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Evaluation of Different Scales for Measurement of Perceived Physical Strain During Performance of Manual Tasks

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The main objective of this study was to evaluate different scales of perceived strain during the performance of various physical tasks. A total of 52 male and female participants took part in 4 experiments to achieve the study objective. The results suggest that a bipolar comfort-discomfort scale is a more appropriate instrument than a discomfort scale for assessing cumulative physical stresses at work, especially at the beginning of the shift. For assessing discomfort at the end of the work shift, a unipolar scale may also be used. On the basis of the obtained results, red, green, and yellow zones are suggested to establish priorities for work redesign efforts in ergonomic control programs.

load handling   perception   psychophysics   practical methodologies

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1. INTRODUCTION

1.1. Background

The assessment of human strain in response to workplace stresses is an integral part of any ergonomic risk evaluation process. Strain assessment has relied on two types of outcome measures, namely, objective and subjective (Ljunggren, 1986). Examples of objective measures are heart rate, oxygen consumption, and myoelectric signal. Subjective measures may include perceived exertion.

Whereas many researchers resorted to the objective evaluation of human strain during the performance of physical activities, it is obvious that there have been problems in the application of these objective measures in the workplace. For example, a frequently cited problem is the interference of measuring procedures and equipment with work performance. In some cases, a response measure may not be adequate to fully capture the multi-dimensional nature of human strain in response to stresses. As a result, additional parameters should be used, which would only further complicate the measurement procedures.

An alternative to the objective measurement of human strain has been the development of subjective methods for assessing the effects of workplace stresses on humans. However, many subjective scales have been used in many studies by researchers without fully testing the appropriate use of a given scale. This is especially important to minimize the bias by humans during the process of subjective assessment. The present study addressed some of the issues involved during the process of subjective assessment of human strain at work.

1.2. Literature Review

Human strain in response to external stresses is usually a multi-dimensional manifestation because of the many physiological systems, which come into play simultaneously. Thus, there is not a single good objective indicator of the degree of physical strain. Borg (1982), however, argued that perceived exertion is the "single best indicator of the degree of physical strain." He pointed out that perceived exertion rating integrates information from various signals, which describe the reaction of physiological sources (e.g., central cardiovascular and respiratory functions, working muscles and joints, and the central nervous system).

Borg (1982) described a new ratio-category, which can be used to assess subjective symptoms such as aches, pains, and discomfort. The basis for this scalar concept is that numbers should relate to verbal expressions that are simple and understandable by most people. The verbal expressions should be placed in the position on a ratio scale where the expressions belong according to their quantitative meaning. Although the new Borg scale has been tested on a limited basis, Ulin, Ways, Armstrong, and Snook (1990) reported that most of their participants preferred the use of the Borg scale in reference to two types of visual analog scales.

Other investigators used different types of scale ratings to assess the effects of ergonomic stresses (e.g., Corlett & Bishop, 1976; Fleishman, Gebhardt, & Hogan, 1984; Saldana, Herrin, Armstrong, & Franzblau, 1994). For example, Corlett and Bishop (1976) used a 7-point scale with *extremely comfortable* and *extremely uncomfortable* at its left- and right-hand ends, respectively. They evaluated postural discomfort for various body parts, namely, lower arms, upper arms, neck, shoulders, upper back, mid-back, lower back, buttocks, thighs, and legs.

Saldana et al. (1994) used a modified version of the Borg ratio-category protocol anchored only at 0 and 10 with *nothing at all* and *worst imaginable*. Their instrument was used to assess musculoskeletal discomforts among rural mail carriers in two post offices.

Fleishman at al. (1984) modified the Borg's 15-graded ratings of perceived exertion (RPE) scale (Borg, 1970) into a 7-graded scale with verbal descriptions from 1—*very, very light*, with 4—*somewhat hard*, to 7—*very, very hard*. The adverb anchors for *light* and *hard* corresponding to the remaining numbers were symmetrical for both halves of the scale. The modified scale was a direct conversion of the RPE scale, with the seven anchors remaining identical, but the numerical intervals reduced by half and beginning with 1 instead of 6.

Borg (1982), Helander and Mukund (1991), Sinclair (1990), and Lunjggren (1986) conducted brief reviews on the subjective assessment of human strain in ergonomics research.

A closer look at the aforementioned studies reveals that the ratio-category scale developed by Borg (1982) is a unipolar scale designed to assess physical strain in one dimension such as discomfort. On the other hand, the scale reported by Corlett and Bishop (1976) is a bipolar scale, which addresses the dual states of comfort and discomfort, although the two end points of the scale were anchored *extremely comfortable* and *extremely uncomfortable*. Also, the Borg protocol is a 13-point scale, whereas the instrument designed by Corlett and Bishop (1976) is a 7-point scale.

It is our hypothesis that a bipolar scale is a more sensitive device for evaluating the effects of cumulative stresses. A bipolar scale can be constructed to measure the dual states of comfort and discomfort. If an employee recovers from the physical stresses of the previous workday, he or she should record ratings in the comfort state at the beginning of the shift. However, if adequate recovery is not obtained, then there is a possibility that the person would record his or her perceived state on the discomfort side. The present study was conducted to compare unipolar and bipolar scales for various physical tasks.

1.3. Study Objectives

The objectives of this study were

1. to examine the effects of scale type (unipolar vs. bipolar) on the perceived strain experienced during the performance of physical tasks;
2. to examine the effects of scale orientations and different experimental conditions (i.e., load, gender, and time) on perceived strain;
3. to determine the most appropriate end points for unipolar and bipolar scales;
4. to establish guidelines for the use of these scales by industrial personnel.

The study consisted of four separate experiments. The first two experiments investigated two types of scales, unipolar and bipolar, and two scale orientations. The third experiment studied the effects of gender and load using a bipolar scale with a lesser number of choices. The fourth experiment examined the effects of duration and load on comfort-discomfort using the same bipolar scale employed in the third experiment with a different number of choices. All experiments were conducted in a well-controlled laboratory (temperature: 19 °C, relative humidity: 48%) with each experimental trial performed by each participant around the same time every day (between 9 a.m. and 12 p.m.).

2. EXPERIMENT 1

2.1. Experimental Methods

2.1.1. Participants

Twelve male college students volunteered to participate in this experiment. Their physical characteristics were age: 27.7 ± 6.0 years, body weight: 90.2 ± 21.1 kg, and height: 1.7 ± 0.2 m.

2.1.2. Experimental design

The effects of scale type, scale orientation, and load on ratings of perceived discomfort at the beginning and end of the experiment were examined by using a mixed design (Keppel, 1991). The type of scale and scale orientation were considered as between-participants factors whereas the load was a two within-participant factor.

TABLE 1. Unipolar and Bipolar Scales Used in the Experiments

Unipolar—0 to 10	**Unipolar—10 to 0**
0	10 *maximum discomfort*
0.5 *just noticeable discomfort*	9
1	8
2 *weak discomfort*	7
3 *moderate discomfort*	6
4	5 *strong discomfort*
5 *strong discomfort*	4
6	3 *moderate discomfort*
7	2 *weak discomfort*
8	1
9	0.5 *just noticeable discomfort*
10 *maximum discomfort*	0
Bipolar—10 to –10	**Bipolar— –10 to 0**
10 *maximum comfort*	–10 *maximum discomfort*
9	–9
8	–8
7	–7
6	–6
5 *strong comfort*	–5 *strong discomfort*
4	–4
3 *moderate comfort*	–3 *moderate discomfort*
2 *weak comfort*	–2 *weak discomfort*
1	–1
0.5 *noticeable discomfort*	–0.5 *just noticeable discomfort*
0	0
–0.5 *just noticeable discomfort*	0.5 *just noticeable comfort*
–1	1
–2 *weak discomfort*	2 *weak comfort*
–3 *moderate discomfort*	3 *moderate comfort*
–4	4
–5 *strong discomfort*	5 *strong comfort*
–6	6
–7	7
–8	8
–9	9
–10 *maximum discomfort*	10

2.1.3. Experimental procedures

Participants were randomly assigned to four groups of 3 participants each. Each group was assigned a given combination of scale type and orientation.

The types of scales were unipolar and bipolar, which were displayed vertically in two different orientations (Table 1). For the unipolar scale, the orientations were from 0 to 10 and from 10 to 0. The orientations for the bipolar scale were from 10 to –10 and from –10 to 10.

The experiment consisted of recording, for a given scale type and orientation combination, the comfort-discomfort experienced before holding a load in the dominant hand and at the end of experimental session. Participants were seated while holding the load with the upper arm close to the body and the elbow flexed at a 90^{o} angle. Six barbell loads were tested: 1.4, 2.2, 4.5, 6.8, 9.1, and 11.4 kg. Each participant performed all loads with at least a 24-hr rest between two consecutive experimental sessions. Loads were randomly chosen for each participant.

Participants were instructed to hold the load until they could no longer sustain it. The duration of holding activity was recorded and termed as "endurance time."

2.2. Results

2.2.1. Descriptive statistics

The means and standard deviations of comfort-discomfort data at the end of the experiment and endurance time are summarized in Tables 2 and 3, respectively. The results of descriptive statistics indicated the following:

1. On the average, the [10, 0] scale yielded higher results than the [0, 10] scale; similarly, the [–10, 10] bipolar scale scored higher values than the [10, –10] scale (Table 3). It seems that the scales with discomfort orientation at the top scored higher for both types of scales.
2. The [10, –10] bipolar scale resulted in higher scores than the [0, 10] unipolar scale. Also, the [–10, 10] scale achieved higher values than the [10, 0] unipolar scale. On the average, the bipolar scale led to higher values than the unipolar scale.
3. Endurance time decreased, as expected, with an increase in the amount of load handled, with lighter loads (1.4 and 2.2 kg) scoring higher discomfort for all scales.

TABLE 2. Means and Standard Deviations of Comfort-Discomfort Data at the End of Experiment 1

	Type of Scale							
	Unipolar				Bipolar			
	0 to 10*		10 to 0**		10 to −10***		−10 to 10****	
Load (kg)	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
1.4	4.67	4.73	5.33	2.52	4.67	1.53	6.67	3.21
2.2	2.67	1.53	5.00	2.00	3.17	2.75	6.33	3.06
4.5	1.33	0.58	3.67	1.53	4.00	0.00	5.67	2.08
6.8	0.83	1.04	4.33	1.15	4.67	2.08	5.00	3.46
9.1	1.17	0.76	4.00	2.00	4.00	2.00	4.33	3.21
11.4	1.00	0.87	3.50	2.60	4.33	0.58	4.67	3.06
Across all loads	1.94	2.27	4.31	1.84	4.14	1.57	5.44	2.71

Notes. *—0 (*no discomfort*) to 10 (*maximum discomfort*), **—10 (*maximum discomfort*) to 0 (*no discomfort*), ***—10 (*maximum comfort*) to −10 (*maximum discomfort*), ***—−10 (*maximum discomfort*) to 10 (*maximum comfort*).

TABLE 3. Means and Standard Deviations of Endurance Time at the End of Experiment 1

	Type of Scale							
	Unipolar				Bipolar			
	0 to 10*		10 to 0**		10 to −10***		−10 to 10****	
Load (kg)	*M* (min)	*SD* (min)	*M* (min)	*SD* (min)	*M* (min)	*SD* (min)	*M* (min)	*SD* (min)
1.4	15.87	5.30	20.59	10.94	28.22	9.54	22.93	10.76
2.2	7.56	3.93	12.54	7.21	12.15	3.25	12.66	2.04
4.5	2.08	0.80	4.10	2.35	5.72	1.83	4.62	1.17
6.8	1.36	0.24	2.15	0.83	2.88	0.42	2.22	0.80
9.1	0.80	0.38	1.24	0.26	1.71	0.22	1.25	0.72
11.4	0.45	0.10	0.87	0.40	1.20	0.30	0.85	0.33
Across all loads	4.69	6.14	6.92	8.78	8.65	10.38	7.42	9.07

Notes. *—0 (*no discomfort*) to 10 (*maximum discomfort*), **—10 (*maximum discomfort*) to 0 (*no discomfort*), ***—10 (*maximum comfort*) to −10 (*maximum discomfort*), ****—−10 (*maximum discomfort*) to 10 (*maximum comfort*).

The means and standard deviations of comfort-discomfort data recorded at the beginning of the experiment are (a) [0, 10] scale: –0. 17 ± 0.49; (b) [10, 0] scale: −0.28 ± 0.49; (c) [10, −10] scale: 8.28 ± 1.07; and (d) [−10,10] scale: 2.69 ± 3.20. For the 0 to 10 and 10 to 0 unipolar scales, 83 and 61% of the scores were obtained in the [0] region, respectively. The remaining responses were obtained in the [0.5–2] discomfort region. Most of the responses were obtained in the comfort zone for the bipolar scales. In fact, the [10, −10] bipolar scale demonstrated all values in the [6–10] comfort region. The [−10, 10] bipolar scale showed 28% of responses in the [6–10] comfort region and 39% in the [3–5] comfort region. Few values were obtained in the discomfort zone with no responses in the [0] region.

2.2.2. Statistical analysis

The results of the analysis of variance indicated that there were no significant effects at the 5% level for the main effects and interactions of type of scale, scale orientation, and load on the comfort-discomfort data at the end of the experiment. On the other hand, endurance time data exhibited a significant main effect of load at the 1% level. The Tukey multiple comparison tests showed that the endurance time values for the 4.5, 6.8, 9.1, and 11.4 kg loads were not significantly different from each other, while significantly different from those endurance times for the 1.4 and 2.2 kg loads.

The comfort-discomfort data at the beginning of experiment 1 demonstrated significant differences at the 5% level for the main effects of type of scale, scale orientation, and their interaction (Table 4). The Tukey multiple comparison test procedure showed that the response measures for the [10, −10] bipolar scale was significantly different from those of other types of scales.

TABLE 4. Analysis of Variance Results for Comfort-Discomfort Data at the Beginning of Experiment 1

Source	*df*	*SS*	*MS*	*F* Value
Type of Scale (A)	1	498.75	498.75	24.50***
Scale Orientation (B)	1	195.03	195.03	9.58**
Type of Scale × Scale Orientation (A × B)	1	182.09	182.09	8.95**
S/AB	8	162.83	20.35	
Load (C)	5	10.98	2.20	1.21
Type of Scale (Load (A × C)	5	7.81	1.56	0.86
Scale Orientation × Load (B × C)	5	7.61	1.52	0.84
Type of Scale × Scale Orientation × Load (A × B × C)	5	12.06	2.41	1.33
C × S/AB	40	72.50	1.81	

*Notes.****—significant at 1%, **—significant at 5%.

3. EXPERIMENT 2

3.1. Experimental Methods

3.1.1. Participants

Sixteen college students, 11 males and 5 females, volunteered to participate in this study. Their physical characteristics were age: 29.1 ± 4.6 years, body weight: 76.8 ± 19.7 kg, and height: 1.8 ± 9.4 m.

3.1.2. Experimental design

The same experimental design procedures employed in experiment 1 were utilized in this experiment.

3.1.3. Experimental procedures

Participants were randomly assigned to four groups of 4 participants each. Each group was used for a given scale type and orientation combination. The scales described in Table 1 were used in experiment 2.

The experiment consisted of recording the comfort-discomfort experienced before a lifting-lowering session and at the end of experimental sessions. Participants were asked to lift and lower a box from floor level to table height (approximately 76 cm above the floor level), at a frequency rate of 6 times/min for 30 min. The weight of the box was set at 11.4, 15.9, and 20.4 kg. Each participant performed the three experimental sessions with at least a 24-hr rest period between two consecutive treatments. The three loads were randomly assigned to each participant for a given scale type-orientation combination.

3.2. Results

3.2.1. Descriptive statistics

The [10, –10] and [–10, 10] bipolar scales recorded, on the average, consistently higher response measure scores than the corresponding unipolar scales at the end of the experiment (Table 5). The [10, –10] bipolar scale recorded higher response measures than the [–10, 10] scale, a finding that is not in agreement with that found in experiment 1. As expected, discomfort increased with an increase in the amount of load handled.

TABLE 5. Means and Standard Deviations of Comfort-Discomfort Data at the End of Experiment 2

	Type of Scale							
	Unipolar				Bipolar			
	0 to 10*		10 to 0**		10 to –10***		–10 to 10****	
Load (kg)	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
11.4	1.50	1.68	1.50	1.29	3.50	3.32	2.50	1.73
15.9	2.25	1.71	2.13	1.65	4.13	3.07	2.75	1.71
20.4	2.50	1.73	2.88	1.65	6.00	1.83	4.50	0.58
Across all loads	2.08	1.61	2.17	1.51	4.54	2.78	3.25	1.60

Notes. *—0 (*no discomfort*) to 10 (*maximum discomfort*), **—10 (*maximum discomfort*) to 0 (*no discomfort*), ***—10 (*maximum comfort*) to –10 (*maximum discomfort*), ***—–10 (*maximum discomfort*) to 10 (*maximum comfort*).

The overall distribution of discomfort data among the [0], [0.5, 2], [3, 5], and [6, 10] regions was very similar for both unipolar scales. About 50% of the scores were reported in the [0] and [0.5, 2] regions with the remaining 50% scored in the [3, 5] region. The bipolar scales exhibited higher values in the [3, 5] and [6, 10] regions and lower scores in the [0] and [0.5, 2] regions than the corresponding unipolar scales.

For the [0, 10] and [10, 0] unipolar scales, the average responses at the beginning of the experiment were slightly above 0 in the light discomfort region, namely, –0.79 (±1.03) and –0.92 (±0.73), respectively. The average and standard deviations of the response measures for the [10, –10] and [–10, 10] bipolar scales were 2.13 ± 2.92 and –0.50 ± 2.16, respectively. The distribution of overall comfort-discomfort in the various regions is summarized in Table 10. For the bipolar scales, the response values were distributed between the two states of comfort and discomfort. The [0, 10] and [10, 0] scales experienced about 17 to 50% of the response scores in the [0] region. This clearly demonstrates the inadequacy of a unipolar scale in determining the exact state of comfort-discomfort at a given point of time.

3.2.2. Statistical analysis

The analysis of variance results indicated no significant effects orientation on the response measure at the end of the experiment at the 5% level for the main effects and interaction of scale type and orientation (Table 6). Load exhibited a significant main effect.

TABLE 6. Analysis of Variance Results for Comfort-Discomfort Data at the End of Experiment 2

Source	*df*	*SS*	*MS*	*F* Value
Type of Scale (A)	1	31.69	31.69	2.74
Scale Orientation (B)	1	2.52	2.52	0.21
Type of Scale × Scale Orientation (A × B)	1	2.52	2.52	0.22
S/AB	12	138.58	11.55	
Load (C)	2	15.29	7.65	7.75*
Type of Scale (Load (A × C)	2	1.63	0.81	0.82
Scale Orientation × Load (B × C)	2	0.79	0.40	0.40
Type of Scale × Scale Orientation × Load (A × B × C)	2	0.29	0.15	0.15
C × S/AB	24	23.67	0.99	

Notes. *—significant at 5%.

There were no significant effects at the 5% level for the main and interaction effects of scale type and orientation on the comfort-discomfort ratings at the beginning of the experiment. The main effect of load and its interactions were not significant.

4. EXPERIMENT 3

4.1. Experimental Methods

4.1.1. Participants

Sixteen young college students, 8 males and 8 females participated in experiment 3. The physical characteristics were age: 25 ± 1.5 years, body weight: 73 ± 14 kg, and height: 1.75 ± 0.15 m.

4.1.2. Experimental design

The effects of gender and load on ratings of perceived discomfort at the end of the experiment were examined using a mixed design (Keppel, 1991). Gender was a between-participant factor and the load was a within-participant factor.

4.1.3. Experimental procedures

The scale tested in this experiment was a [5, –5] bipolar scale where 5 was denoted as *strong comfort* and –5 was treated as *strong discomfort*.

The experiment consisted of recording the comfort-discomfort experienced after the participant repeatedly lifted a load for 15 min. Participants were seated while lifting the load from a table through the full range of motion (similar to a curling exercise). The upper arm was kept close to the body and the elbow flexed at a 90° angle. Three barbell loads were tested, namely, 0.5, 2.3, and 4.1 kg. Each participant performed all three experimental sessions in a random fashion with at least a 24-hr rest period between two consecutive treatments.

4.2. Results

4.2.1. Descriptive statistics

The average response was consistently higher for females than males (Table 7). There was an increase in discomfort with an increase in the amount of load handled.

TABLE 7. Means and Standard Deviations of Comfort-Discomfort Data at the End of Experiment 3 (Bipolar Scale)

	Gender			
	Femeles		Males	
Load (kg)	*M*	*SD*	*M*	*SD*
0.5	3.25	0.46	3.88	0.64
2.3	–1.44	0.62	–0.25	0.96
4.1	–4.75	0.46	–3.94	0.78
Across all loads	–0.98	3.39	–0.10	3.35

Notes. Positive values denote comfort scores whereas negative values denote discomfort scores.

Most of the female participants scored –5 for the heaviest load, which probably indicates that –5, or *strong discomfort*, is not adequate to capture the upper level of discomfort perceived by the participants.

Both males and females reported comfort ratings for the lightest load, which addresses the importance of a bipolar scale in documenting the dual states of comfort and discomfort perceived by the participants in response to the intensity of physical work.

4.2.2. Statistical analysis

The analysis of variance results for comfort-discomfort data at the end of experiment indicated significant differences at the 1% level for the main effects of gender and load. Their interaction was not statistically significant (Table 8). The Tukey multiple comparison test procedure indicated that the three levels of load were significantly different from each other.

TABLE 8. Analysis of Variance Results for Comfort-Discomfort Data at the End of Experiment 3

Source	*df*	*SS*	*MS*	*F* Value
Gender (A)	1	9.19	9.19	47.13*
S/A	14	2.73	0.19	
Load (B)	2	502.26	251.13	424.02*
Load (B) × Gender (A)	2	0.66	0.33	0.55
B × S/A	28	16.58	0.59	

Notes. *—significant at 1%.

5. EXPERIMENT 4

5.1. Experimental Methods

5.1.1. Participants

Eight male college students volunteered to participate in this experiment. Their physical characteristics were age: 28.0 ± 3.7 years, body weight: 75.1 ± 19.5 kg, and height: 1.78 ± 0.14 m.

5.1.2. Experimental design

The effects of time and load on ratings of perceived discomfort were examined in this experiment using a within-participant factor design (Keppel, 1991).

5.1.3. Experimental procedures

The scale tested in this experiment was a [7, –7] bipolar scale where 7 was denoted as *very strong comfort* and –7 represented *very strong discomfort*.

The experiment consisted of recording the comfort-discomfort ratings at three time intervals, namely, before holding a load in the dominant hand, after 15 min of holding the load, and after 5 min of recovery. Participants were seated while holding the load with the upper arm close to the body and the elbow flexed at a 90° angle. Three barbell loads were tested: 0.5, 2.3, and 4.1 kg. Each participant performed each treatment with a 24-hr rest period between two consecutive treatments. Loads were randomly assigned for each participant.

5.2. Results

5.2.1. Descriptive statistics

The means and standard deviations of comfort-discomfort ratings are depicted in Table 9. At the beginning of the experiment, all participants reported their scores in the comfort state. As each participant performed the load holding task, the comfort ratings dropped and switched to the state of discomfort particularly for the 2.3 and 4.1 kg loads. After the 5-min recovery, the discomfort ratings dropped markedly, however, they did not reach the levels achieved prior to holding the loads.

TABLE 9. Means and Standard Deviations of Comfort-Discomfort Data for Experiment 4 (Bipolar Scale)

	Time					
	Start		End		Relax	
Load (kg)	*M*	*SD*	*M*	*SD*	*M*	*SD*
0.5	5.50	1.69	2.44	2.48	4.38	1.92
2.3	5.00	1.41	–2.13	1.22	0.75	1.69
4.1	5.38	1.60	–5.63	1.30	–1.69	1.19
Across all loads	5.29	1.52	–1.77	3.77	1.15	2.98

Notes. Positive values denote comfort scores whereas negative values denote discomfort scores.

At the beginning of the experiment, all responses were recorded in the [3, 5] and [6, 7] regions of the comfort state. No responses were reported in the [0] region. At the end of the experiment, no responses were reported in the [–6, –7] region of discomfort for the 0.5 and 2.3 kg loads whereas about 63% of the scores were obtained in this region for the 4.45 kg load.

5.2.2. Statistical analysis

The analysis of variance results indicated significant main and interaction effects at the 1% level for time and load (Table 10). The Tukey multiple comparison procedure indicated that the response measure scores at the end of the 5-min recovery period were (a) significantly different from those obtained at the end of the experiment for all three loads and (b) different from the response measures collected prior to the start of the load holding task for the 2.3 and 4.1 kg loads.

TABLE 10. Analysis of Variance Results for Comfort-Discomfort Data of Experiment 4

Source	*df*	*SS*	*MS*	*F* Value
Time (A)	2	604.59	302.30	104.97*
A × S	14	40.30	2.88	
Load (B)	2	275.09	137.55	66.45*
B × S	14	28.97	2.07	
Time (A) × Load (B)	4	136.41	34.10	29.91*
A × B × S	28	32.03	1.14	

Notes. *—significant at 1%.

6. DISCUSSION

6.1. Scale Type and Orientation

The discomfort ratings recorded at the end of experiments 1 and 2 were higher for bipolar scales than for unipolar scales. These differences, however, were not statistically significant. Furthermore, the two scale orientations yielded different results in both experiments. These differences were also not statistically significant. Thus, one can conclude that neither scale type nor orientation have a significant impact on discomfort data collected during the course of performing physical activities.

The analysis of data taken at the beginning of each session in experiments 1 and 2 revealed the significance of scale type effect. In experiment 1, the unipolar scales reported more than 60% of the scores in the [0] region, whereas the bipolar scales resulted in values in the state of comfort. In experiment 2, about 17 to 50% of the scores obtained for the unipolar scales were in the [0] region, whereas the bipolar scales reported no more than 9% of the scores in the [0] region. The bipolar scale used in experiment 4 resulted in ratings recorded in the state of comfort with no responses obtained in the [0]region. These results seem to indicate that a bipolar scale is a more sensitive instrument than a unipolar discomfort scale to detect the effects of cumulative stresses in the workplace particularly at the beginning of the shift.

Further analysis of the results obtained at the beginning of experiment 1 reveals that a significant interaction of scale type-orientation was found. The [10, –10] bipolar scale had significantly higher rating in the state of comfort than the three other scales. In experiment 2, no statistically significant effect of scale orientation was reported; however, descriptive statistics indicated that only the overall rating of the [10, –10] bipolar scale was in the comfort zone. The aforementioned results seem to indicate that a [10, –10] bipolar scale is more appropriate for assessing the perceived strain at the beginning of work.

6.2. Load and Gender

As expected, load reported a significant effect on the discomfort ratings at the end of sessions for experiments 2, 3, and 4; however, there were no significant differences among loads in experiment 1 because participants were asked to hold the loads until they could no longer maintain them. This means that participants were consistent in assessing their upper limit of physical exertion for holding tasks.

Females reported significantly higher comfort-discomfort ratings than males. However, the overall distribution of comfort-discomfort was similar for both males and females.

6.3. Appropriate End Point Values

Given that a [10, –10] bipolar scale seems to be a more appropriate instrument for assessing perceived strain, other questions ought to be answered. For example, is a bipolar scale with [10] and [–10] end points appropriate for assessing perceived strain provided that employees are not expected to work until exhaustion? To answer this question, we analysed the results of all experiments.

In experiments 1 and 2, no more than 33% of the responses were recorded in the [–6, –10] discomfort region of the [10, –10] bipolar scale. Of those 33%, 25% were reported in the [–8, –10] discomfort region. The lower concentration of responses in the [8, 10] region seems to indicate that a good end point for a scale would be [–7].

In experiment 3, 100% of the responses for the 4.1 kg load were concentrated in the [–3, –5] discomfort region for both males and females. This indicates that a scale with a [−5] end point was inappropriate for the proper assessment of discomfort.

In experiment 4, about 37% of the responses for the 4.1 kg load were reported in the [−3, −5] discomfort region and 63% in the [−6, −7] discomfort region. As not all responses were obtained in the [−6, −7] discomfort region, a scale with a [−7] end point seems to be appropriate. Further support is provided by the fact that no responses were reported in the [−6, −7] discomfort region for the 0.5 and 2.3 kg loads.

For the comfort end point, a [7] is also appropriate because no more than 22% of all responses were reported in the [8, 10] comfort region in experiment 1, with 22% for the [10, −10] scale and 0% for the [−10, 10] scale. In experiment 2, no scores were obtained in this region. Additionally, about 54% of the scores in experiment 4 were reported in the [6, 7] comfort region.

The aforementioned discussion supports the notion that a more appropriate scale for assessing discomfort seems to be a bipolar scale with 7 and −7 end points. This is the case if individuals are not working until complete exhaustion like in experiment 1.

6.4. Warning Zones

To further the use of the [7, −7] bipolar scale by industrial personnel, one should ask questions about the practical use of such an instrument. For example, is it possible to establish a warning zone on the basis of perceived strain in order to prevent musculoskeletal injuries? We propose to establish red, yellow, and green zones in both comfort and discomfort states of the bipolar scale.

On the discomfort side, the [−5, −7] region would be defined as a red zone or a strong level of discomfort. This means that a serious and potentially dangerous situation exists and requires immediate attention. The [−2, −4] zone, which represents a moderate level of discomfort, would indicate that the situation is under control but requires periodic monitoring. The [0, 1] green zone has a similar meaning to the yellow zone in that no serious and potentially dangerous situation exists, and is defined as light discomfort. Consistent measures in this zone may indicate, however, that workers' capacities are physically underloaded.

In experiment 1, 6% of the discomfort data were recorded in the green zone, 61% in the yellow zone, and 33% in the red zone. The high percentage in the red zone is attributed to the fact that loads were held until complete exhaustion. In experiment 2, 16% of the values were in the green zone, 42% in the yellow zone and, 42% in the red zone. The heavier loads studied in this experiment may explain the values in the red zone. In experiment 3, about 25% of the female scores were reported in the yellow zone and 75% in the red zone for the 4.1 kg load. For males, 75% of the scores were reported in the yellow zone and 25% in the red zone. For the 0.5 and 2.3 kg loads, no responses were reported in the red zone. In experiment 4, about 12% of the responses for the 4.1 kg load were reported in the yellow zone and 88% in the red zone. No responses were reported in the red zone for the 0.5 and 2.3 kg loads.

On the comfort side, the definition of the zones would be as follows. The [0, 1] red zone would mean that a serious and potentially dangerous situation exists and requires immediate attention. The [2, 4] yellow zone would indicate that the situation is under control and no further action needs to be taken. The [5, 7] green zone means that no serious and potentially dangerous situation exists. Responses on the discomfort side before work will indicate even a worse situation. In other words, responses in the comfort red zone and the discomfort side at the beginning of work indicate that total recovery from work did not occur and that corrective actions need to be instituted.

6.5. General Comments

The results of this study are not only applicable to the assessment of perceived strain, but they can be utilized in other research areas as well. The main point is that any measuring instrument should be designed as a bipolar scale in order to allow individuals to express their perceived evaluation along the continuum of dual states.

For example, when one designs a scale to measure employee satisfaction, the bipolar scale should allow the measurement of the dual states such as satisfaction on one side and dissatisfaction on the other side. According to his motivation-hygiene theory, Herzberg (1987) determined experimentally that the factors involved in producing job satisfaction are separate and distinct from the factors that lead to job dissatisfaction. On the basis of his experimental findings, Herzberg deduced that the factors affecting job dissatisfaction (i.e., company policy and administration; supervision; relationship with supervisor, peers, and subordinates; work conditions; salary) can be thought of as a built-in drive to avoid pain from the environment, as well as all the learned drives that become conditioned to the basic biological needs. The other set of factors producing job satisfaction (i.e., achievement, recognition, work itself, responsibility, advancement, growth) relates to that unique human characteristic, the ability to achieve, and through achievement, to experience psychological growth. Although the Herzberg study confirms the necessity to use a bipolar scale, it is also important to examine the factors affecting each of the scale's dual states.

7. CONCLUSIONS

In this study, the bipolar comfort-discomfort scale appeared to be a more sensitive instrument than the unipolar discomfort scale with respect to detection of the effects of cumulative stresses in the workplace especially at the beginning of the shift. For assessing body discomfort at the end of the shift, the unipolar scale may be sufficient. Although scale orientation did not show a significant effect on perceived strain, a [10, −10] bipolar scale seems more appropriate for detecting cumulative stresses at the beginning of the shift.

Load lifted had a significant effect on discomfort ratings. Discomfort ratings increased with an increase in the amount of load handled. As workers are not expected to work until exhaustion, an appropriate end point for the unipolar and bipolar scales is [−7]. A value of [7] seems to be appropriate as an end point for the measurement of comfort purposes.

To interpret the results on the discomfort side in unipolar and bipolar scales, we propose to establish the following zones on the basis of frequency distribution:

- A [−5, −7] red zone means that a serious and potentially dangerous situation exists and requires immediate attention.
- A [−2, −4] yellow zone indicates that the situation is under control and requires periodic monitoring.
- A [0, −1] green zone does not contain any serious and potentially dangerous situation. However, consistent measures in this zone may indicate that workers' capacities are physically underloaded.

If a bipolar scale is used, we suggest to establish the following zones for interpreting results in the comfort side:

- A [0, 1] red zone would mean that a serious and potentially dangerous situation exists and requires immediate attention.

- A [2, 4] yellow zone would indicate that the situation is under control and no further action needs to take place.
- A [5, 7] green zone suggests that no serious and potentially dangerous situation exists.

Finally, the responses in the comfort red zone and on the discomfort side of a bipolar scale at the beginning of work indicate that the total recovery from work did not occur, and that corrective actions are needed.

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