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Testing to Identify Submaximal Effort: Lifting to a Perceived 50% Effort vs. an Assigned Submaximal Load

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Abstract

Swift, MC, Townsend, R, Edwards, D, and Loudon, J. Testing to identify submaximal effort: Lifting to a perceived 50% effort vs. an assigned submaximal load. *J Strength Cond Res* XX(X): 000–000, 2020—The ability to accurately measure effort during postinjury functional testing allows for the validation of displayed physical limitations by injured workers. The Cross-Reference Testing System (XRTS) has been developed to identify submaximal efforts through distraction-based dynamic material handling testing. The XRTS material handling assessment compares dynamic lifts of weights in a crate and lifts using a lever arm device. The purpose of this study was to determine whether subjects lifting an assigned submaximal load influence test results compared with subjects lifting to but not exceeding a 50% perceived effort. Subjects in group A ($n = 35$) were assigned the condition to attempt to lift to but not exceed a randomly assigned weight value for both the crate lift and XRTS at 3 lifting heights. Subjects in group B ($n = 32$) were asked to lift to but not exceed 37.5 lb from the same 3 lifting heights. The reproducibility of effort was measured with current validity criteria for distraction-based material handling testing. Using the percent difference values, a 2×3 (group, lifting height) analysis of variance (ANOVA) was performed to test the hypothesis. The alpha level was set at 0.05. The mean percent change between comparative lifts was 31.13%, 95% CI (22.51–39.75) for group A and 29.26% 95% CI (21.91–36.61) for group B. The 2×3 ANOVA demonstrated no significant difference ($p = 0.751$) between groups. The results indicate attempting to lift to a perceived 50% effort was not significantly different from attempting to lift to but not exceed an assigned submaximal load.

Key Words: functional capacity evaluation, distraction-based testing, cognitive-motor interference

Introduction

Physically demanding occupations, similar to competitive athletics, occasionally result in injury (15,21). Workplace activities for occupations such as firefighters include heavy lifting, climbing, and pulling while performing normal job duties (13,19). Tactical strength and conditioning specialists identified similar tasks for military and public safety personnel (2). Construction workers and laborers have on-the-job activities, such as heavy lifting, repetitive movements, and challenging physical positions (8,20). Public sector jobs such as law enforcement, emergency medical technician, firefighters, and military all have defined physical demands as per the U.S. Department of Labor Dictionary of Occupational Titles (DOT) (6). The DOT classifies strength requirements for occupations into the following categories: sedentary, light, medium, heavy, and very heavy (6). The very heavy physical demand level classification is defined as producing force greater than 100 pounds occasionally (up to 33% of the

workday), greater than 50 pounds frequently (34–66% of the workday), or greater than 20 pounds constantly (up to 67–100% of the workday).

Physical rehabilitation is often required in the form of physical or occupational therapy to address the type and severity of injury. In the case of the injured worker, as progress is made with physical rehabilitation, the need to assess their ability to achieve normal job demands increases. Multiple means of testing for function or predicting performance on physically demanding occupations such as military or public safety personnel have been previously studied (7,22,24). A physical performance test, which has been termed a functional capacity evaluation (FCE), is used to determine whether an individual can perform their normal job demands. The purpose of an FCE is to define the physical capabilities and physical limitations of the injured worker (assessment of disability) because it relates to their required physical job demands (1,23,25,28,42,43). In addition to determining physical capacity, the need to validate the test results is required (1,3,5,10,12,14,19,34,42).

Workers' Compensation Law entitles injured workers to payment of 66.6% of their income if they are unable to perform their job demands (16). This law also ensures payment for medical treatment/rehabilitation. Financial settlements of workers' compensation claims also take into consideration the worker's loss of function after injury. Behavioral components have been known to skew the measured FCE results, thus impacting the amount of financial settlement (10–12,19,28,42). These behavioral components include fear of reinjury, kinesiophobia, catastrophization,

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and socioeconomic influences (37). This creates an increased demand for the accuracy of measures and validity of classifying an injured worker's level of function. Calibrated and accurate equipment for FCE testing is necessary. The results of FCEs impact future decisions and actions by numerous parties. It assists the physician in determining the need for a continued plan of care. The injured worker's future financial and employment possibilities can also be influenced by the measured results of FCEs. In addition to measuring functional levels of the injured worker in relation to job requirements, FCEs have assessed client participation or effort (1,3,41).

Methods of assessing effort have been the topic of numerous studies (3,14,26,31,35,36,40,41). Common methodologies used to assess effort have been identified to have limitations in accuracy. These methods include isometric lift testing, visual estimation of effort, and grip and pinch testing along with physiologic measures (30,31,33,34,36,40). By stark contrast, there is a highly accurate method that uses repeated trials in conjunction with the component of distraction (31,32,38,39). This method assesses reproducibility with the same activity under 2 different conditions. The Cross-Reference Testing System (XRTS), based in Overland Park, KS, centers on distraction-based testing. The XRTS protocol has 2 independent distraction-based tests as follows: the hand strength assessment using a hand grip dynamometer and pinch gauge and the material handling assessment using unmarked weights lifted in a crate and unmarked weights loaded on a lever arm device for comparison (31,32,35). Criteria to identify sincere and insincere levels of effort have been supported by published research (35,39). To the authors' knowledge, no studies have identified limitations with this method of distraction-based testing.

The XRTS hand strength assessment criteria for identifying insincere effort have been measured with 99.5% accuracy (99% sensitivity and 100% specificity) during a control study (31). Distraction is used in the hand strength assessment by comparing reported maximal force capabilities in unilateral with those in bilateral trials of hand and pinch gauge measures. The XRTS material handling assessment compares maximal safe lifting capacity between 2 modes of dynamic lifting of different physical appearance. Comparisons between lifts of weighted crates and lifts on a lever arm device are made at various starting heights of hand placement at 10", 15", and 20" from the floor. The criteria for identifying feigned weakness are based on the percent differences between crate and lever arm lifts. The lever arm device allows for multiple positions of the weight placement on the lever arm (Figure 1). Positions of the weight on the lever arm can be located from one end to the other. In addition to changing the position of the weight on the lever arm, the configuration or amount of the weight loaded on the lever arm can change in appearance or absolute value. This creates a situation in which the subject has limited capability of knowing the force required to lift the device. Previous research has indicated an average error in visually estimating the load of 43.0% (35). In control studies, subjects assigned to give maximal effort lifting have been measured with 100% specificity (38,39).

Townsend et al. (39) performed a control study, which measured the sensitivity of the XRTS material handling assessment criteria. Limitations identified in this study were based on psychological or situational differences in asymptomatic, noninjured subjects and injured workers. Some of the psychological/situational differences in injured workers may

not be able to be reproduced in asymptomatic subjects. Another limitation was having subjects attempting to lift to but not exceed a 50% perceived effort. The situation of an injured worker knowing lifting requirements for normal job duties may place a different cognitive demand for asymptomatic subjects when compared with attempting to stay under a perceived 50% effort.

The purpose of this study was to determine whether subjects lifting an assigned submaximal load influence XRTS material handling test results compared with subjects lifting to but not exceeding a 50% perceived effort. Attempting to lift to a known submaximal load produces a different cognitive demand than lifting to a perceived 50% effort. This study will replicate the situation of an injured worker attempting to stay under the lifting requirements of normal job demands. We hypothesize that subjects performing submaximal lifting to a perceived 50% effort will produce similar percent differences between crate and lever arm lifting as subjects performing submaximal lifting to an assigned load. Similarly, there will be no significant differences between the number of failed criteria when identifying submaximal efforts.

Methods

Experimental Approach to the Problem

The Internal Review Board of Rockhurst University approved this research project that took place in February 2018. Injured workers are typically aware of the threshold weight to be lifted to be deemed functioning within normal job demands. To replicate this situation, a cross-sectional study of subjects attempting to lift to a 50% perceived effort of 75 pounds were compared with the condition of lifting to an assigned submaximal load. The independent variable in this study was the cognitive demand of each condition, and the dependent variable for both conditions was the percent difference between baseline lifts and XRTS lifts at 3



Figure 1. XRTS.

different heights. This study was performed using equipment manufactured specifically for the purposes of performing the XRTS methodology. The baseline lifting crate was produced by Charloma, Inc. (now Forte Products), Cherryvale, KS; the lever arm and all weights used for the XRTS protocols were produced by JR Custom Metal, Wichita, KS.

Subjects

A convenient sample of 67 subjects between the ages of 20–64 years was recruited through email advertisement. Inclusion criteria for all subjects were the subjects being healthy with no injury to the neck, arms, legs, or the lower back in the previous 12 months. Subjects were excluded if they were pregnant or currently suffering from an injury. Subjects were informed of the risks and benefits of the study before any data collection and then signed an institutionally approved informed consent form. In addition, demographic data including age, gender, height, and body mass of subjects were self-reported. The subjects included in this study were 42 women and 25 men between the ages of 18–65 years. Based on a power analysis that was performed with a G Power sample size calculator, a mixed model of fixed and random effect was used (9). The alpha level was set to 0.05 and effect size = 0.025. The sample size indicated was 14 for each group or a total of 28. Descriptive statistics were used to report the height and body mass of the subjects who participated in group A and group B (Table 1). Independent *t*-tests revealed no significant difference between group A and group B for height ($p = 0.36$) and body mass ($p = 0.31$).

Materials

The XRTS lever arm (Figure 1) has been designed to replicate the same starting height and hand width grip of the crate lift and is used to measure the maximal amount of the weight a client can lift (35). Clinicians are using this device in clinics across the country and have found this tool to be useful in documenting objective progress in FCEs. Researchers and clinicians have developed a specific protocol to evaluate sincere effort using unmarked weights added to the XRTS lever arm (Figure 1) and to a traditional 2.5-pound crate that is 12" × 12" × 10 1/2" (Figure 2). For the purpose of this study and performing the testing clinically, public knowledge to identify the value of each weight added to the crate or lever arm would diminish the accuracy and defeat the purpose of the test. The act of attempting to estimate the load being lifted would add an element of dual-tasking for the subject, which may increase the likelihood of failing established validity criteria. Current criteria for a valid XRTS material handling assessment test are defined as an average of 3 comparative lifts being <20% difference, a majority of lifts <25% difference, and no lifts ≥30% difference. The identification of the absolute value of each weight is proprietary information to the owners of the testing

system. Each weight used in this study was calibrated for accuracy within less than or equal to 0.05 pounds.

Procedures

Subjects were required to complete a blinded qualifying lift of 75 lb to be able to participate in this study (see Appendix A, Supplemental Digital Content 1, <http://links.lww.com/JSCR/A184>). Before attempting the blinded qualifying lift, subjects viewed a video that outlined the proper techniques for performing the qualifying lift using the crate. In addition, a single investigator demonstrated the lift. The subject's lifting techniques were not critiqued in any way after the initial demonstration. The subjects were then randomly assigned to either group A or group B using a random number generator, iRandomizer application (Figure 3).

Group A. Subjects in group A were assigned the condition to attempt to lift to but not exceed a randomly assigned weight value of 15, 20, 25, 30, 35, or 40 pounds using the iRandomizer application for both the crate lift (see Appendix B, Supplemental Digital Content 1, <http://links.lww.com/JSCR/A184>) and XRTS lever arm lift (see Appendix C, Supplemental Digital Content 1, <http://links.lww.com/JSCR/A184>) at 3 lifting heights off the ground to waist level: 10, 15, and 20 inches. Before the crate lift and XRTS lever arm lift, each subject viewed a video that outlined the proper techniques for performing the crate lift and XRTS lever arm lift. In addition, a single investigator demonstrated the lift.

Group B. Before the crate lift and XRTS lever arm lift, each subject viewed a video that outlined the proper techniques for performing the crate lift and XRTS lever arm lift. In addition, a single investigator demonstrated the lift. Subjects in group B were randomized into 2 subgroups, B1 and B2, using the iRandomizer application. Both subgroups were assigned the condition to attempt to lift to but not exceed 50% of the 75 lb blinded qualifying lift for the crate and XRTS lever arm. All group B subjects were first asked to lift to but not exceed 50% of the 75 lb blinded qualifying lift from 10" using the crate lift at 3 lifting heights: off the ground to waist level, 15" off the ground to waist level, and 20" off the ground to waist level (Appendix D, Supplemental Digital Content 1, <http://links.lww.com/JSCR/A184>).

Then, subjects in B1 were asked to lift to but not exceed 50% of the 75 lb blinded qualifying lift at the same lifting heights using the XRTS lever arm that was pre-set in an overloaded configuration at the beginning of testing (Appendix E, Supplemental Digital Content 1, <http://links.lww.com/JSCR/A184>). Subjects in B2 were asked to lift to but not exceed 50% of the 75 lb blinded qualifying lift at the same lifting heights using the XRTS lever arm that was pre-set in an underloaded configuration at the beginning of testing (see Appendix F, Supplemental Digital Content 1, <http://links.lww.com/JSCR/A184>).

Statistical Analysis

The actual amount of the weight lifted by each subject for the crate and XRTS lever arm lift was recorded at 3 lifting heights: 10" off the ground to waist level, 15" off the ground to waist level, and 20" off the ground to waist level. The percent difference between the crate lift and XRTS lever arm lift at the 3 lifting heights was calculated and used in subsequent statistical analysis. Using the percent difference values, a 2 × 3 (group, lifting height) analysis of variance (ANOVA) was performed to test the hypothesis. The alpha level was set at 0.05.

Table 1
Demographic information of subjects ($n = 67$).

Demographic information	Group A (absolute) ($n = 35$)	Group B (perceived) ($n = 32$)
Height (cm)	76.1 ± 18.3	78.5 ± 19.3
Body mass (kg)	170.3 ± 11.6	171.3 ± 8.6



Figure 2. Traditional crate.

Results

The mean percent change between the 3 crate and lever arm lift comparisons was 31.1%, 95% CI (22.51–39.75), effect size = 0.077 for the absolute value group and 29.3%, 95% CI (21.91–36.61), effect size = 0.077 for the perceived 50% effort group. The 2×3 ANOVA demonstrated no significant difference ($p = 0.751$) between group A and group B and no significant difference within group A and group B ($p = 0.082$) (Table 2). There was also no significant difference within the criteria for the mean number of comparisons $\geq 25\%$ change ($p = 0.297$) and peak percent change of the 3 comparisons ($p = 0.420$).

Discussion

The primary findings indicate there is no significant difference in the percent change when comparing the crate and lever arm lifting results under 2 conditions. Subjects performing submaximal lifting to a perceived 50% effort or an attempting to lift to but not

exceed an assigned submaximal load had also no significant difference in the number of XRTS validity criteria that failed for identifying feigned weakness.

The cognitive demand placed on individuals performing physical tasks has been theorized to create a dual-task interference (4,17,18,27). The theory of dual-task interference has identified that both extrinsic and intrinsic factors on an individual may influence attention allocation when performing physical activity (4,29). Extrinsic factors would include the element of distraction, which in this study was comparing test results between 2 modes of lifting. Intrinsic factors would include the cognitive demand of the subjects. During distraction-based testing of this study, the attention allocation of attempting to perform submaximally resulted in inconsistent measured test results. In control studies using distraction-based testing, failed XRTS validity criteria only occurred when individuals intentionally gave a perceived 50% effort (39). This study used the condition of a different cognitive demand that was more closely related to an injured worker attempting to stay under known job demands in addition to the subject lifting to a level of perceived effort. The results of this study indicate the cognitive demands of both conditions did not change the percent difference between crate and lever arm lifts.

The sensitivity for identifying feigned weakness using the XRTS material handling assessment in the previous control study was 20% using established validity criteria (39). The results of this study indicated a higher failure rate of established criteria at 62.5% for the perceived effort group and 64.7% for the absolute value group. The procedures of the previous control study used 1 weight configuration for each of the 3 comparative lifts (39). This study used weight configurations on the lever arm that would change during progressive lift testing. This indicates the cognitive demand placed on subjects may be more influenced by the extrinsic factor of the appearance of the weight on the lever arm device compared with the condition of lifting to a perceived 50% effort or assigned submaximal load.

In addition to having a fluctuating weight configuration on the lever arm device during distraction-based testing, this study used a nonuniform progression in load increase. The previous control study using the XRTS lever arm progressively increased trials of lifting by 15% of the initial baseline lift (39). During this study, the progression in the weight included an assigned change of the position of the weight loaded on the lever arm in addition to a fluctuating configuration. This created a progression in the amount of the weight lifted that was not a uniform increase with each attempt. This was also

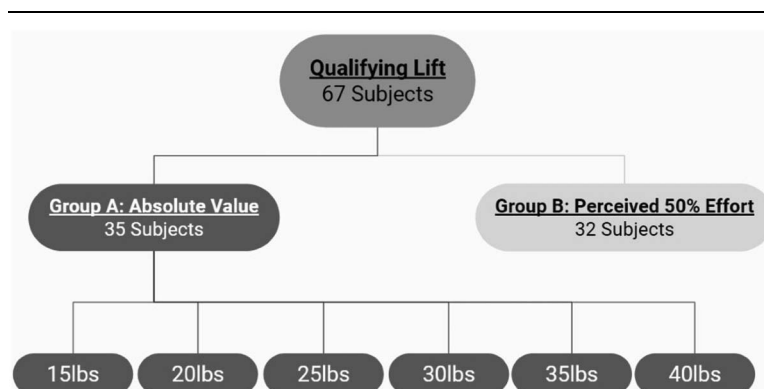


Figure 3. Randomization of subjects to group A and group B.

Table 2**Percent differences of comparative lifts.**

Lifting height	Group A (absolute) (n = 35) percent difference (mean ± SD)	Group B (perceived) (n = 32) percent difference (mean ± SD)
20 inches off ground	0.278 ± 0.275*†	0.296 ± 0.241‡
15 inches off ground	0.328 ± 0.290	0.312 ± 0.245
10 inches off ground	0.328 ± 0.271	0.269 ± 0.230

*No significant difference between group A or B.

†No significant difference within group A.

‡No significant difference within group B.

a change of an extrinsic factor that potentially influenced the attention allocation of the subjects, which resulted in a higher percentage of subjects failing XRTS validity criteria when performing submaximal lifting under the 2 assigned conditions.

Townsend et al. (39) reported the differences in the psychological states of injured workers and asymptomatic subjects as a potential cause for the low sensitivity of 20% in identifying submaximal efforts using the XRTS lever arm. It was suggested that the instructions to lift to a perceived 50% effort were not specific to the situation of work injury claimants attempting to stay under a known load was a limitation of the study by Townsend et al. The results of the study by Townsend et al. indicated the intrinsic factor of lifting to a perceived 50% or assigned submaximal absolute load did not result in a significant difference in the percent difference between crate and lever arm lifting. Extrinsic factors such as the fluctuation in the appearance of the weight on the lever arm device and nonuniform progressive increase in lifting trials appeared to have influenced the failure rate of validity criteria.

St. James et al. examined the percent difference between crate and lever arm lifting results with a population of 200 consecutive FCE subjects. Unlike the population of the control studies, these subjects had applied for benefits in connection to reported work-related injury or long-term disability. St. James et al. (35) identified high percent differences between crate and lever arm lift results during FCEs in which individuals failed 2 or more criteria of the XRTS hand strength assessment, which has a measured accuracy of 99.5% in identifying feigned weakness. The results of the study by St. James et al. indicated only 8.1% of individuals failing the XRTS hand strength assessment criteria passed the XRTS material handling assessment criteria. Previous research has identified intrinsic, psychological, and socioeconomic factors can prolong the length of time off work during a work injury claim (11,12,16,19,41,42,44). The presence of secondary gain may have influenced the results in the study using 200 FCE subjects. The intrinsic factors that exist in a work injury population that may disrupt attention allocation in attempts to reproduce effort when distracted are difficult to simulate in an asymptomatic control subject population.

The results of the present study indicated that changing the appearance and weight of the configuration loaded on the lever arm increased the correct identification of submaximal efforts using existing validity criteria. The nonuniform progression of weight increase during lever arm testing may have also contributed to a greater relative number of subjects correctly identified as giving a submaximal effort. Future research should investigate the extent of intrinsic factors such as perceived pain or kinesiophobia has on the ability to pass established criteria when a maximal

effort is given. Future work should also investigate to what extent secondary gain has on the ability to pass validity criteria when a maximal effort is given.

Practical Applications

Practitioners who perform functional testing of the industrial athlete should recognize nonphysical components that may interfere with test results after injury. The need to validate displayed physical limitations during testing has been well documented (1,3,5,12,23,26,34,42). The use of distraction-based testing has been shown to properly classify individuals giving a full or instructed 100% effort during control studies (37,39). There appear to be similar responses in the rate of failed XRTS validity criteria between subjects instructed to lift to a perceived 50% effort and those who are assigned to lift to an absolute value—assigned load. A submaximal effort, regardless of the instructed target endpoint of testing, did not significantly impact the percent difference comparing crate lifts with lifts with a lever arm device. The test protocol appears to have a significant role in correctly identifying individuals giving a submaximal effort during functional testing when compared with previous study results using uniform weight progression. A change in the visual appearance of the weight being lifted between trials also increased the relative number of correctly identified subjects giving a submaximal effort. Practitioners should realize the lack of variety in visual appearance or progression of loads lifted may limit test effectiveness when attempting to validate displays of dysfunction.

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References

1. Allison S, Galper J, Holyle D, Mecham J. *Current Concepts in Functional Capacity Evaluation: A Best Practices Guideline* 2018, 2018. Available at: https://www.orthopt.org/uploads/content_files/files/2018%20Current%20Concepts%20in%20OH%20PT-FCE%2006-20-18%20FINAL.pdf. Accessed May 22, 2019.
2. Barringer ND, McKinnon CJ, O'Brien NC, Kardouni JR. Relationship of strength and conditioning metrics to success on the army ranger physical assessment test. *J Strength Cond Res* 33: 958–964, 2019.
3. Brubaker PN, Fearon FJ, Smith SM, et al. Sensitivity and specificity of the blankenship FCE system's indicators of submaximal effort. *J Orthop Sports Phys Ther* 37: 161–168, 2007.
4. Chua ECP, Fang E, Gooley JJ. Effects of total sleep deprivation on divided attention performance. *PLoS ONE* 12: e0187098, 2017.
5. De Baets S, Calders P, Schalley N, et al. Updating the evidence on functional capacity evaluation methods: A systematic Review. *J Occup Rehabil* 28: 418–428, 2018.

6. *Dictionary of Occupational Titles*. Available at: https://occupationalinfo.org/appendxc_1.html. Accessed November 13, 2019.
7. Eagle SR, Keenan KA, Connaboy C, et al. Bilateral quadriceps strength asymmetry is associated with previous knee injury in military special tactics operators. *J Strength Cond Res* 33: 89–94, 2019.
8. Eaves S, Gyi DE, Gibb AGF. Building healthy construction workers: Their views on health, well being and better workplace design. *Appl Ergon* 54: 10–18, 2016.
9. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods* 39: 175–191, 2007.
10. Geisser ME, Robinson ME, Miller QL, Bade SM. Psychosocial factors and functional capacity evaluation among persons with chronic pain. *J Occup Rehabil* 13: 259–276, 2003.
11. George SZ, Dover GC, Fillingim RB. Fear of pain influences outcomes after exercise-induced delayed onset muscle soreness at the shoulder. *Clin J Pain* 23: 76–84, 2007.
12. Gross DP, Battie MC. Factors influencing results of functional capacity evaluations in workers' compensation claimants with low back pain. *Phys Ther* 85: 315–322, 2005.
13. Hyden JR, Borges AS, Sharp MA. Systematic review and meta-analysis of predictors of military task performance: Maximal lift capacity. *J Strength Cond Res* 31: 1142–1164, 2017.
14. Isernhagen SJ, Hart DL, Matheson LM. Reliability of independent observer judgments of level of lift effort in a kinesiofunctional capacity evaluation. *Work* 12: 145–150, 1999.
15. Kerr ZY, Roos KG, Lincoln AE, et al. Injury incidence in youth, high school, and NCAA men's lacrosse. *Pediatrics* 143: e20183482, 2019.
16. Knoblauch DK, Cassaro S. Workers compensation. In: *StatPearls*. Treasure Island, FL: StatPearls Publishing, 2019 Available at: <http://www.ncbi.nlm.nih.gov/books/NBK448106/>. Accessed: May 22, 2019.
17. Kotani S, Furuya S. State anxiety disorganizes finger movements during musical performance. *J Neurophysiol* 120: 439–451, 2018.
18. Kozel FA, Padgett TM, George MS. A replication study of the neural correlates of deception. *Behav Neurosci* 118: 852–856, 2004.
19. Li-Tsang CWP, Chan HHK, Lam CS, Lo-Hui KY, Chan CCH. Psychosocial aspects of injured workers' returning to work (RTW) in Hong Kong. *J Occup Rehabil* 17: 279–288, 2007.
20. Lunde LK, Koch M, Veiersted KB, et al. Heavy physical work: Cardiovascular load in male construction workers. *Int J Environ Res Public Health* 13: 356, 2016.
21. Marcum JL, Foley M, Adams D, Bonauto D. Characteristics of construction firms at risk for future workers' compensation claims using administrative data systems, Washington State. *J Saf Res* 65: 53–58, 2018.
22. McDonough SL, Phillips JS, Twilbeck TJ. Determining best practices to reduce occupational health risks in firefighters. *J Strength Cond Res* 29: 2041–2044, 2015.
23. Mecham J. Under closure scrutiny: Functional capacity evaluations must be evidence based and valid. *Adv Directors Rehabil* 17: 47–48, 2008.
24. Moore KJ, Penry JT, Gunter KB. Development of a walking aerobic capacity test for structural firefighters. *J Strength Cond Res* 28: 2346–2352, 2014.
25. Oliveri M, Jansen T, Oesch P, Kool J. The prognostic value of functional capacity evaluation in patients with chronic low back pain: Part 1: Timely return to work and part 2: Sustained recovery. *Spine* 30: 1232–1233; author reply 1233–1234, 2005.
26. Owen TR, Wilkins MJ. Sincerity of effort differences in functional capacity evaluations. *J Rehabil* 80: 53, 2014.
27. Papegaaij S, Hortobágyi T, Godde B, et al. Neural correlates of motor-cognitive dual-tasking in young and old adults. *PLoS One* 12: e0189025, 2017.
28. Peppers D, Ficoni SF, Carroll BW, et al. Influence of functional capacity evaluation on physician's assessment of physical capacity of veterans with chronic pain: A retrospective analysis. *PM R* 9: 652–659, 2017.
29. Plummer-D'Amato P, Brancato B, Dantowitz M, et al. Effects of gait and cognitive task difficulty on cognitive-motor interference in aging. *J Aging Res* 2012: 583894, 2012.
30. Roussel NA, Truijien S, De Kerf I, et al. Reliability of the assessment of lumbar range of motion and maximal isometric strength in patients with chronic low back pain. *Arch Phys Med Rehabil* 89: 788–791, 2008.
31. Schapmire D, St James JD, Townsend R, et al. Simultaneous bilateral testing: Validation of a new protocol to detect insincere effort during grip and pinch strength testing. *J Hand Ther* 15: 242–250, 2002.
32. Schapmire DW, St James JD, Feeler L, Kleinkort J. Simultaneous bilateral hand strength testing in a client population, Part I: Diagnostic, observational and subjective complaint correlates to consistency of effort. *Work* 37: 309–320, 2010.
33. Schapmire DW, St James JD, Townsend R, Feeler L. Accuracy of visual estimation in classifying effort during a lifting task. *Work* 40: 445–457, 2011.
34. Simons G. Credibility crisis in FCEs. *Phys Ther Prod* 3: 1–3, 2006.
35. St James JD, Schapmire DW, Feeler L, Kleinkort J. Simultaneous bilateral hand strength testing in a client population, part II: Relationship to a distraction-based lifting evaluation. *Work* 37: 395–403, 2010.
36. Stokes H. The seriously uninjured hand-weakness of grip. *J Occup Med* 25: 683–684, 1983.
37. Sullivan M. *PGAP Client Workbook*. Halifax, Nova Scotia, Canada: PDP Program, 2014.
38. Swift MC, Townsend R, Edwards DW, Loudon JK. Decision-making data: Expectations for reproducibility of lifting on separate days. *Prof Case Manag* 23: 204–212, 2018.
39. Townsend R, Bell S, Harry J. Accuracy of distraction based lifting criteria for the identification of insincere effort utilizing the under loading method. *Work* 55: 873–882, 2016.
40. Townsend R, Schapmire DW, St James J, Feeler L. Isometric strength assessment, part II: Static testing does not accurately classify validity of effort. *Work* 37: 387–394, 2010.
41. Trippolini MA, Dijkstra PU, Jansen B, et al. Reliability of clinician rated physical effort determination during functional capacity evaluation in patients with chronic musculoskeletal pain. *J Occup Rehabil* 24: 361–369, 2014.
42. Tüscher J, Burrus C, Vuistiner P, et al. Predictive value of the fear-avoidance model on functional capacity evaluation. *J Occup Rehabil* 28: 513–522, 2018.
43. Wind H, Gouttebarga V, Kuijer PPFM, Sluiter JK, Frings-Dresen MHW. Effect of functional capacity evaluation information on the judgment of physicians about physical work ability in the context of disability claims. *Int Arch Occup Environ Health* 82: 1087–1096, 2009.
44. Young AE, Besen E, Willetts J. Expectations for return to work after workplace injuries: The relationship between estimated time to return to work and estimate accuracy. *J Occup Rehabil* 28: 711–720, 2018.