# Establishing a Comparative Best Effort Physical Performance and Physio-Behavioral Pain Component Baseline for Use in a Functional Restoration Program

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The general issue of functional restoration following physiological impairment and dysfunction is discussed in this manuscript. Relating certain strategies and approaches to relevant literature, the authors make a case for a multidisciplinary approach employing a myriad of diverse services including pain management, cognitive behavioral therapies, occupational reframing, and active mobilization of injured body areas in order to be effective. Several studies are reported to substantiate service approaches. Functional restoration is primarily achieved through functional improvement – not the cessation of all complications.

## Introduction - Part I

Functional restoration can be thought of as an outpatient intervention for chronic pain. It is designed for use in medically stable, non-surgical candidates who, after exhausting all other treatment options, demonstrates a physiological impairment, or dysfunction, that prevents their return to work, attaining full-duty or pre-injury status, or reaching maximum medical improvement. In general, a functional restoration program usually requires a multidisciplinary approach that frequently employs a myriad of diverse medical services including pain management, cognitive behavioral therapies, occupational reframing, and active mobilization of injured body areas in order to be effective.

When considering the scope of this paper, in light of these multidisciplinary approaches, a decision was made by the authors to limit discussions to the two relevant issues of how to properly measure a best effort physical performance capability and how to quantify physio-behavioral pain components that could be used as a comparative starting point in the functional restoration process. As such the reader should be aware that this paper is not intended to provide a complete or exhaustive discussion of all possible facets of a functional restoration program.

Even with this self-imposed restriction the authors recognized that the concepts to be discussed are of sufficient breadth that several components found in this paper could be considered as separate research topics in their own right. Notwithstanding, the authors also concluded that to present such topics separately would meaningfully detract from a thorough discussion of the essential cornerstone elements required to establish an evidenced-based functional restoration baseline.

### The Problem

Chronic (non-malignant) pain, generally defined as discomfort lasting more than 3–6 months (Glass, 2004; APA) can impair function, mood and the overall quality of life. Chronic pain is considered to be the single greatest health factor leading to disability in the U.S. Various sources estimate the cost of chronic pain to be about $50-$100 billion in productivity losses each year (Fryemore & Cats-Baril, 1991).

Studies have also shown that workers who are absent from work for more than six (6) months have an approximate 50% probability of returning to work, diminishing further to 25% after being absent for one year (Glass, 2004). Consequently, disabilities caused

by chronic pain can hold significant financial, social and personal consequences if not properly addressed.

### The Solution

The most effective means of managing a disability caused by chronic pain, and where objective findings are generally absent or disproportional to subjective complaints, is a well-designed functional restoration program that meets the following two objectives:

1. Identifies the safe *best effort* physical performance capability (baseline employability) of a chronic pain individual, and
2. Mitigates (normalization) any discomfort and/or physio-behavioral pain components, in whole or in part, to allow for greater functioning (mobilization) and the return toward normalcy (restoration).

Unlike acute pain management, the ultimate goal of a functional restoration program is to provide rehabilitation that leads to optimal functional recovery / maximal medical improvement (MMI) rather than seeking the elimination of pain, which may not be possible or realistic. In a functional restoration program the goals of self-care and/or successful reintegration into the work environment are paramount.

### Essential Baseline Components

For purposes of this article the authors determined that the following five components were essential to establish a best effort physical performance and physio-behavioral pain component baseline for an effective functional restoration program that is also consistent with the principles and recommendations made by the American College of Occupational and Environmental Medicine (Glass, 2004) for managing the resumption of function in chronic pain patients: 1) physical performance capability testing, 2) cross validation of performance results, 3) normalization of discomfort patterns, 4) mitigation of physio-behavioral interferences, and 5) rapid, yet careful, mobilization of injured body areas that demonstrates clear functional improvement.

These essential baseline components allow the clinician to:

1. Accurately quantify and separate physical performance capabilities (what can they do) from what they "feel" they can do or what they "want" to do,
2. Objectively differentiate and validate if physical performance results represent under-performance (false negative), over-performance (false positive) or the true *safe and sustainable* work capability of a patient (is it their best effort),
3. Measure how patient perceptions of discomfort change under varying physical performance conditions allowing for the careful targeting of rehabilitation therapies to effect discomfort normalization (how does perceived discomfort affect work performance),
4. Identify and assess physio-behavioral pain factors that may impede functional improvement so that remedial medical, cognitive and psychosocial therapies may be implemented (are subjective complaints based on functional pathology or behavior), and
5. Implement a systematic restoration process through rapid mobilization and improvement of function leading to maximum medical improvement in the shortest time possible (restorative therapy).

## Methods

### Component #1 – Determining What Can They Do?

The first step in establishing a physical performance baseline is to take inventory of the existing physical capabilities of the functional restoration candidate. Traditionally, the tool most often used for quantifying physical performance is called a functional capacity evaluation (FCE), work capacity evaluation (WCE) or functional abilities evaluation (FAE) [herein referred to as "FCE system(s)"] for which there exist more than a dozen different methodologies from which to choose.

Consequently, in preparation for this study, an invitation was extended to several functional capacity system vendors/manufacturers (See Table 1) to provide information regarding their assessment methods so that the researchers could determine which FCE system(s) were best suited for measuring physical performance capabilities in an evidence-based functional restoration program. Each vendor was asked to supply descriptive literature presenting the unique features of its system, copies of available technology/method specific scientific studies supporting their scientific content, and sample detailed data reports from which conclusions of work capabilities were drawn.

Upon receipt, each system was then reviewed and evaluated based on three criteria: 1) the objectivity of its *data collection* techniques including the extent of raw performance detail, 2) the validity and reproducibility of its *analysis methods* for calculating functional performance levels, and 3) the availability of method or technology-specific juried journal published studies that met evidence-based *scientific content*.

To evaluate which FCE system(s) were best suited for use in a functional restoration program a total of 36 individual system features (11 data collection; 17 analysis methods; 8 scientific content) were deter-

**Table 1: Functional Capacity Systems & Methods**

| FCE Types | Used To Address | Methods & Manufacturers | Researcher's Comments |
|---|---|---|---|
| Functional Goal Setting | Ability To Perform Key Tasks Compared To Pre-Injury Ability | Used to establish therapy goals; *ARCON, BTE / Hanoun, Cybex, Chattanooga, Isotechnologies, Lafayette, Loredan and Smith & Nephew Rolyan, ErgoScience* | Face validity data collection; Test end-points linked to subjective complaints; Claimant controlled exam process; Normative testing is foundation for claim of discrimination; Lack of independent brand specific juried journal scientific study publications; Incomplete scientific documentation. |
| Disability Rating | Loss of Work Capacity in Contrast with Normal Values | Used to measure loss-of-performance in key functional areas as ESTIMATE of disability; *Blankenship, Matheson, EPIC, Key, ErgoScience* | Face validity data collection; Test end-points linked to subjective complaints; Claimant controlled exam process; Normative testing is foundation for claim of discrimination; Lack of independent brand specific juried journal scientific study publications; Incomplete scientific documentation. |
| Job Task Matching | Adequacy for Job Compared To Specific Job Demands | Combines manual job analysis with medical exam to identify specific physical abilities that require functional evaluation; *BTE / Hanoun, EPIC, Isernhagen Work Systems, WEST, Loredan and Smith & Nephew Rolyan, ErgoScience* | Face validity data collection; Test end-points linked to subjective complaints; Claimant controlled exam process; Normative testing is foundation for claim of discrimination; Lack of independent brand specific juried journal scientific study publications; Incomplete scientific documentation. |
| Occupational Matching | Adequacy for Occupation Compared To Own Occupation Work Demands; Usually Skill Based Rather Than Whole Body Testing | Occupational physical demands obtained from DOT / NOC that are compared to a combined medical and functional capacity test for determining maximum functional capabilities within a particular occupational job class; *Valpar Work Samples (manual)* *ERGOS - SimWork Systems (US)* | Criterion-based data collection; extensive use of MTM, CV specific performance testing; Brand specific scientific study documentation in juried journal publications evidencing validity, reliability, reproducibility, clinical and longitudinal predictive abilities of technology; Standardized protocol construction; Work sample manual testing (Valpar); Technology based work simulation (ERGOS). |
| Work Capacity Evaluation (WCE) | Maximum Dependable Whole Body Ability Matched To General Employment Work Demands In Any Occupation | Most comprehensive type of FCE used to match functional capacity to competitive employment for ANY DOT/ NOC defined occupation using international court-tested employment standards & methods; *ERGOS - SimWork Systems (US)* | Criterion-based data collection; extensive use of MTM, CV specific performance testing; Brand specific scientific study documentation in juried journal publications evidencing validity, reliability, reproducibility, clinical and longitudinal predictive abilities of technology; Standardized protocol construction; Technology based work simulation (ERGOS). |

mined by the researchers to be critical for meeting the five essential functional restoration components previously discussed in this article. For each desirable feature that a system possessed a value of plus one (+1) was given (i.e., a juried journal published validity study, industry accepted use of methods-time measurement [MTM, 1988], cross validated best effort quantification, co-efficient of variations [CV], etc.), a minus one (–1) was given for any undesirable or counterproductive feature (i.e,. lack of criterion-based testing, improper use of MTMs, use of normative comparative data, etc.), while zero (0) values were assigned for any missing or partial/incomplete feature needed to create a functional restoration baseline.

Of the available respondent information (Matheson, Iserhagen, Blankenship, Key, ErgoScience, Spinoscope, ERGOS Work Simulator, ARCON, BTE/Hanoun) all of the systems were found by the researchers to have limitations in meeting the 36 essential features needed for establishing an evidenced-based functional restoration baseline (Gouttenbarge et al., 2004; King et al., 1998).

The primary reasons for these limitations were because many systems and methods of evaluation:

- Relied on face validity (evaluator observation) data collection techniques, rather than criterion-based testing, which allowed for an unacceptable degree of evaluator bias during test administration and interpretation,
- Incorporated subjective/somatic test endpoints that allowed the patient to control the test environment based on subjective response thus circumventing functional restoration techniques designed to achieve discomfort breakthrough (i.e., pushing past somatic end-points),
- Used non-homogeneous normative or "norms" values as comparative benchmarks resulting in potentially discriminatory test conclusions,
- Could not demonstrate reproducible results leading to generalization and gross estimation of functional performance,
- Failed to establish, in the literature, sufficient studies to authenticate the scientific validity,

reliability, reproducibility and/or predictability of their conclusions,
- Lacked one or more major system components, most notably in dealing with the measuring and analyzing of discomfort and physio-behavioral pain components, needed to properly measure the efficacy of functional restorative therapies, and/or
- Lacked sufficient measures of internal validity to evaluate the level of consistency in the data to answer the question "how do we know they tried their best?"

From the available data (See Table 2), one important finding worth mentioning was the superior ability of technology-based FCE systems (i.e., work simulators) in collecting detailed physical performance data over manual FCE systems. This was evidenced by the fact that the majority of these technology-based systems scored more than twice as high as the manual FCEs in data collection techniques. This observation led the researchers to the conclusion that the use of a work simulation device to achieve effective functional restoration was a much more efficient method than manual testing alone.

Typically, work simulators provided better data collection techniques through the use of computerized test administration, more exacting performance data recordings, the incorporation of methods-time measurement (MTM), co-efficient of variations (CV) and muscle contraction/effort graphs.

In contrast to this, all but one of the technology-based work simulation systems used normative (norms) data comparisons of validity. This feature significantly degraded the value of their analysis methods as such data has been determined to be prejudicial when performing disability and employment testing under the guidelines of the Americans with Disability Act (ADA, 1983). Consequently, the data from this type of work simulator was significantly compromised as a tool for establishing an evidence-based functional restoration baseline from which to measure the efficacy of restorative mobilization therapies.

### FCE System Rankings

Of the systems reviewed the ERGOS Work Simulator (ERGOS) scored the highest overall rating, meeting 75.0% of the essential criteria for establishing a functional restoration baseline. The second highest score was achieved by the BTE/Hanoun system at 33.3% of the criteria, however, as previously discussed much of the Hanoun data had to be discounted as this system used "normative" data comparisons during analysis suggesting potential age, gender and disability biases.

All manual traditional functional capacity systems scored less than 20.0% overall and were found to be inaccurate as a measurement or restorative therapy tool. One system (Spinoscope / Spinex), that combined surface scanning EMG (SEMG) and video recordings during a manual functional capacity evaluation, based on a literature review, was found to lack a substantiated scientific basis altogether (Pullman et al., 2000; Leclaire et al., 1996).

Based on this review the researchers concluded, that for the purpose of this study, that the ERGOS Work Simulator presented the best tool of choice to measure baseline physical performance capabilities (employability) of chronic pain patients. Noted desirable strengths found within this system included:

- The exclusive use of criterion-based performance assessment methods that related physical performance directly to the job requirements being tested.
- Physical performance measurements recorded at a rate of 20 samplings per second, or 100 samplings per test repetition, to create muscle contraction graphs that were correlated with the use of CVs during all static test activities

**Table 2: FCE System Ratings**

| FCE System | System Type | Data Collection | Analysis Methods | Scientific Content | Overall Rating |
|---|---|---|---|---|---|
| ERGOS Work Simulator | Technology | 76.5% | 54.5% | 100.0% | 75.0% |
| BTE / Hanoun | Technology | 23.5% | 18.2% | 75.0% | 33.3% |
| Matheson System | Manual | 5.9% | 9.1% | 50.0% | 16.7% |
| VerNova /ARCON | Technology | 11.8% | 18.2% | 12.5% | 13.9% |
| Key | Manual | 5.9% | 9.1% | 25.0% | 11.1% |
| Isserhagen | Manual | 5.9% | 9.1% | 12.5% | 8.3% |
| ErgoScience | Manual | 5.9% | 9.1% | 12.5% | 8.3% |
| Blankenship | Manual | 5.9% | 9.1% | 0.0% | 5.6% |
| Spinoscope | Technology | 0.0% | 0.0% | -75.0% | -16.7% |

and internationally accepted MTM scores for all dynamic work activities,
- Detailed measurement of muscle fatigue impacts on biomechanical performance with correlation to whole day work capabilities for all work frequencies (i.e., occasional, frequent & constant),
- The use of American Psychology Association compliant cognitive distraction protocols for evaluating consistency of performance results,
- The incorporation of the essential physical demand requirements for each subject's usual and customary job assignment at all work frequency levels, as defined by the U.S. Department of Labor's Dictionary of Occupational Titles (DOT), as a comparative benchmark to identify functional deficiencies,
- Enhanced objectivity supported by a juried journal published technology-specific concurrent validity study that demonstrates that a four-hour ERGOS exam will yield information on functional strength and endurance comparable to a comprehensive, multidisciplinary 2-week traditional functional capacity evaluation ($p< 0.0001$), and
- Possessing the industry's only 6-year, 700 case longitudinal study, currently being compiled at the Work Evaluation Research Center, demonstrating the technology's ability to forecast "safe and sustainable" (predictability) functional performance levels.

Notwithstanding the apparent advantages of the ERGOS over competing systems, it was noted that this system did not entirely meet all of the essential components needed to establish a baseline comparative functional restoration dataset either. The deficiencies found with this system included:

- A lack of integrated intra-data cross-validation algorithms to correlate & reconcile distracted and non-distracted physical performance results (best effort quantification),
- A lack of a systematic method for gathering multi-factorial discomfort and behavioral pain component factors during physical performance testing (identifying prime factors), and
- The lack of the incorporation of a system of weighted measurements and computational algorithms to allow for the determination of a definitive causal conclusion regarding the nature of the discomfort and behavioral factors collected (factorization)

It should be noted, however, that most of the deficiencies found within the ERGOS system more accurately reflects the current state-of-the-art for physical performance testing, rather than the specific failure of this system to perform assessments for which it was not originally designed. This underscores the need for further scientific research and development by this industry in order to address the demands for effective functional restoration therapies.

### Component #2 – Is It Their Best Effort?

Measuring physical performance capabilities is not the same as measuring "best effort", as muscular effort is often influenced by other variables such as pathology, behavior, discomfort perceptions, conditioning levels and muscle fatigue. What functional restoration clinicians are attempting to achieve is the accurate measurement of an individual's true *safe and sustainable* physical performance work capability.

This is contrasted against "under performance" capability which is a false negative that tends to exaggerate perceptions of disability, while hidden residual physical capabilities remain undisclosed, and "over performance" capability that creates a false positive that reflects momentary maximum capability, but does not indicate sustainable functional capabilities when applied over any length of performance period, generally defined in the workplace as an 8-hour workday. Consequently, accuracy in physical performance testing is critical to create realistic and safe baseline physical performance levels from which to implement rapid progressive muscle loading during restorative therapy.

To address this need for identifying a true *safe and sustainable* (best effort) baseline, and noting the ERGOS lack of intra-data cross validation capabilities, the researchers found it necessary to implement several mitigating test procedures during this study including:

- Measuring each biomechanic at least twice to as many as seven times for comparative analysis of consistency in performance,
- Employing cognitive distraction principles where the test subject was unaware of what particular biomechanic was being tested at any given time,
- Measuring postural biomechanics using short-term repetitive movements as well as long-term sustained biomechanical motions, and
- Re-measuring strenuous biomechanics such as lifting & carrying utilizing specific endurance test protocols designed to measure the effects of muscle fatigue.

This created multiple data sets for each biomechanic that provided the researchers with a fuller understanding of the effort levels being provided by the test subjects during physical performance testing.

To analyze this data, comparative algorithms incorporating the use of co-efficient of variations (CVs) for all static work, and method-times measurements (MTMs) for all dynamic work activities were applied. These al-

gorithms provided the researchers with the ability to do an apple-to-apple cross-validation comparison of multiple datasets of performance results to accurately measure the consistency of a test subject's performance, and to identify *best effort* physical performance capability for use as a baseline.

**Study Design #1**

***Disability Impairment Ratings vs. Employability***

To explore the issue of disability and employability (best effort physical performance capability), a prospective blinded cohort study was conducted involving 220 chronic pain subjects, consisting of 44% federal government, 16% public & state and 40% private industry workers. The pre-examination disability status of this group revealed that 198 (90%) of the 220 test subjects were certified as being *"totally disabled"* at the time of the evaluation. These ratings were based on the prevailing permanent disability impairment rating guidelines (AMA, 5th Ed.) in effect at the time when the subject was made permanent and stationary by their treating physician. An additional eight (8) subjects (3.6%) were given physical impairment rating levels that equated to 25% or less than the physical demands requirements of their usual and customary job, as defined by the U.S. Department of Labor's Dictionary of Occupational Titles (1991), essentially labeling 93.6% of the total study subjects as *"unemployable."*

Each subject in this study was administered a 4-hour evaluation using the computerized ERGOS system in accordance with the peer-reviewed testing protocols established by the manufacturer. Data comparisons were then made between the subject's pre-examination disability rating and their *best effort* physical performance levels determined by criterion-based work simulation testing and the application of intra-data cross-validation algorithms as previously described.

***Data Collection, Analysis & Blinding***

Data collection for this study was conducted using experienced medically trained (RN) certified work capacity evaluators. The evaluating clinicians responsible for the collection of physical performance, discomfort and physio-behavioral raw data were unaware of the clinical results of the biomechanical tests during the examination process. The application of comparative and intra-data cross validation algorithms were completed after the conclusion of the examination period. Statistical analysis of the aggregate biomechanical data for this study was completed after all subjects had been tested.

Analysis of the data collected, along with the compilation of all conclusions, was completed using scientific and medical interpretation algorithms designed by a multidisciplinary medical, scientific, research and vocational panel consisting of:

- A Certified Occupational Heath Nurse Specialist (RN COHN-S) & experienced work capacity evaluator; (BioFunction, USA),
- A medically trained (RN) Certified Ergonomic Compliance Director (RN CECD) & experienced work capacity evaluator; (BioFunction, USA),
- A Board Certified Occupational Medicine & Family Practice Physician (MD); (The Medical Corner, USA),
- A Director of Research / Clinical Services & Qualified Expert Witness in Work Capacity Evaluation (MPE; PhD); (Work Evaluation Research Center, CAN), and
- A Certified Work Adjustment Specialist & Qualified Expert Witness in Work Capacity Evaluation (MS Vocational Evaluation CWA); (SimWork Systems, USA)

All load capacities and algorithms used to determine performance capabilities were designed to be consistent with prevailing industry standards including ergonomic equivalency conversion ratios established by the U.S. Department of Labor's Revised Handbook for Analyzing Jobs (1992), and definitions of work frequency as defined by the U.S. Department of Labor's Dictionary of Occupational Titles (DOT, 1991), and the American Medical Association's Guide To The Evaluation of Permanent Impairment (AMA, 5th Ed.).

All job standards used as a basis of comparison of the test subjects work performance were based on the physical demand requirements as listed in the DOT (1991), except as modified by an employer specific job analysis, for the subjects usual and customary job preceding injury.

## Results

Analysis of the data indicated that 219 of 219 (100)% test subjects, who completed the 4-hour examination, were found to have *best effort* functional levels *higher* than their pre-examination disability ratings (See Table 3). The one subject that did not have a functional level higher than their pre-examination disability rating refused to complete the examination without attempting any biomechanical test protocols representing a drop-out rate of 0.45% for this study.

Upon further review of the data the researchers noted that 79 subjects (36.1%) were found to have met, or exceeded, the full duty physical demand requirements of their usual and customary (U&C) job, while another 7.3% of the subjects (Physical Demand Category: 75 – 99%) arguably could have been provided minor ergo-

**Table 3: Pre & Post-Exam Distribution**

| % Usual & Customary Job Level | Pre-Exam Count | % | Post-Exam Count | % |
|---|---|---|---|---|
| 0% | 198 | 90.0% | 0 | 0.0% |
| 1 – 25% | 8 | 3.6% | 35 | 16.0% |
| 26 – 50% | 13 | 5.9% | 72 | 32.9% |
| 51 – 75% | 1 | 0.5% | 17 | 7.7% |
| 76 – 99% | 0 | 0.0% | 16 | 7.3% |
| 100%+ | 0 | 0.0% | 79 | 36.1% |
| Dropout Rate | NA | NA | 1 | 0.5% |

nomic job task adaptations, workload shifting and/or work environment adjustments so that more than 43% of the *totally disabled* subjects in this study could have resumed a normal, or very near normal, lifestyle.

Notwithstanding, the job accommodation factor, this study comparison suggests that there is *poor correlation* between disability impairment rating levels and the actual work capabilities (employability) as demonstrated by these subjects following examination. It also clearly demonstrates that significant functional residual capability and potential improvement can be achieved for most chronic pain patients previously classified as *"irreparably"* disabled.

### Why Such Disparity?

Possible explanations for this disparity may include one or more factors such as the passage of time between *rated* disability and the exam dates that allowed for greater normalization of function through continued healing, better patient adaptation to discomfort patterns previously perceived as the cause of functional impairment, and improved conditioning due to psychosocial adjustments in lifestyle as a reaction to permanent disability. While it was not the purpose of this study to examine the impact of these specific factors, it was noted that the average length of time between disability rating and examination for each of these test subjects exceeded 2 years duration in a range of 3 months to 23.6 years.

It should also be noted that *disability impairment ratings* followed rating criteria found within industry standard guidelines that are designed to measure loss of joint function, including components of range of motion, motor function and sensation as a percentage of whole body impairment (AMA, 5th Ed.). Upon review of these guidelines it was noted that physicians who are responsible for developing disability ratings (i.e., IME, QME & AMEs) are being forced to use rating tables and formulas, to determine the strength and endurance of a disabled individual, that do not address real world physical performance capabilities (what they can do) as they relate to actual job demands (employability). This situation was further evidenced when the researchers noted that all functional performance capabilities for test subjects in this study were based on subjective treating physician anecdotal experience, or a gross ordinate scaling, that appeared to be inconsistently applied as no physical performance testing was completed in any of these subjects prior to disability rating.

As a result, one subject could be rated as having lost 50% of their joint function but only be able to perform 20% of their usual and customary job, while another subject could have the same percentage of joint function loss but be determined to be able to meet 80% of their job demands. This underscores an inherent weakness in the impairment rating method when used to determine work function and/or employability.

In contrast, data gathered from this study rather suggests that disability impairment does not necessarily translate into a loss of employment potential. It also supports the conclusion that accurate best effort physical performance testing is needed during functional restoration so that maximum return to a productive lifestyle, including reintegration into the work environment, can be effectively achieved.

## Introduction - Part II

### Mitigating Discomfort and Behavioral Pain Components

According to the ACOEM, chronic pain patients frequently demonstrate psychological reactions to pain that lead to impaired physical performance and function. Examples of these reactions include escape/avoidance behaviors, fear of pain behaviors, guarding, increased anxiety, depression and diminished participation of the patient in their own recovery (Glass, 2004). The key in functional restoration is to objectively identify these barriers simultaneously with physical performance testing by using controlled observations of the effects of pathology, discomfort & be-

havior so that determinations may be made on how these pain components impede functional improvement.

### Measuring Pain & Behavior

The prevailing medical opinion is that pain cannot be objectively measured(Glass, 2004). This is a result of the recognition that no two individuals interpret the same pain stimuli in exactly the same way (IASP; Mersky & Bogduk). This difference in discomfort perception is attributed to the presence of physiological and psychosocial factors too numerous and complex to quantify. However, while this consensus is well supported as to the quantification of pain when comparing two separate individual's response to the same pain stimuli, it does not apply when comparing inter-subjective time differentiated experiences of discomfort within a single individual.

In reality, inter-subjective patterns of pain perception, as well as changes to these patterns, can be objectively measured. The basis for this declaration lies in the fact that every individual reframes each time differentiated pain encounter using their own personal physiological and psychosocial biases as a comparative means for judging whether they are experiencing a *"good day"* or a *"bad day."* It is this inter-subjective quantification process that offers a consistent framework for quantifying and comparing segregated intervals of pain perception. This quantification process may also be applied in a functional restoration program to identify patterns that can be used to facilitate normalization of discomfort while advancing functional improvement.

What can be said of the complexities of quantifying discomfort can be equally said of measuring physio-behavioral response. Even more so since behavior can further be complicated by known pathology interferences, unconscious fear-of-pain perceptions as well as conscious secondary gain motivations. In a functional restoration program it is these very factors that the clinician must mitigate to achieve an advance in functional improvement.

## Methods

### Discomfort Measuring Tools

Notwithstanding the difficulties inherent in the process of assessing the nature of pain, various pain assessment models have emerged to help providers understand the effects of discomfort on physical performance (e.g., Pain Scales - Acute Pain Model, Adaptation To Pain, Admission Assessment, Brief Pain Inventory [BPI], Faces Rating Scale, Flowsheets, Graphic Rating Scale [GRS], Numerical Rating Scale [NRS], Simple Descriptor Scale [SDS] and Visual Analog Scale [VAS]). However, upon detailed review of these pain assessment models, most were found to be inadequate for use in a functional restoration program.

This is because many traditional pain models only offer information regarding the discomfort perception response itself, with no correlation or determination as to their impact on functional performance during a specific activity. They also frequently employ a linear discomfort quantification process that encourages the patient to choose a higher level of discomfort when noting even minute qualitative changes to their discomfort perceptions.

In reality, this response choice is more accurately describing that a physical activity caused a perceptual change to their pain level, but it does not necessarily suggest that this change reduced their ability to perform a given function. Furthermore, research has shown that individuals will quickly adapt to the effects of pain and that the absence, or the suppression, of behavioral and physiological signs of pain does not necessarily equate to the absence of pain itself. (Glass, 2004; Cooke et al., 1994; Menard & Cooke, 1995).

### Physio-Behavioral Pain Component Measuring Tools

Upon searching for various tools that could be used for the collection and evaluation of physio-behavioral pain factors, the researchers encountered a widespread paucity of available tools and methods for achieving this purpose. Furthermore, most behavioral assessment methods tended to generalize that if any physio-behavioral components were demonstrated during physical performance testing that it was for the purpose of either a secondary gain (malingering) motive, or it represented a stress-induced consequential condition believed to be related to the chronicity of pain caused by the original injury or illness.

While both of these extremes are important considerations that should be explored by the clinician, they do, however, ignore what is believed by the researchers to be a much larger middle ground of behavior patterns associated with physio-behavioral pain response. This middle ground is characterized by activity avoidance and fear of pain behaviors that become amplified when individuals make a subtle psychological mind shift where they stop viewing themselves as an "injured workers" and rather start viewing themselves as "disabled persons."

Based on experiences of the researchers this mind-shift phenomenon is generally observed to occur at about six months post-injury. As a result of this mind-shift the chronic pain individual is lead to the realization and subsequent resignation that they may never again be whole. This realization is often further reinforced through repeated interactions with the medical community that ever reminds the subject with each visit, or

therapy session, that they are not still "capable" and that they have residual incompleteness of functional abilities. This in turn fosters a more passive participation by the individuals in their own recovery process. Individuals are also frequently noted to shift the responsibility for recovery away from their selves by creating greater dependency on the healthcare professional.

Consequently, these individuals stop believing that there is anything they can do to resolve their present condition. They begin substituting the willingness to get well with a resignation that they will be disabled. Such adjustment frequently results in expressions of loss, blaming behaviors and expectations of entitlement for real and perceived physiological and psychological damages, especially when impairment results in loss of employability and/or dire socioeconomic hardships (i.e., loss of property, loss or relationships, loss of family, loss of lifestyle, etc.).

### New Clinical Tools: Discomfort & Behavioral Factoring Scales

As a result of the paucity of available tools the researchers arrived at the conclusion that in order to achieve efficient and consistent data gathering, for factors of discomfort and physio-behavioral pain components, that two new clinical evaluation tools (Biofunction, 2003) would have to be created to accomplish the objectives of this study. Due to the complexity inherent in measuring these multiple and varied physio-behavioral and discomfort responses, it was also determined that this process was best facilitated through the use of computerized classification and analysis algorithms that could be consistently applied to the raw data results so that interpreter subjectivity could be eliminated when drawing conclusions from the data. Subsequent to these findings, and upon designing these clinical tools, the researchers concluded that the most robust scientific method for meeting all these developmental characteristics would be through the application of the science of *factorization*.

Factorization is the systematic collection and classification of independent factors (finding and characterizing primes), that when weighted values of measurement (computational algorithms) are applied a definitive causal conclusion (factoring algorithm) can be reached regarding the nature of the object being measured. The science of *factoring* also contends that the greater the number of factors being gathered, the greater the probability, reliability and accuracy its conclusions will be once the factorization processes has been applied (Sprites et al., 2000)

### Component #3 – Discomfort Factoring Scales

When applied in a specific application, such as a *discomfort factoring system*, factorization involves the collection and comparative analysis of data regarding the nature, severity, frequency and duration of reports of discomfort under load and no-load test environments. These factors are used to quantify the nature of the patient's perception of discomfort and are collected using a modified non-escalating verbal graphic rating scale (VGRS).

Concomitantly, independent data is also gathered by the clinician regarding the functional impact of these factors on demonstrated work performance, including functional deficiencies, the presence or absence of physiological compensatory pain responses, work pacing, muscular coordination, and overall activity performance. These functional performance observations are also collected using a corresponding non-linear functional VGRS scale to allow the evaluator to correlate the patient's perceived discomfort to objective observations of functional performance.

It should be understood by the clinician that the goal of discomfort factorization is not to prove, or disprove, if a patient is experiencing discomfort. Quite the contrary, as it is recognized that chronic pain patients are most likely never to reach a pain-free state. This process, instead, acknowledges pain as a *given functional inhibitor*, but then seeks to evaluate how these pain patterns impact the patient's abilities to function at progressively advancing levels of performance through careful yet rapid muscle loading to facilitate resumption of function. They are also used to suggest approaching biomechanical dysfunction where breakthrough chronic pain interventions (i.e., cognitive behavioral pain therapy, anti-depressant medication, analgesic loading, long-term sustained-released opiate use, occupational therapy, etc.) might be effective in helping the patient mobilize their function to greater levels of performance and to restore a higher quality of life for these disabled individuals.

### Component #4 – Behavioral Factoring Scales

When applied in a *behavioral factoring system*, factoring includes the collection and comparative analysis of known physiological responses to pathology as well as behavioral factors that suggest fear of pain, avoidance behaviors, as well as motivational, affective, cognitive and behavioral overlays.

Once these behavioral factors are collected, computational algorithms can be applied using a weighted numerical rating system (NRS) to determine specific patterns of behavior and to identify causal relationships. Reliability of casual relationships is further enhanced through the use of cognitive distraction testing and repetitive test scenarios.

Overall, the researchers identified 13 individual indexes of physio-behavioral reliability for dynamic work (work performed over distance) and 17 indices for static work (postural work). These indices encompassed 76

independent prime factors that could be readily identified and applied to a single biomechanical movement during work simulation testing. Some examples of known reliability indices included breakdown in biomechanics, repetitive physical compensatory pain responses, co-efficient of variations, methods-time measurement values, muscle contraction unit graphs of muscle ramp-up, fatigue and muscle deceleration, physical exertion indicators and consistency of effort through cross-validated test performances.

The researchers, prior to this study, identified these reliability indices, and their corresponding factors, by conducting more than 300 work simulation examinations. The researchers then reviewed these factors with medical professionals, who specialized in disability quantification and ratings, in the fields of occupational medicine, physiatry, orthopedics, orthopedic surgery, neurology, and pain management.

From this review, the researchers developed a consensus of weighted values for each factor that were then incorporated into computerized computational algorithms to achieve a conservative interpretation for the data collected. Once these values were assigned, patterns of behavior could be classified in relation to functional performance.

In this manner the researchers were then able to quantify subjective responses of discomfort and measure physio-behavioral pain components and correlate changes in patient perceptions to changing functional load stimuli during criterion-based work simulation testing.

### Study Design #2

To evaluate these factoring scales in relationship to functional deficiencies found during physical performance testing a second prospective blinded cohort study was conducted by the researchers. The focus of this study was to examine how to properly quantify discomfort and physio-behavioral pain components to be used as baseline comparative data to measure the effectiveness of normalization and mobilization therapies in a functional restoration program.

### Subjects

A total of 58 subjects, consisting of 22 men and 36 women, aged 21 to 65 were included in the study (See Table 4).

Each subject had been previously determined by his or her treating physician to have a chronic pain condition that was rated as being permanent and stationary. One hundred percent (100%) of the subjects had no prior physical performance testing and their durations of disability averaged 2.5 years in a range of approximately 6 months to 8.5 years.

**Table 4. Subject Characteristics**

| Variable | Men | Women |
|---|---|---|
| Sample Size | 22 | 36 |
| Age (yrs) | | |
| Mean | 42.9 | 45.2 |
| Range | 21 - 65 | 30 - 65 |
| Time Since Injury (mo) | | |
| Mean | 28.4 | 32.0 |
| Range | 6.7 – 103.4 | 6.4 – 94.8 |
| Injury Areas (%) | | |
| Cervical | 9.1 | 22.2 |
| Thoracic | 0.0 | 5.6 |
| Lumbar | 50.0 | 38.9 |
| Shoulder | 18.3 | 11.1 |
| Arm | 4.5 | 0.0 |
| Elbow | 0.0 | 2.8 |
| Wrist/Hand | 9.1 | 8.3 |
| Knee | 4.5 | 8.3 |
| Ankle/Foot | 4.5 | 2.8 |
| Surgery (%) | | |
| No | 77.3 | 88.9 |
| Yes | 22.7 | 11.1 |
| Job Classifications | | |
| Sedentary (<10 lbs) | 0.0 | 5.5 |
| Light (11 – 20 lbs) | 18.2 | 27.8 |
| Medium (21 – 50 lbs) | 54.5 | 41.7 |
| Heavy (51 – 100 lbs) | 22.7 | 27.8 |
| Very Heavy (100+ lbs) | 4.6 | 25.0 |

The pre-examination disability rating status of the subjects revealed that 46 of the 58 test subjects were certified by their primary treating physician as being totally disabled at the time of the evaluation. Eleven participants were given physical restrictions that were equivalent to 25% or less than the physical demands requirements of their usual and customary job, and one participant met 60% of their job standard as defined by the U.S. Department of Labor's Dictionary of Occupational Titles (1991).

All test subjects were cleared by their primary treating physicians to be tested to physical tolerance and all test subjects were simultaneously rated using the factoring scales (2003) as previously described in this article.

### Test Samplings – Discomfort & Behavioral Pain Components

On average, each subject completed 52 separate biomechanical tests, in a range of 21 to 72 tests, during the 4-hour work simulation session. Biomechanical test selection was determined based on relevant tests appropriate to the subject's particular diagnosis, as well as, incorporating the core examination tests of the essential physical work demand requirements for the subject's usual and customary job assignment as defined by the U.S. Department of Labor's Dictionary of Occupational Titles (1991).

Biomechanical test protocols were grouped into six separate workstations. These stations were designed to measure whole body range of motion, static strength capacity, dynamic lifting capabilities, standing work tolerances, seated work tolerances, and work endurance / fatigue. This grouping also yielded three (3) loaded and three (3) non-loaded workstations to allow for randomization of biomechanical protocols and the redundant patterning of the subject's responses to validate consistency of discomfort and physio-behavioral pain component complaints. Cognitive distraction testing was conducted for every biomechanical test at least once, to as many as seven times, to add further randomization and validation of performance.

Discomfort data was collected on pre-test and after each panel workstation yielding seven separate periodic test samplings per subject per body part, from which specific discomfort patterns were derived. On average each subject reported discomfort complaints affecting 12 individual body parts in a range of 0 to 49, with 685 total body part patterns reviewed by the researchers. This yielded 4,795 total test samplings of discomfort.

Physio-behavioral pain components, and known pathology interferences, were collected for each independent biomechanical test. This resulted in a total of 3,039 test samplings from which behavior patterns were identified.

All raw performance data, discomfort and physio-behavioral observations were analyzed in a computer database that allowed the researchers to consistently apply pre-designed factoring algorithms to derive final conclusions regarding the causal nature and relationship of physio-behavioral pain components to performance results.

## Results

### Discomfort Factoring Findings

Discomfort factoring scales yielded three separate distinct results: decreasing, level or escalating discomfort patterns. Within the context of a functional restoration program these patterns have significant importance as they can be used to objectively demonstrate the presence, or absence, of normalization during progressive biomechanical loading through repeat testing, factoring and comparison.

Clinically, these discomfort patterns also provide important clues to the restoration process as well. The researchers noted that a decreasing discomfort pattern underscored the principle that "motion is lotion". This is a positive indicator that increased physical performance reduces, and/or alleviates, the subject's pain response. This means that subjects demonstrating this type of discomfort pattern directly benefit from increased physical performance activity that can lead to the amelioration of some, or all, of their discomfort; at least in regards to the short-term effects of the discomfort response.

Though not the focus of this study, it was recognized by the researchers that further investigation and study should be done to measure and quantify the lasting effects of the "motion is lotion" response to evaluate whether an endorphin-induced response is being triggered as a temporary mask of discomfort, or whether permanent discomfort reduction is actually being achieved with activity.

Level discomfort patterns indicate that the effects of load and no-load activities have no direct relationship on the subject's perceptions of discomfort. In these subjects, it is also appropriate to establish an occupational goal that encourages the individual to return to a productive lifestyle, as it is unlikely to significantly alter their pain response. However, it should also be noted that these subjects may still require supplemental pain control therapies (i.e., anti-inflammatory medications, steroid injections, nerve blocks, acupuncture, TENS units, narcotics, etc.) to assist with mobilization efforts during restoration therapies, to manage periodic flare-ups and to provide long term maintenance of discomfort while achieving normalization goals.

Finally, escalating discomfort patterns provided baseline data that helped to separate if discomfort responses were based on pathology interferences triggered by specific physical activities, if cognitive behavioral overlays associated with fear of pain were inhibiting functional restoration, or if secondary gain behaviors were being used by subjects who saw escalating subjective complaint responses as a potential means for perpetuating and/or exaggerating their disability level. When escalating discomfort patterns were compared under load and no-load scenarios while using repetitious cognitive distraction testing, patterns of consistency, or the lack thereof, emerged. It was these patterns that then led the researchers to the conclusion that not only was factorization of discomfort critical to functional restoration but that factorization of physio-behavioral response was needed as well.

### Behavioral Factoring Findings

In the analysis of behavioral factorization the researchers were able to identify five distinct behavioral patterns that could impede functional performance and be used as baseline comparative data through repeat performance testing. Each behavior pattern was readily discoverable in the raw performance data of the subjects through the use of muscle contraction graphs, MTM rankings, intra-data cross-validation comparisons and CV scores. These identified patterns included: self-limited performances, guarding behaviors, inordinately slow movement patterns, uncooperative/avoidance behaviors, and refusals.

The most prolific behavioral response (See Table 5) noted by the researchers, based on the frequency of the behavior's appearance during examination, was *self-limited performance*. This behavior appeared in 20.1% of the 3,039 biomechanical test samplings administered during this study and was used by 75.9% of the test subjects. Test subjects exhibiting self-limited performance behaviors were noted to have completed the assigned biomechanical test protocol, but they also consciously gave less than a full effort during the protocol activity. On cross-validation, using cognitive distraction protocols for the same biomechanic, these test subjects were noted to consistently achieve higher scores when contrasted against their performance during non-distracted protocols.

From a functional restoration perspective, this type of subject can be readily counseled to achieve functional improvement. The cross-validated performance result demonstrates a residual capability that the clinician may utilize to guide the functional restoration process and to correct the subject's conduct through open counseling that confronts this behavior. The researchers noted that once the subject understood that his/her performance was being quantified without their knowing (cognitive distraction) they were more likely to give a more honest performance on the next round of testing. If not, and the subject continued to exhibit repeated self-limited performance behaviors, then they were determined to no longer be an appropriate candidate for functional restoration as such behavior could then be properly interpreted as a secondary gain motive.

The second most frequent behavior pattern was *guarding*, which appeared in 17.0% of the test samplings. Guarding behavior is very similar to self-limited performance except that the individual continues to increase their muscle loading in small increments until they feel that the load will trigger a pain response, and having reached this threshold they then begin deceleration of the muscle contraction. This type of behavior may be an unconscious reaction, or it may be a learned response resulting from repeated failed activity trials during the acute phase of their injury, that creates a conditioned pain response that they do not wish to trigger. Unlike self-limited performance, "guarding" test subjects demonstrated consistent performance results when cognitive distraction protocols were administered and the multi-dataset results were cross-validated for consistency.

Counseling guarding subjects is often more difficult than correcting self-limited performances. Depending on the vividness and severity of the learned pain response, clinicians should understand that individuals may be reluctant to address specific biomechanical movement activities. Their successful rehabilitation rests on the ability of the clinician to reduce their "fear of pain" response. The focus of restoration is to help them understand that only certain biomechanical movements, not all, are causing their guarding response. It should also be repeatedly emphasized to these subjects that their fears are best resolved by "facing and conquering" the very biomechanical motion they wish to avoid, while simultaneously reassuring them of safety and providing supportive counseling while addressing the fear.

These types of subjects may need to go slower in a functional restoration regimen using smaller load increments to progressively desensitize them to their fears. They may also benefit from supplemental pain control interventions and/or cognitive therapy treat-

### Table 5. Behavioral Overlay

| Behavior | Subjects Exhibiting Behavior | Average Frequency of Behavior |
|---|---|---|
| Self-Limited Performance | 75.9% | 20.1% |
| Guarding Behavior | 89.7% | 17.0% |
| Refusals / Secondary Gain | 46.6% | 8.3% |
| Inordinately Slow | 46.6% | 5.7% |
| Uncooperative / Avoidance | 22.4% | 1.0% |

ment to help reduce their fears. In the failure to resolve an individual's fear of pain they should then be counseled in any work-around solutions that may still provide improvement to the overall quality of their lives before termination of their functional restoration program.

Consistent with the use of court-tested international productivity work standards (MTM, 1988), *inordinately slow* performance classifications may be categorized as a contrived behavioral pattern. These performance patterns may also have their origin in extreme self-limited performance behavior. In this type of behavior the researchers noted that the test subjects in this category utilized an extremely slow movement pattern that could not otherwise be duplicated without giving conscious effort to restricting the movement of the specific biomechanic that was being tested. The predominant explanation given by these subjects for their inability to perform the biomechanical motion was due to reports of excessive amounts of discomfort and/or pathology interferences that inhibited their full performance in the biomechanical function while completing the task.

It is here that the value of cognitive distraction protocols and cross-validation again provides the clinician with an analysis of the real underlying capacity of the "inordinately slow" subject. Physiologically, when the test subject slows a biomechanical motion down to the level of an inordinately slow movement pattern, they are actually demonstrating the ability to achieve sustained prolonged biomechanical movement over long periods of time (i.e., a greater, not lesser, performance capability).

Consequently, these controlled inordinately slow performance patterns ultimately disclose the subject's true physical capability, as it requires greater muscular strength and coordination for them to perform these contrived movements than it does to perform the short-frequency movement cycles used during work simulation testing.

Correction of inordinately slow behaviors during functional restoration should follow the same recommendations as previously discussed under self-limited behavior. In the absence of voluntary correction of this behavior by the subject, after repeated counseling sessions, then this behavior would rise to the level of a repetitious uncooperative behavior (i.e., refusal) and could then be properly labeled as secondary gain. At this point, the subject would no longer be a candidate for continued functional restoration.

During the examination period nearly 25% of the test subjects demonstrated *uncooperative / avoidance* behavior. However, based on further in-depth analysis by the researchers, this behavior was noted to occur usually in relation to a specific biomechanical action. Overall, the test subjects demonstrated only an average uncooperative/avoidance behavior in 1% of the total test protocols completed.

Frequent subject responses, when asked by the clinician as to why they felt they could not participate, resulted in comments such as "I am afraid I will hurt myself" (fear of pain), "I don't think I can do that" (avoidance), and "my doctor/therapist told me not to do that type of activity" (seeking advocacy). Nearly all test subjects held the opinion that their inability to perform this single specific biomechanical function was their sole reason for being determined as "*unemployable.*"

When confronted with these types of replies the evaluators were trained to respond to the subjects by first drawing their attention to the fact that they had not even attempted the test protocol. This response was to see if the subject would approach their anxieties without further clinician prompting. If successful the test proceeded. If the subject persisted in their avoidance routine, then they were counseled further.

Second level counseling included discussing with the subject that they had previously been cleared by their treating physician to be tested "for tolerance" which meant that they may have to go beyond the physical restrictions previously imposed by their doctor so that they could see if improvement was occurring. All test subjects were then counseled that all test protocol were designed to start at safe load levels and would be advanced in small incremental steps as they demonstrated the successful ability to progress. They were also informed that without an attempt to "try" the protocol that a "refusal" behavior would have to be reported to the parties involved in their claim. They were also reassured that if they failed an honest trial attempt that it would not be counted against them as a conscious behavioral interference if they were unable to finish the test protocol.

In this manner the researchers found that these subjects were able to begin addressing their varied anxieties. Some subjects switched their behavioral responses and employed self-limited behaviors during the trial while others resorted to guarding. Only a few were noted to persist in their avoidance behavior beyond this second counseling phase and were subsequently rated as a refusal.

It is very important that the clinician carefully notes and documents this type of behavior, as it is the best clue into the psyche of the subject's fears about returning to an active lifestyle. Because this type of response is usually elicited commensurate with strong feelings against performing a specific movement, that the subject cognitively frames as unsafe for them to do, they will most likely require some cognitive behavioral therapies to assist them in resolving these fears.

Upon review of the 3,039 behavioral test samplings the researchers noted that refusal behavior (i.e., failure to complete at least a trial attempt at a requested protocol after repeated counseling attempts) was used by nearly 50% of the subjects. On average the test sub-

jects refused 4.3 out of 52 protocols. Observations by the researchers noted only two reasons for this behavior: subject's who used persistent uncooperative/avoidance behaviors having failed to mitigate their "fear of pain" even after counseling, and those who were overtly seeking secondary gain by being unwilling to be tested.

To make allowance for this behavior the researchers, prior to this study, determined that in order to have a successful chance in functional restoration the test subjects must acceptably participate in at least 80% of the baseline examination protocols before recommendations for a functional restoration program could be made. While this benchmark was arbitrarily established by the researchers it was felt that less cooperative participation by a subject would introduce too much behavioral contention during mobilization therapies and would jeopardize achieving a successful progressive corrective outcome.

Interestingly enough, after the researchers pre-determined this threshold, and then applied it to the performance results of the test subjects, it was noted that those subjects who failed to achieve the 80% threshold had an average refusal rate (25.7 protocols) that was nearly six times the number of average refusals demonstrated by the entire group (4.3 protocols).

In segregating and comparing the average refusals of the "over 80% threshold" group with the average refusals of the "under 80% threshold" group it was noted that the "under 80% threshold" group exhibited refusals 18.5 times greater (25.7 protocols) than those "over the 80% threshold" (1.4 protocols) mark. Even the test subject demonstrating the lowest refusal rate in the "under 80% threshold" group had a rate nearly double (19 protocols) that of the highest subject in the "over 80% threshold" group (10 protocols).

On closer examination of the "over 80% threshold" group data, the researchers noted that these refusals were generally limited to specific biomechanical movements relating to the injured body part. Of equal importance was the realization that subjects who were seeking secondary gain (under 80% threshold group) were decidedly more overt in their efforts and were more likely to refuse protocols on biomechanical movements unrelated to their injury pathology. Consequently, this tended to reinforce the utility of using the 80% threshold rule to provide the clinician with a clear methodology for selecting which candidates should be considered for inclusion, and which should be considered for dropout, in a functional restoration program.

## Component #5 – Restorative Therapy

### Work Performance & Sustainability

The yardstick by which an effective functional restoration program must measure itself is its ability to improve work performance (functional improvement). Essential to this equation is not only the careful and accurate quantification of work capability but also the need for the clinician to identify *sustainability* of work function.

Sustainability of function represents maximum muscle activity minus the effects of fatigue extending over a period of time, generally defined as an 8-hour workday. Sustainability is crucial in functional restoration as without it repeated excessive voluntary muscular effort would lead to accelerated muscle fatigue, increased stress to the body, possible exacerbation or acceleration of an underlying pathology, or additional injury altogether.

The key to identifying sustainability is the repeated and redundant testing of biomechanical performances for consistency during load (weight bearing) and no-load (non-weight bearing) test scenarios. Even better is when physical testing of short duration biomechanical performances is cross-validated against the same biomechanical activity performed during sustained work efforts using cognitive distraction testing. This provides the clinician with the ability to properly evaluate any effects of fatigue and allows them to identify "safe & sustainable" biomechanical performance, as separated from "maximum" (false positive) capability, to establish a true 8-hour workday capacity.

### Rapid Resumption of Function

The ACOEM, in their textbook on Occupational Medicine Practice Guidelines, points out that improvement in the restoration of function can be achieved through the mitigation of pain-related fears. They also note that most traditional short-term physical therapy and exercise programs are not of sufficient duration to create a lasting physiological effect or change in function (Glass, 2004). The researchers of this study would concur with ACOEM's premise that restoration of function requires aggressive and intense restorative therapies to effect mobilization of function to maximum medical improvement, but would also add that it must also seek as a goal the normalization of discomfort and behavior simultaneously in order for the functional improvement to be permanent and long-lasting.

Such a program must combine aerobic conditioning, stretching to improve range of motion & flexibility, patient education in coping skills and lifestyle adjustments, along with strengthening to correct de-conditioning and to effect muscle retraining (mobilization) to maximum function. By analogy, functional restoration is not unlike a "spring training" program that

professional athletes use in preparation for their upcoming "season of work."

It is also important to note that functional restoration differs greatly from acute physical therapy techniques. Functional restoration does not focus on correcting the pathology of a single muscle, or muscle group, but rather aggregates total body function through the use of primary and collateral muscle conditioning.

By example, the goal is not to strengthen the subject's quadriceps but rather to restore walking as a function, which involves a much more complicated coordination of varied muscle complexes that are also causally linked to perceptual reactions referred to as discomfort and behavior pain components that need to be mitigated simultaneously to achieve successful restoration. Failure in recognizing and addressing this relationship will result in the failure of a functional restoration program and will likely lead to re-injury.

Consequently, to achieve this rapid resumption of function clinicians will require sophisticated tools and means such as those described in this study for effecting muscle loading in the shortest time possible, for without work simulation to gauge and monitor incremental advances, and the use of factorization to separate out causal interferences for correction, the goal of rapid resumption could not otherwise be done in a safe and scientific manner.

Common parameters frequently suggested by various sports medicine, exercise physiology, and corresponding medical community professionals would call for a restoration therapy that is done at least four (4) hours per day, 3 – 5 times per week with the goal of progressively achieving full restoration to maximum medical improvement in 30 – 90 days from onset of a program.

The advantage of using work simulation over traditional muscle strengthening is that a work simulator utilizes *job specific work movements, posturing & functional activities along with controlled work pacing* to achieve functional improvement. Manual FCE systems are simply not robust enough to capture minute changes in physiology and to separate causal relationship of pathology, discomfort and behavioral pain components while employing progressive muscle loading. They also fail to meet requirements of validity and reliability to meet the criteria required of evidence-based systems as they rely on poor construct and face validity analysis, which constitutes the lowest form of scientific evidence.

Even with technology based approaches, care must be given to avoid normative, potentially discriminating test comparisons, as well as test protocols that use a somatic, or subjective, test-end points that will negate the goal of normalization via discomfort and behavioral breakthrough. In addition, technology specific validity and reliability needs to be well established, not merely the reference to scientific principles that bear no relation to the equipment or the biomechanical protocol itself.

Using such a program as described in this paper, with sophisticated analysis to measure the impact of restorative therapies on function, will yield clear patterns of progress and/or lack of progress. In the event that restorative therapy demonstrates measurable functional improvement then the rule should be to continue progressive muscle loading until a plateau is reached. Once this plateau has been accomplished then this is the signal that maximum medical improvement has been achieved and the functional restoration program should be stopped, as it is unlikely that further therapy interventions will be as intense as those encountered in the functional restoration program and will most likely not produce any additional significant functional improvement benefits.

## Conclusions

There is considerable complexity in gathering comparative data of work capability, fatigue cycles, and the sophistication needed to do an "apples-to-apples" comparative study. To do this objectively and effectively MTM analysis of biomechanical movement patterns can be used to stem the difficulty in applying ergonomic equivalency conversion ratios for time and load to properly identify commensurate work frequency levels to meet any and all work environments. Because of this, as previously concluded by the researchers, it seems inconceivable to try and conduct functional restoration without the use of technology-based work simulation. The authors would also add to this conclusion that computerized factorization and analysis of discomfort and physio-behavioral patterns are essential tools as well, given that perceived discomfort and behavioral interferences can dramatically affect sustainability of physical performance.

As discussed factorization represents the best scientific method for gathering, evaluating, and separating factors of pathology, discomfort and behavior through the use of reliability indices. While no one single index can be relied upon as the sole determinant of reliability, the grouping of multiple indices can point to causation.

Correlating this information with the cross-validated examination results, obtained during criterion-based work simulation, allowed the researchers to apply causative computational algorithms using conservative industry interpretations that resulted in an overall rating (34.5% pathology / 65.5% behavior) of the group, as well as an individual rating for each test subject based on their dominant performance pattern (See Table 6).

From these ratings, 31.0% of the test subjects did not require any functional restoration interventions as

they demonstrated physical performance capabilities that met the full duty physical demand requirements of their usual and customary job assignment; 56.9% demonstrated biomechanical deficiencies that were deemed appropriate for recommendation to a functional restoration program; and 12.1% were found to be unacceptable candidates for a functional restoration program.

The desired end-point of a functional restoration program is the return to function (functional improvement), rather than the complete or immediate alleviation or cessation of pain (Glass, 2004). To achieve this desired end-point a functional restoration program must provide for the rapid but careful resumption of function through active mobilization of injured body areas and subsequent normalization of function.

This goal is best accomplished using a scientifically engineered system of progressive incremental muscle loading that results in "*safe and sustainable*" physical restoration to maximum medical improvement, or in the instance of an occupational injury at least to full duty work capability.

### Essential Baseline Comparative Criteria

Since the primary goal of a functional restoration program is functional improvement it stands to reason that a baseline assessment is required to act as a comparative benchmark for measuring the efficacy of functional restoration therapies. Based on this study "essential baseline comparative data" for an evidenced-based functional restoration program is defined as a system of physical performance measurement that is supported by the following criteria:

- Method or technology-specific juried journal published scientific studies illustrating the validity, reliability, reproducibility, clinical correlation and longitudinal predictability of performance results (evidence-based),
- Criterion-based physical performance testing protocols to assure the accurate quantification of biomechanical function (validity & reliability),
- The use of internationally accepted gender and culturally fair comparative performance quantifiers (e.g., methods-time measurement & coefficient of variation) to ensure objectivity (non-discriminatory),
- The use of muscle contraction unit graphs of muscle ramp-up, fatigue and ramp-down slopes for measuring the quality of biomechanical performances (safe & sustainable performance),
- The use of American Psychological Association (APA) compliant cognitive distraction techniques to validate consistency of effort (reproducibility),
- The incorporation of, or the ability to design, a progressive program for incremental muscle loading (physical restoration),
- Intra-data cross validation algorithms that correlate & reconcile distracted and non-distracted physical performance results (best effort quantification),
- Systematic method(s) for gathering body part specific discomfort, and protocol-specific physio-behavioral pain component factors, during physical performance testing using load and no-load biomechanical stressors (identifying prime factors), and
- The incorporation of a system of weighted measurements and computational algorithms that allow for the determination of a definitive causal conclusion regarding the nature of the factors collected (factorization).

In the manner described above this study design was then able to meet all of the essential requirements for establishing a clear evidence-based comparative functional restoration baseline. This baseline could then be used for measuring the impact of changes to a subject's subjective complaint perceptions and physio-behavioral interference patterns to evaluate the effectiveness of restorative rehabilitation efforts. Periodic repeated measurement of protocols during the functional restoration program would yield comparisons as to whether these discomfort and/or behavior patterns were decreasing, increasing or staying the same to ascertain the likelihood of continuing therapy in effecting continued physiological improvement

**Table 6. Overall Rating**

| Performance Pattern | Participants | % | Functional Restoration |
|---|---|---|---|
| Full Duty (Pathology) | 10 | 17.2% | Not Applicable |
| Pathology Focus | 10 | 17.2% | Yes |
| Full Duty (Behavior) | 8 | 13.8% | No Applicable |
| Behavioral Focus | 23 | 39.7% | Yes |
| Secondary Gain | 7 | 12.1% | No |

(Discomfort Scales, 2003; Tamerius, 1994; Cahill, 2003); Farrar et al., 2001).

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