Functional capacity evaluation of manual materials handlers: a review

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Abstract

Purpose: To summarize currently existing research regarding the assessment of functional capacity in low back injured workers.
Method: Literature review.
Results: Methods of functional capacity evaluation are described and critical components of an examination of functional capacity identified in relationship to federal occupational categorization and guidelines.
Conclusions: Evaluation of the predictive validity of existing functional capacity evaluation templates is not possible given the absence of thorough descriptions in the published literature. While substantial research exists enabling comparison of the injured workers’ manual materials handling ability to normative psychophysical data the validity of this approach remains uncertain.

Introduction

Increasing compensation costs make necessary the ongoing evaluation of tools currently used to facilitate resolution of disability claims and return to work. Functional capacity evaluations (FCE) are increasingly used to facilitate these goals. For the purpose of this review function will refer to the ability of the injured worker to accomplish a task, specifically a vocational task, without accommodation or greater than normal difficulty. Function is the result of learned individual technique and must be examined in an applied setting. An accurate assessment of available function should therefore quantify the injured workers’ ability to perform the critical demands of his or her job. Our ability to define the functional capacity of an injured worker will become increasingly important as a large proportion of the population pass 45 years of age (The World Health Organization (WHO) defined start of physical decline as cited by Chan et al.) and a diminishing health status in a decreasing work force is realized.

PURPOSE

The focus of this review is to describe those methods used to quantify the impairments of a worker suffering from a low back injury mainly through an examination of methods used to assess manual materials handling. It is taken that an examination of manual materials handling ability is a valid method of evaluating vocational function in jobs requiring large components of manual materials handling. A detailed discussion regarding the measurement of psychosocial factors is not included. Furthermore it is important to note that the application of the FCE is by no means limited to the industrial setting. The value of functional assessments in nonworking populations such as the handicapped and the elderly has been established.

Methods of evaluating functional capacity

Traditional methods of determining functional capacity following injury are based on the subjective reports of the injured worker and a cursory physical examination. Such assessments have been established as less valuable than a thorough analysis in an appropriate setting. Cursory physical examinations drawing largely from the subjective report of the worker may fail to accurately assess critical aspects of the job such as aerobic and strength capacities, dexterity, and agility. Examinations that do not assess critical components may therefore be limited in their ability to examine manual materials handling tasks beyond the sedentary or light level. Under a more specific definition of FCE the results of the examination may frame the functional capacity of the worker in reference to a specific job or
accepted occupational standard. Functional capacity examinations may be broadly categorized into three groups dependent on the desired outcome as described by Hart et al.8

**Baseline capacity evaluation.** Seeks to quantify the workers ability to perform the 20 job activities described in the Dictionary of Occupational Titles (DOT).9, 10

**Job capacity evaluation.** Specific job is known and the evaluation seeks to quantify the workers' abilities in direct comparison to the identified critical demands of the specific job in question.

**Work capacity evaluation.** Specific job not identified and the evaluation seeks to determine whether or not the worker is able to return to competitive employment.

The FCE (work or job capacity) as it is implemented in today's medical system seeks to define the functional capacity of the injured worker on the 20 physical factors described by the DOT. The functional capacity of the injured worker, for the purposes of awarding disability status, has been defined by the US social security administration as 'what the person is capable of doing despite medical impairment'.11 Establishment of the validity of an FCE may be based on correlation between tasks assessed by the evaluation and those recognized to be present by the Federal description of occupations. The DOT classifies occupations into sedentary, light, medium, or heavy categories based on the weight the worker is commonly required to lift and carry. Weights distinguishing between vocational categories are described in table 1. The use of the strength factors of lifting and carrying is based on research available describing acceptable levels of each. This research has been summarized into guidelines by the National Institute of Occupational Health and Safety (NIOSH) of the US in the revised lifting equation.12 Assessment of manual materials handling ability draws on the research used to form these guidelines. However, describing in any detail only two of the physical components present in the job may not allow an accurate picture to be drawn of the critical demands, and thus the DOT in this application may lack comprehensiveness.13–15 A thorough job demands analysis (JDA) may be necessary to completely describe the critical demands of the specific job in question. Tests designed to evaluate manual materials handling capacity, which reflect Federal guidelines, are therefore limited to the scope of such guidelines.

### Templates Currently in Use

Many FCE templates currently used in North America and Europe are proprietary in nature and have not been thoroughly described in the peer reviewed literature. In some cases aspects of the templates have been described (e.g. lifting assessment or consistency of effort testing) but a thorough description of the entire testing procedure used has not been presented for critical evaluation. For this reason templates currently in use may have only established the reliability and validity of certain aspects of the evaluation and not the evaluation as a whole. In some cases the pursuit of reliability and validity has been undertaken with small sample sizes selected through a review of closed cases in rehabilitation centre settings using examiners trained in the template in question.16 Generally, establishing the validity of a template has been addressed through context correlations to the physical factors described in the Federal occupational classifications.17, 18 A template may therefore establish content validity by either describing specific job demands or by covering all 20 physical demands of work as described by the DOT. By this standard King et al.13 reports that several FCE’s were judged to have good content validity by the US Department of Labour. Those FCE’s listed were; the Physical Work Performance Users Guide, Work Ability Mark III Users Guide, Isernhagen Work System Users Guide, Key Method Users Guide and ERGOS Users Guide (as cited by King et al.13)). Further, on review of currently existing literature examining FCE templates and their examiners guides, King et al.15 reported the following:

#### Table 1 Dictionary of Occupation Titles: limits of weights lifted/carried or force exerted

<table>
<thead>
<tr>
<th>Rating</th>
<th>Occasionally</th>
<th>Frequently</th>
<th>Constantly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>*–10</td>
<td>*</td>
<td>–</td>
</tr>
<tr>
<td>Light</td>
<td>*–20</td>
<td>*–10</td>
<td>*</td>
</tr>
<tr>
<td>Medium</td>
<td>20–50</td>
<td>10–50</td>
<td>10–10</td>
</tr>
<tr>
<td>Heavy</td>
<td>50–100</td>
<td>25–50</td>
<td>10–20</td>
</tr>
<tr>
<td>Very heavy</td>
<td>100+</td>
<td>50+</td>
<td>20+</td>
</tr>
</tbody>
</table>

Limits of weights distinguishing between occupational categories as described by the DOT. Occasionally refers to those activities or conditions which exist up to 1/3 of the time. Frequently refers to those activities or conditions which exist from 1/3 to 2/3 of the time. Constantly refers to those activities or conditions which exist greater than 2/3 of the time. Table and definitions as they appear in the US Department of Labour, Employment, and Training Administration Revised Dictionary of Occupational Titles, 1991.

*Negligible weight.
Only the Physical Work Performance Evaluation and the West–epic (lifting capacity section only) have an assessment of reliability published in reviewed journals.19, 20

Only the Physical Work Performance Evaluation has an examination of validity published in reviewed journals.19

Some components of the Blankenship FCE (The Blankenship System Users Guide) are based on methods developed and studied by other investigators.9, 10, 19, 21 – 33

No peer reviewed research documenting reliability or validity of the Blankenship FCE, Work ability Mark 3, Iserhagen Work System, Arcon, Key Method, WorkHab, AccessAbility, or ERGOS has been published in peer reviewed journals.19

Due to the lack of research examining the specific components of each of the above templates, it is necessary to examine the state of knowledge regarding the assessment of manual materials handling tasks. It is believed that an assessment based on the evaluation of these manual materials handling tasks is a valid method of examining occupational function.

CLASSIFICATION OF TEMPLATES

By the organization proposed by Tramposh 1992 FCE’s are classified according to structure and work task simulation.2 This information is presented for the reader in tables 2 and 3. In general as the examination procedure becomes increasingly structured (standardized), in both task and instruction, the validity and reliability of the evaluation becomes less difficult to establish. Most importantly standardization of testing procedures ensures the safety of the evaluatee and allows the cost of the evaluation to be loosely controlled. However, as the examination becomes more structured the clinician becomes less able to incorporate professional opinion and job specific testing. This may potentially effect the correlation between the examined and actual task, affecting the validity of the evaluation. In order for test procedures to yield accurate data from which to form valid conclusions both standardization of testing procedures (assisting reliability) and job specific testing (assisting validity) are necessary. Development and use of a test must be undertaken within the context of the following five criteria as described by the US Department of Labour; safety, reliability, validity, practicality and utility.16 Through standardization of testing procedures and assessment of critical demands or physical factors a FCE may meet these criteria.

TABLE 2 Types of FCE’s

<table>
<thead>
<tr>
<th>Type</th>
<th>Actual simulation</th>
<th>Predicts ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled</td>
<td>Authors instruct in process. Tests are actual simulation of physical demands.</td>
<td>Authors instruct in process. Tests simulate components of physical demands and predict physical demands.</td>
</tr>
<tr>
<td>Uncontrolled</td>
<td>Instruction maybe by test authors, self taught, or by others who have been instructed. Test are actual simulation of physical demands.</td>
<td>Instruction maybe by test authors, self taught, or by others who have been instructed. Tests simulate components of physical demands and predict physical demands.</td>
</tr>
</tbody>
</table>

Categorization of FCE’s into controlled and uncontrolled as described by Tramposh 1992.

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to compare those values with normative databases or demands analysis of eligible jobs to determine the fit between the work environment and the worker. Fishbain et al. 1994 and 1999 have developed a residual functional capacity test battery based on the assessment of the 20 physical factors presented by the DOT and have tested its predictive validity on a group of chronic back pain patients. Compensation status and pain level at discharge were found to be the most predictive in this trial. The observed loss of predictive power may be due to poor distinction between groups through low levels of data in outcome variables, small group sizes and large number of variables analysed. Further research examining the predictive power of a standardized assessment utilizing the physical factors (critical demands) present on the job site in the evaluation is needed.

**Critical components of a functional capacity examination**

The components described here should be included in any examination of function wishing to determine the functional capacity of the low back injured worker. Generally, those functional tasks that have demonstrated a correlation with low back injury are those tasks with the most research describing and supporting testing methods. Federal occupation classification and guidelines are based on this research and testing procedures are designed to reflect these standards. However, weighting of the necessary components of a FCE by supportive research present may not be the most accurate representation of that factor’s role in determining work capacity, as the assessment technique of some factors (e.g. lifting) may be somewhat limited in its ability to predict work capacity. For example, guidelines for infrequent lifting based on compressive force at the L5/S1 vertebral level may prove to be a less valid method of quantifying work load then a method capable of considering cumulative load.

**INTERVIEW**

Collection and review of medical data prior to contact with the worker is necessary before beginning a FCE. Medical information regarding the history of the injury, diagnostic tests performed, surgical procedures and follow up reports, etc. must be reviewed to determine stage of healing as well as cautions and contraindica-

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**Table 3  Advantages and disadvantages of the various types of FCE’s**

<table>
<thead>
<tr>
<th>Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled actual simulation</td>
<td>Reasonable change of Inter/intra rater reliability</td>
<td>Evaluator lacks flexibility to simulate a specific job.</td>
<td>Polinsky FCA</td>
</tr>
<tr>
<td></td>
<td>Content validity easy to show</td>
<td></td>
<td>Iserhagen FCA</td>
</tr>
<tr>
<td></td>
<td>Easy to use in court due to standard protocol.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Patients see job relatedness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controlled predicts ability</td>
<td>Best chance of inter/intra rater reliability.</td>
<td>Evaluator lacks flexibility to simulate a specific job.</td>
<td>ERGOS system</td>
</tr>
<tr>
<td></td>
<td>Easier standardization of test</td>
<td>Relies on construct validity.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Easy to use in court due to standard protocol.</td>
<td>More difficult for patients to see job relatedness.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Easiest research to control due to control and standardization.</td>
<td>Tends to be the most expensive (for therapists to purchase).</td>
<td></td>
</tr>
<tr>
<td>Uncontrolled actual simulation</td>
<td>Content validity easy to show</td>
<td>Inter/intra rater reliability difficult to control</td>
<td>Blankenship FCE</td>
</tr>
<tr>
<td></td>
<td>Easier standardization of test</td>
<td>More difficult to use in court—lack of protocol control</td>
<td>Wx: Work</td>
</tr>
<tr>
<td></td>
<td>Patients see job-relatedness</td>
<td>Hardest to research due to lack of standardization and protocol control</td>
<td>Capacities FFFWA</td>
</tr>
<tr>
<td></td>
<td>Most accessible for therapists</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncontrolled predicts ability</td>
<td>Easier standardization of test</td>
<td>Inter/intra rater reliability difficult to control.</td>
<td>Isometric/isokinetic equipment</td>
</tr>
<tr>
<td></td>
<td>Relies on construct validity.</td>
<td>More difficult to use in court—lack of protocol control</td>
<td></td>
</tr>
<tr>
<td></td>
<td>More difficult for patients to see job relatedness.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The advantages and disadvantages of FCE templates classified into controlled and uncontrolled approaches as described by Tramposh 1992.
tions to testing. Through the review of medical documentation and the workers’ report of the events leading up to and following the injury, inconsistencies that may need to be addressed within or outside of the functional capacity examination may be discovered. For a thorough list of questions the reader is referred to Kraus. Administration of functional status and psychosocial questionnaires to assess these factors may also be appropriate during the interview.

ORTHOPEDIC ASSESSMENT

The predictive value of orthopedic assessment tools is currently in question. Measures such as range of motion, strength, radiography, MRI, and general medical reports of signs and symptoms corresponding to injury of the low back have all been shown to be of limited predictive value. Clearly decisions regarding functional status based on orthopedic examination have limited predictive ability. In quantifying loss of function however, as is required by legal and compensation systems, objective orthopedic evaluation defining the extent of medical impairment is secured out of necessity.

THE ASSESSMENT OF MANUAL MATERIALS HANDLING ABILITY

As much as 30% of the US and 50% of the global work force regularly performs potentially hazardous manual materials handling as part of their jobs. There is a significant amount of evidence to support the relationship between low back pain and job demand. Further, it is generally accepted that the risk of suffering a low back disorder is associated with lifting activities at the work place. The manual materials handling task of lifting is a whole body task which, given the predominance of biomechanical stress on the back and lower back injuries, is often the limiting factor in vocational performance. Further, lifting ability is taken to be representative of other manual materials handling tasks. It is perhaps for this reason that standardized functional testing of lift capacity has been described in peer reviewed literature where other manual materials handling tasks have not.

Within a FCE it is then necessary to quantify the injured workers’ ability to perform the manual materials handling through identifying that component of the functional task that serves as the limiting factor in job performance. Having identified the ‘weak link’ in functional task performance the examiner may correlate the findings to observed performance on other tasks. Through this correlation the examiner then may develop a profile of the injured workers’ capabilities as they relate to the critical demands of a job.

Both static and dynamic strengths may be measured in an evaluation of function. However assessment utilizing either technique may be of limited value given the research findings summarized in table 4.

Isoinertial strength is commonly assessed through psychophysical means and therefore measures the maximum amount of weight the evaluee is willing to handle given a freely chosen speed. Through use of the psychophysical criterion the maximum acceptable weight of lift is assessed, incorporating both biomechanical and physiological factors resulting in a higher degree of accuracy. Further, validation of the psychophysical criterion’s ability to predict occurrence of low back pain is documented in the literature. Tests using an isoinertial protocol and psychophysical criterion are most appropriately used in a FCE due to the higher correlation between isoinertial techniques and actual work tasks and the ethical demands necessitating the use of

| Table 4 Limitations of static and dynamic strength measures |
|---------------------------------|--------------------------------|
| **Category of strength measure** | **Research findings**          |
| Static                          | Static strengths may overestimate the workers’ ability to perform manual materials handling tasks. Static strength is not able to account for the effect of inertial forces leading to an underestimation of the musculoskeletal joint load during the performance of a dynamic task. Individuals with the similar static strengths may have different dynamic strengths, and those dynamic strengths more closely correlate to the task performance abilities of the worker. |
| Isotonic                        | In a dynamic activity the load lifted will require differing forces due to changing muscle moment arms as the load is moved, therefore there is no true isotonic movement and its application for the purposes of functional evaluation is limited. |
| Isokinetic                      | Isokinetic strength testing requires an exertion along a fixed path at a constant velocity with the force required to overcome the initial inertia of the lift. Therefore measures of isokinetic strength do not consider the components of agility and coordination. |

Limitations of static, and dynamic strength measures as discussed in the literature.
psychophysical ‘stopping points’. Further, existing normative psychophysical data allows relative ranking of the evaluatee’s capabilities that may provide increased predictive ability.

THE REVISED NIOSH LIFTING EQUATION

Peer reviewed tests of functional lift capacity appear to be reflective of NIOSH lifting guidelines. Through a discussion of the formation of these guidelines, limitations in lift capacity assessments are addressed and areas requiring future focus are illustrated. The revised NIOSH lifting equation is designed to limit 90% of the working population’s exposure to levels of lifting leading to increased risk of injury. However, this equation only considers two-handed lifting from floor to shoulder level in a frequent (greater than 4 lifts per minute) and infrequent framework. Lifts that involve one hand, lifting while sitting or kneeling, lifting in a constrained work space, lifting temperate items, high speed lifting (lifting that is performed in a 2–4 second time frame) lifting wheel barrels, or shoveling are not considered.12 Tests designed to reflect the NIOSH guidelines may therefore be limited to the above situations. Using the framework presented by NIOSH, the maximum functional lifting capacity of a worker is determined by considering biomechanical, physiological and psychophysical criteria. Levels of exposure beyond which there is an increased risk of injury are therefore defined.12 Through consideration of these factors in a functional assessment of lifting capacity, the examiner may arrive at an appropriate method of testing based on a ‘weakest link’ framework. The component of the lifting task, be it physiological, biomechanical, or psychophysical, most quickly exceeded in the type of lift examined should be the critical factor determining functional work ability. Comparison of observed ability versus these defined levels may then allow the examiner to describe the functional capacity of the worker in the following ways:

Comparison vs NIOSH guidelines to arrive at ability to return to conforming tasks.

Comparison vs job specific demands to arrive at ability to return to work.

Comparison vs normative psychophysical data to arrive at percentile rank.

Recent studies have examined the predictive ability of the revised NIOSH equation in identifying jobs with an increased risk of low back injury.61, 83 Marras et al. 1999, in a study of 353 industrial jobs representing over 21 million person hours of exposure reported that although 73% of the high risk jobs were correctly classified, 45% of the low risk jobs were incorrectly classified and over 66% of the medium risk jobs were incorrectly classified using the revised NIOSH equation.61 It is suggested that the high rate of misclassification into higher risk categories may be due to the overestimation of risk through the multiplier variables considered in the equation.61 The various multiplier variables were tested using a Wald analysis and it is reported that only the horizontal distance multiplier and box weight multiplier contributed significantly to the equation.61 The authors suggest that the lack of predictive contribution of the other variables may be due to low variability between groups or lack of description regarding the specifics of assessment.61 The authors also report the ability of predicted load moment alone to identify the jobs with elevated risk of injury.61 Clearly the role of the various multiplier variables must be considered in any equation seeking to identify recommended weight limits targeted at decreasing the incidence of back injury, however more research describing the relative role of each of these multipliers is needed.

LIFT CAPACITY

Review of the literature and discussion thus far has indicated that isometric strength testing for the purposes of determining functional ability in the injured worker yields a less accurate assessment of lifting capacity then an isoinertial method. In contrast then, when considering isoinertial lifting techniques it is possible to more closely examine ‘real world’ lifting by incorporating the initial inertia required to move the load and the speed at which the load may be lifted in the industrial context. An isoinertial test of lift capacity incorporating the psychophysical data provided by Snook et al.84 may therefore provide a useful method of quantifying the functional lifting capacity of the injured worker. There are two such measures currently presented in the literature; the Progressive Isoinertial Lifting Evaluation (PILE) presented by Mayer et al.32, 47, 85–87 and the Employment Potential Improvement Corporation (EPIC) lift capacity test (ELC) presented by Matheson et al. and Jay et al.16,88,89 Both tests are briefly described in the peer reviewed literature for the purposes of introduction and validation.
The PILE examination as described by Mayer et al.\textsuperscript{32} is an isoinertial lifting examination designed to determine the subjects’ frequent lift capacity (maximum weight tolerated when lifted 12 times per minute). Results of the examination are expressed in terms of maximum weight lifted, endurance time to discontinuation of test, final and target heart rate, total work and total power consumption. Within the PILE Mayer et al.\textsuperscript{32} describes a method of normalizing lift capacity to arrive at an adjusted weight through a method of calculating ideal body weight. Mayer et al.\textsuperscript{32} uses this ideal weight to determine a subject specific safe end point as well as a normalizing factor for inter-subject comparison. Through comparing the subject with a normal database the PILE then provides a level of work corresponding to the subjects’ frequent lift capacity.

It has been suggested that the PILE test is gender biased, subject to increased variability between and within raters, incorporates too many lifts per minute to achieve reliability in the clinical setting and uses loads that are too large to be safe.\textsuperscript{16} Gender bias has been reported by Matheson et al.\textsuperscript{16} in regards to differential weight increases in males and females (5.9 kg and 3.6 kg respectively) and vertical lift height requirements not scaled to the height of the evaluatee. Increased risk of measurement bias has been presented by Matheson et al.\textsuperscript{16} in regard to the lack of an examiners manual. Unsafe load increments were also reported by Matheson et al.\textsuperscript{16}, however this is indirectly refuted by Mayer et al.\textsuperscript{32} with the report of no incidence of injury in over 10000 applications\textsuperscript{16, 87}

The ELC assessment is an isoinertial evaluation similar in structure to the PILE examination and is described in relative detail by Jay et al.\textsuperscript{90} Occasional and frequent lift capacity are measured in three subtests; knuckle to shoulder, floor to knuckle, and floor to shoulder lifts. Gender differences are attenuated by use of vertical ranges for lifting that are linked to the subject’s height in keeping with the legal requirements of employment tests in the US. The same test protocol is used without regard to the gender of the examinee.\textsuperscript{90} Heart rate, body posture, body mechanics and psychophysical response are collected and used to determine maximal acceptable load.\textsuperscript{90} The ELC incorporates the use of many tools designed for the test but not explained in detail or validated elsewhere. Testing procedures such as the ‘high risk work style measurement guidelines’, those aspects of altered performance that constitute ‘changes in posture and muscle recruitment’, the specific calculation for arriving a restricted load proportional to ideal body weight based on gender, height and weight and the ‘acceptability of perceived load scale’ based on the Borg scale. The ELC has been shown to correlate well to the revised NIOSH equation recommended weight limits, showing that recommended weight limit is consistent with test performance.\textsuperscript{16} To date peer reviewed literature demonstrating adequate test retest reliability in a large sample of healthy subjects and small sample of disabled subjects has been reported. In addition the responsiveness in subjects before and after conditioning treatment has been established, as well as resistance to reactivity and ability to detect sincerity of effort in two groups of subjects with previously diagnosed musculoskeletal impairment.\textsuperscript{16, 88}

PUSH AND PULL CAPACITY

Nearly half of all manual materials handling consists of pushing and pulling tasks.\textsuperscript{91} Asfahl 1984 reported that for every one ton of product manufactured 80 – 150 tons of materials are moved.\textsuperscript{92} Assessment of the manual materials handling task of push and pull is therefore justified in an evaluation of functional work capacity.

Biomechanical criteria

Significant compressive forces are generated during both push and pull activities. Pushing activities have been reported to generate over twice the compressive load at the L5/S1 level as the corresponding pulling activity by biomechanical modeling in both isometric and isokinetic trials.\textsuperscript{93} Therefore, if the functional activity assessed is limited by the biomechanical criterion it is reasonable to assume that the compressive forces generated during the pushing task will most quickly reach the point of psychophysical stoppage. Further, those compressive forces observed in pushing tasks will be strongly correlated to those forces generated during the lifting evaluation should compression represent the ‘weak link’. Compressive force is directly related to the point at which the force is initiated and thus a thorough biomechanical analysis is needed to correctly approximate the force at the L5/S1 level. Kumar 1994 demonstrated that the mean compressive forces on maximal exertion at the L5/S1 level in push activities may exceed 5.4 kN in both isometric and isokinetic activities in males at low heights and may exceed mean forces of 3.6 kN in females.\textsuperscript{89} The values observed certainly approach the 3.4 kilo Newton biomechanical limit of the revised NIOSH equation for one time lifting exertion.\textsuperscript{12} The status of shear with respect to injury causation and its role in FCE is currently disputed.
Psychophysical criteria

The most comprehensive collection of psychophysical data to date in regards to push/pull activities was presented by Snook et al.\cite{80} and revisited in 1991.\cite{84} Tables provided by the above authors describe initial and sustained force values for push and pull tasks according to percentile of the population (10th through 90th) at various handle heights, time intervals and distances. Recent studies have shown however, that the experimental set up used originally by Snook et al.\cite{94} may have resulted in values lower than may be perceived acceptable through psychophysical testing. Cireillo et al.\cite{94} report that maximal acceptable initial and sustained forces of pushing a high inertia cart were significantly higher than those observed during magnetic particle brake treadmill testing such as that used by Snook et al. 1978, 1991.\cite{80,84}. Assessment of push pull ability in the clinical setting commonly uses a friction sleigh and not a magnetic particle treadmill. For this reason direct comparison to the normative data presented by Snook et al.\cite{80,84} is not possible. Indirectly however, through calculating the force required to initiate and sustain motion in the friction sleigh, the examiner may correlate observed ability to normative data and arrive at percentile rank.

Physiological criteria

Push and pull tasks involve a significant degree of static activity in the trunk and upper extremities. Due to the large component of static activity and the dynamic nature of the task, aerobic capacity guidelines during repetitive exertions of push and pull tasks may be quickly exceeded. Close monitoring of the heart rate and oxygen consumption during the task is therefore essential to ensure the safety of the evaluatee. Observed endpoints should be correlated with those observed during assessment of other dynamic activities to develop a profile of the functional abilities of the worker.

CARRYING CAPACITY

Standardized tests of carrying capacity for clinical use have not been presented in the peer reviewed literature. Assessment of carrying capacity should follow the procedures used in Snook et al. 1978,\cite{80} and revised in 1991\cite{84} to enable comparison to the normative database therein. Psychophysical normative data is presented for carrying tasks over three distances at four heights at seven frequencies.\cite{80,84} Analysis of biomechanical compressive load and physiological strain during task performance should be monitored using techniques similar to those used in lifting and push/pull tasks according to guidelines presented in Waters et al.\cite{12}.

GENERAL WORK TASKS

The assessment of decreased functional ability in general work tasks should be quantified and correlated to previous orthopedic assessments due to the lack of peer reviewed standardized tests. General work tasks for the purposes of this review are those physical factors of the Federal classification of occupations that must be evaluated using a clinical knowledge of safe technique and physical impairment. The tasks referred to are the physical factors of walking, climbing, stooping, kneeling, crouching, crawling, reaching, and sustained postures. In order for the quantification of functional impairment in these tasks to aid the predictive validity of the evaluation, data of more depth than a nominal dichotomous level should be used. Through quantifying the distance walked into categories or specific units of measurement (e.g. metres) discrimination between workers is achieved, and predictive validity of the functional test is enhanced. Further, simply stating the injured workers’ ability to perform an activity hinders the clinician’s or case management officer’s ability to determine what activities, if any, should be restricted upon return to work.

DEXTERITY

Dexterity is indirectly assessed through body mechanics employed during manual materials handling tasks. Examiner training is likely necessary in this regard to produce reliable assessments. However, no peer-reviewed studies directly examining the reliability and validity of the observed evaluation of safe technique or altered body mechanics is present. In determining the workers’ ability to perform the specific job task in question as close a representation of that task should be reproduced. Should restrictions in the workers’ functional ability to perform these tasks be found, the relationship between the functional findings and the findings of the orthopedic exam should be correlated.

BALANCE

Functional balance is dependent on three sensory inputs; somatosensory visual and vestibular. Techniques used to assess the dynamic balance of the injured worker should quantify impairment according to deficits in
these areas. Generally, techniques for quantifying functional balance from either anatomical derangement or neurological impairment follow a progression of balance challenges; decreased external support, decreased base and stability of support, addition of body segment movement and introduction of perturbation. Practical job simulated testing may apply the described progression to a simulated activity in order to determine the ability of the worker to safely function in the work environment. In addition to job related testing the referring party may require a quantified measure of balance as determined by standardized procedure. However, standardized measurement tools used in the assessment of balance have largely been validated in non-working populations.95-97 Many tests evaluate basic activities of daily living tested at a level not relevant in considering appropriate placement in return to work. It is the ‘ceiling effect’ of tools such as the Berg balance scale, Tenietti Balance Test of the Performance Oriented Assessment of Mobility Problems and the Physical Performance Test that limit their utility in the assessment of functional balance in an injured worker population.95-97 Testing procedures to be used for the purposes of assessing functional balance of the injured worker must quantify the degree of impairment and optimally relate that impairment to specific deficits in the three sensory input areas. The most thorough analysis of the injured workers’ dynamic balance utilizes technical testing procedures such as platform posturography, however such testing procedures are not commonly available to the examiner. Balance tests such as the Clinical Test of Sensory Interaction and Balance (CTSIB) may be adaptable to for FCE application.98 Further the CTSIB has been found to correlate well to platform posturography.99 Through use of the CTSIB the examiner is able to separately assess the role of somatosensory and visual inputs, thus allowing the examiner to make reliable conclusions regarding the appropriateness of return to work. The functional reach test and timed one leg standing test also provide the examiner the ability to assess dynamic balance in the clinical setting. The functional reach test in its current form is limited in its applicability due to the test only considering loss of balance as a result of forward weight shift. Research into the application of the test in the lateral directions and posteriorly has been undertaken and presented in abstract form.100,101 Research validating the use of the CTSIB, functional reach or one leg standing in the injured worker population has not been reported. Further, normative databases from which to quantify the findings of these tests are not currently available.

CONSISTENCY OF EFFORT

Determination of consistency of effort during a FCE is necessary to ensure the evaluate is fully cooperating with the assessment process. As no thorough description of a functional capacity evaluation test battery is available in the published literature, a summary of the findings of Lechner et al.102 are presented for the reader in table 5 in order to highlight the limitations of each approach.

Introduction to the utility of the job demands analysis

JDA seeks to provide a description of the specific occupation in question through an ergonomic framework. Further, it may function as a template from which to identify the critical demands of the job in question for functional capacity examination in terms of the physical factors identified by Federal classification documents. Specifically JDA may examine the following categories of work demand:

Work organization. Pace of work, working hours, variety.

Psychological factors. Work roles, participation, control.

Ergonomic factors. Repetitive jobs, posture, handling of heavy material, speed, precision, anthropometric changes.

Physical factors. Noise, vibration, heat, pressure, lighting.

Each category influences the functional capacity of the injured worker and should therefore be included in any such evaluation. A description of the minimal demands of the job in question may be formulated through collection of the above information and the fit between the workers’ functional capacity and those minimal demands may be assessed. The minimal demands of the job have been described by Fishbain et al.14,44 as the demand minimal functional capacity (DMFC). Without access to the DMFC of the job in question, the critical demands of the job may be best described by the Federal occupational classification documentation (DOT) or job description provided by the employer. In the absence of a DMFC, conclusions
regarding the injured workers’ ability to return to work are based on a general description of a category of occupations such as those found in the DOT, or the description provided by the employer, both of which may fail to address specific critical demands. Further, the DMFC in this instance may only describe, in limited detail, the general strength requirements of lifting and carrying. The remaining physical factors may not be addressed or are simply listed as commonly present. Factors such as repetition, force (including but not limited to lifting and carrying), awkward postures, and so on may only be accurately identified through an onsite analysis of the specific job. Only through use of a JDA is the evaluator introduced to the specific environment to which the worker may be returning, identifying ergonomic factors present both adaptable and not. Without such a description the evaluator may be left only with a brief description of a job category, defining risk factors which may or may not be present, and a general classification of strength requirements based only on the average lifting and carrying requirements of the occupational category. Clearly, without a more detailed description of the functional requirements any examination whose purpose it is to evaluate fit between worker and work environment is limited in both its validity and reliability.

**Conclusion**

Lack of published descriptions of currently used FCE templates makes evaluation of their component parts difficult. It is therefore necessary to examine current research, Federal documentation, and guidelines regarding critical job factors in an analysis of FCE. Through an analysis of functional tasks the evaluator is able to assess that one criterion (biomechanical, physiological or psychophysical) likely to function as the limiting factor in occupational performance. Further, the evaluator is able to quantify the limiting factor in relationship to absolute values for comparison with those recognized on the job site by JDA (prediction of work tolerance) or comparison to population norms. Current studies supporting the predictive value of the physical components (primary and functional) in FCE are lacking. Additional research is needed in order to draw conclusions regarding the predictive value of the physical factors or functional manual materials handling tasks assessed in the FCE. The predictive value of tools used
to evaluate functional capacity in manual materials handlers remains in question.

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Evaluation of manual materials handlers

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