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What A Starting Point Language Set to Support Performing Safe Exertions in the Workplace—Part 1--Temporality

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Abstract: Even though there have been decades of increasing automation in almost every aspect of people at work, there remains a great amount of our modern world where workers use their musculoskeletal system in the performance of work tasks. Health and safety programs have long contained aspects that attempt to speak to, and to provide training for, workers to help them understand how to safely perform exertions that are necessary in their work tasks. It is useful to develop a language that supports the principles of performing safe exertions at work, and there have been various efforts to develop this language. However, there is not a commonality of language for performing safe exertions that exists with other aspects of health and safety programs, such as hearing protection, respiratory protection and fall protection. The goal of this article was to pose a starting point language set that may universally apply to the performance of safe exertions in the workplace. The language set was developed, based on existing research on population musculoskeletal capabilities and kinesiology. Human exertions in the workplace can be highly varied, depending on the workplace setting, so this starting point language set was framed to support whole-body exertions rather than exertions isolated to the upper extremities, for example. The language set begins with the first principle in this paper, to be followed by the additional principles in a future paper. Together these principles are crafted to be helpful for training, task evaluation, and application by front-line workers on up to senior management.

Keywords: manual materials handling, lifting, safety

1. Introduction

Overexertion and bodily reaction are injury events to the musculoskeletal system. They are usually a non-impact event from excessive physical effort and are commonly from worker activities such as lifting, pulling, pushing, holding, carrying, and throwing. Overexertion and bodily reaction injury events can also be from bodily motion activities including bending, crawling, reaching, twisting, climbing, kneeling, and ambulating. According to the National Safety Council of America (2022), overexertion and bodily reaction has been the leading or second leading nonfatal injury event involving days away from work over several years. As an example, in 2020 there were 1,176,340 total events or exposures in the United States and 255,490 were overexertion events, with a median 14 days away compared with 12 days away for all events or exposures. In 2020, 66% of overexertion injuries were sprains, strains, tears and 22% were soreness, and pain. Part of body affected: 31% involved the upper extremities (primarily shoulders), 46% involved the trunk (primarily back) and 16% involved the lower extremities (primarily knee).

Muscle tissue may contract in three ways, concentrically (shortening), isometrically (no movement), and eccentrically (lengthening). The details of the physiology and biomechanics of muscle tissue, and all the connective tissues such as tendon and fascia, can certainly be found in detail elsewhere. In basic terms, eccentric muscle contraction can create approximately 120% the force generation of concentric and isometric contractions. Thus, there generally may be an elevated risk of an overexertion injury for eccentric contraction work. In similar respects unaccustomed chronic exposure to eccentric contraction, which may approach higher levels of exertion, invariably leads to delayed onset of muscle soreness (LaStayo et al. 2003).

A key component to help understand the use of human physical exertion and safety in the occupational setting has been understanding and quantifying human strength capacity. Kroemer (1970) helped to distill the development of the science of human strength 50 years ago and is a seminal article that even today can be referred to for its importance in the subject. Kroemer (1970) proposed that "strength is the maximal force muscles can exert isometrically in a single voluntary effort". Caldwell et al. (1974) subsequently developed a proposed standard procedure for strength testing, some highlights

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being to measure isometric strength, to increase to a maximum exertion (without any "jerk"), strength testing conditions and subject descriptions be reported along with specific reporting of the data. Chaffin (1975) re-stated proposed guidelines for the assessment of human static strength and argued that assessment of dynamic strength, by comparison, is much more complicated and subject to "many additional influences and potential errors". Chaffin (1975) assimilated the advice from experts for static strength testing and included discussion on testing various parts of the body (not just lifting strength) and the added issues of balance and stability during exertions. Chaffin (1975) cautioned that the findings of strength data collectively agree that strength in one area of the body was a poor predictor of strength in other areas of the body, and that strength testing should be designed to be biomechanically related to specific job requirements. These early articles on strength testing for humans were helpful to build databases of population strength capabilities, which continue to be added to and to be used decades later in the form of biomechanical modeling of static strength capability (University of Michigan, 2021; Kerk et al., 1994).

Exertions in the workplace remain a necessary aspect of work and can take all forms of physical activity including lifting. Chaffin (1974) set out to determine if there was a correlation between a person's isometric strength for a lifting task and the incidence rate of low-back pain (LBP). This study involved evaluation of 103 different jobs and 411 men and women participants over a 1-year period for 17,430 person/weeks of exposure, during which 25 LBP incidents occurred. The jobs were evaluated and categorized by their largest value of their *Lifting Strength Rating*, which was the ratio of each weight lifted to predicted lifting strengths for a large/strong man in job lifting positions. The LSR scaled 0-1.0 where 1.0 represented lifting that a very strong person could perform. Workers in the 103 jobs were recruited if they agreed to participate in the study and perform a strength test. A *Job Strength Ratio* (JSR) was created and compares the weight lifted on the job to the average (mean) strengths of the employees on that job. The LBP incidence rate data monitored for the year was plotted according to jobs grouped by their JSR. A JSR category of JSR=0-0.5 was described as a group of employees stressed to a max of less than one half of their measured strength capabilities as a job group. The category of JSR=0.5-1.0 was described as a job group of workers performing up to their measured maximum tested strength, while for JSR>1.0 the worker job group was performing lifting requirements beyond their measured maximum tested isometric lifting strength. From this early research it was determined that there exists a wide range for isometric lifting strength among the population of males and females tested. Also, there was virtually no difference in LBP incidence between the JSR=0-0.5 and JSR=0.5-1.0. However, for job strength demands above one's measured personal isometric maximal strength (i.e. JSR>1.0), LBP incidence increased by a factor of 3:1 compared to the other two JSR categories. One issue regarding this research was the potential difference between static strength testing and possible dynamic effects associated with actual dynamic job tasks.

Chaffin et al. (1978) continued their strength testing research to "evaluate the practicality and potential effectiveness of preemployment strength testing in reducing the incidence and severity of musculoskeletal and back problems in materials handling jobs". 551 employees (446 men, 105 women) participated in a series of isometric strength tests where exertions were performed to the level felt to be his/her maximum volitional force producing capability. The employees were subsequently monitored for 18 months, and all medical incidents were documented. Chaffin et al. (1978) showed similar results for the back as Chaffin (1974). Chaffin et al. (1978) also reported results for all other musculoskeletal injuries, which "increase when a person is performing exertions close to or exceeding their demonstrated isometric strength on a fairly frequent basis". It is worth noting that the job exertions were largely dynamic whereas the strength testing involved static exertions, and no injury during strength testing was reported. Zeh et al. (1986) studied isometric strength testing procedures among 826 men and 249 women employed at the Boeing Commercial Airplane Company and found they could limit the repetitions to minimize LBP during strength testing with no statistically significant differences in results.

De Looze et al (1994) set out to compare static versus dynamic biomechanical modeling for lifting/lowering tasks performed using 3 lifting techniques and 3 speeds of movement. Lifting techniques were a back-lift (stoop lift), a leg-lift (legs bent with torso upright), and a technique that combines partial back-lift and leg-lift. Lift speed was based on the vertical velocity of the load and were 0.2m/s (slow), 0.4m/s (normal), and 0.8m/s (fast). While lifting technique did not result in significant differences, speed of movement for normal and fast conditions were significantly different between the static versus dynamic biomechanical modeling. Specifically at the slow lifting/lowering speed, the static modeling method resulted in 91% of the peak L5/S1 moment compared with dynamic modeling (not significantly different), while at normal lifting/lowering speed the result was 79% (at p=0.005), and at fast lifting/lowering speed the result was 58% (at p=0.0001). This research demonstrated that there was a significant, measurable biomechanical penalty for normal to fast movements during a simulated lifting/lowering task.

Strength testing and an effort to measure job physical exertion demands continues today. While only a small number of publications have been discussed here, there are basic elements important for the occupational setting. Static, or near static exertions, even when those exertions are maximum volitional efforts, appear to be reasonably safe from musculoskeletal injury. Overexertion in the workplace is more likely to be associated with dynamic work and eccentric work, according to strength testing and job incident reports.

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It is not possible to eliminate exertions in most, if not, all types of work. Occupational training in lifting has been a mainstay in many workplaces. It is proposed that since there will always exist exertion in jobs, a language set that supports the decades of knowledge becomes a guideline. Human performance in the world of sports seeks to achieve the highest levels of human capacity and it is universally accepted that musculoskeletal overexertion injuries will occur. The occupational setting must be the opposite of this mantra. In the occupational setting, human performance must be within each individual's control while adhering to sound safe exertion principals. The purpose of this article is to introduce the proposed language set that may guide training for workers to participate in safe exertions in the workplace.

2. Discussion

The language set discussed here is not entirely new and much of this language has been used for decades to train workers with the intent of improving their safety in the workplace. What is perhaps new is that this proposed language set is based on all types of exertions and may be applicable to the whole body, and not just focused on the low back, as an example. Furthermore, most all workers may not have an appreciation of biomechanical principles, and it is recognized that effective but fewer words are optimal for training purposes. The first language principle involves the temporality of exertion performance.

Specifically, the language ***"Exert slowly and smoothly"*** is proposed as the first principle. Accelerating loads and parts of the body introduces additional inertial forces to the task. Jerking efforts may also be far less controllable and may have unanticipated consequences. The word, "slow" is a communication or language anchor point. As discussed in De Looze et al. (1994), when exerting with "slow" effort, inertial forces are held to a minimum and are not significant. Moreover, several authors, have found that when whole-body exertions are performed slowly and smoothly (no jerking), the risk of injury is minimal (Chaffin et al., 2006; Kumar, 2004). We suggest that when the Job Strength Ratio, as described above, exceeds 1, the individual is accomplishing the work task by jerking on the load, or, otherwise, generating inertial loading, hence, the elevation of risk of injury. Alternatively, the risk in injury, is substantially lower for Job Strength Ratios that are below 1.0—where inertial loading is at a minimum.

We further propose: what if employees were empowered not to do the task if he/she cannot do so following this first principle? Therefore, to protect employees in this circumstance an administrative control needs to be in place and communicated to employees: Do not exert beyond your exertion capacity using slow, smooth manual material handling methods. Such administrative controls have been found to be effective at reducing the risk of musculoskeletal injury in the railroad industry (Page et al. 2015).

3. Conclusions

The above introduction and discussion of the topic of a language set to support performing safe exertions in the workplace first addresses temporality of exertion. This principle is, we believe, simple and straight forward. Many workplaces may already advise their employees to perform manual materials handling tasks with this first principle. Some may not. But the key to our discussion is the basis for the wording selection: slow and smooth. Both words provide language anchors to the user, instructing him or her how to exert, and, conversely, how not to exert. This first principle is tied to the performance of exertions in a manner that does not incorporate inertia to aid in task performance, and it is tied to the good safety record of the performance of whole-body static strength testing tasks, which emphasize exerting smoothly (not jerking).

Future principles will address additional aspects of safe whole-body exertion performance.

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