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Force Analysis of Individuals and Calibration of the Dynamic Force Monitor Prototype

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ABSTRACT

Force analysis of individuals and calibration of the Dynamic Force Monitor Prototype. The assessment of performance plays an important role in athletics. Athletes are constantly monitoring how their body is performing and whether or not their training regiments are effective in improving their performance. A relatively new assessment tool, the Dynamic Force Monitor, was calibrated and used to assess a small group of individuals. The goal of this study was to calibrate the DyForMon and attempt to assess individual's force capabilities, while monitoring fatigue.

Keywords: DyForMon, Force, Fatigue

INTRODUCTION

The Dynamic Force Monitor (DyForMon) was invented in 1980 by Dr. Kent Noffsinger, of McPherson College, and Dr. William Kreamer, of Ball State University, while they attended graduate school at the University of Wyoming. In the fall of 1997, McPherson College had the opportunity to obtain one (the DyForMon prototype) of two machines existing in the United States. The other, called ABLE I, is currently being used for research studies at Penn State University, where Dr. Kreamer previously resided.

In comparison with free-weights, the DyForMon is gravity independent. Also injury that possibly can occur from free-weight mishaps is virtually eliminated with the DyForMon system. Concern about dropping the bar on the chest or the need of bar spotters is not needed with this system. People who have performed preliminary workouts on the DyForMon say that their muscles fatigue much faster than with free-weights. Therefore it has been calculated that the system cuts workout time by nearly one-half or more of that of free-weights.

It is postulated that the system causes more microtearing of the muscles at a faster rate. Also persons using the system are able to focus their intensity level higher, that in the end, produces faster results. The DyForMon must meet certain safety requirements before each use. Physical examination of the machine must be performed before each use and a log book signed telling the time and date of each use. Also an experienced operator must be present while the machine is in operation, to prevent injuries.

The paradigm of the DyForMon is very unique and revolutionary. It can be described as a "Dynamic/Isometric" system, which is in fact an oxymoron. It is similar to isokinetic exercises in that there is constant motion throughout any given lifting exercise. But in isokinetic exercises, the user provides the force necessary to move the equipment. The DyForMon system, itself, provides the movement while the user resists the motion; which is referred to as an "impingement exercise" or a psuedoisokinetic exercise. It uses a five horsepower motor as a power supply and is capable of producing up to 5000 pounds of force while moving the olympic style bar in an "up and down" motion. Parameters can be set so that the bar will move through a variety of ranges around several center points and with a variety of speeds. The subject using the DyForMon would simply resist the movement of the machine. For example, on the bench press, the subject would lie on a bench under the bar and constantly push up, resisting the machine in its down-stroke attempting to force the bar upward.

Muscle Action: Terminology and Definitions

To be able to continue with the study further, the appropriate terminology and definitions must be explained. According to Knuttgen and Kraemer, skeletal muscle can exhibit two types of activity: static and dynamic. Muscle action that is isometric is considered to be a static activity because the muscle exerts force but does not lengthen or shorten. This is because either the forces acting to lengthen the muscle are equal to the forces acting to shorten the muscle or the ends of the muscle are fixed. Dynamic activity of muscles includes both concentric and eccentric type actions. Concentric action occurs when a muscle exerts force to contract and the ends of the muscle move closer together, shortening it. Eccentric action is when a muscle exerts force to contract and the ends of the muscle are moved further apart by an external force. There are also two additional terms that are associated with dynamic muscular action, isotonic and as previously mentioned, isokinetic. However the two terms mainly refer to the mode of activity rather than to the action of the muscle itself. The term isotonic refers to an action in which a muscle exerts constant force through an entire movement. The term isokinetic refers to a muscle moving with constant velocity through a range of motion, normally controlled by an ergometer.

Since the DyForMon has never really been calibrated, one of the purposes for this study was to calibrate the relationship of voltage generated by mechanical strain gauges to how many pounds of force were applied to the bar through any given motion. The other purpose of the study was to measure and analyze real time data on performance and fatigue.

MATERIALS AND METHODS

The Dynamic Force Monitor (DyForMon) is the primary piece of equipment involved in the experiment. A computer and hookup capabilities were also used to measure mean power output and to graph results of the experiment. Two voltage gauges were used to connect the DyForMon to the computer. Flexible tape was used to measure arm, chest, and thigh girth. A bench, weight bar and weights from the McPherson College weight room were used in the calibration of the DyForMon. A maximum of 20 subjects with a minimum of 10 subjects were required to produce significant results. All of the subjects were given demonstrations of how the DyForMon functioned and all signed waivers of liability. Four different subjects were used in the initial testing and calibration of the DyForMon and ten additional subjects were used for the testing of maximal force output and fatigue profiles.

Connected to each side of the DyForMon exercise bar are voltage gauges that measure the amount of force that is placed either up or down on the bar. Two voltage detectors were connected to the gauges and then routed to the computer. Also a position vs. time monitor was set up and connected to the computer so that the position of the bar could be determined in the final examination of data.

To calibrate the voltage gauges a fulcrum was placed at exactly the middle of the bar. A 45lbs weight-lifting bar was then placed on the fulcrum so that force would be upward on the DyForMon bar. Weights of 25lbs, 45lbs and 70lbs were placed on the weight-lifting bar. The amount of force pushing up on the bar was calculated using typical lever arm-torque relationships. After calibrating each side of the bar it was noticed that the two sides did not behave exactly the same, making a probable 10 % error in measuring force. The calibration graphs are included.

Small group of four subjects were asked to perform bench presses on the DyForMon. Before any exercise was performed, the subjects were asked to lie under the bar and place their hands in a comfortable grip. On both the left and right side, a measurement from the outside of the bar to the small finger of the hand was taken. To protect against bias, the same measurements were used each time the subjects performed exercises on the DyForMon. Before the DyForMon was started the subjects were asked to perform warm-up repetitions to prevent any harm that might occur from improperly warmed muscles. The subjects were asked to provide maximal effort through the full range of motion, at a medium speed, for three to five repetitions.

Later, ten subjects who were on the McPherson College football team and who regularly lifted weights were chosen to perform bench presses on the DyForMon. Before any exercise took place the subjects were given a brief lecture about the principle of the DyForMon, the potential hazards that are present with use of the machine, and how to perform a bench press properly using the machine. The subjects were arranged by order of height (range 6’1”-5’4”), were numbered and assigned codes for purposes of categorizing data. Before every subject performed maximum repetitions on the machine, they were asked to warm up by exerting roughly 20-60% of their max. force capability. The subjects then performed nine repetitions of maximal force at a medium average speed of 0.29 meters per second and a maximum speed through center point motion of 0.41 meters per second. Because of time constraints, only four subjects were able to perform nine repetitions at a fast average speed of 0.49 meters per second and a maximum speed through center point motion of 0.69 meters per second. Motion of the bar in all cases was sinusoidal in time.

RESULTS

Calibration Curves

The calibration curves for both the right and the left voltage gauges were what was expected, linear--a direct translation could be made from voltage to

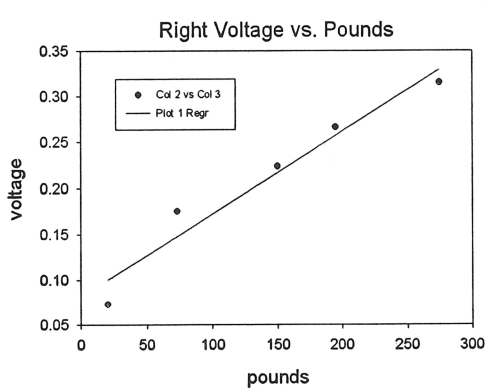

Figure 1.

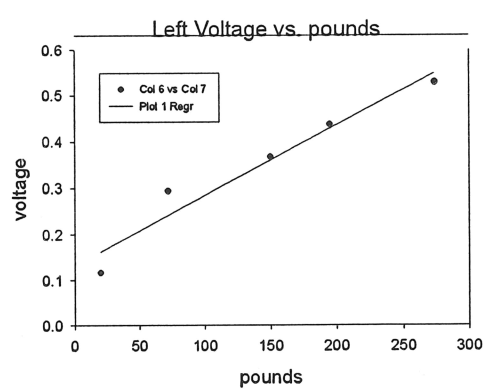

Figure 2.

pounds. There is some indication that at the lower end of the curves, the relationship may not be linear. Determination for this region requires further investigation. This possible nonlinearity most likely would have had a minimal amount of effect in the interpretation of the results.

Force And Fatigue Analysis

Results from the initial four subjects showed linear fatigue in roughly five repetitions. Max. force can be determined by looking at the max. voltage and then using the calibration curves to make the conversions.

Results from the second 10 subjects were less clear than the first four, due mostly in part to momentary pauses at the top and bottoms of the lifting motion.

DISCUSSION

The original course of the study was long term which was to compare results comparing the use of the DyForMon bench press to that of a free-weight bench press. But due to problems with liability and time constraints the study was changed to short term, but not diminished in importance of information obtained.

The voltage gauges, particularly the left side, produced small amounts of artificial noise or interference that confounded the results slightly. This could be that the strain gauges are old or that there was interference between the voltage detectors and the computer.

A noticeable "habit" that all free weight lifters encounter, to some degree, was easily seen in the graphs that were produced from the data. Most people who perform exercises on a free weight bench press have a tendency to pause both at the top and at the bottom of the motion. The pause at the top of the lift is most likely used as a small resting period where the lifter can regenerate more energy to perform another repetition. The pause at the bottom of the lift is usually seen because the lifter allows the bar to strike the chest, temporarily relieving the muscles and "bouncing" the bar upward as a small head start toward another repetition. The pauses were read by the DyForMon because the subjects momentarily stopped putting force on the bar and voltage gauges at the top and bottom of the motion. The pauses can be seen as downward spikes in voltage on the graphs provided. Fatigue was not able to be assessed on those who did pause at the tops and bottoms of the motion because the downward spikes in the data threw any attempt of a regression line off. It did appear that most of the football players paused (fig. 4 and fig. 5). If constant force was provided during the entire exercise, a linear fatigue should have resulted (fig.3).

The four preliminary subjects showed a better lifting style for the DyForMon. This is most likely because the preliminary group had several opportunities to work out with machine and therefore became more accustomed to it. Whereas 10 secondary subjects had no opportunity to work with the machine prior to testing.

Trends in peak force were monitored and it appeared that most of the subjects who were larger appeared to generate a greater peak force (most of whom was football players) than those who were of smaller mass.

It was also noticed that the force output decreased as the speed increased. This is true, because as a muscle moves faster, the less force it will generate.

The results that did show a linear fatigue as each repetition was performed was most likely due to the maximal effort that was put into each repetition. Maximal effort means more microtearing of the muscles and maximal use of the phosphagen system (ATP-PC system), while minimizing the use of the anaerobic glycolosis system (lactic acid system). It could also be theorized that increased rate of fatigue is due to the fact that the muscles do tear faster, thereby actually using less ATP than what would be used in free-weights (Fox, 1993).

Future Research

The Dynamic Force Monitor could possibly take training to another level and by far its capabilities have not yet been fully explored. Basically the DyForMon can be used in two separate areas. The first being the assessment of force and intensity that an individual can produce, such as in this experiment and others performed by Dr. Kraemer and his colleagues. The second area is the actual use of the DyForMon itself in improving strength and performance.

It is clear that the DyForMon provides a closer mind-body relationship than that of free weights, because the user gets out of the machine what he or she puts into it. Also there are certain psychological barriers that are associated with free weights. For example as person increases the amount of weight that they can lift on a free weight bench press the more likely certain psychological barriers will interfere at workout times. The person might become intimidated with lifting greater amounts of weight and therefore precondition themselves into performing below maximum capabilities. The DyForMon has none of these limitations.

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