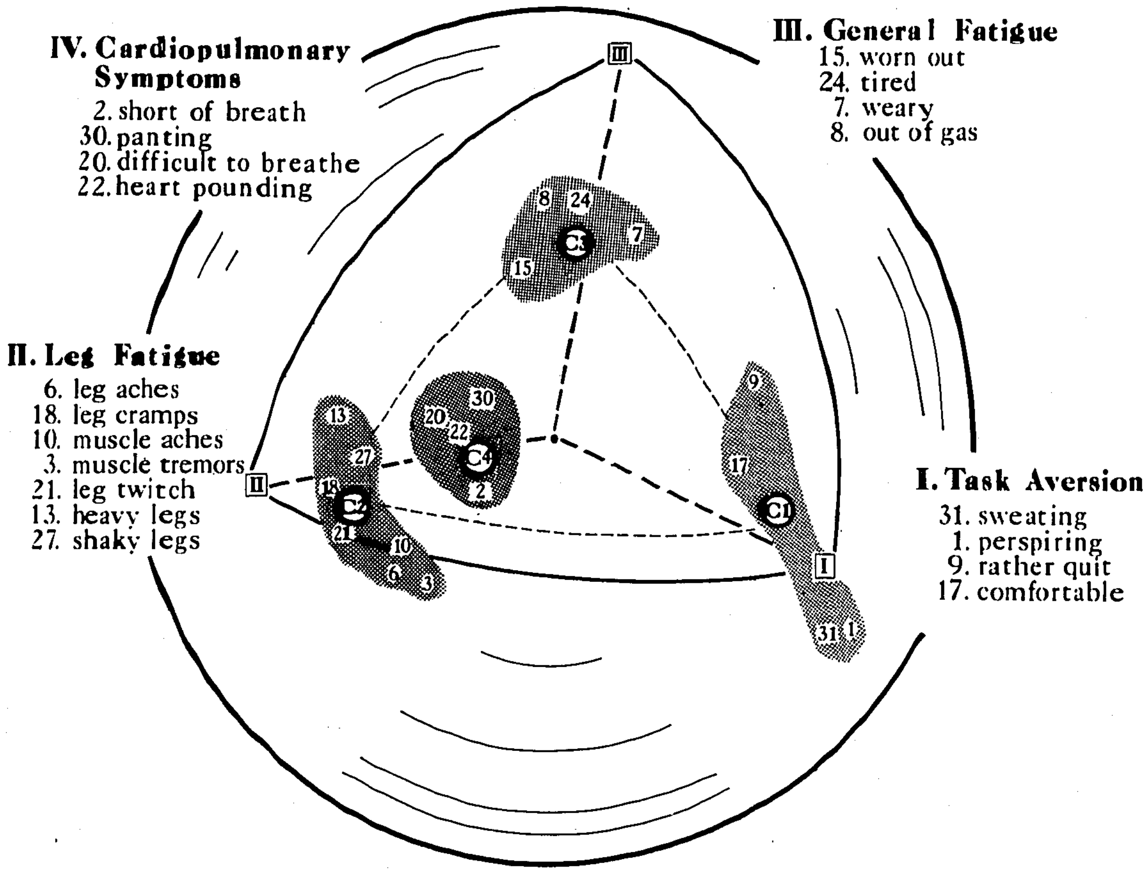

Figure 2 — Spherical analysis (SPAN) diagram of four clusters at end-of-ride 2. Note that the cluster labeled Cardiopulmonary Symptoms (IV) is not the same cluster labeled CIV in Table 2 and the text.

The cardiopulmonary symptoms, Short of Breath, Panting, Difficult to Breathe, and Heart Pounding, appear to represent a conceptually unique set of items within the Leg Fatigue cluster, having an end-of-ride mean of 2.26. This set of items also forms a distinct grouping on the SPAN diagram, located apart from the leg symptoms. Cardiopulmonary symptoms may thus be regarded as another possible component of the PAQ Fatigue Cluster.

To examine the relationships of the end-of-ride cluster scores with ride duration and HRI, correlation coefficients were determined (Table 6). Ride duration was uncorrelated with Task Aversion, Leg Fatigue, or General Fatigue. HRI from 5 to 13 min was significantly related to ride duration and the two components of the Fatigue Cluster but was independent of Task Aversion.

DISCUSSION

The Fatigue Cluster of the Physical Activity Questionnaire (9) has a general and leg-specific component. Each component contains conceptually similar items which have high collinearity and reliability. The ability of the components to measure subjective responses to prolonged work appears validated as scores after both rides increased significantly relative to initial levels. There was more independence between clusters for end-of-Ride 2 than for Ride 1, suggesting that experience in reporting end-of-ride symptomatology is advisable before beginning a study. Yet both Leg Fatigue and General Fatigue demonstrated high stability upon replication, with good agreement of cluster structure between both rides, and test-retest reliability coefficients exceeding .74.

We could find no reports in the literature relating the task quantitatively to the specific types of symptoms reported. Since bicycle riding is leg dependent, it would be expected to produce the discomforting symptoms of the Leg Fatigue Cluster. Our results also showed a correlation of .58 between Leg Fatigue and General Fatigue, indicating a 34% overlap of variability between the two components. The specific manner in which Leg Fatigue contributes to overall symptoms of General Fatigue cannot be evaluated from the current data. Further research should be directed at studying the effects of age, physical conditioning (especially endurance capacity), and disease on these symptoms of fatigue.

TABLE 3. Cluster Score Correlations and Reliabilities for Ride 2.[a]

	Task Aversion (CI)	Leg Fatigue (CII)	General Fatigue (CIII)
RIDE 1			
Task Aversion (CI)	.82	.26	.57
Leg Fatigue (CII)		.88	.72
General Fatigue (CIII)			.87
RIDE 2			
Task Aversion (CI)	.86	.32	.43
Leg Fatigue (CII)		.93	.58
General Fatigue (CIII)			.92

[a] Alpha reliabilities are underlined on the diagonal of the table for each ride.

TABLE 4. Cluster Score Means and Standard Deviations.[a,b]

	Ride 1		Ride 2	
	Pre	End	Pre	End
Task Aversion (CI)	9.16±2.55	15.44±2.89	8.09±2.19	15.53±2.95
Leg Fatigue (CII)	8.42±2.40	16.09±4.78	8.75±2.81	16.36±5.66
General Fatigue (CIII)	9.00±3.69	14.11±3.16	8.38±3.23	13.88±3.69

[a] Task Aversion (CI), Leg Fatigue (CII), and General Fatigue (CIII) have 4, 7, and 4 items, respectively. The score could range from 4 to 20 for Task Aversion, 7 to 35 for Leg Fatigue, and 4 to 20 for General Fatigue.

[b] Data are based on 64 subjects with several missing item values of 4 subjects being replaced by the mean item value.

TABLE 5. Leg Fatigue Item Means and Standard Deviations for Ride 2.[a]

No.	Item	Pre	End
18.	Leg Cramps	1.14 ± .43	1.97 ± .98
21.	Leg Twitching	1.22 ± .65	2.00 ± 1.05
3.	Muscle Tremors	1.11 ± .36	1.90 ± .82
10.	Aching Muscles	1.42 ± .71	2.45 ± .96
6.	Leg Aching	1.31 ± .53	2.39 ± .99
25.	Weak Legs	1.39 ± .61	3.16 ± 1.07
13.	Heavy Legs	1.34 ± .60	2.95 ± 1.03
27.	Shaky Legs	1.20 ± .48	2.69 ± 1.04
2.	Short of Breath	1.06 ± .25	2.32 ± 1.05
30.	Panting	1.04 ± .21	2.22 ± 1.00
20.	Hard to Breathe	1.06 ± .24	2.12 ± 1.03
22.	Heart Pounding	1.19 ± .47	2.39 ± .94

[a] Data are based on 64 subjects, where various missing items of subjects were replaced by the mean item value.

TABLE 6. Correlations between Ride Duration, Heart Rate Increment, and Cluster Scores for Ride 2.[a]

	HRI	Task Aversion (CI)	Leg Fatigue (CII)	General Fatigue (CIII)
Ride Duration	—.41[b]	.06	—.21	—.16
HRI		.14	.38[b]	.35[b]

[a] All correlations with HRI are based on the 55 subjects having heart rate data at the 5th and 13th min. All other correlations are based on 64 subjects.

[b] Significant at $p < .05$ level.

General Fatigue and Leg Fatigue were independent of ride duration with increased end-of-ride scores of the same magnitude reported for rides of both short and long duration. This suggests that the decision to stop riding was associated with a specific level of reported leg and general fatigue symptoms.

Endurance fitness, as defined by ride duration, is related to the maintenance of a steady work heart rate. HRI and scores for both Leg and General Fatigue were slightly, but significantly related: the more fit for endurance, the lower the scores tend to be for these symptom clusters.

Of the many possible physiological processes underlying the reported changes in symptomatology, only changes in *heart rate* were evaluated. Further research should evaluate the relationship(s) of symptomatology changes to other underlying physiological processes such as changes in EMG activity (4,7,10,11,15), redistribution of effort to red muscle hyperpolarization of muscle membrane (2), increased motoneuron inhibition (2), and altered sensitivity of chemoreceptors.

Two additional sets of items were identified as potential PAQ Clusters. A group of cardiopulmonary symptoms associated with the Leg Fatigue cluster appeared to have a distinct oblique factor structure separate from Leg and General Fatigue (Figure 2). Two collinear items, Thirsty and Dry Mouth, were also described by the empirical key cluster analysis. These sets of items need further clarification.

The Task Aversion cluster represents a reliable set of items very similar to that found before (9). Correlation coefficients and the SPAN diagram show that Task Aversion is moderately related to General Fatigue but only slightly related to Leg Fatigue. Sweating and Perspiring, both key definers of Task Aversion, were poorly related to either Leg or General Fatigue. Task Aversion was independent of both ride duration and HRI.

High variability between subject symptom scores is illustrated by the standard deviation of the Leg Fatigue cluster. This cluster of 7 items had a mean score for end-of-Ride 2 of 16.4 ± 5.7 resulting in a coefficient of variation ($SD/\overline{X}$ x 100) of 35%. That is, both long and short riders reported high and low scores. However, the subjects did report highly reliable, collinear cluster scores.

Quitting times were as heterogeneous as the subject's scores for the symptomatology clusters. 17% of the variability in ride duration was accounted for by the HRI criterion of endurance fitness. A substantial amount of the remaining variability could be attributable to the motivational and personality characteristics of the subject. This was expected in that the instructions required individual interpretation by each subject and did not explicitly demand riding to complete exhaustion. Petrie (14) has reported a relationship between tolerance to discomforting conditions and two extreme personality types called "reducers" and "augmenters." "Reducers" tend to minimize the effects of discomfort and have been described as extroverted, active, and likely to have participated in athletics; at the other extreme, individuals labeled "augmenters" tend to exaggerate stimulation, be introverted, less active, and less likely to have participated in athletics. Accordingly, during exercise some individuals may tend to report less subjective discomfort and perform longer than anticipated by physiological indices of endurance fitness while others may exaggerate the reports of subjective discomfort and quit earlier than anticipated. Components of the PAQ Fatigue Cluster, as described in this paper, could be used to evaluate this possibility in future studies.

In summary, the results of this paper and the previous article (9) strongly support the use of symptomatology reports as a reliable means to study subjective responses to physical work and to assess the relationship(s) of work tolerance, such as ride duration, to these reports.

[2] Key cluster factoring selects as definers of clusters the most collinear and independent subsets of variables within the multivariate score space. The degree of collinearity is described by an index of proportionality (P^2, with limits of 0.0 to 1.0). P^2 reflects the extent to which two variables have the same pattern of correlations across all other variables included in the multivariate score space. For our analyses, defining items of each cluster were selected according to the standard collinearity criteria used by BCTRY Key Cluster Analysis. See Tryon & Bailey (16), pp 289-290) for a detailed account of this procedure.

[3] Alpha reliability is $r_{tt} = n[1-(\Sigma V_i/_t)]/n-1$ where V_i is the item score variance and V_t is the total composite score variance. This form of the reliability coefficient measures the internal consistency, or inter-item agreement, of items comprising the cluster (5, 15).

[4] Collinearity refers to the degree that items within a cluster show similar correlation profiles across the other items as schematized in Figure 1 for end-of-Ride 2 clusters.

[5] In key cluster analysis, hypothetical factors are identified within the score space which are necessarily orthogonal, i.e., independent, with each factor after the first based on the residual correlation matrix. Orthogonal factor coefficients are the *estimated* correlations of any variable with these hypothetical independent factors. Oblique factor coefficients, in contrast, are the *real* correlations between each variable and the actual oblique cluster domain defined by a composite score of the cluster's defining variables. Thus, oblique factor coefficients are neither estimated nor independent of one another, but they represent the real configuration of relationships between each variable and the cluster domains.

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