ASSESSING RELIABILITY OF PERFORMANCE IN THE FUNCTIONAL CAPACITY ASSESSMENT

LESTER A. OWENS, DO, RPT, RODNEY L. BUCHHOLZ, MED
GREEN BAY, WISCONSIN

ABSTRACT

Evaluating an individual's performance credibility is an important element of the functional capacity assessment (FCA). Consistency of performance, measured by the coefficient of variation (CV), has been used to objectively measure performance reliability. The CV alone cannot consistently detect an individual who performs at submaximal effort. An analysis of healthy and injured individuals was performed using isometric lift, push, and pull tasks. Heart rate increase, EMG activity, and force coefficient of variation were measured to determine acceptable measures of effort and consistency. It was concluded that measuring effort as well as consistency will increase the accuracy of performance reliability determination.

KEY WORDS: FUNCTIONAL CAPACITY ASSESSMENT, HEART RATE, ELECTROMYOGRAPHY, ISOMETRIC CONTRACTION, EXERTION

Founder and President
Rehabilitation Resource Group, Ltd.
Green Bay, Wisconsin

Exercise Physiologist
Rehabilitation Resource Group, Ltd.
Green Bay, Wisconsin

Introduction

Physical work capacities can be assessed by functional capacity assessment (FCA). One cannot assume that all individuals will perform to the best of their ability. Several factors may be potential barriers to a maximum volitional effort:

1. Motivational or secondary gain
2. Psychological factors
3. Emotional factors
4. Unidentified physical impairment
5. Muscle fatigue
6. Malingering

The credibility* and validity of the FCA are important in determining an individual's safe functional capabilities. Identifying an individual performing at a submaximal level and documenting the performance credibility is important for medical and legal purposes. The credibility of the FCA may be challenged by the individual, the employer, or the attorneys. In such a dispute, FCA must be defendable.

A commonly used objective measure of performance credibility is the consistency of multiple trials of maximum voluntary effort. The statistical technique often used is the coefficient of variation (CV), defined as the quotient of the standard deviation divided by the mean, multiplied by 100. The use of consistency of performance for measuring performance credibility is based on three assumptions listed by Matheson[1]:

1. Given an inherently reliable procedure where body posture, individual joint angles and muscles used are carefully controlled, individuals giving maximum effort during an assessment of strength will show a high level of reliability and low variance during closely spaced serial trials.
2. The individual who is magnifying dysfunction consciously or unconsciously will not give maximum effort during physical testing.
3. Lack of maximum effort is associated with inconsistency or unreliability of performance.

An investigational method of determining performance credibility is heart rate monitoring. An increase in heart rate is noted with whole-body isometric activity. The degree or intensity of physical exertion correlates with heart rate response. The greater the physical exertion, the greater the increase in the heart rate.[3,4,5,6,7,8,9,10,11] Lewis et al[4] suggests that the heart's response to a static contraction is closely linked to the relative force exerted within a given muscle group. Several studies have shown that a large exercising muscle mass will elicit greater increases in heart rate than a smaller muscle mass, whether the activity is dynamic or static in nature.[12] Drury and Spitz[13] showed that the heart rate increase is independent of the muscle group contracting, and that rates may rise by over 30 beats per minute during contractions approaching the limit of endurance.

*Matheson used the term "performance reliability" in his explanation to answer the question "How do we know that he tried his best?"[1] To avoid confusion with the statistical definition of reliability, the term "performance credibility" will be used in this report.

Another method of evaluating degree of physical exertion is the surface electromyography (EMG) recording. Surface EMG has been used for many years to measure muscle tension levels. The positive relationship between the amplitude of the EMG signal and the force produced by the contracting muscle is well documented.[13,14,15] EMG amplitude response is another physiological measure of muscle activity, indirectly reflecting effort.

The goal of this study was to illustrate the need for measures in addition to consistency for determining an individual's performance credibility. Isometric lifting, pushing, and pulling test results were analyzed to determine if an individual can perform inconsistently at a maximal effort and consistently at submaximal effort.

Methods

Two groups of data were collected and analyzed for this study. Group I involved 71 non-injured, healthy subjects in the working population. Subjects were screened for orthopedic problems (Table 1). Group II was derived from 362 patients with musculoskeletal injuries at Rehabilitation Resource Group, Ltd, Green Bay, Wis, and included 221 males and 141 females (Table 1). Injuries had resulted from subacute and chronic work-related occurrences and motor vehicle accidents and were of 6 weeks duration or longer. Injury diagnosis included muscular strains of the lumbar, thoracic, and cervical regions, post-operative herniated nucleus pulposus, postoperative laminectomy, various chronic shoulder injuries, myofascial pain syndromes, tendinitis, fibromyalgia, arthritis and carpal tunnel syndrome.

Table 1.—Group Characteristics

	Health Group	Patient Group	Male Patients	Female Patients
Number of Subjects	71	362	221	141
Age ± SD (yrs)	30.5 ± 10.0	39.2 ± 11.1	39.8 ± 11.0	38.2 ± 11.3
Height ± SD (cm)	176.3 ± 8.9	172.5 ± 10.9	178.3 ± 7.9	164.1 ± 9.1
Weight ± SD (kg)	79.1 ± 15.2	83.0 ± 20.9	88.4 ± 19.4	74.8 ± 20.6

The testing procedure and risks were explained to the subjects and the patients, and all signed an informed consent document prior to the testing. Five isometric tasks were performed: (1) low-level lifting in a squat position, hands at 16 inches from the floor; (2) mid-level lifting in a standing position with the hands at hip height; (3) high-level lifting with the hands at chin height; (4) pushing at waist height with one leg forward and one leg back; and (5) pulling at waist height with one leg forward and one leg back. Three 5-second trials were performed at each task with a minimum of 60 seconds of rest between trials. A minimum of three minutes of rest occurred between each of the tasks while the isometric testing device was adjusted for the next position and the task demonstrated. All subjects or patients did not perform all of the tasks. The patient group performed the tasks after 30 to 45 minutes of finger-dexterity and grip-strength tasks performed while sitting.

All tasks were performed with the Isometric Strength Testing Unit (ISTU) (Ergometrics, Inc, Ann Arbor, MI 48104). Peak force during the contraction and the average force during the last 3 seconds of the 5 second contraction were recorded. Heart rate was digitally displayed using a single lead ECG. ECG electrodes were placed over the upper or the lower chest, whichever caused less muscle artifact. The standing resting steady-state heart rate prior to the contraction was used as the pretrial heart rate. Peak heart rates were determined as the maximum heart rate that occurred immediately following the trial.

EMG activity was monitored over the fourth and fifth lumbar paraspinal muscles during the low- and mid-level lifts, over the anterior deltoid during the high-level lift and push, and over the posterior deltoid during the pull. The J & J I-330 physiological data collection system (J & J Engineering, Inc, Paulsbo, WA 98370) was used. The EMG signal was amplified and rectified with peak values recorded during the 5-second contraction.

A t-test was used to determine differences between the healthy and the patient groups; significance was determined at the 0.05 level of confidence. Performance consistency was measured by the coefficient of variation of the average force exerted during the last 3 seconds of the contraction. The value "n" rather than "n-l" was used in the denominator in the equation for standard deviation since the entire population of trial scores was used for calculating the coefficient of variation.

Results

The mean and standard deviation for the 3-second average force CV, average heart rate (HR) difference, and average peak rectified EMG values for healthy, patient, male patient, and female patient groups are listed in Tables 2, 3, 4, and 5, respectively. All averages are based on three trials.

The isometric tasks caused increases in heart rate and EMG activity in all groups. The average heart rate increase ranged from 14.3 beats per minute (bpm) in the female patient group performing the pull task, to 25.1 bpm for the healthy group performing the low-level lift. In all groups, heart rate increase was greatest when performing the low-level lift and smallest when performing the pull.

The average heart rate increase and the average peak EMG amplitude for the patient group was significantly less ($p<0.05$) than that of the healthy group in all tasks for the mid-level and low-level lifts; differences between the patient group and the healthy group peak EMG were significant ($p<0.05$) for all but the pull task.

Comparisons of the CV of the average trial forces reveal that the healthy group was more consistent than the patient group for all tasks; the difference between these groups was statistically significant ($p<0.05$) for the low-level lift, push, and pull.

Minimum heart rate and EMG values were determined for each task to establish indicators of "significant" effort. These values were derived from the statistical mean minus one standard deviation, which statistically would allow 84% of the group to demonstrate

Table 2.—Healthy Group

Variable	N	Mean	SD	Minimum	Maximum
High-Level Lift					
CV	34	10.13	5.92	0.40	24.10
HR Difference	34	20.80	8.66	8.00	45.00
Peak EMG	34	114.69	20.54	82.30	150.50
Mid-Level Lift					
CV	46	8.58	6.13	1.20	26.50
HR Difference	46	20.37	7.78	6.70	40.70
Peak EMG	46	46.31	26.33	15.40	129.50
Low-Level Lift					
CV	71	6.78	4.84	0.70	22.30
HR Difference	71	25.08	11.40	4.70	68.30
Peak EMG	70	45.99	29.44	7.30	132.90
Push					
CV	42	6.40	3.36	1.50	41.00
HR Difference	34	20.87	9.10	7.00	41.00
Peak EMG	34	92.89	30.20	23.30	151.70
Pull					
CV	41	5.67	3.74	0.70	15.50
HR Difference	34	18.35	8.77	4.40	54.20
Peak EMG	34	29.38	19.62	7.30	108.70

N: Number of Individuals
SD: Standard Deviation

Table 3.—Total Patient Group

Variable	N	Mean	SD	Minimum	Maximum
High-Level Lift					
CV	348	10.28	8.87	0.40	59.30
HR Difference	351	18.36	18.36	0.00	64.70
Peak EMG	344	80.47	35.45	3.10	150.60
Mid-Level Lift					
CV	354	10.13	9.82	0.40	72.00
HR Difference	355	17.75	11.46	0.30	61.30
Peak EMG	350	23.56	13.44	0.30	103.50
Low-Level Lift					
CV	320	10.70	11.25	0.30	80.30
HR Difference	320	19.89	10.88	1.00	55.30
Peak EMG	306	24.14	14.96	1.60	120.50
Push					
CV	339	8.12	7.98	0.50	60.50
HR Difference	342	18.15	11.53	0.30	58.30
Peak EMG	173	58.27	35.03	2.00	142.80
Pull					
CV	338	7.32	8.33	0.50	72.50
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 4.—Male Patient Group

Variable	N	Mean	SD	Minimum	Maximum
High-Level Lift					
CV	210	9.96	9.11	0.60	59.30
HR Difference	214	19.68	10.68	0.00	54.30
Peak EMG	207	87.22	32.78	5.50	150.60
Mid-Level Lift					
CV	214	8.93	7.58	0.40	48.00
HR Difference	214	19.68	11.59	1.00	61.30
Peak EMG	210	25.67	14.34	0.30	103.50
Low-Level Lift					
CV	198	10.71	11.26	0.30	80.30
HR Difference	199	1.35	11.13	1.70	55.30
Peak EMG	190	25.71	13.85	2.30	120.50
Push					
CV	208	7.50	7.95	0.60	60.50
HR Difference	210	20.44	11.73	1.30	58.30
Peak EMG	113	56.12	33.61	5.50	142.80
Pull					
CV	205	6.79	7.89	0.50	72.50
HR Difference	210	19.28	11.71	1.00	60.60
Peak EMG	113	28.08	20.63	2.10	127.60

N: Number of Individuals
SD: Standard Deviation

Table 5.—Female Patient Group

Variable	N	Mean	SD	Minimum	Maximum
High-Level Lift					
CV	138	10.77	8.51	0.40	41.50
HR Difference	137	16.30	11.10	0.70	64.70
Peak EMG	137	70.26	36.97	3.10	146.50
Mid-Level Lift					
CV	140	11.97	12.31	0.40	72.00
HR Difference	141	14.83	10.66	0.30	54.00
Peak EMG	140	20.43	11.29	2.50	63.70
Low-Level Lift					
CV	122	10.69	11.27	0.40	66.70
HR Difference	121	17.46	10.05	1.00	48.30
Peak EMG	116	21.57	16.37	1.60	101.10
Push					
CV	131	9.08	7.97	0.50	44.70
HR Difference	132	14.51	10.24	0.30	44.30
Peak EMG	60	62.33	37.52	2.00	138.20
Pull					
CV	133	8.13	8.93	0.50	50.00
HR Difference	131	14.26	10.13	0.30	47.30
Peak EMG	61	21.67	14.32	1.90	49.00

N: Number of Individuals
SD: Standard Deviation

significant effort based on each variable. Only patients whose heart rate and EMG values exceeded the minimum for a given task were classified as performing at maximal effort in that task. A cutoff point, derived from one standard deviation above the mean, was established for the force CV to determine acceptable performance consistency. This value statistically allowed 84% of the group to have a consistent effort. Using the heart rate and EMG criteria, 76.5% of the patients demonstrated significant effort in all five tasks. Among these patients, 94.5% were also consistent. Therefore, 5.5% of patients who demonstrated significant effort were inconsistent, or 4.2% of the total patient group. The FCA results of the individuals in this situation might be grossly misinterpreted.

To determine if a submaximal effort may result in consistent effort, patients whose heart rate and EMG were below the cut-off values were analyzed. Using this criterion, 5.1% of the patients did not perform a given task with significant effort; 51.1% of these patients were consistent. Therefore, the FCA results of 2.6% of the total patient group in this situation might be grossly misinterpreted. A total of 6.8% of the FCA results might be misinterpreted due to either an inconsistent performance with significant effort, or consistent performance with insignificant effort.

Comparison with the healthy group revealed statistically significant ($p<0.05$) differences in physiological responses in 9 of the 15 variables for the patient group (Table 6) and in 10 of 15 variables for the male patient and female patient groups (Table 7).

Table 6.—Significant* Differences in Performance: Healthy Group vs Patient Group

High-Level Lift Peak EMG
Mid-Level Lift HR Difference
Mid-Level Lift Peak EMG
Low-Level Lift CV
Low-Level Lift HR Difference
Low-Level Lift Peak EMG
Push CV
Push Peak EMG
Pull CV

*p < 0.5

Table 7.—Significant* Differences in Performances: Healthy Group vs Male and Female Groups

High-Level Lift HR Difference
Mid-Level Lift Peak EMG
Mid-Level Lift CV
Mid-Level Lift HR Difference
Mid-Level Lift Peak EMG
Low-Level Lift HR Difference
Low-Level Lift Peak EMG
Push HR Difference
Push HR Difference
Pull Peak EMG
Pull CV

*$p < 0.5$

Discussion

Our study was designed to differentiate the credibility of an individual's effort during tasks involving lifting, pushing, and pulling. In addition to using three averaged force trials to assess performance consistency, we monitored heart rate response and surface EMG response during the performance trials. Our results showed that an individual exerting a higher level of effort not only performed more consistently between three averaged force trials, as indicated by CV, but also had a greater increase in heart rate and surface EMG amplitude.

Matheson stated that one cannot assume that all patients will perform the FCA at maximum ability.[1] Accepting this observation and assuming that our healthy group performed with a reasonable maximal effort, it follows that the average heart rate increase and peak EMG would be greater in the healthy group than the patient groups. Our results demonstrated that consistency between the three-trial average force was greater when tasks were performed with higher effort than when tasks were performed with poor effort. This finding supports the traditional use of multiple trial force consistency for determining performance credibility. For most isometric task assessments, the force CV will provide an accurate determination of performance credibility.

However, using force CV alone may result in significantly discounting the influence of motivational and psychophysiological factors (fear, anxiety, motivation) on FCA performance credibility. Twenty-five percent of the subjects in the patient group had mixed levels of effort and consistency. We found two subgroups of these subjects, which we labeled "conditionally credible": those with consistent CV but minimal effort indicated by heart rate and EMG; those with inconsistent CV but high heart rate and EMG. The first group represents a submaximal performance and the second group represents an over-ererted performance.

Data analysis revealed that a consistent force CV can occur when a task is performed with relatively little effort. This situation can occur if the individual is consistently limited by psychophysical factors and cannot perform with enough effort to increase heart rate or EMG. It also may occur if motivational factors, such as secondary gain, enable an individual to voluntarily perform consistently at a submaximal effort. Any psychophysiological or motivational factors should be identified since they will affect the credibility of the FCA and its interpretation. If an individual is putting forth submaximal or poor effort, the interpretation of the FCA data may underestimate his or her actual functional capabilities.

Force CV can be inconsistent when the task is performed with relatively high effort. An overly motivated individual might not be able to duplicate over-exertion on subsequent trials. The significant between-trial inconsistencies will result in an elevated force CV.

CONCLUSION

To achieve a reliable and valid interpretation of the FCA results, criteria in addition to the CV of three averaged force trials must be used. Other significant measures are heart rate and surface EMG amplitude. Both measures improve FCA credibility. The CV of three average force trials of whole-body isometric tasks alone is inadequate to draw a conclusion on performance lifting reliability and might lead to gross misinterpretation of the FCA 6.8% of the time.

Using heart rate and EMG measures enhances the accuracy of performance credibility by providing interpretation of an FCA. These additional data can distinguish individuals who are consistently putting forth their best, honest effort from those putting forth various degrees of submaximal effort or overexerting during the evaluation.

Validity is a crucial limitation to isometric lift testing because this method may not accurately indicate an individual's true dynamic lifting ability. However, if an isometric lift is performed as part of the FCA, the individual's proclivity to exert maximal effort and provide a reliable performance can be determined.

CV, heart rate and EMG responses to the five tasks differed significantly when the healthy group was compared to the overall patient group (9 of 15 variables) and to the male patient and female patient groups (10 of 15 variables). This finding points out the need for using subjects that are part of the group to which the results will be generalized.

The greatest heart rate increase occurred in the low-level lift for all groups. This is in agreement with the findings of Seals et al,[6] who demonstrated a direct relationship between the size of the active muscle mass and the magnitude of heart rate increase. Performing the lift in a squat position enables greater muscle mass to be employed than in the other tasks.

REFERENCES

1. Matheson LN: How Do You Know That He Tried His Best? The Reliability Crisis in Industrial Rehabilitation. Ind Rehab Q 1:1-12, 1988.
2. Niemeyer LO, Matheson LN, Carlton RS: Testing Consistency of Effort: BTE Work Simulator. Ind Rehab Q 2:5-32, 1989.

3. Sagiv M, Hanson P, Goldhammer E, et al: Left Ventricular and Hemodynamic Responses During Upright Isometric Exercise in Normal Young and Elderly Men. Gerontology 34:165-170, 1988.
4. Lewis S, Nygaard E, Sanchez et al: Static Contraction of the Quadriceps Muscle in Man: Cardiovascular Control and Responses to One-Legged Strength Training. Acta Physiol Scand 122:341-353, 1984.
5. Sagiv M, Hanson P, Beesozzi M, et al: Left Ventricular Responses to Upright Isometric Handgrip and Deadlift in Men with Coronary Artery Disease. Am J Cardiol 55:1298-1302, 1985.
6. Seals DR, Washburn RA, Hanson PG, et al: Increased Cardiovascular Response to Static Contraction of Larger Muscle Groups. J Appl Physiol 54(2):434-437, 1983.
7. Lewis SF, Snell PG, Taylor WF, et al: Role of Muscle Mass and Mode of Contraction in Circulatory Responses to Exercise. J Appl Physiol 58(l):146-151, 1985.
8. Bezucha GR, Lenser MC, Hanson PG, et al: Comparison of Hemodynamic Responses to Static and Dynamic Exercise. J Appl Physiol 53(6):1589-1593, 1982.
9. Asmussen E: Similarities and Dissimilarities Between Static and Dynamic Exercise. Circ Res: 48(Suppl I):I3-I10, 1981.
10. Nagel FJ, Seals DR, Hanson P: Time to Fatigue During Isometric Exercise Using Different Muscle Masses. Int J Sports Med 9(5):313-315, 1988.
11. Vitcenda M, Hanson P, Folts J, et al: Impairment of Left Ventricular Function During Maximal Isometric Dead Lifting. J Appl Physiol 69(6):2062-2066, 1990.
12. Pollock ML, Wilmore JH: Exercise in Health and Disease: Evaluation and Prescription for Prevention and Rehabilitation. Philadelphia, Pa: WB Saunders Company; 1990:569 571.
13. Drury CG, Spitz G: Strength, Duration, and Recovery Mechanisms. In: Safety in Manual Materials Handling. Cincinnati, Oh: National Institute for Occupational Safety and Health, 1976: 46-51.
14. Goodgold J, Eberstein A: Electrodiagnosis of Neuromuscular Diseases. Baltimore, Md: The Williams & Wilkins Company; 1972:28-30 68.
15. DeLuca CJ, Knaflitz M: Surface Electromyography: What's New? Boston, Mass: Boston University; 1992.