Prevalence of "Own-Design" Functional Capacity Evaluation Regarding Work Physiology Science

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The most prevalent methodology used in conducting FCEs is "own-design" protocol. The science of work physiology, and in particular the heart rate reserve formula, is an essential factor for time tolerance of work, but is not present in the "own-design" and commercial FCE methods. Across the spectrum of FCE provider protocols, and FCE report methods, there is a varying range of approaches used to determine the full-time work status of the examinee. A scientifically recognized work physiological standardization—the heart rate reserve formula—was utilized for comparative analysis on 151 FCE reports to determine work time tolerance assessment practices. Results: There are two categories of FCE protocols, the "own-design" method and commercial method. Neither of these use the heart rate reserve formula as a quantitative procedure; which identifies lack of professional competence, flawed methodology, and lack of scientifically supported opinions. The professional dictum of evidence-based practice demands that the FCE body of knowledge and providers embrace the science of work physiology as a benchmark. All FCE providers and commercial vendors should be expected to have professional work physiology credentials, discard procedures which are not heart rate reserve methods, and adopt transparent procedures so that there is credibility in the time tolerance opinions in the FCE.

Protocols for conducting functional capacity evaluations (FCE) have methodologies that purportedly include criteria for determining an examinee's tolerance for full time work. The emphasis of this research investigation is to ascertain if FCE examiners are correctly including, incorrectly including or not including, the science of work physiology as a basis for an opinion of full-time work. The FCE has been described in literature as an attempt to assess work tolerance, however; tolerance in this context lacks scientifically measurable or verifiable constructs (Randolph, Nguyen, & Osborne, 2003). Other authors have stated that FCE is a totally subjective test with no objective basis (Hendler, 2013). It has been reported that capacity, in regards to FCE, refers to what a person can do repeatedly for an extended period of time (Farag, 1995). Considering these parameters, this paper will address design and implementation issues regarding the completion and interpretation of Functional Capacity Evaluations.

FCE methods are loosely reported as being introduced in the early 1970s. Therapists in that era were compiling existing human performance tests, or "self-developed" tests, for inclusion to test batteries called an FCE (Reneman, 2003). There are limited publications with a definition of functional capacity (FC). Among the proposed definitions of FC is, "An assessment process that translates findings of physical, physiological, and functional measures into performance potential for activities of daily living and/or work tasks" (Abdel-Moty et al., 1993).

APTA Guidelines

The American Physical Therapy Association (APTA) has purposed the establishment of guidelines for FCE testing. This proposal includes commentary that directs the FCE process be addressed to neuromuscular conditions, but does not include systemic diagnosis, diseases, or the residual presentation resulting from treatment for these entities. The word "capacity," according to the APTA document, implies "potential" which by definition cannot be tested. The FCE is said to measure the ability of the individual to perform functional or work-related tasks, and implies or predicts the potential to sustain work-related tasks over a period of time (Alpert, 1996). In subset 4.0, the knowledge base, there is a directive that the examiner must have competency criteria; however, there is no cited professional certification, directed in regards to work physiology (Alpert, 1996; American Physical Therapy Association [APTA], 2008). In subset 4.1, 4.1.1, and 6.7.5, the FCE is to include cardiovascular and pulmonary data, as well as lift and carry endurance data. Subset 6.8.5 advises physiological responses and associated clinical findings (Feeler, St. James, & Schapmire, 2010). There is also a subset, 3.21.3, which is a directive to assess work tolerance for eight hours and twelve hours (APTA, 2008). All of these subsets, including the 6.0 subset (Feeler et al., 2010), are devoid of general instructions to use the science of work physiology, and there is no language that speaks directly to work physiology, heart rate methodology or fatigue determination. There is no reference to specific work physiology formulas, such as the heart rate reserve method (Becker, Morrill, & Stamper, 2007) and there are no bibliographic citations in general, or related to work physiology and that science, applied to outlining a determination to full-time work.

A review of the contributors includes Kevin Basile, PT; Drew Blossen, PT; Larry Feeler, PT; Glenda Key, PT; Margot Miller, PT; Gwen Simons, PT, JD; Rick Wickstrom, DPT, CPE, CDMS; Jill Galper, PT; Susan Isernhagen, PT; and Nicole Matourshek, MPH, PT (APTA, 2011). Of these contributors, none have a professional designation or certification related to work and/or exercise physiology through an organization such as the American College of Sports Medicine (ACSM, 2010) or the American Society of Exercise Physiologists (ASEP, 2013). None of these contributors are professionally cited in work physiology certification literature. Of those vendors who distribute and sell commercial FCE systems, such as Susan Isernhagen and Glenda Key, it will be noted in this research that none have correct scientific work physiology formulas, or work physiology methodological inclusions. In relation to a scientific work physiology determination for establishing full-time work, these contributors clearly will be categorized as "own design" providers of FCE systems, or encouragers of "own design" FCE methods. **[Editor's Note: The Editor has not confirmed these statements offered by the author of this article. This information is included as a historical framework, offered by the article's author. The Editor encourages readers to consult with applicable organizations to confirm this information. Or, if any of the referenced persons or organizations wish to offer a rebuttal, the Editor will allow such responses and rebuttals to be published in later issues of this journal.]**

There is a lack of consensus on the method to be used to determine functional capacity (Abdel-Moty et al., 1993). Two types of FCE have been identified, the controlled and the uncontrolled. The controlled is a methodology created by vendors where the offering company can provide instruction. The uncontrolled is a "self developed" method by the user (Jones et al., 2003). The vendor or commercially available FCE has been referred to as a standardized FCE, whereas the self-developed or "self/own design" has been referred to as a non-standardized FCE (James, 2011).

As far back as 1982, when interest in physical capacities was just emerging, there were few rehabilitation practitioners familiar with formalized functional capacity testing protocols and there were no commercially available or standardized formats (Harrand, 1986). Currently, rehabilitation and industrial therapists use both the standardized or commercial product, and the non-standardized self-developed or own-design protocols (King, 2004). Vendors of the commercial/standardized protocols insist that their propriety equipment, processes and training are necessary to control the variance in the methodologies. These commercial providers espouse observational methods and lack physiology responses, such as heart rate, which results in an inability to determine full-time work tolerance and maximum effort (King, 2004).

In a New South Wales (NSW) survey, 75% of the rehabilitation providers were conducting "own-design" FCEs (Hettinger, Newton, Horvath, Issekutz, & Rodahl, 1961). Another survey in 2009 found that 52% of the respondents were using an "own-design" or non-standardized methodology. The use of non-standardized methodology raises questions regarding how to assess function and consistency of assessments. It also presents the prospect of non-scientific data interpretation (James & Mackenzie, 2009a). As such, this paper will examine the prospect or opportunity for "own design" FCEs as a standard protocol.

Types of FCEs

A review of FCEs shows there are three general types: those relating to psychophysical techniques, those having biomechanical components, and those referring to metabolic criteria. Psychophysical processes overestimate responses. Biomechanical process use observational techniques: subjective or proprietary "safe" or "unsafe" factors. Metabolic technique is a scientific work physiological process measuring work stress using parameters such as oxygen consumption and/or heart rate (Gardener & McKenna, 1999). The commercial FCE methods championed by vendors have relied on limited—or no—independent scientific research, and no commercial FCE is deemed to be superior to other competitor products (Gibson & Strong, 2005).

FCE Testing Packages

FCE products, or testing packages, are typically batteries of pre-existing or published processes that assess the physical abilities of persons with musculoskeletal disorders (MSD). These products have not been developed to address non-MSD pathological disorders (Wind, Gouttebarge, Kuijer, Sluiter, & Frings-Dresen, 2009). The reason that the FCE commercial products focus on MSD is related to the inclusion of methodologies that are observational of general posture, and standardized range of motion or non-quantifiable strength/force techniques such as manual muscle testing. There are no inclusions for work physiology, determination of fatigue effects, or analytics of non-MSD pathological effects on work tolerance (Hettinger et al., 1961).

Universal Standards

There are no universally accepted standardized or commercial methods or procedures for administering physical capacity evaluations. The term physical capacity evaluation is sometimes used synonymously with work capacity evaluation or functional capacity evaluation (Hettinger et al.,1961). The methodology and processes of FCEs, both commercial and own-design, have no standardization. The commercial developers and therapist user/creators of own-design have based decisions on content by using historical concepts rather than innovative scientific research and evidence-based practice (James & Mackenzie, 2009b). Studies have shown that while therapists state they value credible assessments, they tend to use non-credible forms of assessment frequently and modify testing instruments for their own design. There are therapist providers who feel that commercial FCE promotion of credibility through intra-rater reliability is questionable (Innes & Straker, 2003).

"Own-Design" as FCE Protocol

Examiners who use own-design are described as using uncontrolled evaluations due to personal preferences and adaptation of protocols. The inclusion of subjective "observed" end-point criteria is considered to be an examiner bias (Innes & Straker, 1998; Jones et al., 2003). Practitioners are cautioned to be leery of proprietary methods, such as interpretative results, proprietary algorithms, and unpublished research techniques. Algorithm procedures do not have meaningful interpretation due to the subjective selection of assigned ordinal rankings, such as those used in Performance Work Physical Evaluation (PWPE) tests. The proprietary algorithm assignment results in inappropriate analysis and statistics (Innes et al., 1998). There are a variety of FCE commercial products but many clinic users develop their own protocols or use components of vendor products. Many FCEs purport to assess similar things such as lifting or carrying; however, the therapist "own-design" procedures of data collection are inconsistent. The inconsistency between "own-design" tests eliminates comparative result analysis (Innes, 2006). Many therapists and clinics have developed "own-design" tests due to the variety of FCE commercial testing products available. The decision to use "own-design" was studied and it determined that not only are methods self-developed, but also tools and equipment. The study found that 80% of FCEs were considered to be adaptations of standardized procedures, and that even within same clinic settings FCE testing procedures, differed among providers (James et al., 2009a).

Therapists who adopt the processes of multiple commercial processes, or those incorporating processes of their "own-design" are referred to as non-standardized tests. The non-standardized approach implies that assessments are inconsistent, lack evidence-based practice, and lack validity and reliability (James, 2011; James, Mackenzie, & Higgenbotham, 2007). No FCE has been thoroughly and comprehensively investigated for all relevant aspects of reliability. FCE construct validity is also problematic because they attempt to measure an ill-defined concept, that of function (King, 2004). Compounding the problem of FCEs is the fact that there are no correct applications of work physiological science to the methods of determining if a person can or cannot work (Gross, 2011).

Surveys of providers regarding preferred FCE methodologies or protocols have found that in New South Wales, Australia, own-design or non-standardized procedures were used by 52% of occupational therapists (OTs) and 60% of physical therapists (PTs) (James, 2011). In regard to consistency of approach to testing, there was a low survey response by providers, where only 18 of 48 responded, or 38%. In a 2006 NSW survey 75% of providers were using "own-design" methods, and in another study 56% of users were employing own-design or non-standardized methods. Another survey found there were at least 11 different stated FCE types (James, 2011).

A general review of FCE protocols research and analysis of FCE commercial products has identified a variety of shortcomings. There are no published studies for Accessibility, Blankenship FCE, California Functional Capacity Protocol (Cal-FCP), Key Method FCA, Quantification FCE, Workability Mark III, and Workhab FCE (Innes, 2006; Wahlund, 1948). In addition, there is no peer-reviewed documentation for Arcon, Ergos, and Isernhagen Work Systems (Jones et al., 2003; King, Tuckwell, & Barrett, 1998; Gouttebarge, 2008), and no published studies for Valpar Joule FCE (Innes, 2006). Of the 34 commercial methodology protocols reviewed by the researchers, only 5 could be considered for review, and the other 29 were not considered worthy of research assessments (Innes, 2006). Commercial FCE products no longer available from the vendors as of 2006 include Arcon, Lido Work Set, Polinsky FCE, Singer/New Concepts VES, Smith PCE, Matheson product West Standard, and Matheson product West 4/4A work box (Innes, 2006).

Criticism of FCE Methodology Sparks Need for Own Design

The criticism of FCE has been due to a lack of objectivity and lack of scientific evidence to support the use of a number of commercial FCE products (Cotton, Schonstein, & Adams, 2006). The authors critiquing and criticizing FCEs determined that there was no data to suggest how much information is necessary to infer from an FCE whether a person being tested can do a job (King et al., 1998; Wind, Gouttebarge, & Kuijer, 2006). Commercial FCE protocols' reliance on proprietary tests brings additional criticism. These proprietary tests, algorithms and research purport to have normative data, but none have been reviewed, published or accepted in peer-reviewed scientific literature. Scientific functional normative data is not available and research to justify claims of credibility for FCE protocols is lacking (Polatin, 1995; Wahlund, 1948). The commercial and "own-design" FCE methods are not standardized, lack comprehensiveness and lack objectiveness in data collection (Wahlund, 1948). The FCE testing process has no universally accepted operational definition, and no standardization for design of protocols and procedures to conduct protocols (Fishbain, 2000; Wahlund, 1948). Operationally, when the FCE is performed there are inconsistent processes, which create great confusion about the kind of information the examiner is revealing, and how it should be used (Fishbain, 2000).

There is a general lack of norms among FCEs: therefore, it is unclear how the examinee's data can be interpreted with regard to a normal population relationship (Fishbain, 2000). Examiners, who need to extrapolate, translate, or project data for the examinee's abilities over an eight-hour period do so, or attempt to do so, without professional knowledge or expertise. The attempts to project endurance time tolerance is done with no knowledge imparted from the vendor instruction seminars or manuals (Fishbain, 2000; Wahlund, 1948). Researchers have found a limited number of commercial vendor assessments that had adequate evidence of reliability (King, 2004).

Traditional FCE methods of determining performance for work following injury are based on subjective reports by the injured party, and the less-than-adequate application of physical examination (Jones et al., 2003). There are numerous measurement procedures that claim to measure return-to-work fitness; however, not only is there a lack of operational definition for this process, but there is also a lack of universally objective methodologies for this purpose. There are no vendor-cited norms from the science of work physiology for a projection to full-time work (Fishbain, 2000). Evaluation of the predictive validity of existing functional capacity evaluation templates is not possible given the absence of thorough descriptions in the published literature (Chen, 2007; Jones et al., 2003).

Earlier studies show that there is evidence of reliability and some validity depending on the FCE protocol. Worldwide, there are multiple FCEs using different protocols from different providers, which all claim to measure the same construct: namely, functional capacity. These claims, however, do not have concurrent validity, and proclamations by the vendors are contradictory and have been found to have moderate to poor acceptance. In addition, when the same protocol is administered in a different environment, and under the direction of different providers, different results are noted (Soer, van der Schans, Groothoff, Geertzen, & Reneman, 2008).

The evolution of the functional test emphasized the evaluation of musculoskeletal conditions. The process included clinical measurement range of motion, evaluation of static posture, and generalized work posture as a simulation. These musculoskeletal-emphasized FCEs had a typical posture analysis component, which were performed in two-to-five minutes or less. The inclusions of the posture tolerances have no foundational scientific basis or supported studies, and are typically projected as an extrapolation without scientific criteria (Osborne, Dakos, & Randolph, 2001). The FCE processes and methods have been presented by vendors as being applicable for musculoskeletal conditions, but have not been evaluated, credited or scrutinized for non-musculoskeletal conditions, pathologies or diagnoses—which negates analytical determination regarding affected populations not studied (Gross & Reneman, 2011). Many tests procedures included in FCEs lack performance standards, and scientific citations to performance standards. This lack of cited standardization and research is evidence noting an absence of reliability and validity of procedures such as a five-minute kneel test or a one-minute crouch test (Reneman, Joling, Soer, Goeken, 2001). These non-scientific inclusions are characterized by no documentation of any kind, and thus lead to a conclusion that there is a lack of support to the validity of the FCE test protocol and the professional credibility of the user examiners (Gardener & McKenna, 1999; Gouttebarge, 2008). Commercial protocol vendors that include non-scientific procedures for musculoskeletal uninjured populations are proprietary methods, analysis, or algorithms (Wahlund, 1948). FCE tests, which seemingly include similar items, have differing methods, which eliminates comparative interchange or comparative analysis, resulting in dissimilar opinion of work tolerance (Innes, 2006).

The considerable differences of the commercial and "own-design" FCE protocols emphasize that there is really no standardized approach (Cotton et al, 2006; Legge & Burgess-Limerick, 2006). The FCE factors promoted as systematic advantages to provide insight into a workers' functional abilities do not include the analysis of work physiological responses to reveal time tolerance to full-time work or fatigue (Wind et al., 2006). There is literature that outlines the limitations of FCE methodologies, especially the lack of perceived usefulness in regard to work physiology (Cotton et al., 2006). A considerable contribution to the lack of methodological usefulness is related to "own-design" procedures.

In New South Wales, Australia, 75% of rehabilitation FCE providers use a methodology of "own-design." Other survey data is similar: only 25% of FCE providers cite a vendor commercial product in use of FCE tests (Cotton et al., 2006). Among the limitations, including the lack of scientific work physiology and "own-design" procedures are procedural downfalls referred to as "limiting subsystems". The deficient process is emphasized by predominant mismatch between job requirements and performance response. Authors have emphasized that research related to studies of FCE and occupational outcomes is needed (Pransky & Dempsy, 2004).

There are a variety of shortcomings for the FCE, which includes the flawed design of commercial products, the use of non-scientific "own-design" procedures, and general methods that do not achieve professional standards (Pransky et al., 2004). These and other internal FCE mistakes are not helpful for practicing clinicians involved in return-to-work decisions.

Arguments against using FCE procedures include inability to determine fatigue, fitness for work, and general constitution (Wind et al., 2006). Many practitioners and administrative entities espouse the need for evidence-based practice using objective, quantifiable procedures; but these outcomes are elusive due to faulty procedures (Hart, 2001). Due to the lack of evidence-based procedures to the FCE, many non-musculoskeletal conditions should not be evaluated. The musculoskeletal-driven FCE procedures have a high level of process uncertainty related to predicting work tolerance in general and are clearly not designed for systemic, pathological or genetic diagnosis (Gross et al., 2011).

There has been no gold standard FCE because of an inability of the methodology to accurately measure functional capacity or work tolerance (Gross & Battie, 2002). A lack of definitions in the FCE methods has interfered with an appropriate test battery to specify work capacity (Abdel-Moty et al., 1993). An example of the weakness in FCE methods is the criteria of ending test protocols when the examiner predicts that the subject "felt unsafe". It is not known how an examiner's observational ability warrants labeling a test procedure gold standard (Reneman, Jaegers, Westmaas, & Goeken, 2002; Takala et al., 2010)

The shortcomings of subjective observational FCE techniques are the existence of only three published studies regarding observations, and the only processes are musculoskeletal clinical exposure. Additionally, FCE providers come from many disciplines and many lack professional expertise or a professional credential in the science of work physiology (Wahlund, 1948). The FCE test methods contain no empirical information about work physiology prediction to time tolerance work from formalized procedures. A sampling of 144 FCE providers in Southern Ontario, Canada, resulted in only 65 respondents. Of those responding there were 23 OTs, 21 kinesiotherapists, 21 physiotherapists, and eight who identified the inclusion of physiological measurement—5% of the providers, or 12% of the respondents (Strong et al., 2004).

There have been research surveys of FCE-related publications with one publication reviewing potential citations. Of the 77 citations reviewed, only 16% were identified for inclusion for assessment of methodological quality. No citation in the review indicated reliability or validity in the Blankenship process. The Isernhagen Work Systems inter-rater reliability was not considered rigorous enough. Ergo Kit did not demonstrate validity (Gouttebarge, Wind, Kuijer, & Frings-Dresen, 2004; Gross & Battie, 2006). Physicians queried about FCE said that processes were poorly defined and there were conceptual problems (Reneman, 2003). Other protocols, such as the Cal-FCP, have a shortcoming due to limited focus measuring the work consequences of soft tissue musculoskeletal disorders. There is concern about protocol inaccuracy in regard to the comparison of physician estimation to unknown pre-injury work capacity (Matheson, Mooney, Leggett, Grant, & Kenny, 1996). There are many negative findings regarding the commercial FCE products including FCEs in general being cited as having modest predictive ability (Astrand & Saltin, 1961; Gross, Battie, & Asante, 2006; Innes, 2006; Kroemer, Kroemer, & Kroemer-Ebert, 1997; Lechner, Page, & Sheffield, 2008).

Specific vendors of FCEs, such as Ergo Kit, were found to have poor concurrent validity; and the Ergo Science Performance Work Physical Evaluation (PWPE) had low reliability in regard to the stair climb, squat, and walk. The Isernhagen WS predictive validity had criteria flaws for lifting in low back patients, and there was no analytical support for the process of determining a return to work (Innes, 2006).

The Progressive Isoinertial Lifting Evaluation (PILE) did not have predictive validity to lifting, and there have been major concerns about the methodology in general (Smeets, Hijdra, Kester, Hitters, & Knottnerus, 2006). The PILE protocol has been suspect due to gender bias, high variability between and within raters, and an incorporation of too many lifts per minute to be considered reliable (Jones et al., 2003). Reviewers and research investigators reviewing the PILE indicated other major concerns including weak correlation of work and activities of daily living (ADL). The PILE criteria of work tolerance is an 85% maximum heart rate as sustained capacity in full-time work, which is not considered credible, and the limits of agreement exceed acceptance—negating any clinical usefulness (Smeets et al., 2006).

Other providers, such as the Gibson Approach to FCE (GAPP), have no validity for return to work decision-making; the Ergos FCE had minimal correlation regarding measuring position tolerance, mobility, and repetitive movement (Lechner et al., 2008). There are many commercial FCE vendor protocols that do not include scientifically valid work physiology such as: Access Ability, ARCON, Blankenship, Ergos, Ergo Science PWPE, Isernhagen WS, Key Method, Matheson, West/EPIC, WorkAbility, and Work Hab (D. Lechner, personal communication, August 5, 2009). It has been determined that in the absence of the scientific work physiological component, the FCE methodology cannot provide high prediction value for work tolerance (Chen, 2007; Lechner et al., 2008).

FCE systems such as Isernhagen WS include "own-design" criteria known as kinesiophysical. This process includes a basis of maximum examinee-decided personal ability using incorporated observational criteria (Isernhagen, 2006; Streibeit, Blume, Thren, Reneman, & Mueller-Fahmow, 2009). It has been determined that the Isernhagen procedure of publishing studies uses an inter-rater reliability measure as a credibility method that is not rigorous enough to allow a positive conclusion (Gouttebarge et al., 2004). The Isernhagen observational kinesiophysical process is a descriptive instrument using criteria, to subjectively assign examinees into groups or characterizations where there can be a perceived difference. Evaluative objective instruments use measureable quantifications, which can document criteria and also allow measureable change over time (Law, 1987). The hypothesis that observational methods of functional tasks or postures at or exceeding job demand levels can serve as a foundation of sustainable return-to-work is not supported (Gross & Battie, 2005). In addition to the inclusion of observational methods in the kinesiophysical process, the Isernhagen method includes "own-design" tests such as a 60-second crouch, or a 30-minute standing test, without peer-reviewed scientific methods regarding conducting or interpreting procedures (Gross et al., 2006). Users of the Isernhagen processes in Germany are deemed worthy of license to use the methodology if the purchasing physiotherapist can complete the academy training by other Isernhagen FCE users (Streibeit et al., 2009). The nature of work capacity evaluation (WCE), like kinesiophysical techniques, is to observe the examinee and rate the performance on a scale of named categories, which are proprietary to the commercial FCE vendor, and not scientifically scrutinized in peer-reviewed publications (Menard & Gorman, 2000).

Methodologies reported by Lechner, which is the use of proprietary algorithms, are not applicable to established science for predictive validity, and are perceived as having limited credibility (Innes et al., 1998; Lechner et al., 2008). The overall Lechner Ergo Science PWPE scoring algorithm does not have the ability to measure clinically significant changes. Among the administrative problems are examiner bias and problems of interpreting the observational algorithmic results (Innes et al., 1998). The PWPE has highly clustered scores such that an evaluation often gives the same score each time despite changes over time. The PWPE cites heart rate as a factor, yet there is no scientific work physiological formula, no scientific methodology for interpretation, and no published scientific formula provided (Denard, Brassard, Hong, Lemaire, & Loisel, 2008).

Endurance determination is the critical factor in establishing an individual's ability to perform the demands of frequency in positional tolerances (Osborne et al., 2001). Endurance determination related to physical work capacity is established by documenting and analyzing heart rate change during activity; FCEs do not have this inclusion (Bonjer, 1962; Wahlund, 1948). The ideal application of heart rate as an endurance factor should be a test-retest protocol where the same task exposure is applied during succeeding bouts of work evaluation, which will then confirm reproducibility. The task exposure posture and position is recommended to be a period of 10-20 minutes, up to 40 minutes, followed by a secondary period of 20 minutes (Lehmakn, 1958; Osborne et al., 2001). The degree of a person's capacity to work includes the utilization of manual materials handling as monitored by heart rate. This process is capable of objectively determining the degree of tolerance for load heaviness and is a far superior method to subjective "effort rating." When mean actual energy expenditure, as measured by heart rate, is used to determine physical working capacity time tolerance of either short or long duration, this is objective determination (Bonjer, 1962; Garg, Chaffin, & Herrin, 1978; Hart 2001). It is important that the functional evaluation protocol have a scientific foundation of projecting an eight-hour work tolerance.

The use of heart rate is the recommended methodology of projecting eight hours of continuously applied work (Garg et al., 1978; Lehmakn, 1958). FCE commercial methods, and "own-design" methods, have no specific formulas for proposing the scientific work physiology approach to eight hours of work, demonstrating a lack of validity and major characteristic methodological flaws (Smeets et al., 2006; Wahlund, 1948).

There is much confusion about terms such as aerobic capacity, and physical work capacity. Aerobic capacity is defined as maximum level of oxygen intake, while physical working capacity is the energy expenditure and heart rate that can be maintained throughout the working time by an individual (Bonjer, 1962). The utility of the FCE should be to provide definitive work time tolerance, but the process lacks objectivity and work physiology, and instead focuses on musculoskeletal parameters. The FCE methodological flaws have been compounded by the variety of "own-design" criteria, differing reporting formats, and conflicting protocols. Therapists were queried as to methods and protocols: eight of 18 gave a range of indicators from biomechanical and psychophysical principles. Eight of the 18 responding therapists reported monitoring heart rate, but none were routinely applying that principle; some only did it for examinees they considered risky, and none used a scientific heart rate protocol as a predictive component for work time tolerance (Gibson et al., 2005).

Endurance as FCE Design Feature

The benefit of work capacity evaluation in determining functional tolerance is the ability to identify endurance (Polatin, 1995). According to Goldmark (1912):

> *Fatigue let run is a debt to be paid in compound interest. When a task is doubled muscle requires not double, but four times as long a rest for recuperation, and a similar need for more than proportionally increased rest after excessive work is true of other tissues, and of our organism in its totality. (pg. 88)*

One of the problems related to FCE is the lack of a work physiology formula that identifies sustainable ability (James, 2011). There are many different commercial FCE test batteries: all of these fail to assess metabolic capacity and document fatigue. Review of FCE literature, even the purported "gold standard" methods fail to provide a record that can be used to evaluate fatigue or fatigue illness because there is no assessment of metabolic capability (Ciccolella, Boone, & Davenport, 2011). The use of work physiology in manual materials handling and physically demanding tasks has a high degree of accuracy and a presentation of fatigue (Jones et al., 2003). In 1967 the International Biological Programme (IBP) convened a bench level group in Toronto. The outcome of this meeting was the determination that the choice of test procedure to measure working capacity was a submaximal testing method that utilized indirect predictors based on linear relationship between heart rate and oxygen consumption (Shephard, 1978). For an FCE to be considered accurate and valuable, the work physiological metabolic responses and heart rate should be performed, particularly on examinees where there is a "red flag" (Lechner, 1998).

The prediction of eight hours of work from a period of testing is essential, and the determination should not be observational (Gross et al., 2011). FCEs that do not use scientific work physiology formulas to predict ability to work eight hours lack validity, and this is a major methodological error. The method of determining eight-hour workday projection requires the measurement of heart rate at rest, heart rate during activity, and the noted change of heart rate with analysis, as well as the recovery to resting time for heart rate (American Industrial Hygiene Association [AIHA], 1971). The commercial FCE protocols do not include scientific formulas for projection to an eight-hour workday (King et al., 1998). Extrapolating performance from subjective or observational method is an example of clinicians making inferences rather than providing opinion from the analysis of data (King, 2004). FCEs do not need to determine maximum aerobic capacity because day-to-day work is performed when workers are engaged in sustainable submaximal aerobic demand. The FCE needs to significantly document the ability to work full time (Gross et al., 2011). There is a need to improve the guidelines and procedures for work physiological inclusion to FCE by monitoring heart rate before, during, and after the testing (Gibson et al., 2005). Authors have indicated that valid dynamic lifting measurements require relevant work physiology (Mayer et al., 1988).

There are a substantial number of FCEs which stipulate that a "safe end point" for heart rate response is an 85% maximum age-adjusted criteria (Gibson et al., 2005; Mayer et al., 1988, Reneman, 2003; Soer, Poels, Geertzen, & Reneman, 2006). There are other FCE commercial methods that espouse an adjusted maximum heart rate of 55-70% as the criteria for "end point testing" (King, 1998; Mayer et al., 1988; McArdle, Katch, & Katch, 1981; Soer et al., 2006). All of these percentage-for-age adjusted heart rates are incorrect: the literature actually stipulates that an eight-hour work tolerance has a criterion of 33% oxygen consumption (King et al., 1998).

There is considerable inconsistency of opinion regarding the inclusion of heart rate, the methods in which heart rate are used, and the clinical criteria used to determine work capacity. There are reported methods to determine when a test is stopped, but these do not include work physiology analysis. The Isernhagen WS and Work Well System advocate that the criteria for ending a test is when the examinee wishes to stop, when signs of maximum lifting are observed, when the observer thinks the examinee is unsafe, when a time lift was reached, or the 70-85% age-adjusted heart rate was identified (McArdle et al., 1981; Soer et al., 2006).

Developers of commercial FCEs have indicated that the heart rate inclusion is only for precautionary measures and has no predictive value regarding endurance work determination (Gibson et al., 2005). It has been determined that aerobic capacity is extremely important because of the need to determine eight hours of work, and that an aerobic endurance protocol should be part of the FCE (Randolph et al., 2003). Of those FCE methods promoting 60% or greater heart rate response when lifting, there is a large amount of error in the estimates which led researchers to conclude those methods were questionable (King et al., 1998). The psychophysical method of lifting includes criteria for voluntary test termination; however this technique has no monitored data reported and there is no predetermining work physiological formula regarding full time endurance (Mayer et al., 1988).

The PILE test procedure end point includes the examiner's subjective determination of "acceptable effort," a subjective determination that the lifting technique was unsafe; or when the 85% age-adjusted heart rate was reached. Analysis on the comparative determination of work profile for the PILE and Work Well found that a data set evaluated by both methods had inconsistent determination of capacity tolerance. The results of the study found the PILE produced criteria of work that was only 75% of what Work Well predicted. The findings determined that the two techniques could not be used interchangeably (Soer et al., 2006). In a review of 18 FCE processes the heart rate criteria work method, or physiological method, was not utilized and there were no documented guidelines explaining why these methods were not included (Gibson et al., 2005).

The Gibson Approach to FCE, or the GAPP FCE, applied to 37 clients was reviewed, and there were only two testing end-point criteria related to physiological responses. This finding of limited use of physiological criteria is inconsistent with the tenets of GAPP FCE protocol. The GAPP FCE calls for resting heart rate determination, heart rate measured at designated periods, heart rate recorded at the end of each demand and a heart rate at the end. The heart rate responses of the GAPP FCE are not compared to work physiological formulas, leaving interpretation up to the discretion of the examiner (Gibson et al., 2005).

Evaluations of other commercial FCE vendors, Blankenship, ErgoKit, ERGOS, and Isernhagen produced no data with a work physiological foundation to identify time tolerance for work, fatigue, or use of heart rate analysis methods. The analysis of ErgoKit also determined that only one of five lifting tests had moderate to valid data for the construction industry and that carry and lifting could not be used for jobs related to manual materials handling. Five of the ErgoKit tests were not supported as having construct validity (Gouttebarge, 2008). Errors with the PILE include incorrect determination of test termination, heart rates which were unchanged from resting during exposure to tasks, and calculations, which were "doubled" in order to be considered of value (Mayer, Gatchel, Barnes, Mayer, & Mooney, 1990). Other random and not widely used techniques regarding heart rate include a standard for determining an individual's sincerity of effort by accepting a 10% rise in heart rate above resting and then designating this as "safe maximum" (Lyth, 2001). Critical commentary of the Isernhagen kinesiophysical method is related to the "observational criteria" as a physiological performance for "safe level", or accepting any refusal for discontinuing by the examinee as a measure of effort. There is no work physiological science applied to the observational kinesiophysical technique; therefore, there can be no possible determination of sustained full-time work or fatigue (James, 2011; Soer et al., 2006). Other reviews of FCE processes by the American Medical Association (AMA) in the text Guide to the Evaluation of Functional Ability have included the interview of FCE vendors. This publication revealed that the commercial providers of the Key Method, Physiometrics, Kinematic Consultants, and WorkHab did not participate, and ERGOS work simulator declined to participate.

The Physiotherapy Associates in the AMA survey of FCE vendors indicated work physiology was not included, and the Quest TBS/Blankenship System did not track heart rate or include heart rate analysis. The WorkAbility FCE had no work physiology, and the WorkWell Systems and Isernhagen WS had no work physiology. Isernhage DSI had no aerobic testing, no work physiological formulas, and no published research regarding predictive ability. BTE did not include work physiology manual materials handling, and ErgoControl had no aerobic endurance criteria and no work physiological formulas. The ErgoScience PWPE had no aerobic testing, utilized proprietary algorithms, and did not include formulas for work physiology regarding walking, carrying and push or pull tasks (Genovese & Galper, 2009). There are no commercial FCE protocols including work physiological tolerances defined as the ability to perform sustained work (Gross et al., 2011).

Work Physiology

The FCE must specifically relate to work that is eight hours per day and 40 hours per week. The test is conducted over a short period of time so endurance components can be adequately evaluated to project the eight-hour workday (Isernhagen, 2006). Physiologic work stress is a function of metabolic response to work such as heart rate, which is considered a valid measurement of determining work capacity (Adams et al., 2010; Borg & Dahlstrom, 1962). When assessing physical work during lengthy periods the individual's heart rate is used as the criterion (Borg et al., 1962). There is a linear correlation between pulse rate and energy expenditure because of the working muscle utilization of oxygen (Cotes & Meade, 1960). This measurement reliability is comparatively high when applied to both intra-test correlations and to test-retest correlations (Borg et al., 1962). The principle of estimating energy expenditure by measuring pulse count is applicable to all normal and work activity

(Datta, Chatterjee, & Ray, 1973; Polatin, 1995). Intensity of work is determined from heart rate and heart rate reserve in work environments. The work can be determined by steady state heart rate 20 seconds after initiation of work task, and then documented at two, four, and six minutes with very good retest correlation and strong reliability (Andrews, 1969; Borg et al., 1962; Kasch, Wallace, & Van Camp, 1985; Polatin, 1995).

Heart rate has been established as the preferred determinant of full-time work tolerance, and is a well-established indicator of work physiological response when the data plot is linear (Garg, Hagglund, & Mericle, 1983). Work capacity refers to endurance tolerance that is measured scientifically and quantifiably (Randolph et al., 2003). Physical work effort as reflected by heart rate has a linear response, which is revealed in the first few minutes of activity, and is plotted as a steady state criteria (AIHA, 1971; Asfour, 1980; Ricci, 1967). The Leistung Pulse Index is a criterion of the oxygen intake that is correlated to the pulse response reflecting the work demand (Snook, Irvine, & Bass, 1970).

There has been a significant lack of understanding between exercise physiology and work physiology. The vendors of commercial FCE methods predicting safe exertion at 60%—85% for full-time work fail to appreciate that their premise is a criteria of graded exercise testing (GXT) and is not a foundation of full- time work as determined by work physiology. Most normal people become quickly exhausted when exposed to work that is 70%-80% of adult oxygen consumption limits (Federal Aviation Agency 1973). There are formulas to predict full-time work that are completely independent of exercise fitness testing (Davies, 1966). Authors such as Abdel-Moty et al. (1993), believe that translating a one-time, one-to-two hour test to a prediction of an eight hour work day is a major conceptual error of a functional capacity test. This premise is incorrect, as the prediction is accurate and reliable for predicting endurance time in work by measuring pulse rate (Davis, Faulkner, & Miller, 1969). The oxygen consumption, and therefore pulse rate, may average a 5% rise over time in 180 minutes of 195 minutes (Subramaniam, 1973). Intaranont identified that a biomechanical approach to lifting is only applicable to occasional lifting, whereas the work physiological approach is accurate for work prediction including repetitive types of lifting. There are physical work metabolic energy expenditures that have been developed for normal men and women that determine work for eight hours per day without fatigue (Intaranont, 1983).

The physical working capacity for 480 minutes, or eight hours, according to the West European norm, is a gross energy expenditure of 5.2 kcal/min for that duration (Bink, 1962). Heart rate is the chosen criterion to determine continuous work (Davis et al., 1969; Snook et al., 1970). Tests of work are not conducted to near exhaustion, such as 85% of age-adjusted heart rate for short bouts: it is detrimental to the examinee, and it is more important to determine the steady state heart rate response as an indicator of economical work (Davis et al., 1969). Without work physiological measurements, an FCE that uses an 85% maximum age-adjusted "safe" fitness test cannot ascertain the subject ability for sustained work, and would place the subject at a physiological risk (Balke, 1963; Morgan, Allison, & Duhon, 2012). There are no FCE commercial vendors who have explained, or published, why a criterion of 85% is unsafe.

The work physiological criteria to determine full-time work includes oxygen consumption and pulse rate reaching constant steady state response to work in 30 seconds to two minutes. The relation between pulse rate and oxygen consumption related to work load has a 0.97 correlation coefficient, meaning that pulse rate is the accurate measure of work intensity tolerance (Davis et al., 1969; de Vries, 1966; Muller, 1953; Rodgers, 1988). Sustained work is represented by a period of over one hour: this is determined by measuring heart rate at two minutes, four minutes, and six minutes, after the start of work and is considered to be steady state thereafter. (AIHA, 1971; Astrand, 1960; Davis et al., 1969; Drury, 1976; Morris & Chevalier, 1961; Rodgers, 1988).

An important indicator for determining full-time work is the restitution of heart rate to resting (Davis et al., 1969). Heart rate in recovery is a practical and effective way to classify the presence or absence of fatigue, thus indicating full-time tolerance to the work exposure (Astrand, 1960; Hoon Yong, 1996; McArdle et al., 1981). If work continues beyond the time for heart rate recovery in the expected period, two-and-a-half-to-three minutes, the muscle energy falls off indicating fatigue (Astrand, 1960; de Vries, 1966; Rodgers, 1988). The relationship between effort and heart rate is the determination of fatigue where the criteria is the heart rate plotted against the task, and the heart rate recovery to resting (Garg et al., 1978).

Normative work tolerance is a sustained capacity founded upon the premise that the expenditure of energy, and recovery, maintain equilibrium. When the work ceases the recovery heart rate to resting takes from one to three minutes, no matter if the work lasted minutes or a few hours. If the pulse rate progressively elevates in linear fashion during work and the recovery to resting heart rate is prolonged, even for a period of an hour, there is work physiological fatigue (Bilzon, Scarpello, Smith, Ravenhill, Rayson, 2001; Intaranont, 1983; Levitt, 1962; Morris et al., 1961; Muller, 1953; Simonson, 1971). When satisfactory recovery does not take place between a series of successive operations, the initial pulse rate after work becomes progressively higher and the heart rate during recovery period remains at an elevated level for a progressively longer time. A very slow return toward the resting level points definitively to the existence of physiological fatigue (Brouha, 1960). The secondary effect of fatigue is poorer performance—despite the individual believing there is no change (McFarland, 1971; Pearson & Byars, 1956). Recovery to resting in less than three minutes is considered normal, and is usually below 90 beats per minute (bpm); and the third minute has a 10 bpm lower response from the first minute (Morris et al., 1961). Fatigue does not appear in the course of one to eight hours if the work rate is at or less than 40% oxygen consumption (Hodgdon, 1986; Troup & Edwards, 1985).

The Physiological Approach

The quantification of metabolic demand during work is established by oxygen consumption as a percentage, and by heart rate response (Bilzon et al., 2001). There is a linear relationship during work between steady heart rate and oxygen consumption (Andrews, 1969; Hermansen & Lange Andersen, 1965; Rowell, 2007; Subramaniam, 1973). The established scientific correlation that determines sustained work is known as the physiological approach (Intaranont, 1983). Physical work capacity from the start of the day to the end of the day has also been known by the Lehman-Michaels pulse rate test scores, where the pulse rate is multiplied by pulse pressure. This process found that the difference in rest pulse rate in the morning compared to mean pulse rate at the end of eight hours of work, or "working pulse" was 28 bpm. The authors generally considered "work pulse" on an average during a workday would not exceed 30-40 bpm above resting (Hettinger et al., 1961).

There have been multiple researchers reporting the full-time eight-hour work tolerances by either heart rate or oxygen consumption. The range of oxygen consumption expressed as full-time continuous work is noted as 21% VO2 max to 40% VO2 max, which avoids fatigue (Ayoub, Bethea, Asfour, Calisto, & Grasley, 1979; Garg et al., 1983; Khalil, Genaidy, Asfour, & Vinciguerra, 1985; Kroemer et al., 1997; Legg & Myles, 1981; Legg & Myles, 1985; McGlothlin, 1996; Nindl et al., 1998; Sharkey & Davis, 2008; Sharp, Holman, Vogel, Knapik, & Legg, 1988; Snook & Irvine, 1969; Snook et al., 1970; Subramaniam, 1973).

Hard work by individuals with average fitness has 33% oxygen consumption during eight hours. When hard work is required of people with low fitness the consumption is 25% during eight hours. Above average fitness individuals tolerate hard work at 40% oxygen consumption for eight hours and highly conditioned individuals can sustain hard work at 50% oxygen consumption for eight hours (Sharkey et al., 2008; Rodgers & Yates, 1990). Research indicates that 45% oxygen consumption is a predictor of one to two hours of work, and exhaustion is likely to occur when more than 50% of maximal activity is required on a job (Berger, 1982; Garg et al., 1983; Kroemer et al., 1997; Roozbazar, 1974; Sharp, Wright, Vogel, Patton, & Daniels, 1980; Troup et al., 1985). In expanded work hours, male industrial workers had 23% oxygen consumption at 12 hours, and female industrial workers had 24% oxygen consumption at 12 hours (Hoon Yong, 1996). Associated with oxygen consumption authors report muscle lactate profiles did not rise at 25% oxygen consumption; however, there were high lactates at the 55%—70% VO2 (Knapik, 1983). If effort intensity exceeds 60% oxygen consumption, the time to recover from the task has been exceeded (Astrand, 1960; Garg et al., 1983; Rodgers, 1988). Heart rate response as a measure of full-time work is reported in a range of 90 bpm to 122 bpm. The heart rate over 130 is considered excessive, and not indicative of full-time work. (AIHA, 1971; Astrand, Rohdahl, Dahl, & Stomme, 2003; Ayoub et al., 1979; Blessey, Hislop, Waters, & Antonelli, 1976; Garg et al., 1983; Grimsby & Saltin, 1966; Hoon Yong, 1996; Jiang, 1984; Jorgensen, Davis, Kirking, Lewis, & Marras, 1999; Kodak, 1986; Kroemer & Grandiean, 2001; Legg & Pateman, 1984; McGlothlin, 1996; Morris et al., 1961; Roozbazar, 1974; Williams, 1964; Wilson & Corlett, 1995). (Table 1).

The work physiological approach to determination of sustained tolerance is compatible with all work, including heavy industries, irrespective of age, sex and other factors (Badger, 1981). Both heart rate and oxygen consumption are scientifically reliable norms upon which to judge work capacity (Astrand, 1960; Maas, Kok, Westra, & Kemper, 1989). There is no single test of physical work capacity testing where scientific measurement is conducted that is substituted by observation techniques such as kinesiophysical methods (Hettinger et al., 1961). For this reason the methodology of the Isernhagen System, and others using kinesiophysical process, has been found to lack the ability to predict work over time (Garg et al., 1983; Kuijer et al., 2006). A task exposure work physiological test is needed to assess not only lifting in manual materials handling, but also to determine the intensity of work time duration. Physiological measurement made during manual materials handling tasks pertains to steady state heart rate and is the most widely accepted, sensitive, and reliable indicator of physiological demand (Garg et al., 1983; Hagen, Hallen, Harms- Ringdahl, 1993; Morrissey, 1987; Sharkey et al., 2008).

Heart rate as used in the work physiological method for FCE has a practical advantage as there are no significant differences between field and laboratory results (Ayoub et al., 1979; Snook, 1971). The use of heart rate is not only a predictor of time tolerance but also as fatigue criterion has shown consistency because of the utility of the linear relationship to oxygen consumption (Astrand, 1960; Rowell, 2007; Sharp et al., 1980). In order for FCE tests to be applied effectively to simulate industry the testing must have both a short administration time and an accurate prediction (Astrand, 1960; Sharp et al., 1980). Among the FCE tests, the dynamic lift testing can rely on pre-established criteria for stopping the test, such as the heart rate reserve method, which is based on work physiological science (Becker et al., 2007; Isernhagen, Hart, & Matheson, 1999; Nindl, 1998). This process of pre-establishing expected response for the FCE examinee using oxygen consumption through heart rate reserve establishes the work requirement that allows the effort level to be related to the duration (Rodgers, 1988).

The use of a generalized equation predicting maximal age-adjusted heart rate, such as (220 - age) x .85 (85%), as an exertion-level comparison is a clinical guide in diagnostic testing, and is inappropriate for FCE testing (Tanaka, Monahan, & Seals, 2001). The estimation of maximum heart rate has been a feature of exercise physiology since the late 1930s. Heart rate response is typically used in clinical analysis to determine exercise intensity, not to determine work tolerance. Users of the maximal age-adjusted heart rate need to be called to explain the error of this FCE criterion and to provide research documentation for that inclusion (Roberg & Landwehr, 2002).

All types of muscular activity, whether at a given intensity or for hours without symptom of fatigue, can be determined using structured heart rate exposure testing (Astrand, 1960; Morris et al., 1961; Muller, 1953). The protocol includes the monitoring of heart rate associated with the task, then continuing to monitor as successive tasks are performed, and recovery to resting (Drury et al., 1989; Garg et al., 1983; Hoon Yong, 1996; Jorgensen, 1999; Rowell, 2007). The resting exposure time for prediction of reliable sustained work over eight hours has been up to eight minutes duration as an accurate sampling related to heavier work, and up to five minutes duration for light work (Astrand & Saltin, 1961). Test exposures of both four minutes and one hour had consistent heart rate response for continuous work profile. A 40-minute work time test accurately reflected daily heart rate workload without significant difference. Another process of work exposure prediction to full-time is four to six minutes of repeated lifting which results in steady state heart rate and oxygen consumption. The test protocol to assure response is a 15-minute duration (Balke, 1963; Hagen, Sorhagen, & Harms-Ringdahl, 1995). Other techniques reported for testing exposure include five-minute work bouts with a three-minute rest as reflecting eight hours (Adams et al., 2010), and a 20-25 minute work exposure for determining a weight that can be handled for eight hours (Hoon Yong, 1996). There is a suggested process of 40-45 minutes as sufficient to determine materials handling for 12 hours, and this includes an initial measurement, intermittent measurements, a measurement during the last five minutes, then recovery to resting (Garg et al., 1983; Hoon Yong, 1996; Snook, 1971). Other methodologies described to expose the examinee for a duration that corresponds to an eight hour tolerance of oxygen consumption includes one to 16 minutes to determine sustained tolerance of light work, and three to 27 minutes to determined sustained tolerance for heavy work (Knapik, 1983). The average maximum weight associated with oxygen consumption is an acceptable criterion for eight hours, or 33% of VO2 max (Snook & Ciriello, 1991).

An extended testing procedure to document the steady state linear heart rate response was conducted over seven hours. The procedure included heart rates measured every two minutes during a 50-minute task followed by a 10-minute rest. The heart rates were determined to be valid and the results included a 5 bpm change during the seven hours, and a mean heart rate of 115 bpm+/- 0.7 bpm, to 119 bpm+/- 0.7 bpm (Keijer et al., 2008). A work cycle of 10 minutes is normally used to determine tolerance related to a projection of eight hours. The process includes heart rate at rest before starting, then a heart rate each minute in the cycle of work, and then a recovery to resting heart rate (Davis et al., 1969). Given the largely linear relationship between heart rate and energy uptake the use of heart rate can be used to establish heaviness of work. Light work is a small expenditure with a heart rate of approximately 90 bpm, and Medium work at a heart rate of 100-118 bpm. Heavy work has a heart rate of 120-138 bpm and Very Heavy work has heart rate of 140-158 bpm (Kroemer et al., 1997). Heart rate of 140 bpm represents working less than two hours, and heart rate of 89% to 92% VO2 max would have a representative heart rate of 166-176 bpm, and would be tolerated for less than 20 minutes (Bilzon et al., 2001; Genaidy, Duyas, & Asfour, 1997; Kroemer et al., 1997).

Heart rate is also a criterion for frequency of tolerance for postures and positions such as stoop, crouch, and squat. Energy consumption studies have shown that squat lifting is metabolically more expensive than stoop, which is why workers seldom use a squat technique. Oxygen consumption and heart rate are significantly higher for the squat versus the stoop, and the stoop and crouch have minimal heart rate response difference (Hagen et al., 1995; Morrissey, 1987).

Gainful employment is typically defined as a 40-hour work-week, and the heart rate and oxygen consumption percentage is the most clinically relevant objective approach to determining work capacity and the documentation of fatigue if it exists (Ciccolella et al., 2011). Functional capacity tests should be performed to document work physiological changes including any changes in workload. The evaluation of workload should be monitored beginning in the first minute and then in each succeeding minute until there is a steady state heart rate comparative to the pre-determined heart rate (Morris et al., 1961; Troup et al., 1985). The steady state heart rates are achieved in a normal linear, curvilinear response during a period of two to five minutes (AIHA, 1971; Knapik, 1983; Rowell, 2007; Wahlund, 1948). The functional test battery should include endurance testing because this is a critical factor in positional tolerance determination (Abdel-Moty et al., 1993; Osborne et al., 2001). The endurance of the examinee is best addressed by pulse rate due to its value as an indicator of both the physiological load or strain, and the physiological response over an extended period (Bainbridge, 1920; Boorens & Hervey, 1960; Llmarinen, 1992; Morris et al., 1961). For any one person there is correlation between heart rate and constant work even if the work is short and delivered anaerobically, or obtained aerobically (Astrand, 1956; Legg et al., 1984). The work capacity steady state endurance is linear for both trained and untrained subjects, and at the end of the work the heart rate returns to resting exponentially, making the energy expenditure a relatively simple process (Andrews, 1967; Morris et al., 1961).

Study of the heart rate during recovery may yield more important data on the functional capacity than during the period of work (Morris et al., 1961). There has been a mandate in court, which upheld work physiology in regard to the metabolic requirements of required duties (Ciccolella, 2011). Continuous work capacity does not decrease with increasing age (Snook et al., 1970); however, there are age-related general physiological parameters, which include a decrease of maximum heart rate, and change in maximum oxygen uptake (Astrand, 1960; Astrand et al., 1961; Kamon & Ayoub, 1976; Kasch et al., 1985).

The FCE test protocols which use the heart rate as a safety monitoring feature, such as 85% age-adjusted maximum, are not providing time prediction to work time endurance. In fact, this promoted 85% age-adjusted maximum heart rate feature shows commercial FCE creators are incorrect in using this criteria because there is no scientific foundation for this method providing sustained endurance related to full-time work (Jones et al., 2003; Wahlund, 1948).

A primary component of an FCE is manual materials handling (Isernhagen, 1999; Sharp et al., 1988). There is no published research by FCE commercial vendors that scientifically validates a reliable manual materials handling procedure, according to work physiology. The first and most reliable work physiological principle is the metabolic approach, which measures heart rate as a comparative to oxygen consumption. The next procedure related to manual materials handling referenced by FCE vendors is referred to as "biomechanical", but this is a subjective observational process without quantitative measurement and is referred to as "kinesiophysical". The major limitation of the kinesiophysical procedure, as promoted by Isernhagen, is the lack of corroborating work physiological validity. The last typical method of manual materials handling promoted by FCE vendors is the psychophysical approach (Gardener et al., 1999). The use of free-style lifting is a choice of evaluating manual materials work administration. This protocol assesses the work stress by evaluating physiological factors, primarily heart rate elevation above resting, and the recovery to resting (Kroemer, 1982). The duration of a meaningful physiological field test of manual materials handling should be at least 12 minutes (Balke, 1963).

The Objective Force Warrior (OFW) test was designed to elucidate the ability to sustain power during repetitive lifting activity. The test intends to determine the effects of self-paced work, not limited by fatigue with a 10-minute box lift procedure (Nindl et al., 2002). Regardless of lifting technique the difference in heart rate between lift from floor-to-knuckle height and from floor-to-shoulder height was negligible. The possible use of a standard fitness test, such as GXT, does not provide correlational response to work lifting task tests (Sharp et al., 1988).

The direct measurement of work is best determined by measuring heart rate, which is an overall physiological profile of employee tolerance (Drury, 1976; Rodgers, 1988). Monitored manual materials handling jobs were found to require between 20%–35% of oxygen consumption by heart rate monitoring (Asfour, Ayoub, Genaidy, & Khalil, 1986; Drury, 1976; Morgan et al., 2012). When workload is calculated by heart rate and compared to data on aerobic capacities, that a 10-hour day for five days can be predicted (Rodgers, 1988).

Of the three materials handling analysis approaches, the psychophysical testing allows the subjects to set their own pace and control the workload. An example of this approach was performed by incorporating three lift and lowering tasks, with four pushes, one pull, one walk and six carrying tasks—which ultimately presents a 40% oxygen consumption reflected by heart rate (Snook et al., 1970). Variations in load weight and work pace in manual materials are monitored by changes in heart rate, with heavier weights handled as a slower pace and lighter weights handled at a faster pace (Hamilton & Chase, 1969). Determination of sustainable full-time manual lifting has physiological responses in the 25%–40% oxygen consumption range with corresponding heart rate in the range of 110-120 bpm (Drury et al., 1989; Hagen et al., 1993; Garg & Banang, 1988). The heart rate monitored response is performed every 30 seconds for the first three to six minutes, which is at the point of steady state, and then after the completion of task there is monitoring of recovery heart rate until the resting level is determined (Datta, Chatterjee, & Ray, 1983; Drury et al., 1989, Franklin, 2000; Sparto, Parpianpour, Reinsei, & Simon, 1997). Manual materials handling in exposure studies monitored by heart rate showed 10 kg loads had steady state response in the range of

112–116 bpm, 20 kg response of 120–122 bpm, and a 30 kg load has a 136–138 bpm response (Datta et al., 1973). Other repetitive manual materials handling tests in floor-to-workbench height transfers were conducted in six-minute stages, monitored by heart rate before, during, and then between stages for one to three minutes, so that there could be a reestablishment of the resting heart rate. The load exposure was ten pounds at each of the stage increments. The lifting process was self-paced beginning at 30 lbs, and progressing sequentially (Pandorf, Nindl, & Mountain, 2003). A weight-carrying test utilized a treadmill set at a comfortable pace in one to three stages. Heart rate and blood pressure were monitored before, during, and at the end until recovery to resting was established. There was a rest period between stages to monitor recovery, and each stage was increased in ten-pound increments using one or two hand dumbbell loads (Pandorf et al., 2003).

Repetition box lifting (RBL) is a test protocol of the military, which requires lifting a 20.5 kg metal box with side handles onto a 1.3-meter high platform for 10 minutes. The RBL required less than 70% oxygen consumption and had a 6% reduction of ability from day one to day four, and was not considered to be statistically different (Nindl et al., 2002; Pandorf et al., 2003). Other manual material testing procedures required a box lift from knee height to waist, then carry five feet followed by placement on a shelf at elbow height. The lifting rate was 4.3 per minute using 10 different loads: 9.1 kg, 11.8 kg, 14.5 kg, 17.2 kg, 20 kg, 29.9 kg, 32.7 kg, 35.4 kg, 38.1 kg and 41.7 kg (Jorgensen et al., 1999). Another repetitive lifting protocol requires 15 lifts per minute from floor to 1.32-meter height and is monitored by heart rate. There was no significant difference in heart rate between men and women. The authors concluded that repetitive lifting should not be estimated from other modes of exercise, such as isometric force tests, but should be assessed in terms of the exact nature of the task (Nindl et al., 1998).

Posture techniques when lifting compared a squat with 90 degree knee flexion and back erect, versus stoop position: there was a 13 bpm higher response for the squat lift (Hagen et al., 1993; Welbergen, Kemper, Kinbbe, Toussaint, & Clysen, 1991). The criteria of heart rate change monitoring during FCE testing protocols has been used to compare "biomechanically safe", or observational decision making, to calculation of safe maximum heart rate. The variables recorded were resting heart rate, peak heart rate, blood pressure, and percent of heart rate change. The researchers pointed out that examinee behaviors, such as voluntarily stopping and uncooperative issues, were barriers to the observational techniques, but did not preclude the collection of heart rate response data. The intent of the study was to establish physiological guidelines for clinicians to use as a compliment to the observational biomechanical decision-making process regarding termination of lift testing.

The procedures of lifting from floor to waist, waist to shoulder, and shoulder to overhead, include continually monitoring heart rate and monitoring of 10% heart rate change as it decreases to pre-lift heart rate between each lift. The process found a statistically different heart rate response between those not trying, or not cooperating, compared to those whose heart rate was considered to be a safe maximum (Morgan et al., 2012). The criteria of steady state physiological response heart rate, found four minutes after the task commences from resting heart rate, is an important parameter in the manual materials handling component of FCE tests. Some commercial vendors of FCE protocols, such as BTE, cannot duplicate real lift work as determined by work physiology (Ting, Wessel, Brintell, Maikala, & Bhambhani, 2000). The Isernhagen DSI company, which uses the kinesiophysical model, does not have a work physiological heart rate analysis component. In a response to a 2009 survey for the American Medical Association (AMA), they indicated that their FCE product had not required any upgrades and if additions were developed they were available to licensed providers (Genovese, 2009).

Methods Time Measurement (MTM)

There are FCE commercial vendors, and own-design providers, who incorporate methods time measurement (MTM) into the FCE evaluation process. It has been determined that MTM methods and standards are physiologically unacceptable for an FCE test. MTM has a performance index of 100%, which indicates the worker is able to meet the company's performance standard. Less than 100% indicates that the worker does not meet the expected company standard of motor skill performance (Garg et al., 1983).

A misconception in the MTM scoring profile is that the motor skill predicts the endurance level of an FCE test examiner. Often the actual motor skill time-performance requirements vary from one job to another dependent on the labor application time and allowance for recovery from the work exposure (Osborne et al., 2001). Physiologically measured heart rate should be the criterion of sustained manual materials handling work performance instead of MTM. The performance standards of work based on MTM are physiologically unacceptable. Workers performing in MTM warehouses were experiencing excessive fatigue as determined by heart rate and heart rate recovery to rest on sequential exposures (Garg et al., 1983). MTM are considered reliable methods but they are based on average experienced workers, which assumes that the individual is familiar and proficient with the task being performed. This is not always the case with injured workers (King et al., 2004; Matheson, Rogers, Kaskutas, & Dakos, 2001).

FCE methods used by providers, either incorporating own-design or commercial products, can be considered inappropriate if inappropriately applied. An example of this is a treadmill test because it often goes beyond collecting information necessary to determine whether the examinee is capable of work task. A treadmill test used in an FCE was considered unnecessary to determine if the examinee could perform a work task and is the kind of examination that the Equal Employment Opportunity Commission considered inappropriate to include in a non-medical physical or ability fitness test. The post-treadmill heart rate measurement was considered a demonstration that the physical capacity exam was a medical evaluation (*Indergard v. Georgia Pacific*, 2009).

In *Boardman v. Edwards Centers Inc.* (2004), the judge wrote, "I find the opinion of the occupational therapy assistant who saw the plaintiff upon only one occasion for the purpose of evaluating his claim is insufficient to overcome credible evidence from a physician" (Wilson, 2009). The court hearing, *Stup v. UNUM Life Insurance Company* (2004), questioned the validity of an FCE based on facts in that case, noting "first and most obviously the FCE lasted only two and a half hours, so the FCE results do not necessarily indicate Stup's ability to perform sedentary work for an eight hour workday, five days a week" (Wilson, 2009).

There are other questionable aspects concerning FCE due to the lack of inclusion of work physiological science. In particular, the terminology associated with kinesiophysical tests, Light, means that signs of effort are "observed," thus no particular fatigue was expected. This observational criterion is deficient in scientific foundation for an extrapolation to tolerance of full-time work. It is unknown if there is accuracy in the assumption of such an extrapolation and if it can be considered reliable (Oliveri, 2006).

Professional correspondence from Ms. Lechner, PT, instructed this researcher that the scoring of the ErgoScience PWPE (Physical Work Performance Evaluation) was observational, and that heart rate was only a "stopping point." There was no information provided about the interpretation of the term "stopping point" and no indication of a work physiological prediction for sustained steady state work. She stated, "I do not believe there is research regarding ASCM exercise test evaluation protocols." The scoring system process she incorporates to the PWPE has a subjective foundation. Her comment about work physiological scientific heart rate response to work was, "Aerobic capacity does not equal work tolerance." Her statement was the PWPE algorithms do not include heart rate as a method of determining sustained full-day work, and heart rates are not compared during the PWPE process to determine tolerance for activity (D. Lechner, personal communication, August 5, 2009). ErgoScience is reported to apply heart rate into the scoring system, but there is no exclusive reliance on heart rate to make projections regarding work tolerance.

The manual materials handling in the PWPE is based primarily on subjective observation with opinion regarding work tolerance based on the quality of the examinee's body position. The measurements incorporated into the PWPE algorithms are variables such as psychosocial, maturational, sociological, fine motor skills, and joint flexibility. There is no predictive work physiology regarding formulas such as the heart rate reserve method; there is no recovery to resting heart rate report or analysis. The only inclusion of heart rate in the PWPE report is the percentage change from the beginning to the end of the test (Gardener, 1999).

FCE Methods and Procedures Typical of Own Design

A variety of FCE protocols have been introduced by commercial vendors, as well as non-commercial or "own-design" protocols. It has been reported that a simple model connecting a physical evaluation of work capacity with work performance is naive and does not present a useful picture (Morris et al., 1961). A review of 10 FCE commercial products determined that a classification system is needed that differentiates these products. FCEs using proprietary methods are not scientifically proven for extrapolation regarding manual materials handling, and are criticized because of the claims made about purported objective methods (Genovese, 2009). The proprietary FCEs, and "own-design" FCEs, do not possess a responsive instrument that is able to measure small work physiological changes within an examinee over time (Law, 1987). The FCE commercial protocols and "own-design" protocols are not considered standardized instruments because there is no publication about extensive development methods, and no detailed manual concerning the development process. The variation of expertise among users and among the FCE instruments contributes to unreliability (Law, 1987).

In general, there are three evaluation methodologies related to material handling: the biomechanical, physiological and psychophysical. Outside of these methods is the non-scientific kinesiophysical process, which is based on observational criteria (Gibson et al., 2005; Gibson & Strong, 1997; Hart, Isernhagen, & Matheson, 1993). The physiological approach relies on measurement of heart rate and is acknowledged as the most accurate determination of work. There is a need for an FCE classification system that provides defined methods. The two current non-defined general classifications are commercially available, and "own-design", by individual providers or individual clinics. The overall goal of providers is to measure and report on the examinee performance, in particular, the performance of the manual material handling methods. These are bouts of work in increasing intensity that require an adequate data collection benchmark, and a criterion which projects eight-hour dependable endurance for the task (Balke, 1963; King et al., 1998; "Blankenship Functional Capacity Evaluation", 2013). Test results that are provided without interpretations are meaningless and misleading ("Blankenship Functional Capacity Evaluation", 2013).

The typical tasks offered in most FCEs do not correspond to actual work demands, and extrapolations from maximal lifting ability to perform occasional lifting and then frequent lifting—such as in Blankenship FCE—lack a scientific foundation (Pransky et al., 2004). A review of the Blankenship System FCE bibliography identifies no citations after the early 1990s and no references to work physiology (Feeler, St. James, & Schapmire, 2010). The Blankenship system relies on extrapolation of dynamic or aerobic tolerance profile from a static lift or isometric lift value. The static lifts are referred to as arm lift, static leg lift, and back/torso lift. These isometric lifts are not appropriate for making predictions to dynamic work physiological lifting capacity. The extrapolations of the Blankenship "own-design" system to work physiological parameters are misleading predictions, and are fraught with potentially significant error (Becker, 2008; Gross & Battie, 2002; Townsend, Schapmire, St. James, & Feeler, 2010). Employers should be cautious about the use of FCE tests that do not have a valid scientific work physiological model (Sharkey et al., 2008).

The work physiological testing methodology has a pre-determined heart rate process that is a steady state work tolerance criterion and presents the highest reliability of endurance prediction (Durand et al., 2004). The metabolic measurement reflected by heart rate gives a good indication of the heaviness of bodily work and enables a determination of an examinee's sustainable work tolerance (Lehmakn, 1958; Ricci, 1967). Physiological methodology for maximum weight handling shows the most advantageous technique is determined by heart rate and oxygen consumption (Genovese, 2009).

The kinesiophysical methods are proprietary protocols that have a foundation of subjective observational criteria where the therapist judges the "safe" level of work performance and effort by the examinee (Gross et al., 2011). The method requires the scoring therapist to use professional judgment in visualizing the body's maximum lifting ability. Therapist testers infer safety exists in this process but there are no scientific references that support the contention. The frequency of the body posture for lifting is also a "judged" observation. The judged observation criteria require a determination if the recruited primary muscles are accomplishing the task or if accessory muscles are also recruited. There is no methodological process of verifying the accessory muscle function because neither electromyographic data (EMG), nor clothing removal with video or pictures, are a specified technique. This methodology has significant limitations of accuracy and there is a lack of scientific rigor, especially concerning females and obese examinees. Precise operational definitions for the judging observations do not exist and the one significant indication of accessory muscle activity involves graduated determination of effort, which is subjective (Durand et al., 2004; Farag, 1995; Gross et al., 2006; Innes, 1998; Tanaka et al., 2001).

Kinesiophysical FCE providers have speculated that a two-day protocol would verify accuracy; however, none of the variables correlated significantly in lifting or carrying. Two-day test criteria were based on the methodological process of safety observation and strength observation; there was an assumption that day two judgments would be lower but that was not confirmed (Reneman, 2003). The kinesiophysical creators and therapist user/providers have relied on inter-rater reliability for credibility. Inter-rater reliability has an expectation that two or more clinicians independently administering the same test to the same group of subjects will score performance similarly, which then determines the relationship. The inter-rater process seeking agreement among judges had the lowest agreement on dynamic strength, and there were disagreements between raters on observed signs. This judgmental process had no data analysis regarding heart rate or work physiology (Durand et al., 2004; King, 2004; Tanaka et al., 2001).

A study by the United States military in 1984 directly contradicts the kinesiophysical method having no significant correlation to lifting or carrying. That research used regression equations to decide that the tasks that would determine work tolerance were lifting, carrying, pushing and pulling. The tests were found to be generalizable, and had a generic application to military occupations (Myers, Gebhardt, Crump, & Fleishman, 1984). In contrast to the kinesiophysical method, an FCE should have clearly defined work physiological end points related to heart rate response, recovery to resting heart rate, and analysis of heart rate changes over time. This assures that there is a determination of tasks which do not reach exhaustion (Borg et al., 1962; Genovese, 2009; Hettinger et al., 1961; Nindl et al., 1998).Other contradictory processes to kinesiophysical observational methods derived from work physiological science include the principle of determining fatigue by quantified measurements, and the testing process of freestyle lifting work bouts interspersed by rest periods which can be continued for eight hours (Becket & Hodgdon, 1987; Franklin, 2000; Sharp et al., 1988).

The Isernhagen WS/FCE (IWS/FCE) includes manual materials handling that evaluates three lifts of five repetitions without heart rate monitoring, as loads are transferred from floor to waist, four foot waist level horizontal carry, and transfer from waist to the top of the head (Borg et al., 1962; Gross et al., 2006; Tanaka et al., 2001). The IWS/FCE also includes a 30-minute observation of sitting and standing; however, these protocols were considered unacceptable for analysis. There is also an IWS/FCE shuttle walk test that reports a heart rate norm, but this had no justification for a match with heart rate in the workplace (Sharp et al., 1988). The IWS/FCE also includes three stationary tests for a period of five minutes, overhead work, crouching and kneeling, which are components of the methodology that are not published in peer-reviewed literature, and have not been scientifically validated. The performance standards are based not on research but on "experience" (Jebsen, Trieschmann, Mikulic, Hartley, & Snook, 1970; Reneman, Joling, Soer, & Goeken, 2001). As a whole, the IWS/FCE is not a sufficient predictor of return to work (Genovese, 2009; Gross, 2006; Innes, 2006; Reneman, 2003). The observational method is considered a behavioral assessment as opposed to an objective measurement of tests (Gross, 2006). The kinesiophysical IWS/FCE technique is limited by the general lack of reliability in the rater's judgment and lack of discriminative ability of the scaled scoring system. The technique is also limited by the fact that a single score was the typical assigned response to all examiners who had independently participated in rating the examinee task performance (Gross, 2006). The IWS/FCE assessment of work-related disability is not sufficient to predict work ability, and the content validity is limited (Keijer et al., 2008). Finally, in relation to an application of work physiology, there is no known criterion to represent work over time, eight hours per day, five days per week, and because of that deficiency there is no foundation to extrapolate an observational judgment to full work days (Keijer et al., 2008; Rodgers, 1988).

Other named FCE methods are also deficient in the application of work physiology as a predictor of full-time work. The BTE process purportedly has a criterion validity determined by comparing endurance time to heart rate during real and simulated lifting, and then deriving predicted lifting tolerance on the work simulator by using an unpublished, non-peer-reviewed regression equation. BTE overestimates real life endurance, and there is lower physiological stress during the BTE simulated lift than in actual real work lifting (Ting et al., 2000).

WorkHab is another vendor using a kinesiophysical process with a criterion of "safe" exertion determined by calculating an 85% age-predicted maximum heart rate. The proprietary scoring is based on observation using a scale of zero to four to determine maximum ability in five criteria. The tasks, postures and positions are stance, posture leverage, torque and pace. There is no inclusion of work physiological analysis, prediction or monitoring heart rate and no recovery to resting methodology (James, 2011).

The Job Fit System is a pre-employment functional assessment (PEFA) using an observational scoring system with grades of one to four, interpreted as "no limitation", to "significant limitation", as applied to reaching forward, reaching overhead, squatting, and stooping. The materials handling includes floor to bench, bench to shoulder, shoulder to overhead, and a carry task. The protocol restricts exposure to 35 kg, there is a self-limiting process, and there are no work physiological parameters for the determination of full-time steady work tolerance. An intra class correlation coefficient score found that squatting was as low as 0.53, and reliability ratings were poor to moderate for stooping and squatting (Legge et al., 2006).

The Functional Range of Motion Assembly Test (FROM) test requires work at a self-selected "safe" pace where methods time measurement (MTM) is included. The tasks are placing 15 pegs to location, overhead reach, stoop reach, and kneel reach, with 15 transfers in one direction and then reversing direction. The three tests have a two-minute break and there is an estimation that the test is completed in four to eight minutes. There is no work physiological component to the testing for determination of full-time steady state tolerance or presentation of fatigue analysis (Matheson et al., 2001).

There is a functional performance test for psychiatric clients called the Bay Area Functional Performance Evaluation (BaFPE). This is a structured interview used to support clinical observations and determine life skills. There is no work physiological component (Managh & Cook, 1993). The Focus on Therapeutic Outcomes (FOTO) is a descriptive questionnaire outcome process where the findings suggest that pain should not be the primary determinant of return-to-work status (Hart, 2001).

The Physiological Monitored Evaluation (PME) assesses demands of activities by monitoring heart rate and blood pressure. There is a baseline heart rate and then monitored heart rate as a determination of the energy cost of tasks. The process does not have an age inclusion and only sets "safe" heart rate guidelines for response to activity. The PME process is discontinued if the heart rate reaches 180 bpm and the monitoring for return to rest is five minutes. There is no formula or calculation regarding predicted steady state tolerance heart rate for a determination of full-time work, and no analytical feature to determined work physiological response to task (Borg et al., 1962).

The Residual Functional Capacity (RFC) was developed by the authors to define a functional battery for physician estimation of use limitation regarding a dedicated population of chronic pain patients (CPP). The author group incorporated the Dictionary of Occupational Titles (DOT) for lifting and carrying; where a norm was not identified in the DOT, they defined a norm based on their clinical experience and acumen (Fishbain et al., 1994)—not on peer reviewed research or scientific inquiry. The development of the DOT-RFC battery of protocols is not published but is available upon request (Fishbain et al., 1994). The DOT-RFC scores on a pass-fail basis for which reliability has not been tested. The test parameters do not include scientific work physiological heart rate collection or analysis, and the validity of the DOT-RFC test battery has not been addressed, nor applied to the "real world". The authors concluded that they could predict employment levels with the DOT-RFC. The bibliographies for the publications do not include citations to the science of work physiology, heart rate data collection or heart rate analysis (Fishbain et al., 1999).

The Arcon methodology referred to in 2006 (Innes) has a commercial availability in 2013 (Arcon Vernova, Inc. 2013). The vendor presentation cites peer-reviewed substantiation as a foundation for credibility, which includes reference to PILE. Research regarding PILE has shown there are no cut-off points for limits of agreement, resulting in the conclusion that the PILE is not clinically useful (Isernhagen, 1999). Other aspects of the Arcon include subjective observation functions and an application of heart rate. The heart rate is used as a pre-and-post test comparison for a determination of exertion—not for a determination of time tolerance, or in relation to a work physiological formula. There is no scientific foundation cited for this protocol in regards to work time tolerance. A significant component of Arcon is the use of isometric static strength referenced in the 1981 NIOSH publication, *Work Practices Guide for Manual Lifting* (Badger, 1981), in regard to the risk of force exposure to the L5-S1 lumbar section. This aspect of the Arcon references a biomechanical model of males, 70 inches, 165 pounds; and females 64 inches and 136 pounds. Based upon this population profile the acceptable maximum load at L5-S1 for males is 90 pounds and 45 pounds for females. The vendor cites page 64 of the NIOSH text to indicate a 56% aerobic tolerance for occasional work, and a 31% aerobic tolerance for continuous work. The vendor "own-design" is to round up 56% to 60%, and round down the 31% to 25%: a change of 10% between the high and low values, which is not scientifically supported or documented. In actuality, page 64 of the text identifies the profile of work in kcal/min for occasional work, and references 33% for eight hours, not 25%. The Arcon vendor "own-design" indicates that 40% is a frequent aerobic tolerance, but cites Astrand 40% aerobic tolerance for continuous work. The actual text citation on page 44 indicates that a physiologic response to maximum isometric static lift is 15% aerobic for 250 seconds, and 50% aerobic for 90 seconds (Badger, 1981). The isometric test process for determining dynamic work has been found to be misleading and fraught with potential errors (Feeler et al., 2010; Townsend et al., 2010), and the Arcon-cited NIOSH text on page 98 instructs that more research is needed to compare static to dynamic work (Badger, 1981). The Arcon "own-design" methodology does not accurately incorporate the science of work physiology, the analysis of heart rate response, the recovery to resting heart rate, and the accurate use of work physiology formulas.

The 2009 American Medical Association (AMA) publication *The Guide to the Evaluation of Functional Ability* provides a consensus opinion that the physiological end point determining work tolerance is 70% to 85% age-related maximum heart rate (Genovese, 2009). This is an incorrect presentation of oxygen consumption correlated to heart rate for a determination of full-time steady state work tolerance, and is significantly inconsistent with peer-reviewed research and institutional research (Genovese, 2009).

The Progressive Isoinertial Lifting Equation (PILE) is a process of manual materials handling where the transfer requires floor-to-waist and waist-to-shoulder locations. Men begin at 10 lbs. and women at 5 lbs., and there are four lift movements performed in 20 seconds. The protocol end point is 85% maximum heart rate, which is not age-adjusted, or 50%–60% of body weight (Genovese, 2009; Polatin, 1995). The PILE process has been assimilated by the Matheson System and EPIC protocol (Jones et al., 2003). It is considered to be gender biased, have moderate correlations to heart rate, and a significant negative correlation with activity avoidance (Innes, 2006; Jones et al., 2003). A sample of the PILE is found in the Back School of Atlanta instructional manual for FCE, chapter 5, page 31, "frequent lifting test". The examinee is 37 years old and the resting heart rate is reported to be 110 bpm. There is also a resting heart rate reported as 100 bpm, which would be considered an inconsistent presentation. Based on the PILE protocol there is a target heart rate of 156 bpm. This determination comes from the calculation 220 - 37 = 183 (.85) = 156 bpm. The reported responses are as follows: maximum occasional lift and carry test is 15 lbs floor-to-waist with heart rate 108 bpm, then 20 lbs floor-to-waist with heart rate of 110 bpm. The waist-to-shoulder transfer is 10 lbs with heart rate of 104 bpm, and then 15 lbs waist-to-shoulder with heart rate of 106 bpm. The overhead tolerance is 10 lbs with heart rate of 100 bpm. The frequent lift responses are eight lbs with heart rate 95 bpm, 13 lbs with heart rate of 102 bpm, and then eight lbs with rate of 110 bpm. The frequent carry was 10 lbs with 90 bpm response, and a maximum carry of 15 lbs with heart rate 100 bpm (Zuccarello, 2008). It is clearly impossible for a response heart rate to be less than the resting heart rate.

When the heart rate reserve method is used, as noted by Becker, Morrill and Stamper (2007), the criterion comparative heart rate for occasional work would be 141 bpm and frequent work would be 127 bpm. Based on this work physiological comparison, the PILE example from the Back School of Atlanta is incorrect. Clearly the work physiological data indicates this examinee had a greater tolerance than he was willing to demonstrate, and the analytical process of the PILE is flawed.

The Ergo Science Physical Work Performance Evaluation (PWPE) is a test designed to determine the function of examinees with any type of musculoskeletal disorder, primarily related to workers disabled due to back pain (Durand et al., 2004; Lechner et al., 2008). The PWPE does not evaluate tolerance regarding systemic disorders, diseases, or infirmities. The PWPE uses proprietary unpublished, non-peer-reviewed algorithms which combine data from three tasks that Ms. Lechner determined to be worthy of inclusion: a squat test, floor-to-waist lift and a stair climb. These are the tasks she uses to project work level for an eight-hour workday, thus presenting a process with limited credibility (Lechner et al., 2008; Tuckwell, Straker, & Barrett, 2002).

The PWPE contains 36 tasks in six sections, in which three sections are dynamic strength, position tolerance, and mobility. There is a determination of "safe" level work (SLW) obtained by a decision algorithm, which processes the number of reps, heart rate, duration of task, and observation of task. Dynamic strength is scored on a six category ordinal scale with posture and mobility scored on a four category ordinal scale (Myers et al., 1984). The ordinal scale decision regarding posture and mobility is the most subjective of the processes; therefore, there is no standardization (Tuckwell et al., 2002). The ordinal scoring on the four point subjective process ranges from judged observation of within normal limits (WNL), to severe deviation of position from expectation. There is no published or peer-reviewed research regarding quantification or objective criteria for the score deviation assignment (Tuckwell et al., 2002). Of the 21 main tests, nine are designated for critical evaluation: floor to waist, bilateral carry, pushing, sitting, standing, kneeling, stair climb, repetitive squatting, and walking (Robertson, 1982; Tuckwell et al., 2002). The research to justify the algorithms designed methods is limited and lacks components of a well-designed test (Tuckwell et al., 2002).

To examine work tolerance for an eight-hour day, the PWPE requires examinees to repeat the first three tasks at the end of the test, which are floor to waist, stair climb and repetitive squat. The heart rate from the pre-tests is supposed to be compared to the heart rate of the same three tests at the end of the PWPE. A judged scoring algorithm is then applied to subjectively determine if findings suggest an eight-hour work tolerance. There is no work physiological science applied to this methodology (Sharp et al., 1980; Tuckwell et al., 2002).

Review of the PWPE showed that the test-retest of the nine identified tasks had reliability that ranged from poor to substantial. The mobility test, stair climbing, repetitive squatting and walk were the least reliable predictors (Innes, 2006). The PWPE results have to be interpreted cautiously due to the inherent flaws, and the rater scoring process is considered to have a bias (Myers et al., 1984). The dynamic testing of the PWPE, lift, carry, push and pull have subjective criteria for assignment to the end of the protocol based upon instructions of "stop when you want," or "when told to stop". There is no work physiological method of heart rate analysis or predictive criterion for termination, or analysis of the tolerance to the test (Gardener, 1999; Tuckwell et al., 2002).

Of the PWPE-included tests, several are considered to be "own-design" inclusions. One of these is the two-minute repetitive squatting, which was chosen by Ms. Lechner because of convenience of application in restricted space and convenience of estimates of aerobic profile. This squatting procedure has been found to be a failed replacement for aerobic endurance such as a step test or a two-mile run, and is considered to have a large prediction error and only fair to moderate reliability (Durand et al., 2004; Tuckwell et al., 2002). The squat procedure entails picking up a box at waist level, turning 180 degrees and then placing the box on the floor. The protocol continues for the two-minute procedure, or a set number of times—or until the therapist gives a stop instruction. The process does not include peer-reviewed squat research or a work physiological protocol for monitoring heart rate, analyzing heart rate or documenting heart rate recovery to resting (Tuckwell et al., 2002; Workwell Systems, 2006). There is no significant correlation between maximum strength or endurance of trunk muscles in the squat test (Zuccarello, 2008).

Another "own-design" process of the PWPE is the stair climb, which is up and down stairs with no pace criteria, no scientific documentation of the number of steps, and no work physiological analysis. This test had slight test-retest reliability (Durand et al., 2004; Tuckwell et al., 2002).

A review of the research literature does not identify squat tests, which are assimilated by the PWPE method. The squat test methods are typically work physiological monitored for heart rate related to oxygen consumption and respiratory response (Hagen et al., 1993; Ting et al., 2000). There are also no normative squat data from the PWPE related to back endurance, associated with defined variables such as age, sex and occupational groups (Alaranta, Hurri, Heliovaara, Soukka, & Harju, 1994). Squat test procedures related to back endurance include a standing position with feet 15 cm apart, a descent to horizontal thigh position, one repetition every two to three seconds for a maximum of 50 repetitions (Alaranta et al., 1994). There are other squat procedures with a reliability of 0.85 that are "half descent" procedures, which measure leg muscle endurance using individual's body weight. The process is to stand back-to-wall and descend to a 90-degree angle of hip, knee and ankle (Zuccarello, 2008). Physiological monitoring of a squat versus a stoop resulted in a heart rate of 125 bpm for stoop and 139 bpm for squat. It was determined through heart rate monitoring that in daily work people prefer to stoop rather than squat (Ting et al., 2000).

Metabolic energy rate suggests lifting by stoop posture is a preferred method. It is not only safer to allow workers to use their common sense, but experienced workers rarely squat to handle heavy loads. The use of a squat posture with knees bent and back straight is not well-substantiated as a preferred manual materials handling method, and it is known that steady state heart rate is the most reliable indicator of sustainable tolerance (Garg & Herrin, 1979; Sekulic, Males, & Miletic, 2006). An FCE provider therapist in Washington State was admonished in August of 2009 for the work physiological errors in his PWPE report that led to an incorrect opinion related to work endurance tolerance. Ms. Lechner was asked to respond to the critical review of the PWPE. She stated, "Mr. 'X' is certified to administer the ErgoScience PWPE but he was not involved in the test development or research so it is difficult for him to answer questions about the work physiological protocol" (Myers et al., 1984). Ms. Lechner has clearly neglected to provide instruction on work physiology and analysis of work physiological data to her ErgoScience-certified therapists, resulting in the conclusion that her PWPE methodology is an "own-design" protocol lacking scientific foundations related to work time tolerance.

The literature identifies FCE commercial software products offered for sale to user therapists as "standardized", and the "own-design" methods created by user therapists as "non-standardized." Evaluating therapists using their "own-design" FCE, or the "own-design" from commercially sold FCEs, are considered to be providing an informal assessment (Tuckwell et al., 2002). Data collection methods used by FCE providers are not universally objective, which is directly opposite of claims made by both FCE vendors and FCE therapist providers (Innes & Straker, 2002; Pransky et al., 2004). Only FCE methods using objective measures in the protocols that lead to reliable and valid decision-making, particularly in regard to work physiology processes, are acceptable for determining full-time work (Innes et al., 2002; Koho, Aho, Watson, & Hurn, 2001; Tuckwell et al., 2002). Judgmental processes, which are subjective, observational, and promoted as "safe," have relatively weak correlations to scientific support or validity (Durand et al., 2004; Pransky et al., 2004).

Validity is the method of determining if the test instrument measures what it says it is measuring. The content validity is comprehensive and represents the characteristics to be measured. The protocol should measure every detail considered to be important by the discipline and body of knowledge that contributes to the purpose. The construct validity of a test instrument has measurement protocols, which conform to the prior science (Law, 1987).

The practice of physical therapy identifies a standard as having a quality or action of an approved binding general statement. Tests provided by vendors must include all research studies and methodologies related to the measurement, and all peer-reviewed publications cited for that test must be supported by published data. Test users who misrepresent their clinical opinions based on test results when proof of such statements are not presented in the research literature violate the rights of the person being evaluated. Therapist examiners must have expertise to identify errors in the analysis of the measuring tools and procedures they use, and must have a professional and academic foundation regarding the test processes. A scientific basis for physical therapy practice is a requirement, and relevant findings require detail so that the tests can be replicated. Research reports and scholarly papers related to FCEs must be divulged, and descriptions related to how the test protocols are used must be reported. Therapist FCE providers have a professional responsibility to maintain current knowledge of the science and methods they are relying on to assure accuracy. Finally, the product vendor must provide evidence of predictive validity of FCE protocols, in particular regarding work physiology. (Rothstein, Campbell, Echternach, Knecht, & Rose, 1991).

The publications and research related to FCE commercial products include surveys, which found that only five of 30 methodologies had construct validity. Among the 25 that had no construct validity were Blankenship, Isernhagen, PWPE, PILE and Matheson (Tuckwell et al., 2002). In regard to "own-design," a survey of 46 clinicians found that 16 were not using a commercial FCE protocol (Hart, 2001). Another review of 15 orthopedic centers in six states where 46 clinicians participated, included 28.6% hospital out-patient locations, 28.5% private practice settings, and 42.9% corporate entities. Of these responders 57.1% were "self-taught" providers and the others used commercial products, which were represented by 14.3% Isernhagen, and 21.4% Key Method (Hart, 2001). A questionnaire soliciting providers' opinions on FCE usefulness resulted in responses from 27% therapists and 53% managers. The majority of the providers use assessment of their "own-design". The respondents commented that there was poor research evidence to support use of a commercial FCE product (Cotton et al., 2006).

In 2003, there were 281 rehabilitation providers in New South Wales, Australia, and 167 conducted FCE. These 167 providers were queried regarding their FCE methodology and of those 113, 75% used their "own-design" of FCE. There were no known studies on the validity of the "own-design" methods (Cotton et al., 2006). A study of 27 therapists with at least six months experience conducted two types of work-related assessments at the workplace for an FCE. The FCEs were referred to as "eyeball functionals" because the tests were not considered comprehensive or extensive. These 27 providers of "functionals" or FCEs did not use standardized tests and the information was reportedly gathered by clinical observation (Innes et al., 2002). In a study to evaluate recommendation of FCE implementation, only 18 of 48 therapists participated; of those 18 there was a universal acknowledgement that they had limited scientific research related to the FCE, and in particular the reliability and validity of the FCE test (Gibson et al., 2005).

In another study, there were 18 OT participants and eight physiotherapist participants, whose experience ranged from eight months to 40 years. These therapists stated the FCEs were considered to lack validity and the process would have had more credibility if the quality of the examiner were higher. Those participants perceived limited validity of the FCE related to lack of relevant subtests for actual work demands, and congruence of test results with therapist observations. The participating therapists felt that intra-rater reliability may exist, but that inter-rater reliability was questionable. They felt a lack of content validity resulted in therapists modifying the FCE to suit their needs (Innes et al., 2003). Under sworn testimony, a provider therapist has explained that his "own-design" protocol never resulted in any less than full-time sedentary work tolerance, and after performing 10,000 FCEs, he never found an examinee incapable of work. His "own-design" protocol was an observational technique (Wilson, 2009). According to Wahlund in 1948, "A working test can be used as a control of the subjective symptoms when a person states that he cannot perform the slightest work, and nothing is found at the usual examination, something must be wrong but apparently not with working capacity." The FCE methodologies are by and large "own-design" in regard to work physiology methods, scientific application, response analysis, and criterion to full-time work, when the FCE creator, FCE vendor, and FCE users have not done their respective academic homework and due diligence. This research has been undertaken with the intent of bringing the FCE provider professionals from all disciplines the knowledge of the extent of "own-design" application of work physiology as it relates to the FCE methodology.

Empirical Investigation of Existing Reports

This study used FCE reports sent to the lead author for critique and review of the methodology of those reports from 2000–2013. The referral sources of the FCE reports for critique and review came from plaintiff attorneys, defense attorneys, vocational experts, claims examiners and physicians. There were 151 reports analyzed for the study; the predominant geographical location of the providers was Washington State (Figure 1; Appendix U). It was expected that each FCE report would include objective work physiological data from the heart rate reserve method. Of the 151 reports, there were no applications of the heart rate reserve method, which is significantly different than expected ($X^2 = 604$, $p < .001$) (Seigel & Catellan, 1988).

In regard to this research process, the science of work physiology—in particular the heart rate reserve method—was reviewed in accordance with previous publications (Gross, 2002; Reneman, 2003). The data collection form (See Appendix T) determined if the provider used an "own-design" (Hettinger et al., 1961) method, also referred to as self-design or non-standardized FCE (James, 2011; James et al., 2007); an uncontrolled method (Jones et al., 2003) or a commercially available standard format (Harrand, 1986) developed by a named vendor. The differentiation of the "own-design" providers versus the users of a commercial product was the determination that the FCE format clearly did or did not name a vendor/commercial process in the entire report. If providers cited sources but did not use a named commercial product in its entirety it was not "own-design" (Table 3). The geographical location of the report was recorded (Figures 1 and 2) as was the professional designation or lack of designation of the provider (Table 2). In cases where no professional designation was determined, an academic citation was recorded; in some instances the provider credential was unknown, or no provider could be identified (Table 4). In accordance with the APTA (2008), a competency criterion in regard to work and/or exercise physiology, such as an ASCM credential, was determined (Alpert, 1996).

The citation to, or the use of the heart rate reserve formula as a comparative criterion was documented as correct work physiological science. Any and all other heart rate determinations such as maximum age- adjusted heart rate were considered incorrect methodology. Additional heart rate criteria recorded include consistency of resting heart rate, heart rate recorded during activities, and a report of heart rate recovery to resting. Results are reported as percentage of the data sample (Table 4).

Findings

- The predominant professional designation was physical therapists, 54%, followed by occupational therapists, 22%, and the combined PT/OTR, 14%.
- The provider methodology was 67% "own-design", followed by commercial products, 33%.
- In regards to work physiology, there were 0% of providers credentialed in work and/or exercise physiology.
- FCE reports citing non heart rate reserve formulas were 12%.
- FCE reports citing heart rate reserve formula were 0%.
- FCE reports citing heart rate recovery to resting were 0%.

Table 1
Classification of Work by Heart Rate and Severity

Workload	Heart Rate (beats/min)
Example 1. (Astrand et al., 2003)	
Light Work	Up to 90
Moderate Work	91 - 110
Heavy Work	111 - 130
Very Heavy Work	131 - 150
Extremely Heavy Work	151 - 170
Example 2. (Williams, 1964)	
Very Low	75
Low	76 - 100
Moderate	101 - 125
High	126 - 150
Very High	151 - 175
Extremely High	176 +
Example 3. (Kroemer & Grandjean, 2001)	
Very Low	60 - 70
Low	75 - 100
Moderate	101 - 125
High	126 - 150
Very High	151 - 175
Extremely High (e.g., sport)	176 +
Example 4. (Wilson & Corlett, 1995)	
Light	Up to 90
Moderate	91 - 100
Heavy	111 - 130
Very Heavy	131 - 150
Extremely Heavy	151 - 170
Example 5. (American Industrial Hygiene Association, 1971)	
Rest, sitting	60 - 70
Very Light Work	65 - 70
Light Work	75 - 100
Moderate Work	100 - 125
Heavy Work	125 - 150
Very Heavy Work	150 - 180
Extremely Heavy Work	180 +

Example 6. (Kodak, 1986)

Workload	Percent Max Aerobic Capacity	Heart Rate Elevation (beats/min above rest)
8 hours	33%	+35
1 hour	50%	+55
20 min	70%	+75
5 min	85%	+90

Example 7. (Jiang, 1984)

Workload	Percent Work	Work Duration	Heart Rate (beats/min)
Moderate	<33%	8 Hrs	90 - 110
Heavy	34% - 50%	8 >1 Hrs	111 - 130
Very Heavy	51% - 75%	1 Hr >20 min	131 - 150
Extremely Heavy	>75%	<20 min	>150

Table 2
Number of FCE Examiners Classified by Professional Licensure

Professional Licensure	Number of FCE Examiners Represented per Licensure	Percent Contribution of Each Licensure to Total Number of FCE Providers Evaluated*
PT	81	54
OTR	33	22
Dual PT, OTR	21	14
Unknown	6	4.0
Other	4	2.6
MD	3	2.0
ATC	1	<1.0
DC	1	<1.0
RKT	1	<1.0

Note. *Denotes a percentage out of 100, based on 151 total examiners evaluated

Table 3
Distribution of Reports Categorized by FCE Method

FCE Method Evaluated*	Number of Reports Evaluated	Percent Contribution of Total Reports
Own Design	102	67
ErgoScience PWPE	13	8.6
Blankenship	12	8.0
Matheson	9	6.0
Arcon	3	2.0
Key	3	2.0
Isernhagen	2	1.3
BTE	1	<1.0
Joule	1	<1.0
Medigraph	1	<1.0
Spinal Logic	1	<1.0
Valpar	1	<1.0
WorkWell Solutions	1	<1.0
Work Solutions DCI	1	<1.0

Note. *Denotes a percentage out of 100, based on 151 total reports evaluated

- FCE reports citing resting heart rate were 63%.
- Consistency of reported resting heart rate was 43%.
- Reported heart rate responses associated with tasks, postures, positions, and physical tasks 45%.
- Reports including work physiology heart rate analysis and interpretation 0%.

Discussion

The use of "own-design" practitioner methods for FCE in this study, 67%, is consistent with publication by Cotton, Schoenstein and Adams, (2006), and Innes and Straker (2003). The research by Cotton reported 75% of New South Wales providers used an "own-design" that was either an entirely independently designed method or an adaptation of a commercial product. Innes reported that therapists use non-standardized or modified commercial methods.

Summary and Conclusions

The emphasis of this study is the determination of FCE practitioner use of work physiological science regarding the heart rate reserve formula method. The literature review clearly shows that there is a direct correlation of heart rate to the category of work, (Wil-

Table 4
Findings by Percentage of Data Sample

Criteria	Percentage of Sample
Professional Designation	
1. Physical Therapy (PT) Providers	54%
2. Occupational Therapy (OT) Providers	22%
3. PT/OT Providers	14%
Exercise and/or Work Physiology Certification	
4. Credential Provided	0%
Provider Methodology	
5. "Own Design" Methodology	67%
6. Commercial Vendor Methodology	33%
Heart Rate Response Analysis	
7. Reports that included analysis of heart rate response	0%
8. Reported heart rate response associated with tasks, postures, positions, manual work	45%
9. Reported resting heart rate	63%
10. Consistency of reported resting heart rate	43%
11. No report of resting heart rate	37%
Application of Work Physiology	
12. Reported heart rate recovery to resting	0%
13. Heart rate reserve method formula applied	0%
14. Non heart rate reserve method formula	12%

liams, 1964) and the AIHA (1971), which predates or approximates the 1970s FCE test batteries (Muller, 1953), and the 1980s formalized FCEs (Mayer et al., 1988). More significant is the chronological comparison of the 1988 Spine publication outlining PILE by Mayer et al. (1988) to the published works of Kodak in 1986, and Jiang 1984 (Ricci, 1967) in regards to work physiology. While Mayer et al. (1988) included an 85% age-adjusted maximum heart rate—which is clearly inappropriate for comparative analysis to full-time work—Matheson et al. (1996) published the same incorrect criterion for a comparison to work. Lechner (1994) also failed to research the science of work physiology in her publication, which only makes a cursory mention of heart rate collected at the beginning and end of testing, while other vendors have no work physiology inclusion (Genovese, 2009). This study, and the author's publication in 2007 (Becker et al., 2007), clearly identified that heart rate comparative analysis, and heart rate reserve formula methods existed; yet commercial vendors then and now have inexcusably omitted these from FCEs, as identified by the 0% usage in this study.

It is no wonder that the "own-design" FCE providers, who in part rely on commercial vendor seminar information or on non-scientific work physiology information, have not used analysis of heart rate to determine work time tolerance. The lack of consistency in documenting resting heart rate, non-reporting of recovery to resting heart rate, and lack of recording heart rate related to task are clear indicators of the significant lack of work physiological science knowledge within both the "own-design" providers and the commercial vendors, and commercial vendor users.

Finally, the limited use and/or absence of work physiological inclusion to the FCEs is a general indication that the provider professionals are not sufficiently trained as indicated by the 0% credentialing in the study. This presentation is a similar presentation of the 0% work physiology credential of the APTA FCE guideline contributors (Alpert, 1996; APTA, 2008), and the fact that those guidelines do not include the terms "work physiology," or "heart rate reserve," or make reference to any of the published research in Table 1. While the 2011 APTA directive emphasizes competency criteria, the PT Practice Act in Washington State as of 2007 (Washington Administrative Code 246-915; RCW 18.47, 2007) had an inclusion that was similar, but this did not serve as an impetus for FCE providers to upgrade their work physiological science skills, or seek information from the existing body of knowledge.

The prevalence of error-prone, inconclusive and unsubstantiated "own-design" FCE reports shows that providers' lack of work physiology science education, and/or lack of professional credential form a strong indication that supports the assertion that an FCE is subjective (Hendler, 2013) and lacks credibility endorsement by physicians (Abdel-Moty et al., 1993). A

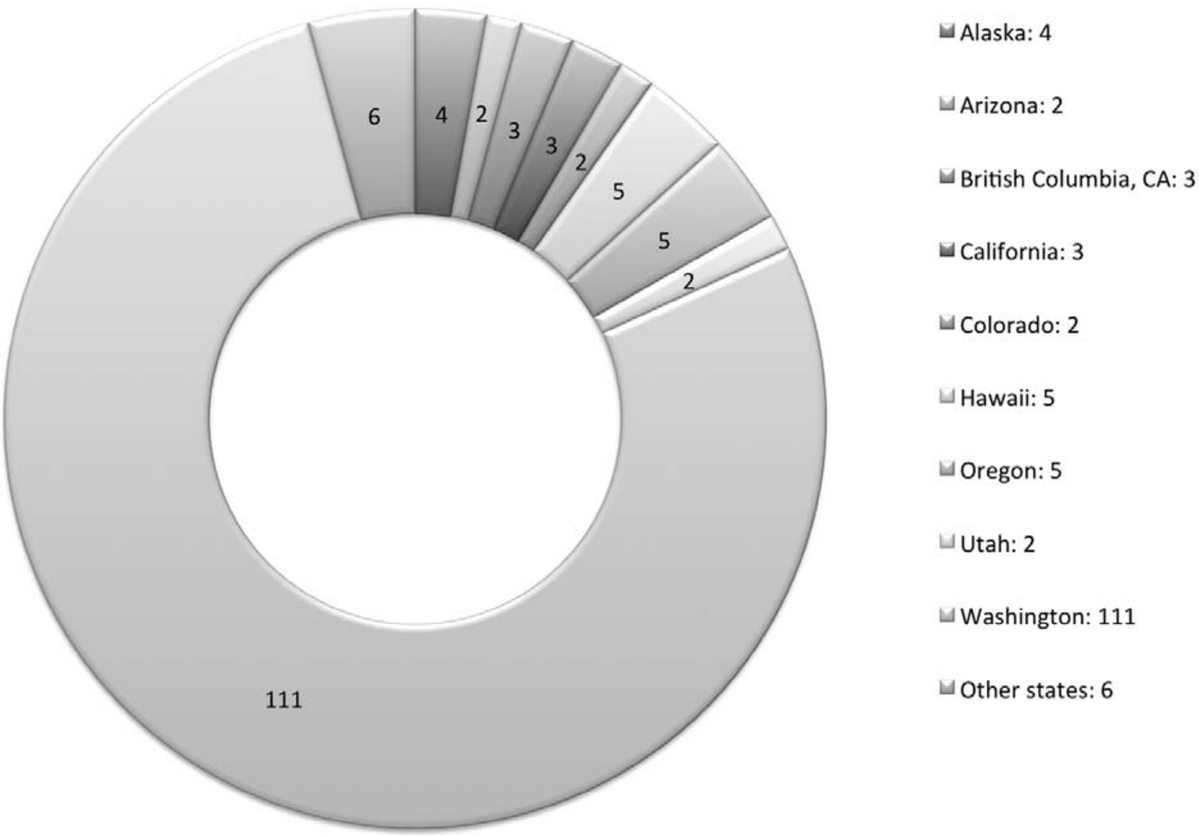

Figure 1. FCE Report Distribution by State

review of testimony under oath in selected cases supports the findings of this study in regards to a lack of credibility of the FCE report work physiology methodology to determine full-time work, and the FCE providers.

This paper evaluates the extent to which FCEs have integrated the science of work physiology into their testing protocols for determination of an individual's endurance and fatigue. The findings suggest little consideration has been given to the application of the heart rate reserve method, which may add value to those assessments administered for the purpose of determining endurance and fatigue.

Conclusion

This study documents the importance of upgrading the work physiology methods regarding work time tolerance for all FCE providers, commercial vendors, and FCE seminar instructors. Additionally, it serves as an impetus to professional organizations, such as APTA, and others, to be specific in the directives concerning the work physiology science applied to FCE. Finally, it is incumbent upon all FCE-related publishers, authors, and researchers to revisit the body of knowledge, acknowledge the errors, incompetencies, omissions, and lack of diligence regarding work physiology applications to FCE and move toward greater credibility.

References

Abdel-Moty, E., Fishbain, D. A., Khalil, T. M., Sadek, S., Cutler, R., & Steele-Rosomoff, R. (1993). Functional capacity and residual functional capacity and their utility in measuring work capacity. *The Clinical Journal of Pain, 9*, 168–173.

Adams, K. J., DeBeliso, M., Sevene-Adams, P. G., Berning, J. M., Miller, T., & Tollerud, D. J. (2010). Physiological and psychophysical comparison between a lifting task with identical weight but different coupling factors. *Journal of Strength & Conditioning Research, 24*(2), 307–312.

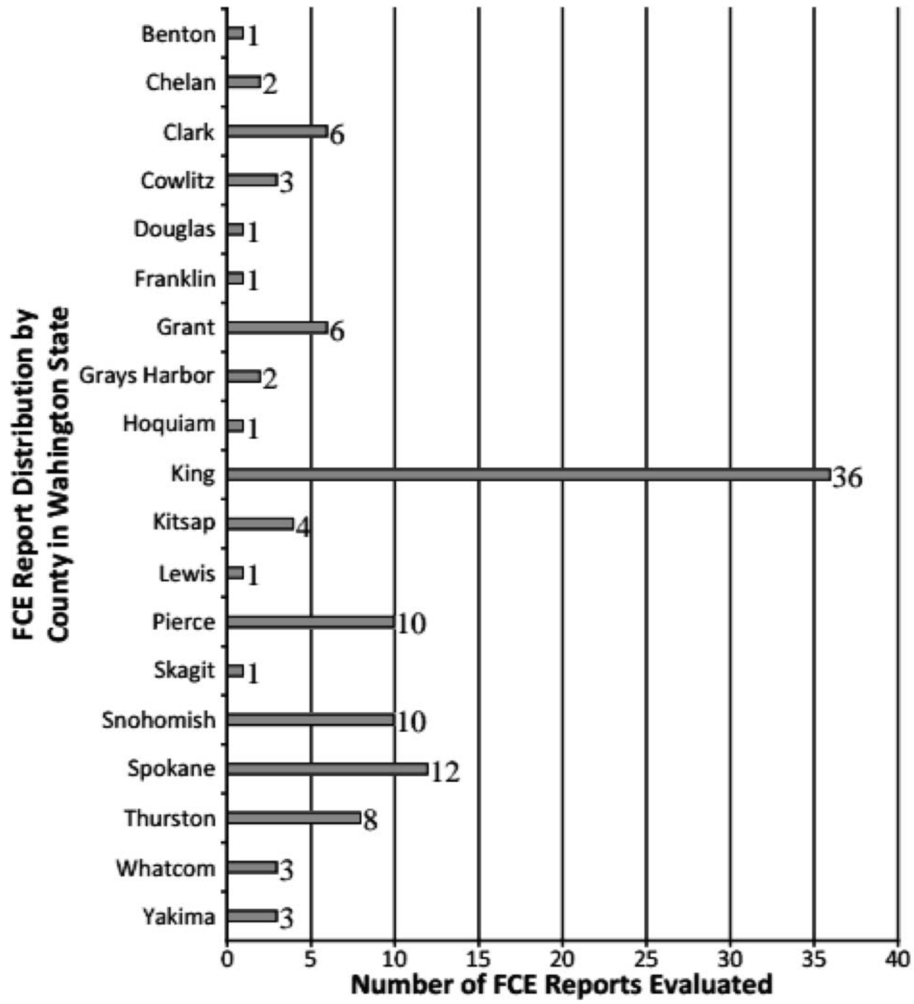

Figure 2. FCE Report Distribution by county in Washington State

Alaranta, H., Hurri, H., Heliovaara, M., Soukka, A., & Harju, R. (1994). Non-dynamometric trunk performance tests: Reliability and normative data. *Scandinavian Journal of Rehabilitation Medicine, 6*(4), 211–215.

Alpert, J. (1996). *California functional capacity evaluation guidelines for physical therapists*. Sacramento, CA: California Chapter, American Physical Therapy Association.

American College of Sports Medicine. (2010). *Resource manual for guidelines for exercise testing and prescription* (6th ed.). Philadelphia, PA: Lippincott, Williams & Wilkins.

American Industrial Hygiene Association. (1971). Ergonomics guide to assessment of metabolic and cardiac costs of physical work. *Ergonomics Guides, 32*(8), 560–564.

American Physical Therapy Association. (2008). *Occupational Health Physical Therapy Guidelines: Evaluating Functional Capacity*. Alexandria, VA: Author.

American Society of Exercise Physiologists. (2013). *Board certification for exercise physiologists*. Retrieved from http://www.asep.org

Andres, T. (2006). Deposition, *Batton v. North Valley Hospital*. Docket No. 05-14354. Board of Industrial Insurance Appeals for the State of Washington.

Andrews, R. (1969). The relationship between measures of heart rate and rate of energy expenditure. *AIIE Transactions, 1*(1), 2–10.

Andrews, R. B. (1967). Estimation of values of energy expenditure rate from observed values of heart rate. *Human Factors, 9*(6), 581–586.

Arcon Vernova, Inc. (2013). *Arcon FCE Description*. Retrieved from http://www.fcesoftware.com/arconfce description.html

Asfour, S. S. (1980). *Energy cost prediction models for manual lifting and lowering tasks* (Doctoral dissertation). Lubbock, TX: Texas Tech University.

Asfour, S. S., Ayoub, M. M., Genaidy, A. M., & Khalil, T. M. (1986). A database of physiological responses to manual lifting. In W. Karwowski (Ed.), *Trends in Ergonomics/Human Factors III* (pp. 801–809). Amsterdam, Netherlands: Elsevier.

Astrand, I. (1960). Aerobic work capacity in men and women with special reference to age. *Acta Physiologica, 49*(169) (Suppl.).

Astrand, P., Rohdahl, K., Dahl, I., & Stomme, S. (2003). *Textbook of work physiology* (4th ed). Champaign, IL: Human Kinetics.

Astrand, P. O. (1956). Human physical fitness with special reference to sex and age. *Physiological Reviews, 36*(3), 307–335.

Astrand, P. O., & Saltin, B. (1961). Maximal oxygen uptake and heart rate in various types of muscular activities. *Journal of Applied Physiology, 16*(6), 977–981.

Astrand, P. O., & Saltin, B. (1961). Oxygen uptake during the first minutes of heavy muscular exercise. *Journal of Applied Physiology, 16*(6), 971–976.

Ayoub, M. M., Bethea, N. J., Asfour, S., Calisto, G., & Grasley, C. (1979). *Review of strength and capacity Data For Manual Materials Handling Activities.* Lubbock, TX: Institute of Biotechnology Texas Tech University.

Badger, D. (Ed.) (1981). *Work practices manual for manual lifting.* Cincinnati OH: National Institute for Occupational Safety and Health.

Bainbridge, F. A. (1920). The relation between respiration and the pulse rate. *Journal of Physiology, 53*(3), 192–202.

Balke, B. (1963). *A simple field test for the assessment of physical fitness.* (0-694-185).Washington, DC: U.S. Government Printing Office.

Balke, B. (1963). *A simple field test for the assessment of physical fitness.* Oklahoma City, OK: Federal Aviation Agency, Aviation Medical Service, Aeromedical Research Division, Civil Aeromedical Research Institute.

Becker, T. J. (2008). Functional capacity evaluations: The work physiology component for predicting full-time work. *Directions in Rehabilitation Counseling*, *18*, 177–186.

Becker, T. J., Morrill, J. M., & Stamper, E. (2007). Applications of work physiology science to capacity test prediction of full time work: eight hour work day. *The Rehabilitation Professional, 15*(4), 45–56.

Becket, M. B., & Hodgdon, J. A. (1987). *Lifting and carrying capacities relative to physical fitness Measures*. San Diego, CA: Naval Health Research Center.

Berger, R. (1982). *Applied exercise physiology.* Philadelphia, PA: Lea & Febiger.

Bilzon, J., Scarpello, E., Smith, C., Ravenhill, N., & Rayson, M. (2001). Characterization of the metabolic demands of simulated shipboard royal navy fire fighting tasks. *Ergonomics, 44*(8), 766–780.

Bink, B. (1962). The physical working capacity in relation to working time and age. *Ergonomics, 5*(1), 25–28.

Blankenship Functional Capacity Evaluation Bibliography. (2013). Macon, GA: Blankenship.

Blessey, R. L., Hislop, H. J., Waters, R. L., & Antonelli, D. (1976). Metabolic energy of unrestrained walking. *Physical Therapy, 56*(92), 1019–1024.

Bonjer, F. (1962). Actual energy expenditure in relation to physical work capacity. *Ergonomics, 5*, 29–31.

Boorens, J., & Hervey, G. (1960). The pulse rate as a means of measuring metabolic rate. *Canadian Journal of Biochemistry and Physiology, 38*, 1301–1310.

Borg, G., & Dahlstrom, H. (1962). The reliability and validity of a physical work test. *Acta Physiologica, 55*, 353–361.

Brouha, L. (1960). *Physiology in industry*. New York, NY: Pergamon Press.

Bullock, D. (2008). Deposition, *Griffin v. Tree Top*, Docket No. 08-10152. Board of Industrial Insurance Appeals for the State of Washington.

Buzel, M. (1994). Deposition, *Dominquez v. Buzel*. Cause no. 93-01196 (15). Circuit Court of the 17th Judicial Circuit in and for Broward County Florida.

Casady, C. (2003). Deposition, *Connell v. Tucci & Sons*. Docket No. 03-12011. Board of Industrial Insurance Appeals for the State of Washington.

Casady, C. (2004). Deposition, *Koshak v. City of Renton*. Docket 03-14044. Board of Industrial Insurance Appeals for the State of Washington.

Casady, C. (2013). Deposition, *McKee v Albertsons* Docket 12-20559. Board of Industrial Insurance Appeals for the State of Washington.

Chen, J. J. (2007). Functional capacity evaluation and disability. *Iowa Orthopaedic Journal, 7*, 121–127.

Ciccolella, M., Boone, T., Davenport, T. (2011). Legal aspects of aerobic capacity: objective evidence of ability to work. *Professionalization of Exercise Physiology*, *14*(9), 1–11.

Cotes, J., & Meade, F. (1960). The energy expenditure and mechanical energy demand in walking. *Ergonomics, 3*(2), 97–199.

Cotton, A., Schonstein, E., & Adams, R. (2006). Use of functional capacity evaluation by rehabilitation providers in NSW. *Work, 26*, 287–295.

Datta, S. R., Chatterjee, B. B., & Ray, B. N. (1973). The relationship between energy expenditure and pulse rates with body weight and the load carried during load carrying on the level. *Ergonomics, 16*(4), 507–513.

Datta, S. R., Chatterjee, B. B., & Ray, B. N. (1983). The energy cost of pulling handcarts (Thela). *Ergonomics, 26*(5), 461–464.

Davies, C. (1966). *Heart rate and respiration in relation to work capacity in man* (Doctoral dissertation). University of Edinburgh, Edinburgh, Scotland.

Davis, H. L., Faulkner, T. W., & Miller, C. I. (1969). Work physiology. *Human Factors, 1*(2), 157–166.

de Vries, H. (1966). *Physiology of exercise.* Dubuque, IA: Wm. C. Brown.

Denard, M., Brassard, B., Hong, Q., Lemaire, J., & Loisel, P. (2008). Responsiveness of the work performance evaluation, a functional capacity evaluation in patients with low back pain. *Journal of Occupational Rehabilitation, 18,* 58–67.

Drury, C. G. (Ed.). (1976). *Safety in manual materials handling*. Cincinnati, OH: National Institute of Occupational Safety and Health.

Drury, C. G., Deeb, J. M., Hartmann, B., Woolley, S., Drury, C. E., & Gallagher, S. (1989). Symmetric and asymmetric manual handling part 1: Physiology and psychophysics. *Ergonomics, 32*(5), 467–489.

Durand, M., Loisel, P., Paitras, S., Mercier, R., Stock, S., & Lemaire, J. (2004). The interrater reliability of a functional capacity evaluation: The physical work performance evaluation. *The Journal of Occupational Rehabilitation, 14*(2), 119–129.

Farag, I. (1995). *Functional Assessment Approaches (*Doctoral dissertation). University New South Wales, Sydney, Australia.

Feeler, L., St. James, J., & Schapmire, D. (2010) Isometric strength assessment, Part I: Static testing does not accurately predict dynamic lifting capacity. *Work*, *37*, 301–308.

Fishbain, D. A., Abdel-Moty, E., Cutler, R., Khalil, T. M., Sadek, S., Rosomoff, R. S., & Rosomoff, H. L. (1994). Measuring residual functional capacity in chronic low back pain patients based on the dictionary of occupational titles. *Spine, 19*(8), 872–880.

Fishbain, D., Cutler, R., Rosomoff, H., Khalil, T., Abdel-Moty, E., & Steele-Rosomoff, R. (1999). Validity of the dictionary of occupational titles residual functional capacity battery. *The Clinical Journal of Pain, 15*(2), 102–110.

Fishbain, D. A. (2000). Functional capacity evaluation. *Physical Therapy, 80*(1), 110–112.

Franklin, B. A. (Ed.). (2000). *ACSM guidelines for exercise testing and prescription*. Philadelphia, PA: Lippincott, Williams, & Wilkins.

Gardener, L., & McKenna, K. (1999). Reliability of occupational therapists in determining safe, maximal lifting capacity. *Australian Occupational Therapy Journal, 46*(3), 110–119.

Garg, A., & Banang, J. (1988). Maximum acceptable weight, heart rate and RPES for one hours repetitive asymmetric lifting. *Ergonomics, 31*(1), 77–96.

Garg, A., Chaffin, D., & Herrin, G. (1978). Prediction of metabolic rates in manual materials handling jobs. *American Industrial Hygiene Association Journal, 39*(8), 661–674.

Garg, A., Hagglund, G., & Mericle, K. (1983). *Physical fatigue and stresses in warehouse operations*. Cincinnati, OH: National Institute of Occupational Safety and Health.

Garg, A., & Herrin, G. (1979). Stoop or squat: A biomechanical and metabolic evaluation. *AIIE Transactions, 1*(4), 293–302.

Genaidy, A., Duyas, J., & Asfour, S. (1997). Physiological stresses associated with manual materials handling of containers of varied sizes and weights: A case study. In W. Karwowski, M. Wogalter, & P. Dempsey (Eds.), *Ergonomics and Musculoskeletal Disorders: Research on Manual Materials Handling, 1983-1996* (pp. 80–84). Santa Monica, CA: Human Factors and Ergonomics Society.

Genovese, E., & Galper, J. S. (2009). Appendix functional capacity evaluation model descriptions. In E. Genovese & J. S. Galper (Eds.), *Guide to the evaluation of functional ability* (pp. 437–516). Chicago, IL: American Medical Association.

Gibson, L., & Strong, J. (1997). A review of functional capacity evaluation practice. *Work, 9*(1), 3–11.

Gibson, L., & Strong, J. (2005). Safety issues in functional capacity evaluation: Findings from a trial of a new approach for evaluating clients with chronic back pain. *Journal of Occupational Rehabilitation, 15*(2), 237–251.

Goldmark, J. (1912). *Fatigue and efficiency: A study in Industry*. Philadelphia, PA: Wm. F. Tell.

Gouttebarge, V. (2008). *Quality of functional capacity evaluation tests: A clinimetric Approach (*Doctoral dissertation). University of Amsterdam, Amsterdam, Netherlands.

Gouttebarge, V., Wind, H., Kuijer, P., & Frings-Dresen, M. (2004). Reliability and validity of functional capacity evaluation methods: A systematic review with reference to Blankenship system, ergos work simulator, ergo-kit, and Isernhagen work system. *International Archives of Occupational and Environmental Health*, *77*, 527–537.

Grimsby, G., & Saltin, B. (1966). Physiological analysis of physically well trained middle aged and old athletes. *Acta Medica Scandinavica, 179*(5), 513–526.

Gronski, J. (2008). Deposition, *Curevac v. Marriott*, Docket No. 05-19060. Board of Industrial Insurance Appeals for the State of Washington.

Gross, D., & Battie, M. (2002). Reliability of safe maximum lifting determination of a functional capacity evaluation. *Physical Therapy, 82*(4), 364–371.

Gross, D., & Battie, M. (2005). Functional capacity evaluation performance does not predict sustained return to work in claimants with chronic back pain. *Journal of Occupational Rehabilitation, 15*(3), 285–294.

Gross, D., & Battie, M. (2006). Does functional capacity evaluation predict recovery in workers compensation claimants with upper extremity disorders?. *Occupational & Environmental Medicine, 63*, 404–410.

Gross, D., Battie, M., & Asante, A. (2006) Development and validation of a short form functional capacity evaluation for use in claimants with low back disorders. *Journal of Occupational Rehabilitation, 16*(1), 53–62.

Gross, D., & Reneman, M. (2011). Functional capacity evaluation in return-to-work decision making: Risk, capacity, and tolerance. In J. Talmage, J., Melhorn, & M. Hyman (Eds.), *AMA Guides to the evaluation of work ability and return to work* (2nd ed.) (pp. 87–98). Chicago, IL: American Medical Association.

Hagen, K., Hallen, J., & Harms-Ringdahl, K. (1993). Physiological and subjective responses to maximal repetitive lifting employing stoop and squat techniques. *European Journal of Applied Physiology, 67*, 291–297.

Hagen, K., Sorhagen, O., & Harms-Ringdahl, K. (1995). Influence of weight and frequency on thigh and lower trunk motion during repetitive lifting employing stoop and squat techniques. *Clinical Biomechanics, 10*(3), 122–127.

Hamilton, B., & Chase, R. (1969). A work physiology study on the relative effects of pace and weight in a carton handling task. *AIIE Transactions, 1*(2), 106–110.

Hansen, R. (2010). Proposed order and decision by industrial appeals judge, The Honorable Randall L. Hansen, *Stokes v Boeing*, Docket 08-22585. Board of Industrial Insurance Appeals for the State of Washington.

Harrand, G. (1986). *The revised Harrand guide for developing capacity evaluations*. Eau Claire, WI: The Career Development Center.

Hart, D. (2001). The power of outcomes: FOTO industrial outcomes tool initial assessment. *Work*, 16, 39–51.

Hart, D., Isernhagen, S., & Matheson, L. (1993). Guidelines for functional capacity evaluation of people with medical conditions. *Journal of Orthopaedic & Sports Physical Therapy,* (6), 682–686.

Hendler, N. (2013). An internet based expert system to control workers compensation costs documented by outcome studies. *Anesthesia, Pain & Intensive Care, 17*(2), 166–170.

Hermansen, L., & Lange Andersen, K. (1965). Aerobic work capacity in young Norwegian men and women. *Journal of Applied Physiology, 20*(3), 425–431.

Hettinger, T., Newton, C., Horvath, S., Issekutz, B., & Rodahl, K. (1961). Assessment of physical work capacity. *Journal of Applied Physiology*, *16*(1), 153–156.

Hodgdon, J. (1986). *Physical fitness as it pertains to sustained military occupations*. San Diego, CA: Naval Health Research Center.

Hoon Yong, Y. (1996). *Psychophysical and physiological study of one handed and two handed combined tasks* (Doctoral dissertation). Texas Tech University, Lubbock, TX.

Indergard v. Georgia Pacific, US. 08-35278. (2009). United States District Court for the District of Oregon.

Innes, E. (2006). Reliability and validity of functional capacity evaluation: An update. *International Journal of Disability Management Research*, *1*(1), 135–148.

Innes, E., & Straker L. (2002). Work place assessments and functional capacity evaluation: Current practices of therapists in Australia. *Work, 18*(1), 51–66.

Innes, E., & Straker, L. (1998). A clinicians guide to work related assessments: Three administrative and interpretation problems. *Work, 11*(2), 207–219.

Innes, E., & Straker, L. (2003). Work place assessments and functional capacity evaluations: Current beliefs of therapists in Australia. *Work, 20*(3), 225–236.

Intaranont, K. (1983). *Evaluation of anaerobic threshold for lifting tasks*. Lubbock, TX: TexasTech University.

Isernhagen, S. (2006) Back to the original job: Less light duty days through job specific tasks. *The Journal of Workers Compensation, 15*(4), 1–11.

Isernhagen, S., Hart, D., & Matheson, L. (1999). Reliability of independent observer judgments of level of lift effort in a kinesiophysical functional capacity evaluation. *Work, 12*, 145–150.

James, C. (2011). *Reliability and validity of the WorkHab Functional Capacity Evaluation*. New South Wales, Australia: University of Newcastle.

James, C., & Mackenzie, L. (2009a). Health professional's perceptions and practices in relation to functional capacity evaluations: Results of a quantitative survey. *Journal of Occupational Rehabilitation, 19*(2), 203–211.

James, C., & Mackenzie, L. (2009b). The clinical utility of functional capacity evaluations: The opinion of health professionals working within occupational rehabilitation. *Work, 33*(3), 231–239.

James, C., Mackenzie, L., & Higgenbotham, N. (2007) Health professionals attitudes and practices in relation to functional capacity evaluations. *Work, 29*(2), 81–88.

Jebsen, R., Trieschmann, R., Mikulic, M., Hartley, R., & Snook, M. (1970). Measurement of time in a standardized test of patient mobility. *Archives of Physical Medicine and Rehabilitation, 51*(3), 170–175.

Jiang, B. (1984). *Psychophysical capacity modeling of in.* Lubbock, TX: Texas Tech University.

Jones, T., & Kumar, S. (2003). Functional capacity evaluation of manual materials handlers: A review. *Disability Rehabilitation, 25*(4-5), 179–191.

Jorgensen, M., Davis, K., Kirking, B., Lewis, K., & Marras, W. (1999). Significant of biomechanical and physiological variables during the determination maximum acceptable weight of lift. *Ergonomics, 42*(9), 1216–1232.

Kamon, E., & Ayoub, M. (1976). *Ergonomics guides to assessment of physical work capacity*. Akron, OH: American Industrial Hygiene Association.

Kasch, F., Wallace, J., & Van Camp, S. (1985). Effects of 18 years of endurance exercise on the physical work capacity of older men. *Journal of Cardiopulmonary Rehabilitation and Prevention, 5*, 308–312.

Kuijer, W., Brouwer, S., Reneman, M. F., Djikstra, P. U., Groothoff, J. W., Schellekens, J. M. H., & Geertzen, J. H. B. (2008). Matching FCE activities and work demands. *Journal of Occupational Rehabilitation, 16*(3), 459–473.

Khalil, T., Genaidy, A., Asfour, S., & Vinciguerra, T. (1985). Physiological limits in lifting. *American Industrial Hygiene Association, 46*(4), 220–224.

King, P. (2004). Analysis of the reliability and validity supporting functional capacity evaluations. *Journal of Forensic Vocational Analysis, 7* (2), 75–82.

King, P., Tuckwell, N., & Barrett, T. (1998). A critical review of functional capacity evaluations. *Physical Therapy*, *78*(8), 852–866.

Knapik, J. (1983). *Physiological, biomechanical and medical aspects of lifting and repetitive lifting*. Natick, MA: US Army Research Institute of Environmental Medicine.

Kodak. (1986). *Ergonomic design for people at work.* New York, NY: Van Nastrand Reinhold.

Koho, P., Aho, S., Watson, P., & Hurn, H. (2001). Assessment of chronic pain behavior: Reliability of the method and its relationship with perceived disability, physical impairment and function. *Journal of Rehabilitation Medicine*, *33,* 128–132.

Kroemer, K., & Grandiean, E. (2001). *Fitting the Task to the Human.* Philadelphia, PA: Taylor & Francis.

Kroemer, K., Kroemer, H., & Kroemer-Ebert, K. (1997) *Engineering physiology* (3rd ed.). Hoboken, NJ: Wiley.

Kroemer, K. H. E. (Ed.). (1982). *Development of LIFTEST: A dynamic technique to assess the individual capability to lift material.* Cincinnati, OH: National Institute of Occupational Safety & Health.

Kumar, S. (2004). Deposition, *Gallegos v. City of Everett*. Docket 03-20409. Board of Industrial Insurance Appeals for the State of Washington.

Law, M. (1987). Measurement in occupational therapy: Scientific criteria for evaluation. *Canadian Journal of Occupational Therapy*, *54*(3), 133–138.

Lechner, D. (1998). Functional capacity evaluation. In P. King (Ed.), *Sourcebook of occupational rehabilitation* (pp. 209–227). New York, NY: Plenom Press.

Lechner, D., Page, J., & Sheffield, G. (2008). Predictive validity of a functional capacity evaluation: The physical work performance evaluation. *Work, 31*(1), 21–25.

Legg, S., & Myles, W. (1981). Maximum acceptable repetitive lifting workloads for an 8 hour work day using psychophysical and subjective rating methods. *Ergonomics, 24*(12), 907–916.

Legg, S., & Myles, W. (1985). Metabolic and cardiovascular cost and perceived effort over an eight hour day when lifting loads selected by the psychophysical method. *Ergonomics, 28*(1), 337–343.

Legg, S., & Pateman, C. (1984). A physiological study of the repetitive lifting capabilities of healthy young males. *Ergonomics, 27*(3), 259–272.

Legge, J., & Burgess-Limerick, R. (2006). *Pre-employment and periodic functional testing: A review of the evidence.* Queensland, Australia: Queensland Mining Industry Health & Safety Conference.

Lehmakn, G. (1958). Physiological measurements as a basis in work organization in industry. *Ergonomics*, *1*(4), 328–344.

Levitt, P. (1962). *The Pulse Rate Recovery Index as an index of fatigue*. Toronto, Canada: University of Toronto.

Llmarinen, L. (1992). Job design for the aged with regard to decline in their maximal aerobic capacity. *International Journal of Industrial Ergonomics 10*(*1*-2), 53–63.

Lomas, S. (1999). Deposition, *Atwood v. St. Mary Medical Center,* Cause no. 97-2-00675-0. Superior Court for the State of Washington, Spokane County.

Lyth, J. (2001). Disability management and functional capacity evaluation: A dynamic resource. *Work*, *16*(6), 13–22.

Maas, S., Kok, M., Westra, H., & Kemper, H. (1989). The validity of the use of heart rate in estimating oxygen consumption in static and in combined static/dynamic exercise. *Ergonomics, 32*(2), 141–140.

Managh, M., & Cook, J. (1993). The use of standardized assessment in occupational therapy: The BaFPE-R as an example. *The American Journal of Occupational Therapy, 47*(10), 887–884.

Matheson, L., Mooney, V., Leggett, S., Grant, J., & Kenny, K. (1996). Standardized evaluation of work capacity. *The Journal of Back and Musculoskeletal Rehabilitation, 6,* 249–264.

Matheson, L., Rogers, L., Kaskutas, V., & Dakos, M. (2001). Reliability and reactivity of three new functional assessment measures. *Work, 18*(1), 41–50.

Mayer, T., Barnes, D., Kishino, N. D., Nichols, G., Gatchel, R. J., Mayer, H., & Mooney, V. (1988). Progressive isoinertial lifting evaluation. *Spine*, *13*(9), 993–997.

Mayer, T., Gatchel, R., Barnes, D., Mayer, H., Mooney, V. (1990). Progressive isoinertial lifting evaluation erratum notice. *Spine, 15*(1), 5.

McArdle, W., Katch, F., & Katch, V. (1981). *Exercise Physiology.* Philadelphia, PA: Lea & Febiger.

McFarland, R. (1971). Fatigue in Industry. *Ergonomics, 14*(1), 1–10.

McGlothlin, J. (1996). *Ergonomic intervention for the soft drink beverage delivery industry*. Cincinnati, OH: National Institute for Occupational Safety and Health.

Menard, M., & Gorman, D. (2000). Work capacity evaluation. *New Zealand Medical Journal, 113*, 335–337.

Milyard, M. (2013). Deposition, *Robinson v. Genie Industries,* Docket 13-10716. Board of Industrial Insurance Appeals State of Washington.

Moon, T. (2003). Deposition, *Mehrer v. Goodyear Tire & Rubber*. Cause No. 01-2-31582-0. Superior Court of the State of Washington for King County.

Moon, T. (2003). Deposition, *Vanweerdhuizen v. Buckley*. Cause no. 02-2-00331-8. Superior Court for the State of Washington, Whatcom County.

Moon, T. (2004). Deposition, *Joseph v. Boeing.* Docket 03-10346. Board of Industrial Insurance Appeals for the State of Washington.

Moon, T. (2008). Deposition, *Solomon v. American Seafoods Company*. Cause No. CV-05-01999 JCC. Superior Court of the State of Washington for King County.

Morgan, M., Allison, S., & Duhon, D. (2012). Heart rate changes in functional capacity evaluations in a workers compensation population. *Work, 42*(2), 253–257.

Morris, W., & Chevalier, R. (1961). Physiological approach to evaluation of physical capacity. *Archives of Environmental Health, 2*, 151–158.

Morrissey, S. (1987). Influences of task posture on physiological task response. *International Journal of Industrial Ergonomics, 1*, 209–217.

Muller, E. (1953). The physiological basis of rest pauses in heavy work. *Quarterly Journal of Experimental Physiology and Cognate Medical Sciences, 38*, 205–215.

Myers, D., Gebhardt, D., Crump, C., & Fleishman, E. (1984). *Validation of the Military Entrance Physical Strength Capacity Test.* Ft. Belvoir, VA: US Army Research Institute for the Behavioral and Social Sciences.

Nindl, B. C., Leone, C. D., Tharion, W. J., Johnson, R. F., Castellani, J. W., Patton, J. F., & Montain, S. J. (2002). Physical performance responses during 72 hours of military operational stress. *Medicine & Science in Sports & Exercise*, *34*(11), 1814–1822.

Nindl, B., Sharp, M., Mello, R., Rice, V., Murphy, M., & Patton, J. (1998). Gender comparison of peak oxygen uptake: repetitive box lifting versus treadmill running. *European Journal of Applied Physiology,* 77, 112–117.

Oliveri, M. (2006). Functional capacity evaluation. In C. Gobelet & F. Franchignoni (Eds.), *Vocational rehabilitation* (pp. 69–93). Paris, France: Springer.

Osborne, P., Dakos, M., & Randolph, D. C. (2001). Functional testing for positional tolerance by frequency classification. *Disability*, *1,* 51–55.

Pandorf, C., Nindl, B., & Mountain, S. (2003). Reliability assessment of two militarily relevant occupational physical performance tests. *Canadian Journal of Applied Physiology, 28*(1), 27–37.

Pearson, R., & Byars, G. (1956). *The development and validation of a checklist for measuring subjective fatigue*. Fort Sam Houston, TX: School of Aviation Medicine, USAF.

Perras, R. (2000). Deposition, *Eelbode v. Chec Medical Centers*. Cause No. 97-2-07239-1. Superior Court of the State of Washington for Pierce County.

Polatin, P. (1995). Work simulation, work hardening, and functional restoration. In A. White & J. A., Schofferman (Eds.*), Spine Care* (Vol 1, pp. 486–545). St. Louis, MO: Mosby.

Pransky, G., & Dempsy, P. (2004). Practical aspects of functional capacity evaluations. *Journal of Occupational Rehabilitation, 14*(3), 217–229.

Randolph, D., Nguyen, T., & Osborne P. (2003). The functional capacity evaluation is it helpful? In J. Talmage & J. Melhorn(Eds.), *A physicians guide to return to work* (pp. 83–93). Chicago, IL: American Medical Association.

Reinertsen, J. (2013). Deposition, *Kolilis v Albertsons,* Docket 13-11535-13-11535-A, Board of Industrial Insurance Appeals for the State of Washington.

Reneman, M. (2003). Introduction to the special issue on functional capacity evaluations: From expert based to evidence based. *Journal of Occupational Rehabilitation, 13* (4), 203–206.

Reneman, M., Jaegers, S., Westmaas, M., & Goeken, L. (2002). The reliability of determining effort level of lifting and carrying in a functional capacity evaluation. *Work, 18*(1), 23–27.

Reneman, M., Joling, C., Soer, E., & Goeken, L. (2001). Functional capacity evaluation: Ecological validity of the static endurance tests. *Work, 16*, 227–234.

Reneman, M., Soer, R., & Gross, D. (2013). Developing research on performance-based functional work assessment: Report on the first international functional capacity evaluation research meeting. *Journal of Occupational Rehabilitation, 23*(4), 513–515.

Ricci, B. (1967). *Physiological Basis of Human Performance*. Philadelphia, PA: Lea & Febiger.

Roberg, R., & Landwehr, R. (2002). The surprising history of the HR max = 220-age equation. *Journal of Exercise Physiology, 5*(2), 1–10.

Robertson, D. (1982). *Development of an occupational strength test battery*. San Diego, CA: Naval Health Research Center.

Rodgers, S. (1988). Job evaluation in worker fitness determination. In N. Weaver (Ed.), *Occupational medicine: State of the art reviews* (Vol. 3, pp. 219–239). Philadelphia, PA: Hanley and Belfus.

Rodgers, S., & Yates, J. (1990). *Physiological basis for manual lifting guidelines*. Cincinnati, OH: National Institute of Occupational Health & Safety.

Roozbazar, A. (1974). *A work physiology study of lifting*. Raleigh, NC: North Carolina State University.

Rothstein, J., Campbell, S., Echternach, J., Knecht, H., & Rose, S. (1991). Standards for tests and measurements in physical therapy practice. *Physical Therapy, 71*, 589–622.

Rowell, L. (2007). *Factors affecting the prediction of the maximal oxygen intake from measurements during submaximal work with observations related to factors which may limit maximal oxygen intake* (Doctoral dissertation). University of Minnesota, Minneapolis, MN.

Seigel, S., & Catellan, N. (1988). *Nonparametric statistics for the behavioral sciences* (2nd ed.) New York, NY: McGraw Hill.

Sekulic, D., Males, B., & Miletic, O. (2006). Navy recruits: Fitness measuring, validation and norming. *Military Medicine, 171*(8), 749–752.

Sharkey, B., & Davis, P. (2008). *Hard Work*. Champaign, IL: Human Kinetics.

Sharp, D. S., Wright, J. E., Vogel, J. A., Patton, J. F., & Daniels, W. L. (1980). *Screening for physical capacity in the US Army: An analysis of measures predictive of strength and stamina*. Natick, MA: U.S. Army Research Institute of Environmental Medicine.

Sharp, M. A., Harman, E., Vogel, J., Knapik, J. J., & Legg, S. J. (1988). Maximal aerobic capacity for repetitive lifting: Comparison with three standard exercise testing modes. *European Journal of Applied Physiology, 57*(6), 753–760.

Shephard, R. (1978). *Human physiological work capacity*. Cambridge, England: Cambridge University Press.

Simonson, E. (1971). Significance of recovery processes for work performance. In E. Simonson (Ed.), *Physiology of work capacity and fatigue* (pp. 440–458). Springfield, IL: Charles C. Thomas.

Smeets, R., Hijdra, H., Kester, A., Hitters, M., & Knottnerus, J. (2006). The usability of six physical performance tasks in a rehabilitation population with chronic low back pain. *Clinical Rehabilitation, 20*, 989–998.

Snook, S. (1971). The effects of age and physique on continuous work capacity. *Human Factors*, *13*(5), 467–479.

Snook, S., & Ciriello, V. (1991). *The design of manual handling tasks.* Boston MA: Liberty Mutual Insurance.

Snook, S., & Irvine, C. (1969). Psychophysical studies of physiological fatigue criteria. *Human Factors, 11*(3), 291–300.

Snook, S., Irvine, C., & Bass, I. (1970). Maximum weights and work loads acceptable to male industrial workers. *American Industrial Hygiene Association Journal, 31*(5), 579–586.

Soer, R., Poels, B., Geertzen, J., & Reneman, M. (2006). A comparison of two lifting assessment approaches with chronic back pain. *Journal of Occupational Rehabilitation, 16*(4), 639–646.

Soer, R., van der Schans, C., Groothoff, J., Geertzen, J., & Reneman, M. (2008). Towards consensus in operational definitions in functional capacity evaluation. *Journal of Occupational Rehabilitation*, *18*(4), 389–400.

Sparto, P., Parpianpour, M., Reinsei, T., & Simon, S. (1997). The effect of fatigue on multi joint kinematics and load sharing during a repetitive lifting test. *Spine, 22*(23), 2647–2654.

Spencer Steffa, E. (2012). Deposition, *Dunn v Motor Cargo*. Docket 12-10642. Board of Industrial Insurance Appeals for the State of Washington..

Streibeit, M., Blume, C., Thren, K., Reneman, M., & Mueller-Fahmow, W. (2009). Value of functional capacity information in a clinical setting for predicting return to work. *Archives of Physical Medicine & Rehabilitation*, *90*(3), 429–434.

Strong, S., Baptiste, S., Cole, D., Clarke, J., Costa, M., Shannon, H., . . . Sinclair, S. (2004) Functional assessment of injured workers: A profile of assessor practices. *Canadian Journal of Occupational Therapy, 17*(1), 13–23.

Subramaniam, D. (1973). Prediction of endurance time limit for muscular work under alternating work load conditions. Lubbock, TX: Texas Tech University.

Takala, E., Pehkonen, I., Forman, M., Hansson, G-Å., Mathiassen, S. E., Neumann, W. P., . . . Winkel, J. (2010). Systematic evaluation of observational methods assessing biomechanical exposures at work. *Scandinavian Journal of Work, Environment & Health, 36*(1), 3–24.

Tanaka, H., Monahan, K., & Seals, D. (2001). Age predicted maximal heart rate revisited. *Journal of the American College of Cardiology, 37*(1), 153–156.

Ting, W., Wessel, J., Brintell, S., Maikala, R., & Bhambhani, Y. (2000). Validity of the Baltimore Therapeutic Equipment Work Simulator in the measurement of lifting endurance in health men.

The American Journal of Occupational Therapy, 55(2), 184–190.

Townsend, R., Schapmire, D., St. James, J., & Feeler, L. (2010). Isometric strength assessment, Part II: Static testing does not accurately classify validity of effort. *Work, 37*, 387–394.

Treciokas, O. (1994). Deposition, *Corbett v. Virginia Mason Clinic*. Cause No. 92-2-28260-7. Superior Court of the State of Washington for King County.

Troup, J., & Edwards, F. (1985). *Manual handling and lifting*. London, England: Her Majesty's Stationary Office.

Tuckwell, N., Straker, L., & Barrett, T. (2002). Test-retest reliability on nine tasks of the physical work performance evaluation. *Work, 19*(3), 243–253.

Wahlund, H. (1948). Determination of the physical work capacity. *Acta Medica Scandinavica, 132*(Suppl.), 215–217.

Washington Administrative Code 246-915; RCW 18.47. (2007).

Welbergen, E., Kemper, H., Kinbbe, J., Toussaint, H., & Clysen, L. (1991). Efficiency and effectiveness of stoop and squat at different frequencies. *Ergonomics, 34*(5), 613–624.

Williams, J. (1964). *Setting job standards and selecting or evaluat*ing workers for physiological work measurement. Los Angeles, CA: University of California Los Angeles.

Wilson, J., & Corlett, E. (1995). *Evaluation of human work*. London, England: Taylor & Francis.

Wilson, R. (2009). Managing the impact of adverse functional capacity evaluations. *ERISA & Disability News, 1*(7), 4. Retrieved from http://www.buchanandisability.com/newsletters/ERISA_Disability_Benefits_Newsletter_Issue_7.pdf

Wind, H., Gouttebarge, V., & Kuijer, P. (2006). The utility of functional capacity evaluation: The opinion of physicians and other experts in the field of return to work and disability claims. *International Archives of Occupational and Environmental Health, 79*(6), 528–534.

Wind, H., Gouttebarge, V., Kuijer, P., Sluiter, J., & Frings-Dresen, M. (2009). Effect of functional capacity evaluation information on the judgment of physicians about physical work ability in the context of disability claims. *International Archives of Occupational and Environmental Health, 82*, 1087–1096.

Workwell Systems (2006). *FCE Research Compendium*. Duluth, MN: Author.

Zuccarello, V. (2008). *FCE manual: The bioergonomic model*. Atlanta, GA: Back School of Atlanta.

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- **The above is arranged in order specified by APA (pg 24 in manual)**
- **Figure 2 needs a title. Both figures need a source if other than the authors**

APPENDICES A-S
Testimony of FCE Providers

Prelude to Appendixes A-S

These examples of providers lacking work physiology expertise and ability to provide substantial foundation for the examiners is problematic for FCE users, such as vocational experts. The accompanying opinions and commentary regarding FCE is testament to the generally poor FCE provider and methodology credibility.

Appendix A. From the deposition of Terence L. Andres, *Batton v North Valley Hospital* (2006), Docket No. 05-14354. Board of Industrial Insurance Appeals for the State of Washington.

Q. So would it be fair to say, then, that the restrictions you have placed upon these activities are based on subjective information, and not the actual objective data from the PCE?
A. For the unrelated knee condition, that's correct. It's heavy on the subjective.
(pg 39:10).

Q. When fatigue is reported, how did you test for that?
A. In this case, for this particular test, there is at this point no real test for fatigue.
(pg 48: 19).

Q. So when you put in your report, for example, under this section, "She reported right shoulder fatigue," that was purely subjective report and not based on any testing that you did?
A. Yes. My report of her report of fatigue is based on what she's telling me.
(pg 49: 2).

Q. Would you agree that the studies as it pertains to heart rates indicate that, in this instance, a heart rate below 112 beats per minute would suggest a task can be carried out continuously?
A. No, I wouldn't ... I wouldn't jump to that conclusion.
(pg 55: 14).

Appendix B. From the deposition of Ona Treciokas, PT, *Corbett v. Virginia Mason* (1994), Cause No. 92-2-28260-7. Superior Court of the State of Washington for King County. Docket 92-1929. Board of Industrial Insurance Appeals for the State of Washington (1992).

Q. Just to clarify for me, if I might, Paul. This is what he actually exerted, the column under "Occasional" pounds, is what he was able to exert.
A. That was his maximum.
Q. Maximum?
A. Correct.
Q. And then the computer goes on and estimates that he can do.
A. Right.
Q. On a frequent basis for eight hours a day, a constant basis for an eight hour day?
A. Right.
(pg 11: line 23).

Appendix C. From the deposition of Robert Perras, PT. *Eelbode v. Chec Medical Centers* (2000). Cause No. 97-2-07239-1. Superior Court of the State of Washington for Pierce County.

Q. Was Mr. Blankenship doing his testing and research toward the development or toward the publication of any article or textbook in this area?
A. After he left our clinic, he became a lecturer, he went on the circuit basically, was, well, doing this...
(pg 13: 4).

Q. And this seminar was geared toward the teaching of his techniques or approach to physical evaluations?
A. Not his. He was basing it on other people, kind of putting it all together to make it so that the average therapist could get up and running on a work conditioning or work hardening program.
(pg 14: 9).

Q. By Keith...
A. Blankenship. Now I didn't attend that seminar, I just got hold of it, I don't know how I got hold of it, but it reaffirms a lot of the materials I'm going to talk about.
(pg 16:5).

Q. Can you explain what it came from?
A. Again Blankenship gave a talk on pre-employment screening and that came from that seminar, but I didn't attend the seminar.
(pg 35: 11).

Q. Did Chec instruct you as to who you should rely upon for follow with regard to these tests?
A. No, it was basically how I was taught how to do the exam through Jude, and then we went from there.
(pg 42: 13).

Appendix D. From the deposition of David Bullock, PT. *Griffin v. Tree Top*. (2008). Docket No. 08-10152. Board of Industrial Insurance Appeals for the State of Washington.

Q. Okay. Did you ever measure his heart rate to determine how long it took for him to get back to resting heart rate after doing any of these things, the sitting, standing, walking, lifting...
A. No.
(pg 53: 19).

Q. Are you familiar with the interrater and test-retest reliability characteristics of a PCE?
A. No.
(pg 54: 17).

Appendix E. From the deposition of Christina Casady, OTR/L. *Connell v. Tucci & Sons*. (2003). Docket No. 03-12011. Board of Industrial Insurance Appeals for the State of Washington.

Q. And how did you conclude that he could only work two and half hours intermittently throughout an eight hour day of standing?
A. It's again kind of a combination, a projection of what he could do, based on what was observed during the clinic time. He was able to stand for a half hour or less during the activities, shifted his weight around a lot. And then over an eight-hour day, with the weakness and other problems he had in his back, that was my projection.
(pg 10: 15).

Q. And how do you conclude 24 pounds?
A. The.that's for occasional lifting. And for occasional lifting you calculate 80 percent of the maximum.
Q. And for frequent it's 50 percent?
A. It's supposed to be 70 percent, but when we tested Mr. Connell on the endurance circuit, which is where we take 70 percent of their maximum and see if they can do it several repetitions, he had a lot of problems in that area.
(pg 18: 19).

Q. And you have no valid criteria or formula to calculate that the claimant can only sit for four hours as compared to say, three or five?

A. Every test is individual. It is individual projection.

Q. So your opinion of four hour basis is solely upon your opinion?

A. Yes.

(pg 108:15)

Q. There is no formula that led you to conclude it is four hours based upon your half hour observation?

A. No, there is not.

(pg 109: 4)

Appendix F. From the deposition of Julie Gronski, OTR/L. *Curevac v. Marriott* (2008). Docket No. 05-19060. Board of Industrial Insurance Appeals for the State of Washington.

Q. Is there a standard or a method that you follow in performing capacities evaluations?

A. Well, UBC, kind of has their own protocol, I guess, you can call it. There's a lot of different organizations out there that offer certifications or classes on PCEs. There doesn't seem to be one that's looked at any higher level than the other from what I can tell. I've gone to a couple of courses by one of those. One of the big ones is called Matheson and I've gone to a course on conducting PCEs with them, but they each have their own certification program and want you to purchase their equipment. So UBC kind of has their own protocol that was in place before I started working for them.

Q. In your protocol through United Back Care, when you do capacities evaluations, do you take photographs?

A. I don't.

(pg 10: 3).

Appendix G. From the deposition of Terry A. Moon, OTR/L. *Mehrer v. Goodyear Tire & Rubber* (2003). Cause No. 01-2-31582-0. Superior Court of the State of Washington for King County.

Q. How do you measure the factor of endurance in your testing?

A. I measure the factor of endurance by movement patterns. So we're looking at velocity, slow, fast. I'm looking to see if in the beginning they did not require an assist to get up off the floor but in the end they did. I'm looking for changes in respiratory patterns, if the respiratory rates appear to be normal and towards the end there is a lot of taking a deep breath...

Q. How do you measure that?

A. If they're sighing, If they're taking a deep breath, so if I can actually hear them breathing. If you can see their shoulders going up and down because they're trying to get air. If need, then I will ... if there's an issue with that then I would be taking respiration rate for each activity.

Q. Let me interrupt one minute. Did you take the respiratory rate before, mid test, and post test?

A. No, I don't.

(pg 29: 16).

Q. Do you have any special certifications or licenses in the area of functional capacity evaluation?

A. Training courses.

Q. Certification, licenses at all?

A. Certification from some testing equipment that I have.

(pg 62: 18.)

Q. Other than the J/Tech certification do you have any other certifications?

A. No.

(pg 63: 7).

Q. In your testing of the physiological indices, take that data and do any evaluation of the data from the standpoint of evaluating a person's response to the testing similar to what Dr. Becker does?

A. Its not my theoretical base of approach, because someone's heart rate, and its proven through biofeedback that I could make my heart rate go up right now if I really thought about it and I could make it go down right now if I thought about it. I could increase the temperature of my skin, I mean these are proven methods of influencing physiological responses, it's actually a treatment of choice for some medical conditions. There- fore what I do when I'm evaluating, and determining someone's level of work, is I'm looking at I do look at heart rate to stay within safe exertional levels in order to determine what they can do, but it's based upon movement patterns, subjective, their body is talking to them, it doesn't talk to me, it gives me indicators of what I may be seeing next, if they are compensating the back versus the neck I may want to look for more compensation.
(pg 68: 11).

Q. Are there any other documented criticisms of functional capacity evaluations for measuring task tolerance?
A. Subjective of the evaluator.
(pg 77: 15).

Appendix H. From the deposition of Terry A. Moon, OTR/L. *Solomon v. American Seafoods Company* (2008). Cause No. CV-05-01999 JCC. Superior Court of the State of Washington for King County.

Q. Do you do that?
A. I look at the heart rate. I may stop a test if the heart rate goes too high. I may stop a test if the heart rate goes too low, so either way. So I use it to stop a test.
(pg 47: 22).

Appendix I. From the deposition of Christina Casady, OTR/L, *Koshak v. City of Renton,* 03-14044 (2004):

Q. The outline of the report, is that a particular physical capacities program?
A. No.
Q. That's something Capen has prepared themselves?
A. Yes. We've developed it.
Q. Was it an offshoot of another program?
A. No.
(pg 9: 15).

Q. Is that a level that someone can function for any amount of time?
A. There's formulas for that sort of thing, but its based on healthy individuals, so I couldn't ... based on Mr. Koshak's disability, I can't say. I can't response to that.
(pg 22: 21).

Appendix J. From the deposition from Steve Lomas, OTR/L. *Atwood v. St. Mary Medical Center* (1999). Cause No. 97-2-00675-0. Superior Court for the State of Washington for Spokane County.

Q. What's the purpose of recording the heart rate at five, six, seven and eight minute marks.
A. To see if there's an increase. To see if they are working harder.
Q. Is there a safety aspect to that also?
A. Yes. You wouldn't want it to get too high otherwise it would be too exhausting.
Q. What's too high?
A. That's...
Q. How do you determine that?
A. Judgment call. It depends on the person. It depends. It depends on what kind of shape they are in. It's subjective.
Q. And are there any guidelines written or otherwise that you follow at St. Mary as to when it might be getting too high?

A. I don't believe so, that I can remember.

Q. I guess my question is, how do you personally know? How have you learned what is safe or unsafe in regards to a person's heart rate while they are exercising in that manner?

A. Well it's... usually, you get their resting heart rate. And then there's an equation, that I cannot remember, that you come up with their exercise heart rate. And you're not to exceed that maximum heart rate, but I can't remember the equation.

(pg 26: 9).

Appendix K. From the deposition of Terry A. Moon, OTR/L. *Joseph v. Boeing* (2004). Docket No. 03-10346. Board of Industrial Insurance Appeals for the State of Washington

Q. As an occupational therapist are you qualified to administer this test? (Reference to GXT)

A. If I'm properly trained.

Q. Have you received this certification?

A. No, I have not.

(pg 91: 1)

Appendix L. From the testimony of Terry A. Moon, OTR/L. *Vanweerdhuizen v. Buckley* (2003). Cause No. 02-2-00331-8. Superior Court for the State of Washington for Whatcom County.

Q. On page 10 of your report, you included graded exercise tests. Were you aware that the graded exercise tests required certification as an exercise technologist to perform?

A. I was not aware of that. This was no performed by myself.

Q. Were you aware of a certification for exercise technology?

A. No, I was not aware of it, that there is a certification for that.

(pg 55: 14).

A. You know, we have used the term graded exercise testing. We have called it this; but it is merely a test of putting someone on a treadmill, getting their pain rating, and asking them if they felt that they could continue or continue with increasing the elevation.

(pg 56: 12)

Appendix M. From the deposition of Michael Buzel, PT. *Dominquez V. Buzel* (1994). Cause No. 93-01196 (15). Circuit Court of the 17th Judicial Circuit in and for Broward County Florida.

Q. Is there a way by use of heart rate to determine whether or not a person is exceeding his capacities in doing too much?

A. Health South has a procedural package for cardiovascular assessment.

Q. Why don't you locate it in Mr. Miller's package?

A. For the cardiovascular assessment we have a protocol where we assess someone's maximum predicted heart rate which is generally 220 minus their age, multiply it by .85.

Q. Is there a formula name to it?

A. There might be. I'm not sure.

(pg 23: 22)

Q. What is the significance of a training heart rate in a functional capacities evaluation if any?

A. I'm not aware of any.

(pg 26: 9)

Q. What I'm asking you though is by using the weights and his pulse rate, could you determine what his METs were for the particular test he was doing?

A. By using the weights and the pulse rate, I can determine the physical demand characteristics using the weights. Pulse rate does not come into the equation, not that I'm aware of.

Q. Have you ever heard of anything called Karvonin's formula?

A. Not off the top of my head.

(pg 62: 4)

Appendix N. From the deposition of Santosh Kumar, MD. *Gallegos v. City of Everett*. Docket 03-20409. Board of Industrial Insurance Appeals for the State of Washington.

Q. You did not measure his heart rate while he was doing lifting, correct?

A. The measurement of heart rate is not pertinent or relevant.

Q. I'm asking you did you or did you not?

A. No.

Q. You did not measure his heart rate while he was doing the squat either?

A. It was not relevant and it was not done.

Q. You did not measure his heart rate for the bimanual lifting?

A. Not relevant, not done.

Q. You could have done it though?

A. Not relevant, therefore not done.

Q. But you could have done it? Yes or no.

A. No, I would not do it. It's not relevant.

(pg 77:7)

Appendix O. From the deposition of Christina Casady, OTR/L. *McKee v. Albertsons* (2013). Docket No. 12-20559. Board of Industrial Insurance Appeals for the State of Washington.

Q. Okay. And we touched on it briefly earlier, and you were performing a three to four hour examination; and you're extrapolating it to a reasonably continuous basis. Can you just summarize can you explain for the record how you can go about extrapolating those findings on a three hour test to a reasonable work, working on a reasonable continuous basis?

A. Well, my training, I guess, would be the main reasons for it. To do physical evaluations, part of the training is learning how to extrapolate the person's performance during the evaluation and looking at the history and what kind of treatment they're had and being able to project that over and eight hour day on a continuous basis.

(pg 31: 13).

Q. Do you hold a certification in work physiology?

A. I do not.

Q. Do you hold a certification or degree in biomechanics?

A. No.

(pg 49: 16)

Q. Have you ever been published in any peer reviewed journals?

A. No.

(pg 50: 22).

Q. So you indicated that you spent approximately three hours with Ms. McKee, and then of those three hours you extrapolated that into determining what her capacities were in an eight hour day. Are you using some sort of guidelines in that Matheson system to do that?

A. Yes. That's part of the training of the system.

Q. Are there other formulas or something else that you're relying upon for those extrapolations of data?

A. It's based on the Matheson system and also my experience and training.

(pg 51: 20).

Q. So there was no opportunity to allow her heart rate to return back to normal?

A. No.

(pg 66: 23).

Q. And is there a scientific formula that you use to calculate how many hours a day she was able to work?

A. No there's not a scientific calculation.

Q. You basically are using your judgment based on what she has told you about what her activity level is and based on what you observed when she was in your office doing the testing correct?

A. It's based on what I observed and looked at her history and also my training.

(pg 100: 26).

Appendix P. From the deposition of Elizabeth Spencer Steffe, OTR/L. *Dunn v. Motor Cargo* (2012). Docket No. 12-10642. Board of Industrial Insurance Appeals for the State of Washington.

Q. Now, with respect to taking his blood pressure and his heart rate, is there a need for you to do that more than once?

A. I do that when they come in to make sure that they're capable of performing the evaluation. If I have an individual with a blood pressure of 206 over 105, I phone their physician, and they're not tested that day. I do not use blood pressure or heart rate as a monitor for lifting or carrying.

(pg 60: 4).

Appendix Q. From the Proposed Order and Decision by Industrial Appeals Judge, The Honorable Randall L. Hansen (2010). Docket 08-222585. Board of Industrial Insurance Appeals for the State of Washington.

On October 10 and 11, 2006, Ms. Stokes underwent a PCE with Susan Mack. As of that time, Ms. Mack understood that Ms. Stokes was still taking morphine, as well as Demerol and Dilantin, although she understood that Ms. Stokes did not take any medication on the day of the testing. A biomechanical evaluation of Ms. Stokes revealed decreased neck and trunk range of motion, decreased ability to elevate both arms, and decreased left arm strength. Ms. Mack also noted decreased cervical and trunk range of motion, decreased lower extremity strength, decreased grip strength, and decreased stamina due to deconditioning. According to Ms. Mack, by the second day of testing, Ms. Stokes demonstrated complete inability to lift anything with her left hand, and a standing tolerances of four minutes. As a result of the testing, Ms. Mack concluded that Ms. Stokes had significant upper extremity restrictions, left greater than right, was not capable of working at even the sedentary level, and was limited to working no more than two and one half hours a day. (pg 6).

On February 13, 2009, Christina Casady performed another PCE. A physical examination performed prior to the PCE revealed decreased cervical range of motion, a possible rotator cuff injury, a nerve root problem to the left upper extremity, and findings consistent with thoracic outlet syndrome. Based on findings from the PCE, Ms. Casady concluded that Ms. Stokes is capable of performing sedentary work, and that she is limited to working no more than six and one half hours per day. (pg 8).

From his biomechanical analysis of still photos, Dr. Becker concluded that Ms. Stokes is able to walk within normal limits, can use both hands to reach overhead, and can perform tasks associated with work without dysfunction. (pg 11).

I, too, am persuaded that the surveillance videos establish that the conclusions reached from the findings of the two PCE's are not credible. Ms. Stokes is clearly capable of standing for considerable periods of time, and walking considerable distances. She does not appear to have any difficulty moving her neck, trunk, or shoulders. Her arm strength does not appear to be limited. If Ms. Stokes is experiencing decreased arm strength, it is unclear how that is as a result of the industrial injury. (pg 11).

As of September 17, 2008, the claimant was not a totally and permanently disabled worker within the meaning of RCW 51.08.160. (pg 15).

Appendix R . From the deposition of Jeri Lyn Reinertsen, OTR/L, *Kolilis v Albertsons*, (2013) Docket 13-11535-13-11535-A, Board of Industrial Insurance Appeals for the State of Washington.

Q. So my question was have you taken any studies related to work in your exercise physiology?
A. Not ... not ... not specifically that.
(pg 5: 5).

Q. There's a citation in that paragraph to 85 percent safe exertion level. Do you see that?
A. Yes.
Q. Where did that come from?
A. Most of these come from standardized recommendations, or studies, or standardized studies, and...
Q. Do you know where that particular citation came from though, what particular study?
A. No, I don't, but I could get that for you.
(pg 15: 1).

Q. Can you tell us or identify any quotes or peer review publications that Mr. Matheson has performed regarding work physiology?
A. No, I can't.
(pg 16: 15).

Q. And you can't quote any of his articles and you haven't read any of his articles, is that right?
A. No.
(pg 17: 3)

Q. You didn't attend though; right?
A. No, my supervisor will often go and then educate us on what she learned.
Q. My question is whether you went. Did you attend?
A. No.
(pg 18: 16)

Q. Is there a difference between.lets talk about that Matheson material provided first. Are you aware of any that has been peer reviewed?
A. No.
Q. Is that a work physiology approach, do you know?
A. I believe so, yes.
Q. Do you know where he got the 85 percent figure?
A. On which part?
Q. The safe exertion?
A. No, I don't.
Q. And you don't know if that's been peer reviewed?
A. No.
(pg 19: 13)

Q. Do you consider yourself an expert in work physiology?
A. No.
(pg 20: 10).

Q. Did somebody tell you just use that 85 percent number?
A. Yes.
Q. Who told you to use that number?
A. Our ... the owner of the company.
(pg 22: 16).

Appendix S. From the deposition of Megan M. Milyard, OTR/L. Robinson v. Genie Industries, (2013). Docket 13-10716, Board of Industrial Insurance Appeals State of Washington.

Q. What did you do prior to employing the Joule system?
A. Prior to Joule, I had a program that I designed myself that was a combination of Matheson and Isern- hagen, which are two schools of thought in the industrial rehab setting.
(pg 21: 15).

Q. Are you aware of any peer-reviewed studies, regarding the system, in research publications?
A. I am not.
(pg 22: 6).

Q. The reason I'm asking is because I've reviewed your report several times over, and I can't find, to save my life, a resting heart rate.
A. You know what? I don't see it either.
(pg 29: 18).

Q. And there's no heart rate at all during the test?
A. Correct.
(pg 60: 18).

Q. Why is there no indication there regarding heart rate?
A. You know what? I'm uncertain.
Q. Do you see that entry there to the right: 75 percent exercise heart rate?
A. Mm-hmm.
Q. Where does that number come from?
A. That number comes from the percentage of the person's age versus male/female and, you know, what their tolerance is at 75 percent.
Q. Do you know, though ... I'm ... the question I'm asking is: Why 75 percent? Why not 70 or 80 percent?
A. We use 75 percent as an upper level to allow us to know what their heart rate is at the upper level for aerobic to anaerobic function.
Q. Do you know why that level was arrived at? I assume it's by Matheson as well?
A. Yes.
Q. Do you know why he arrived at that number?
A. You know, I'm assuming, because that puts him into an anaerobic function.
(pg 76: 14)

Appendix T. Data Collection Form

Facility Name:
Facility Location/State (Province) & Country:
Provider Name & Credential:
Commercial Product? (Y/N) If Yes, name of product or method:
numCertification Credential for Work/Exercise Physiology (Y/N):

Work Physiology Criteria
Using Heart Rate Reserve Method (Y/N):
Using Non Heart Rate Reserve Method (Y/N):
Report Resting Heart Rate (Y/N):
Reports consistent Resting Heart Rate before each appropriate test & throughput (Y/N):
Reports Heart Rate Responses during test (Y/N):
Reports recovery to resting heart rate (Y/N):
Reports Heart Rate Analysis And/Or Interpretation (Y/N):

Appendix U: FCE Examiners Listed by Clinic Name, Location, and Corresponding FCE Commercial Product

Clinic	Providers	State/County	FCE Commercial Product
A Medical Corporation	Michael D. Roback, unknown	CA/Los Angeles	own design
Advanced Rehabilitation and Occupational Solutions	Farooz Sakata, unknown	AK/Anchorage	own design
Alaska Spine Institute Physical Therapy and Rehabilitation	John DeCarlo OTR	AK/Anchorage	Blankenship
Alpine Physical Therapy	McCarthy PT, OTR/L	AK/Anchorage	KEY
Andres Work Assessment	Terence Andres RKT	WA/Spokane	own design
Apple Physical Therapy: Bothell	Stacey Ellingson PT	WA/Snohomish	ErgoScience PWPE
	Sue Kabeary PT	WA/Snohomish	ErgoScience PWPE
Apple Physical Therapy: Mountlake Terrace	Jennifer T. Henriksen PT	WA/Snohomish	own design
Apple Physical Therapy: Other Locations	Shonna R. Moak PT	WA/Snohomish	ErgoScience PWPE
	Monica Lemone OTR	WA/Thurston	ErgoScience PWPE
	Mike O'Brien PT	WA/Thurston	ErgoScience PWPE
	Andrew J. Wodka PT	WA/Thurston	own design
Arizona at Work	Mary Louise-Hymen OTR	AZ/Maricopa	own design
Associates in Physical Therapy, PLLC	Keith Franzen PT	WA/Douglas	own design
	Douglas Harris PT	WA/Chelan	own design
Athletic and Therapeutic Institute Physical Therapy	Elizabeth Little ATC	IL/DuPage	KEY
Bellevue Physical Therapy	Robert Tutland PT	WA/King	own design
Capan and Associates	Christina Casady OTR	WA/Pierce	Arcon
Cascade Sports Medicine & Industrial Rehabilitation	PT, OTR	WA/Pierce	own design
	Unknown OTR	WA/Pierce	own design
Cashmere Physical Therapy	Steve Mongeion PT	WA/Chelan	Blankenship
Columbia Physical Therapy: Kennewick	Brooks PT	WA/Benton	own design
Columbia Physical Therapy Inc.	Kirk Holle PT	WA/Grant	own design
	Kelley PT, OTR	WA/Grant	Matheson
	Thornton PT, OTR	WA/Grant	Matheson
	Wright PT, OTR	WA/Grant	Matheson
Columbia Rehabilitation	Karnofski PT, OTR	WA/Cowlitz	own design
Correl	Brobeck PT, OTR	WA/Whatcom	Blankenship
D & W Rehab Inc	Liz Dowler PT	AK/Anchorage	own design
Dell Felix	Allen Thurston PT	UT/Salt Lake	own design
Dynamic Evaluation Center	St. John PT, OTR	HI/Oahu	Blankenship
Eagle Rehabilitation Corporation	Stephens PT, OTR	WA/Spokane	Blankenship
Electrodiagnosis & Rehabilitation Medicine	Santosh Kumar MD	WA/Snohomish	own design
Frankhauser	Rob Frankhauser PT	WA/Snohomish	own design
Franciscan Health System	Eileen Rollins OT	WA/Pierce	own design

Clinic	Providers	State/County	FCE Commercial Product
Functional Assessment Rehab & Physical Therapy	Sarah Marchant PT	UT/Salt Lake	BTE
Functional Capacity Evaluation/ Representative Occupational Profile	Jalil Rashti MD	CA/Los Angeles	own design
Genesis Physical Therapy	Todd Ball PT	CO/Denver	own design
Harbor Physical Therapy	Jill Wilson PT	WA/Grays Harbor	own design
Hawaii FCE and Rehabilitation Services	Florian Flores PT	HI/Oahu	Blankenship
HealthSouth Industrial Rehabilition Associates: Seattle	Mary Wightman OTR	WA/King	own design
	Jeff Goesling PT	WA/King	own design
	Leah Darrow OT	WA/King	own design
	Motley, unknown	WA/King	own design
	Janet Spaeth PT	WA/Spokane	own design
	Anita Romero OTR	WA/Spokane	own design
HealthSouth Sports Medicine and Rehabilitation Center	Michael Buzel PT, OTR	WA/King	own design
Highline Hand Therapy	Beverly Andersen OTR	WA/King	own design
	Elizabeth Spencer-Steffe OTR	WA/King	own design
Hoquiam Physical Therapy Services	Daniel Burns PT	WA/Hoquiam	ErgoScience PWPE
Human Function LLC	Ian A. Johnson PT	WA/King	own design
Human Performance Center	Donald Ayres PT	WA/King	Blankenship
Human Performance in Industry: Everett	William Moynihan PT	WA/Snohomish	Arcon
Human Performance in Industry: Arlington	Michelle Lehmann PT	WA/Snohomish	Arcon
ISR Physical Therapy	Trevor Bardarson PT	LA/Terrebone	own design
Kitsap Physical Therapy	Kelly B. Campo PT	WA/Kitsap	own design
	Eric Roth PT	WA/Kitsap	ErgoScience PWPE
Lynnwodd Sports & Physical Therapy	Edwin Malijan PT	WA/King	Valpar
Maximum Function	Sharik L. Peck PT	UT/Cache	Work Solutions DCI
Midtown Occupational Health Services	Kristine Couch OTR	CO/Denver	Blankenship
Minneapolis Clinic of Neurology, LTD.	Brent D. Jensen BS	MN/Hennepin	KEY
Momentum Physical Therapy & Industrial Rehab	Rod Strom PT	WA/Spokane	own design
Monlux Health Center	Monlux PT	WA/Snohomish	own design
Mormile Physical Therapy	Mormile PT	AK/Anchorage	own design
Moses Lake Sports Physical Therapy	Randy T. Hermans PT	WA/Grant	Isernhagen
Mountain View Physical & Occupational Rehabilitation	Thomas Keith PT	WA/Vancouver	own design
MVP Physical Therapy	Lynda White PT	WA/King	ErgoScience PWPE
	Nina Marie Altman PT	WA/Pierce	ErgoScience PWPE
Northwest Evaluation for the Injured Worker	Ackerman OTR	WA/King	own design
Northwest Physical Therapy and Sports Rehab Center Inc.	Daniel Crowley PT	WA/Skagit	own design
Northwest Return to Work	Josh Cobbley OTR	WA/Snohomish	own design
	Susan Dumelin PT	WA/Snohomish	own design

Clinic	Providers	State/County	FCE Commercial Product
Northwest Work Options	Jonathan Harrison OTR	WA/Yakima	Matheson
NovaCare Rehabilitation	Robert Kieffman PT	MI/Wayne	own design
Olympic Sports and Spine Rehabiliation	Michael Tollan PT	WA/Pierce	own design
Onsite Physical Therapy	Elyse Berkovitch PT	OR/Multnomah	own design
Ortho-Rehab Inc	Scot Miller PT	WA/Thurston	own design
Our Lady of Lourdes Hospital	Brian Brooks PT	WA/Franklin	own design
P.T. Northwest Physical Capacity Evaluation	Dan Hughes PT	WA/Cowlitz	own design
Pace	Steve Ehlert MA	WA/Spokane	own design
Pacific Physical Therapy Inc	Eve Colley PT	WA/Grays Harbor	own design
Pacific Presbyterian Medical Center	David Deschenes PT, OTR	CA/San Francisco	own design
Peoples Injury Network Northwest (PINN-Kent)	Barbara Harrington OTR Bruce Parker PT Lee Caton PT	WA/King WA/King WA/King	own design own design Matheson
Peoples Injury Network Northwest (PINN-Olympia)	Terry Mertens OTR Lisa M. Bowling PT Mike O'Brien PT	WA/Thurston WA/Thurston WA/Thurston	own design own design ErgoScience PWPE
Peoples Injury Network North-west (PINN-Tacoma)	Steven Haskey OTR Craig Faeth OT	WA/Pierce WA/Pierce	own design own design
Peoples Injury Network Northwest (PINN-Vancouver)	Dominique Martin-Mitchell OTR Don Houck PT James Franck PT	WA/Clark WA/Clark WA/Clark	Matheson own design Matheson
Performance Work Rehabilitation, Inc.	Dawn Jones OTR Susan Mack PT	WA/Pierce WA/Pierce	Isernhagen own design
Physical Therapy & Sports Medicine	Wallin PT	WA/Snohomish	own design
Physiometrics	Jim Gaffney BA	PA/Philadelphia	own design
Portland Providence Medical Center Worker Rehab	Trevor Tash OT	OR/Multnomah	own design
Proactive	Alstot PT	OR/Clackamas	own design
Progressive Rehab Associates	Debbie Dodge PT, OTR	OR/Multnomah	own design
Providence Physical Therapy	William Linnenkohl PT	WA/Lewis	own design
PT Northwest	Dan Hughes PT	WA/Cowlitz	own design
Puget Sound Physical & Occupational Therapy	L. King Smith PT	WA/King	Arcon
Puget Sound Physical Therapy	Erick Wilson PT	WA/Whatcom	own design
Rehabilitation Hospital of the Pacific	Unknown	HI/Oahu	ErgoScience PWPE
Rehabilitation Institute of Washington, PLLC	Randy T. Hermans PT Shelly Appleton PT	WA/King WA/King	own design own design
Riverton	Andersen, unknown	WA/King	own design
Seattle Hand	Brady PT, OTR	WA/King	own design
Sisters of Providence	Leidig PT, OTR Durham PT, OTR	WA/Snohomish WA/Snohomish	Matheson own design
South Sound Physical & Hand Therapy	Jeanette Clark PT	WA/Thurston	own design

Clinic	Providers	State/County	FCE Commercial Product
Spinal Logic	McCoy DC	WA/King	Spinal Logic
Spokane Sports and Physical Therapy	Craig L. Stephens PT Amy Forrey PT, OTR	WA/Spokane WA/Spokane	own design own design
Sports Reaction Center of Physical Therapy for Active People	Neil Chasan PT	WA/King	own design
St. Joseph's	Panton-Bernard OTR	WA/Whatcom	own design
St. Luke's Rehabilitation Institute	Elizabeth Gilbert PT	WA/Spokane	Joule
Stevens Memorial Hospital	Carver PT	WA/Snohomish	own design
Summit Physical Therapy	Kim, unknown Phillip Drussel PT	WA/Spokane WA/Grant	Blankenship WorkWell Systems
Summit Rehabilitation Associates	James Strandy PT Robert Hocker OTR	WA/Spokane WA/Spokane	Blankenship Blankenship
Target	Johnson PT, OTR	HI/Hawaii	own design
The Blankenship Group	Unknown PT	GA/Macon	Blankenship
The Rehabilitation Center Columbus Regional Hospital	Philabaum PT	IN/Bartholomew	own design
The Valley WERC	Christopher Cooke BA	British Columbia	own design
Therapeutic Associates of Maui, LLC	John Mizgouchi OTR	HI/Maui	ErgoScience PWPE
Timberline Physical Therapy	Zane Smith PT	WA/Clark	Medigraph
Totem Sports Clinic	Ludwick PT, OTR	WA/King	own design
UBC Inc.	Chan Hwang MD Sandy Gilroy OTR Jacalyn R. Breidenback PT Heidi Vogel PT Dina Lund OT Maggie Vennarucci OTR Susan Chamberlain OTR	WA/King WA/King WA/King WA/King WA/King WA/King WA/King	own design own design own design own design own design own design own design
Valley Medical Center	Janine Douglas OTR Barbara Agregger PT	WA/King WA/King	own design own design
Vancouver Coastal Health Authority	Fraser PT, OTR	British Columbia	own design
Vancouver Rehabilitation and Therapy	Unknown PT	WA/Clark	own design
Virginia Mason	Ona Treciokas PT, OTR	WA/King	Ergoscience PWPE
Westside Physical Therapy	Kim Newman OTR	WA/Yakima	own design
Work Strategies	Walter Scarborough PT	PA/Bucks	own design
WorkAble Solutions	Eunice Gong PT Terry Moon OTR	WA/Snohomish WA/Snohomish	own design own design
Working Well & Associates	Unknown, OTR	WA/King	own design
Worknet	Harvey PT, OTR Carla Haney PT	WA/King WA/King	own design own design
Workwise Therapy Services	Megan M. Milyard OTR Terrie Roberts PT	WA/Kitsap WA/Kitsap	own design own design
Yakima Valley Memorial	Unknown PT, OTR	WA/Yakima	Matheson