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Characteristics of subjective symptom changes during prolonged bicycle riding were explored in this study. On two occasions, 64 male subjects (mean age 22·9 years) rode a bicycle ergometer at $55 \cdot 6 \pm 2 \cdot 8\%$ aerobic capacity with instructions to continue riding until it became so discomforting that they felt it necessary to stop. Mean quitting times were 36 ± 24 min and 36 ± 22 min for Rides 1 and 2, respectively. Each item of an initial group of 63 adjectives potentially descriptive of subjective changes during exercise were arranged along a 5-point scale of severity (1 = absent; 5 = severe) and administered before and at the end of both rides.

Through key cluster analysis of the 41 items showing at least 10% change during exercise, an 18 item Physical Activity Questionnaire (PAQ) was derived. It was composed of three unique, collinear symptom clusters labeled Fatigue, Task Aversion, and Motivation. Comparative key cluster analysis showed good similarity between clusters of both rides.

Mean pre- to end-of-ride changes during both rides for the overall PAQ, Fatigue, Task Aversion, and Motivation clusters were 61%, 100%, 69%, and 16%, respectively. Coefficients of stability for the pre- to end-of-ride change of the overall PAQ, Fatigue, and Task Aversion were 0·82, 0·83, and 0·65. The Motivation cluster had a considerably lower coefficient of stability, 0·38, than did the other PAQ clusters. These results suggest that subjective changes during exercise tend to group into unique clusters of symptoms that can be reliably measured.

Introduction

Individuals engaged in sports or any type of physical activity involving prolonged, strenuous exercise must continually determine the level of energy expenditure and the length of time they are willing to participate. In such activities the subjective experience of fatigue could become an important limiting factor. For example, the point at which a person quits might correspond to when he ‘ feels very tired ’ or ‘ worn out ’.

While fatigue has often been discussed as a subjective experience, most current formal definitions of fatigue have referred almost exclusively to events occurring at diverse levels of biological organization. These definitions vary from the failure of *in vitro* muscle preparations to maintain contraction during repeated stimulation up to task impairment of the behaving whole organism (Bartley and Chute 1947, Bartley 1964, Simonson 1971). Subjective symptoms of fatigue have been viewed as difficult to measure adequately. Consequently they have been neglected by most investigations in favour of more directly observable physiological, neurological, or behavioural events (Welford 1966). From the point of view of the *whole person*, however, the subjective experience of fatigue is still the most obvious consequence of prolonged strenuous work.

The investigation of subjective fatigue and its role as a limiting factor in work tolerance can only begin once an adequate means of measurement is developed. A simple, unidimensional scaling of the feeling of tiredness or subjective effort (e.g., Pearson and Byars 1956, Borg 1962) disregards the essential complexity of the range of subjective changes experienced during exercise. Certain types of subjective symptoms occurring with exercise, as noted by Bartley and Chute (1947), should be considered conceptually discrete from the somatic subjective symptoms. Thus, prolonged exercise may also produce subjective symptoms such as boredom or an aversion to the physical activity which may be significantly related to work tolerance.

During work, subjective symptomatology may be hypothesized to be a set of conceptually clear, discrete symptoms which increase together. At a minimum, the means to quantify these subjective changes should be based on an attempt to empirically derive sets, i.e., clusters, of subjective symptoms having (1) relative independence between the symptom sets; (2) adequate internal consistency within sets; and (3) meaningful change for each set during exercise which is consistent upon replication. This study presents the development of such a self-report questionnaire.

Four stages were involved in the development of a Physical Activity Questionnaire; (1) initial selection of a wide range of adjective items potentially descriptive of subjective symptoms experienced during exercise; (2) arrangement of each adjective item along a 5-point scale of severity for presentation in an initial Adjective List; (3) development of a Modified Adjective List through the elimination of all scaled adjective items showing negligible change from rest to the end of two rides to exhaustion on a bicycle ergometer; and (4) derivation of a Physical Activity Questionnaire from the Modified Adjective List by key cluster analysis (Tryon and Bailey 1970).

2. Methods

2.1. *Questionnaire Development*

2.1.1. *Initial item selection*

Initial development of the Physical Activity Questionnaire (PAQ) involved the selection and scaling of a set of adjectives or adjective phrases for an

Table 1. Items presented in the Initial Adjective List[a]

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

[a]Items 1 to 41 inclusive were retained for the Modified Adjective List.

Initial Adjective List which could describe the subjective changes from rest to the end of prolonged physical activity. The adjective items for the Initial Adjective List were assembled from previously reported measures of fatigue (Pearson and Byars 1956, McNelly 1966), the General High Altitude Questionnaire (Evans 1966), and a large group of descriptive adjective items assembled by this research team. Preliminary review of the adjective set eliminated any obviously ambiguous or redundant items. Table 1 lists the 63 adjective items selected for inclusion in the Initial Adjective List.

2.1.2. *Initial Adjective List* (IAL)

The descriptive items were then arranged along a 5-point continuum (scale) of severity by using appropriate modifiers ranging from absent (1) to severe (5), according to procedures described by Nowlis and Nowlis (1956). Examples of the scaled items as they appeared in the 6-page IAL booklet are presented in Table 2. In practice, the subject could rate his level of subjective experience by circling the applicable descriptive phrase defining a point along the 5-point scale. The development of response sets were controlled as follows: first, the items were randomized in regard to order of appearance in the IAL; second, order of presentation of items within the IAL was additionally controlled by randomly assigning one of six page sequences to each subject; finally, half of the items of the IAL were scaled from absent to severe (1 to 5) while the remainder were scaled from severe to absent (5 to 1). Experience prior to the study indicated that after two practice presentations the IAL could be completed comfortably within a two-minute period.

2.2. *Experimental Procedure*

2.2.1. *Subjects*

Sixty-four (64) male volunteers from the military and civilian personnel of Fitzsimons General Hospital, who ranged in age from 17 to 27 (mean age 22·9 years) were studied. Preliminary medical examinations eliminated those subjects with physical conditions which precluded safe participation in strenuous exercise.

2.2.2. *Bicycle ergometer task and procedure*

On two occasions, all subjects rode the bicycle ergometer at 60 r.p.m. and a workload approximating 56% of their estimated aerobic capacity. During a preliminary session, within 7 to 30 days before the first exercise task, the aerobic capacity ($M\dot{V}_{O_2}$) of each subject was estimated using the bicycle ergometer, work pulse extrapolation method of Åstrand and Ryhming (1954). Two five-minute work periods were used; the second was 300 kpm/min greater than the first. A two-minute rest period separated the work periods. If the two measures of $M\dot{V}_{O_2}$ differed by more than 400 ml/min, aerobic capacity was estimated again at least two days later. Such a resolution was required in only seven of the 64 subjects studied.

Ride 1 was performed in the afternoon at a room temperature ($\pm$ S.D.) of 79 ± 4°F, while Ride 2 was performed in the morning two to four days later at 74 ± 4°F. Each subject was given explicit instructions to ride until he became so discomforted that he felt it was necessary to stop. All subjects were shirtless and dressed in loose fitting surgical pants and low-cut hard soled shoes for the rides.

Immediately before Ride 1, the IAL was completed twice to provide experience with the use of the instrument. The subject then mounted the bicycle ergometer and was given the exercise instructions. The end-of-ride IAL was completed while sitting on the bicycle immediately upon quitting, with the instructions to describe the subjective experience of fatigue while riding just before termination of the ride. The IAL was administered in an identical manner before and at the end of Ride 2.

2.3. *Statistical Analysis*

Key cluster analysis (Tyron and Bailey 1970) was used to identify nonredundant sets of items (clusters) describing unique aspects of subjective change. Briefly, clusters of items were empirically grouped by key cluster analysis according to the following three criteria: (1) high collinearity between items within a cluster, i.e., the items defining the cluster share a similar pattern of correlations across all other items of the score space, (2) maximum independence between clusters of items, and (3) maximum accountability for the total variation within the score space. The empirically determined clusters may be regarded as subscales with scores determined by adding the individual member item values. All statistical analyses for this study used the computer programs of the BC TRY System which is described in detail in Tryon and Bailey (1970).

3. Results

3.1. *Modified Adjective List (MAL)*

Items retained for the MAL were those showing appreciable pre-ride to end-of-ride changes. Selection was made, first, by ordering all items on the IAL according to their mean pre- to end-of-ride changes. Of the original IAL items, 18 showed less than a criterion of 10% change from pre- to end-of-ride and were excluded from the MAL. Second, four additional items of the IAL were apparently redundant and were excluded from the MAL in favour of similar items which showed at least a 4% greater pre- to end-of-ride change. For the 22 IAL items excluded from the MAL, the pre- to end-of-ride change ranged from 0% to 28% (mean 10·4%), while for the items included in the MAL, the pre- to end-or-ride change ranged from 10% to 84% (mean 39·9%).

Figure 1 depicts characteristic pre- to end-of-ride changes for the MAL items. The items categorized into three groups, i.e., Type 1, 3, and 1–3, based on the modal pre-ride item scale-point choice. For Type 1 items, the pre-ride modal choice was 1 on the 5-point scale. Twenty-one items of the MAL were Type 1 with a mean pre- to end-of-ride change of 45·2% for both rides. Type 3 items, of which there were ten on the MAL, had a modal value of 3 on the 5-point scale and a mean change of 36·6%. Type 1–3 items were bimodal at scale points 1 and 3 during rest. Ten Type 1–3 items were on the MAL having a mean pre- to end-of-ride change of 31·9%. The response to the Type 1–3 items was quite variable at rest. However, the items always had a unimodal distribution for end-of-ride and an acceptable pre- to end-of-ride change, suggesting that they should be retained in the MAL.

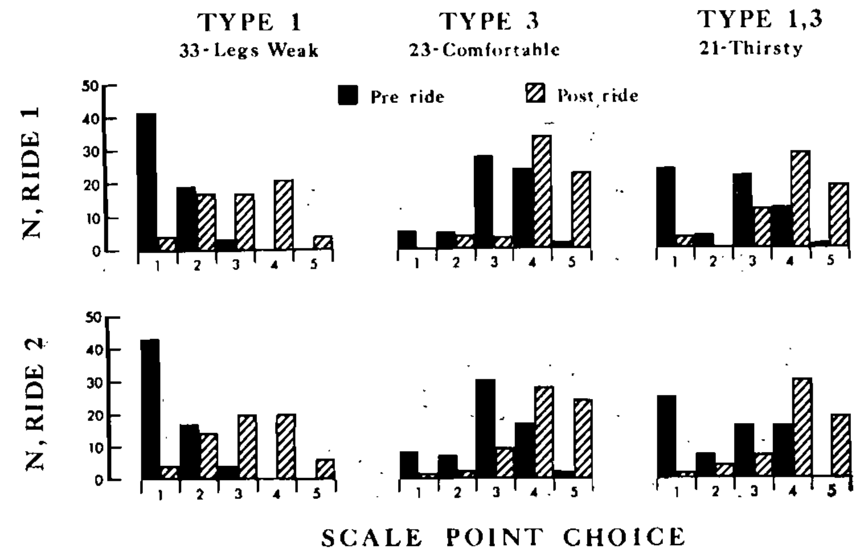

Figure 1. Scale point choice frequencies of the 3 types of items obtained from the pre- and end-of-ride Modified Adjective Lists of Rides 1 and 2.

3.2. *Derivation of the Physical Activity Questionnaire* (*PAQ*)

A key cluster analysis was performed on all items of the two end-of-ride MALs to empirically identify symptom clusters and their defining items. Together, the key cluster analyses identified seven clusters of items initially labeled C1 to C7. Cluster C4 (Ride 1 only) and C5, C6, C7 (Ride 2 only) were dropped from further consideration since they proved to be unique to the analysis of only one of the rides. Additionally, they exhaused less than 8% of the initial estimated communality or were redundant and highly correlated with a more substantial cluster. Only C1; C2, and C3 were common to both rides, although minor differences occurred in regard to the specific defining items of each cluster. In general, the differences between the item content of the clusters for Rides 1 and 2 were resolved by *selecting* for definers of clusters C1, C2, and C3 those items that appeared at least as a defining item of a cluster on one of the rides and a highly collinear nondefiner of the corresponding cluster for the other ride. One exception to this rule was made: Item 13 (Aching Muscles) was a highly collinear nondefiner for both rides, but it appreciably improved the internal consistency of C1. This item was preset as a definer of C1 in subsequent analyses.

The Physical Activity Questionnaire (Table 2), derived on the basis of this analysis, is an 18 item questionnaire providing an overall score and three cluster scores by simple addition of the individual item scores of each cluster. On a conceptual basis, the clusters C1, C2, and C3 were labeled Fatigue, Task Aversion, and Motivation, respectively.

3.3. *PAQ Preset Key Cluster Analysis*

The ability of the PAQ clusters to account for the total variability represented in the initial MAL correlation matrix, was assessed by a pre-set key cluster analysis for both rides. In this analysis of the MAL, clusters C1, C2, and C3 were preset by designating the PAQ items as the cluster definers.

Table 2. Physical Activity Questionnaire derived by key cluster analysis[a]

Item No.[b]	Cluster Membership[c]					
1	C2	Perspiring severely	Perspiring badly	Perspiring some	Perspiring a little	Not perspiring at all
2	C1	Severely short of breath	Quite short of breath	Some shortness of breath	A little short of breath	Not at all short of breath
9	C3	Very lively	A little lively	About as lively as usual	Less lively than usual	Not at all lively
13	C1	Severely aching muscles	Badly aching muscles	Mucles aching some	Mucles aching a little	No aching muscles at all
20	C1	Severely worn out	Badly worn out	Worn out some	A little worn out	Not at all worn out
22	C3	Very determined	A little determined	About usual determination	Less determined than usual	Not at all determined
23	C2	Very comfortable	A little comfortable	About usual comfort	Less comfortable than usual	Not at all comfortable
26	C1	Very hard to breathe	Quite hard to breathe	Some difficulty in breathing	A little difficulty in breathing	Not at all difficult to breathe
29	C3	A lot of drive	A little drive	About average drive	Less drive than usual	No drive at all
30	C1	Severe heart pounding	Bad heart pounding	Some heart pounding	A little heart pounding	No heart pounding at all
33	C1	Severely weak legs	Quite weak legs	Some leg weakness	A little leg weakness	No leg weakness at all
34	C1	Severely drained	Quite drained	Drained some	A little drained	Not drained at all
35	C2	Want to do something else very much	Want to do something else a little	Want to do something else as much as usual	Want to do something else less than usual	Do not want to do something else at all
36	C1	Severely shaky legs	Quite shaky legs	Some leg shakiness	A little leg shakiness	No leg shakiness at all
38	C3	Very vigorous	A little vigorous	About usual vigor	Less vigorous than usual	Not at all vigorous
39	C1	A severely dry mouth	A badly dry mouth	Some dryness in the mouth	A little dryness in the mouth	No dryness in the mouth at all
40	C1	Panting severely	Panting badly	Panting some	Panting a little	Not panting at all
41	C2	Severely sweating	Bad sweating	Some sweating	A little sweating	Not sweating at all

[a]According to order of appearance in the standard form of the Initial Adjective List.
[b]Items 9, 22, 23, 29, and 38 were scaled from 1 (absent) to 5 (severe) while the remainder were scaled from 5 (severe) to 1 (absent).
[c]C1 = Fatigue; C2 = Task Aversion; C3 = Motivation.

Table 3. Summary of preset key cluster analysis for Modified Adjective Checklist of end-of-Ride 2

	Variables	Preset definers[a]	Orthogonal factor coefficients & communalities				Residual correlations			Oblique factor coefficients		
			C1	C2	C3	h^2	< 0·1	< 0·2	< 0·3	C1	C2	C3
Fatigue (C1)												
40	Panting	C1	0·87	0·01	−0·05	0·75	37	4		0·87	0·34	0·18
2	Short of breath	C1	0·86	0·07	0·08	0·74	39	2		0·86	0·39	0·32
20	Worn out	C1	0·82	0·02	0·12	0·68	33	8		0·82	0·29	0·33
34	Drained	C1	0·81	0·08	0·18	0·70	37	4		0·81	0·39	0·40
33	Weak legs	C1	0·81	−0·04	0·12	0·67	37	4		0·81	0·27	0·33
30	Heart pounding	C1	0·75	−0·04	−0·12	0·58	35	5	1	0·75	0·25	0·08
5	Weak		0·74	0·22	0·07	0·61	34	7		0·74	0·49	0·29
26	Difficult to breathe	C1	0·76	−0·02	−0·07	0·58	37	4		0·76	0·27	0·14
3	Muscle tremors		0·76	0·18	−0·29	0·70	29	12		0·76	0·46	−0·05
36	Legs shaky	C1	0·75	−0·06	−0·10	0·57	31	10		0·75	0·22	0·10
13	Aching muscles	C1 (New)	0·74	0·18	−0·07	0·55	34	6	1	0·73	0·26	0·12
24	Leg cramps		0·73	−0·15	−0·27	0·63	33	8		0·73	0·13	−0·09
39	Dry mouth	C1	0·66	0·05	−0·10	0·44	39	1	1	0·66	0·29	0·09
8	Leg aches		0·71	0·05	−0·09	0·51	29	11	1	0·71	0·31	0·11
17	Heavy legs		0·67	−0·13	−0·05	0·47	28	12	1	0·67	0·14	0·12
28	Leg twitching		0·66	−0·02	−0·18	0·48	27	13	1	0·66	0·24	−0·00
18	Numb		0·42	0·11	−0·10	0·20	32	8	1	0·42	0·26	0·03
16	Sore from sitting		0·43	0·09	0·21	0·24	27	11	3	0·43	0·24	0·33
Task Aversion (C2)												
41	Sweating	C2	0·30	0·85	−0·10	0·82	38	3		0·30	0·90	0·09
1	Perspiring	C2	0·21	0·82	−0·09	0·72	36	5		0·21	0·84	0·07
23	Uncomfortable	C2	0·38	0·48	0·12	0·39	37	2	2	0·38	0·59	0·28
19	Easygoing		0·45	0·47	0·24	0·48	33	8		0·45	0·60	0·41
35	Do something else	C2	0·22	0·56	0·07	0·36	36	4	2	0·22	0·60	0·19
15	Bored		0·11	0·45	0·27	0·29	28	11	2	0·11	0·46	0·35

Motivation (C3)											
29 Drive	C3		0·15	0·19	0·74	0·60	37	4		0·15	0·23	0·77
38 Vigorous	C3		0·29	0·06	0·64	0·49	36	5		0·29	0·16	0·70
22 Determined	C3		−0·11	0·04	0·69	0·49	32	8	1	−0·11	0·00	0·63
9 Lively	C3		0·38	0·04	0·48	0·38	36	5		0·38	0·18	0·57
31 Refreshed			0·42	0·26	0·43	0·43	28	12	1	0·42	0·40	0·56
Unique Cluster (C5)												
21 Thirsty	C4	(Out)	0·47	0·05	−0·26	0·29	29	9	3	0·47	0·22	−0·12
39 Dry mouth	C4	(Out)	0·66	0·05	−0·10	0·44	38	2	1	0·66	0·29	0·09
Unique Cluster (C6)												
27 Easy to Concentrate	C5	(Out)	0·40	0·26	0·33	0·34	32	7	2	0·40	0·39	0·45
6 Easy to think	C5	(Out)	0·35	0·20	0·27	0·23	33	7	1	0·35	0·31	0·37
12 Rather quit			0·52	0·42	0·28	0·52	25	15	1	0·52	0·58	0·46
4 Test attention			0·13	0·10	0·19	0·06	25	12	4	0·13	0·14	0·23
Unique Cluster (C7)												
20 Worn out	C6	(Out)	0·82	−0·02	0·12	0·68	33	8		0·82	0·29	0·33
32 Tired	C6	(Out)	0·66	0·10	0·21	0·48	32	7	2	0·66	0·34	0·38
10 Weary	C6	(Out)	0·63	0·16	0·13	0·45	33	6	2	0·63	0·39	0·32
11 Out of gas	C6	(Out)	0·68	−0·00	0·03	0·46	31	8	2	0·68	0·25	0·21
7 Physically tired			0·76	0·20	0·03	0·62	30	11		0·76	0·47	0·25
37 Hard going			0·58	0·35	0·28	0·54	28	11	2	0·58	0·55	0·47
25 Working hard			0·45	0·08	−0·24	0·27	27	12	2	0·45	0·24	−0·10
14 Lazy			0·36	0·08	0·24	0·19	29	9	3	0·36	0·21	0·33
Per cent Communality Exhausted			69·34	15·65	15·01							
Per cent of Total Residuals							79	18	3			

[a]Labelled items were definers of the individual clusters for the end-of-Ride 2 empirical analysis. For the preset analysis reported here, clusters C1, C2, and C3 were preset since they were common to both rides. Item 13 was added to C1. Clusters C5, C6, and C7 were unique to Ride 2 and were excluded from the preset key cluster analysis. Cluster C4 did not appear for Ride 2. See text for further explanation.

Table 3 shows the defining items and highly collinear nondefining items comprising each cluster of the *empirical* analysis for end-of-Ride 2. The final item composition for the *preset* key cluster analysis is also shown. The results for the orthogonal and oblique preset key cluster factoring show that without exception factor coefficients are higher within than between clusters. Partial communalities (h^2) for the items ranged from 0·84 to 0·58 in C1, 0·82 to 0·38 in C2, and 0·59 to 0·41 in C3. The cluster C1 exhausted most of the initial estimated communality, 69%, while C2 and C3 exhausted 16% and 15% of the initial estimated communality, respectively. For the preset key cluster analysis for end-of-Ride 1, the percentages of the initial estimated communality exhausted by the individual clusters were in close agreement: 75%, 16%, and 11% for C1, C2, and C3, respectively. Since the percent of the initial estimated communality exhausted is based on the residual correlation matrix after the first cluster, it is a biased estimate of cluster generality, i.e., the amount of the initial correlation matrix accounted for by each cluster. An unbiased estimate of generality can be obtained by reversing the factoring process, and using each cluster on a first factor basis to reproduce the original raw correlation matrix. Applying this procedure, C1 reproduced 80% of the initial correlation matrices for both rides; C2 reproduced 26% and 17% for Rides 1 and 2, respectively; and C3 reproduced 28% and 9% for Rides 1 and 2. Of the residual correlations remaing after the three cluster preset solution, 79% were less than 0·10, indicating that clusters C1, C2, and C3 were able to account for almost all of the initial raw correlation matrix.

3.4. *PAQ Structural Description*

If the PAQ has an adequate cluster structure, then its clusters should be characterized by high collinearity and independence. Since these measures capture the essence of the key cluster analysis approach, both of these structural characteristics were evaluated in detail.

Collinearity, i.e., the degree to which the items within a cluster share similar patterns of correlations with other items of the score space, is summarized schematically in Figure 2. The Fatigue cluster appears to be a very tight, highly collinear cluster, with Motivation noticeably less collinear. In agreement with the figure, the index of average collinearity, P^2 (where $0 \leqslant P^2 \leqslant 1$), was higher for items within rather than between clusters. Mean P^2 values for end-of-Ride 2 were 0·94, 0·78, and 0·44 for C1, C2, and C3 respectively.

In Figure 3, the spherical analysis (SPAN) diagram of the BC TRY system is reproduced showing the loci of the clusters for end-of-Ride 2 on the surface of a three dimensional spherical space. The boxes labelled I, II, and III are the termini of the orthogonal axes which are located by the factoring process and pass through the origin of the sphere to form the orthogonal factor structure. The orthogonal structure serves as a frame of reference to locate the oblique clusters similar to the coordinates on a map. The loci of the oblique clusters form an invariant configuration on the sphere, labeled C1, C2, and C3, which are inter-connected by the dotted arcs. The oblique cluster structure describes the actual relationship that exists between the clusters.

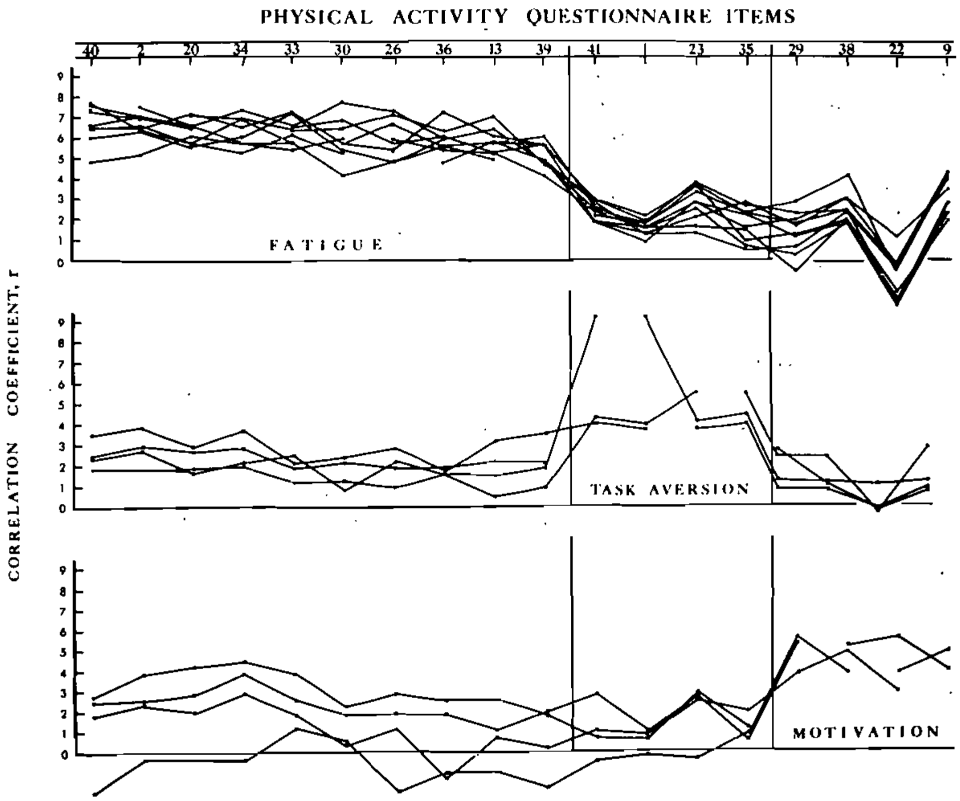

Figure 2. Collinearity of the Physical Activity Questionnaire clusters for end-of-Ride 2. Note that the correlation coefficient of each item with itself, being 1·00, was not plotted. For the name of each numbered item, see Table 2.

Within the SPAN diagram, collinear items tend to group and are more tightly packed, the greater the cluster collinearity. C1 again appears as a dense, relatively tight cluster in the SPAN diagram showing excellent collinearity between the cluster items.

Figure 2 also provides information concerning cluster independence for end-of-Ride 2. In the SPAN diagram, highly independent clusters tend to be widely spaced and to group around the termini of the orthogonal axes. In Figure 2, all clusters appear relatively independent, an observation supported by the low inter-cluster raw score correlations shown in Table 4 for end-of-Rides 1 and 2. In addition, internal consistency reliabilities shown on the diagonals of Table 4 are high for all clusters, ranging from 0·94 for C1 to 0·77 for C3. Ride 2 shows a greater intercluster independence, while the internal consistency reliabilities remained at the same level as Ride 1.

Presetting the clusters as well as their defining items for both rides, permits a direct comparison for both rides through comparative key cluster analysis. This analysis describes the similarity of the cluster structure between replications of a study by providing an index of similarity (Cos θ, where $0 \leqslant \cos\theta \leqslant 1$), which reflects the extent to which the oblique factor coefficients of the cluster defining items share the same patterns across the other items of the score space

(Tyron and Bailey 1970). In brief, if the replications are for the same subjects at different times, as in this study, Cos θ describes the stability of the cluster configuration. The clusters are seen in Table 5 to be highly similar between Rides 1 and 2, having Cos θ values of 0·88, 0·84, and 0·75 for C1, C2, and C3, respectively. This result indicates that the Physical Activity Questionnaire can serve as a reliable instrument.

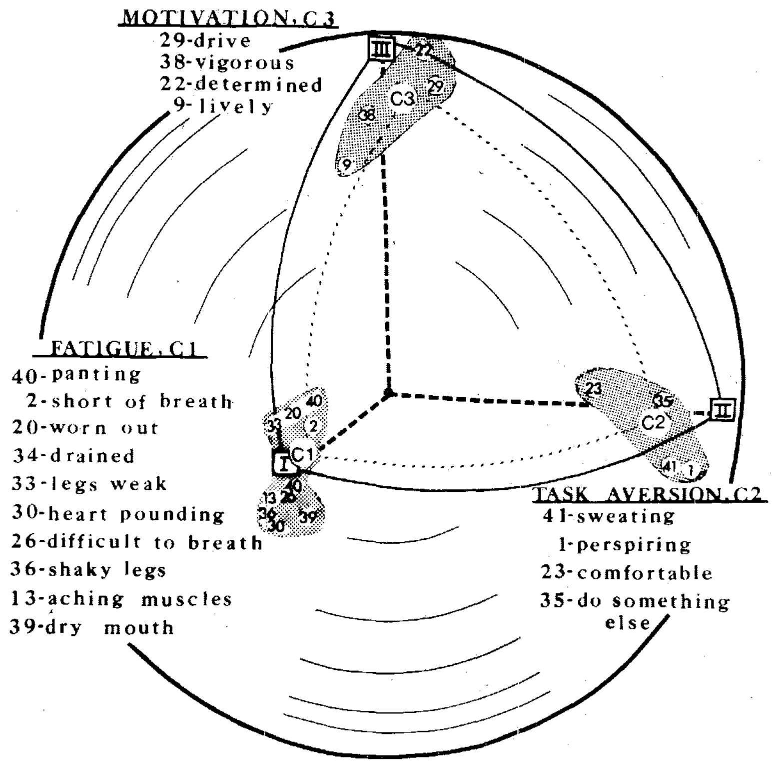

Figure 3. Spherical configuration of Physical Activity Questionnaire clusters for end-of-Ride 2. For explanation, see text.

Table 4. End-of-Ride raw cluster score correlations and reliabilities[a]

	Fatigue (C1)	Task Aversion (C2)	Motivation (C3)
RIDE 1			
Fatigue (C1)	0·92	0·48	0·53
Task Aversion (C2)		0·83	0·21
Motivation (C3)			0·77
RIDE 2			
Fatigue (C1)	0·94	0·34	0·23
Task Aversion (C2)		0·83	0·17
Motivation (C3)			0·78

[a] Reliabilities are underlined and shown on the diagonal.

Table 5. Cos θ values comparing key cluster analyses solutions for end-of-Rides 1 and 2[a]

Comparison	Fatigue (C1)	Task aversion (C2)	Motivation (C3)
	Fatigue (C1)		
Ride 1	(1·00)	0·55	0·66
Ride 2	(1·00)	0·41	0·30
Ride 1 vs. 2	0·88	0·47	0·48
	Task Aversion (C2)		
Ride 1	0·55	(1·00)	0·24
Ride 2	0·41	(1·00)	0·20
Ride 1 vs. 2	0·47	0·84	0·22
	Motivation (C3)		
Ride 1	0·66	0·24	(1·00)
Ride 2	0·30	0·20	(1·00)
Ride 1 vs. 2	0·42	0·22	0·75

[a]Underlined Cos θ values index the collinearity for *corresponding* clusters between Rides 1 and 2. Values in parentheses index collinearity for a cluster compared with itself within a ride and are therefore unity values. The remaing Cos θ values index collinearity between *different* clusters within and between rides.

3.5. *Magnitude and Consistency of Symptomatology Change During Physical Activity*

The subjects rode at $55{\cdot}6 \pm 2{\cdot}8\%$ of their estimated aerobic capacity which ranged from 2·65 to 4·90 litres O_2/min (mean 3·3 L/min). Quitting times were 36 ± 24 min and 36 ± 22 min for Rides 1 and 2, respectively. Pre- and end-of-ride raw score means and standard deviations for each cluster and the overall PAQ are shown in Table 6. To obtain these values, the individual item scale scores of each subject were summed for clusters C1, C2, C3, and the overall PAQ. The mean pre- and end-of-ride raw scores were in close agreement for Ride 1 and Ride 2. Fatigue and Task Aversion show a greater magnitude of change than Motivation for both rides. All pre- to end-of-ride changes were statistically significant (all $P\text{s} < 0{\cdot}01$).

Mean percent pre- to end-of-ride change for the overall PAQ score was 57% for Ride 1 and 64% for Ride 2. The individual cluster scores, C1, C2, and C3, showed mean changes of 95%, 58%, and 11% for Ride 1 and 105%, 80%, and 21% for Ride 2. Coefficients of stability for the pre- to end-of-ride change in overall and individual cluster scores between rides were 0·82, 0·83, and 0·65 for the overall PAQ, C1, and C2, respectively. C3 (Motivation) had a considerably lower coefficient of stability, 0·38, than did the other individual clusters of the PAQ.

Table 6. Pre- and end-of-ride means and standard deviations for raw cluster scores and overall PAQ[a,b]

	Ride 1		Ride 2	
	Pre	Post	Pre	Post
Fatigue (C1)	$13{\cdot}37 \pm 3{\cdot}16$	$26{\cdot}12 \pm 7{\cdot}28$	$12{\cdot}80 \pm 3{\cdot}30$	$26{\cdot}25 \pm 8{\cdot}27$
Task Aversion (C2)	$10{\cdot}05 \pm 2{\cdot}58$	$15{\cdot}88 \pm 2{\cdot}87$	$8{\cdot}77 \pm 2{\cdot}10$	$15{\cdot}82 \pm 2{\cdot}96$
Motivation (C3)	$11{\cdot}65 \pm 3{\cdot}12$	$12{\cdot}95 \pm 2{\cdot}89$	$11{\cdot}37 \pm 3{\cdot}22$	$13{\cdot}73 \pm 2{\cdot}82$
Overall PAQ	$34{\cdot}98 \pm 6{\cdot}53$	$54{\cdot}95 \pm 10{\cdot}68$	$33{\cdot}93 \pm 6{\cdot}16$	$55{\cdot}80 \pm 10{\cdot}76$

[a]Fatigue (C1), Task Aversion (C2), and Motivation (C3) have 10, 4, and 4 items, respectively, resulting in the 18 item Physical Activity Questionnaire. The possible raw score ranges are from 10 to 50 for Fatigue, 4 to 20 for both Task aversion and Motivation, and 18 to 90 for the overall Physical Activity Questionnaire.

[b]Data are based on 60 subjects. Four subjects were excluded due to missing data points.

4. Discussion

This study supports the hypothesis that subjective changes during exercise are multi-dimensional and, on an empirical basis, tend to group into unique clusters. Key cluster analysis (Tryon and Bailey 1970) identified three internally consistent clusters of subjective change subsequently labeled Fatigue (C1), Task Aversion (C2), and Motivation (C3). The Fatigue cluster consists of those subjective symptoms specifically descriptive of *bodily feeling states* associated with prolonged exercise. Task Aversion appears to measure a general level of *discomfort* and *disinclination to continue* the task. The Motivation cluster consists of subjective items describing change in *arousal* and *activation* level. The present Physical Activity Questionnaire is an 18 item self-report questionnaire that can measure change in each of these three subjective symptom clusters during strenuous exercise. Use of the PAQ requires only that the subjects be practiced in regard to the rating of subjective symptoms by several administrations of the questionnaire prior to study.

Of the individual clusters, Fatigue is the most conceptually clear, internally consistent, and has the highest stability of change upon replication. In addition, it is the most general cluster in that it reproduced nearly 80% of the initial correlation matrix of the Modified Adjective List. Task specific (e.g., Legs Shaky and Legs Weak) and general fatigue items (e.g., Worn Out and Drained), are included in the cluster. Although derived independently, the general fatigue items are similar to those of a subjective physical fatigue dimension found by Wolf (1967) and reproduced by Wijting *et al.* (1970). A second key cluster analysis solution of the current data, using only the 26 items of the Initial Adjective List showing the most pre- to end-of-ride change, identified separate Leg Fatigue and General Fatigue clusters (Weiser *et al.* 1971b). For tasks such as bicycle riding, the highly specific leg fatigue items could be expected to change along with items describing general fatigue. Tasks using other muscle groups, e.g., those used in carpentry or bricklaying, require additional items specific to that type of work. Techniques such as those used in this study would identify appropriate items to be used in a modified PAQ.

Task Aversion, which at first appears less conceptually clear than the Fatigue cluster, had a high internal consistency and excellent stability of change upon replication. These items appear to measure aversion to the task in response to discomfort; as such, this cluster may prove useful in differentiating between individuals showing similar physiological response to exercise, yet differing in regard to their work tolerance. While further clarification is needed, the inclusion of the doublet symptom set, Perspiring and Sweating, appears reasonable in view of a study by Gagge *et al.* (1969) which indicated that the sensation of thermal discomfort during exercise was principally related to skin conductance and sweating. Inclusion of items describing the subjective feeling of warmth (e.g., overheated, hot, etc.) during exercise in future studies may further clarify the meaning of this cluster.

Finally, the Motivation cluster while conceptually clear has a relatively low internal consistency and stability of change upon replication. Both of these reliability measures may be improved by the addition of new items. An adequate Motiviation cluster has high potential utility since the pre-work motivational level, in addition to motivational changes during work, may be importantly related to work tolerance (e.g., see Bartley and Chute 1947).

The approach used in this study regards the derivation of the unique subjective symptom changes during strenuous exercise as a problem capable of empirical attack. Recently, there has been some renewed interest in measuring discrete aspects of subjective change during prolonged work. The Industrial Fatigue Research Committee of Japan has suggested a checklist to measure three components of fatigue, including a ' dull, sleepy ' factor, a ' decline of working motivation ' factor, and a factor ' describing the projection of fatigue to some parts of the body ' (see Kogi *et al.* 1970 and Yoshitake 1971). There appears to be an interesting correspondence between the conceptual content of these factors and our empirically derived subjective symptom sets of Fatigue (C1) and Motivation (C3).

We think it is significant that quitting times varied substantially in this study, ranging from 1½ min to 98 min, even though all subjects performed at close to 56% aerobic capacity. Other factors in addition to aerobic capacity are obviously required to account for differences in work tolerance during strenuous exercise. For example, the greater the heart rate increment of our subjects during an early period of exercise, the sooner they stopped riding (Weiser *et al.* 1971a). Change in subjective symptomatology may show a similar relationship. In this regard, we are currently examining the change in PAQ subjective symptom clusters during exercise, and their relationships to heart rate increment and work tolerance.

In contrast to undimensional measures of subjective fatigue or effort (Pearson 1957, Borg 1962, McNelly 1966), adequate multidimensional measures of subjective change during exercise permit typological analysis of subjective symptom change. Differences may exist between identifiable types of individuals in regard to their pattern of changes across various clusters of subjective symptomatology. For example, during a given task, one type of individual may tend to terminate his work in response to increased subjective symptoms of Fatigue, while another may do so in response to both a decrease in Motivation and an increase in Task Aversion. In addition, unique patterns of subjective changes across independent clusters of subjective symptoms may be associated with specific tasks and task conditions. In our view, such complex patterning of subjective change is highly probable and could obscure any direct relationships between work tolerance, subjective changes, and physiological factors. The lack of direct relationships between underlying physiological factors during exercise and unidimensional measures of subjective change may have been paritally responsible for the rejection of subjective symptomatology during physical activity as a valid area of study.

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Cette étude s'était proposée d'étudier les modifications dans les symptomes subjectifs survenant au cours d'une épreuve prolongée sur un ergocycle. Au cours de deux séances, 64 sujets de sexe masculin (âge moyen: 22,9 ans) devaient fournir sur un ergocycle un travail équivalent à $55{,}6 \pm 2{,}8\%$ de la capacité aérobie, avec la consigne de poursuivre le pédalage jusqu'à éprouver un inconfort les obligeant d'arrêter l'épreuve. Les délais d'abandon étaient en moyenne de 36–24 mn, pour la première séance et de 36 ± 22 mn pour la deuxième séance.

Chaque item d'un ensemble initial de 63 adjectifs décrivant les changements subjectifs ressentis pendant l'épreuve reporté sur une échelle de sévérité à 5 points (1 = absence, 5 = sévère). Cette épreuve d'estimation était administrée avant et après chaque épreuve de pédalage.

Après une analyse des configurations-clés portant sur les 41 items présentant au moins 10 p. 100 de changements, il a été élaboré un questionnaire d'activité physique (PAQ) comportant 18 items. Il était formé de trois configurations uniques et colinéaires de symptomes et appelées Fatigue, Aversion pour la tâche et Motivation. Les analyses comparatives des configurations-clés ont mis en évidence un bon accord entre la première et la deuxième épreuve.

Les variations moyennes avant-après, pour les deux épreuves, se rapportant aux configurations relatives au PAQ global, à la Fatigue, à l'Aversion et à la Motivation étaient respectivement de 61 p. 100, de 100 p. 100, de 69 p. 100 et de 16 p. 100. Les coefficients de stabilité correspondant au PAQ global, à la Fatigue et à l'Aversion étaient respectivement 0,82; 0,83 et 0,65. La configuration Motivation présentait un coefficient de stabilité de 0,38 qui s'avérait ainsi considérablement plus faible que celui des autres configurations PAQ. Ces résultats suggèrent que les changements subjectifs survenant au cours d'une épreuve musculaire tendent à se regrouper dans des configurations uniques de symptomes qui peuvent être mesurés fidèlement.

Die Charakteristik der Veränderungen subjektiver Symptome während lang fortgesetzter Radfahrarbeit wurde in dieser Studie erforscht. Bei zwei Gelegenheiten fuhren 64 männliche Personen (mittleres Alter 22,9 Jahre) auf einem Fahrradergometer mit 55,6% ihrer aeroben Kapazität mit der Instruktion, die Fahrt solange fortzusetzen, bis sie so unangenehm wurde, dass sie eine Beendigung für notwendig hielten. Die mittleren Schlusszeiten waren 36 ± 24 min und 36 ± 22 min für die erste bzw. zweite Fahrt. Jedes einer Anfangsgruppe von 63 Merkmalen, welche die subjektiven Veränderungen während der Arbeit beschrieben, wurden längs einer 5-Punkte-Skala der Schwere (1 = Fehlanzeige, 2 = schwer) vor und am ende beider Fahrten aneordnet. Durch eine Schlüsselanalyse der 41 Merkmale, die wenigstens 10% Änderungen während der Arbeit zeigten, wurde aus 18 Merkmalen ein Physischer Aktivitäts Fragebogen (PAQ) abgeleitet. Er bestand aus drei einzigen. collinearem Symptomhaufen, bezeichnet als Ermüdung, Arbeitsabneigung und Motivation. Vergleichende Analyse zeigte eine gute Ähnlichkeit zwischen den Haufen beider Fahrten.

Die mittleren von Anfang bis Ende während beider Fahrten erfolgenden Änderungen für die Gesamt-PAQ, Ermüdung, Arbeitsabneigung und Motivation-Haufen betrugen 61%, 100%, 69% und 16%. Die Stabilitäts-Koeffizienten für die von Anfang bis Ende erfolgende Änderung der Gesamt-PAQ, Ermüdung und Arbeitsabneigung betrug 0,82, 0,83 und 0,65. Der Motivationshaufen hatte einen beträchtlich niedrigeren Stabilitätskoeffizienten, 0,38, als die anderen PAQ Haufen. Diese Resultate lassen vermuten, dass subjektive Änderungen während der Arbeit die Tendenz haben, sich in einem einzigen Haufen von Symptomen zu gruppieren, die zuverlässig messbar sind.

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