VCU

Virginia Commonwealth University

Functional Capacity Evaluation Course

Williamsburg, Virginia
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ARCON
VerNova FCE

Part 3
Work Physiology & Strength Testing

work physiology

I. Testing Guidelines
II. Vo_2 Submaximal Testing Protocols
III. Comparison to Work Requirements
IV. Issues in Testing and Interpretation

WHAT YOU NEED TO KNOW

- contraindications
- how to perform the test
- compare results to work requirements

FITNESS FOR DUTY

The main objective of fitness testing and comparison to work requirements is to ensure that the evaluee can work safely without undue stress or fatigue. Scientific studies and practical experience have demonstrated that a worker can only perform at 33% of aerobic capacity throughout an 8 hour day. Many factors, such as age, gender, heat, and muscle groups involved affect the sustainability of work, but general principles can be followed to cover the majority of evaluees. Work physiologists have formulated these general principles into mathematical equations that guide the evaluator.

MATCHING THE WORKER TO THE JOB

Consider two workers evaluated for a job loading rail cars by hand. The task has a *very heavy* workload demand of 7 kcal/min. Worker #1 weighs 220 lb. (100 kg) and has a Vo_2 max of 52 ml/kg/min. Worker #2 weighs 150 lb. (68 kg) and has the identical Vo_2 max of 52 ml/kg/min. Worker #1's maximal aerobic capacity expressed in the same terms as the workload is 26 kcal/min, while worker #2's maximal aerobic capacity is 17.68 kcal/min. Worker #1 is within the recommended 33% of maximal aerobic capacity, while worker #2 is at 40% of maximal aerobic capacity. Hence, worker #1 can meet the metabolic requirements of the job, while worker #2 would likely experience fatigue, and potentially pose a safety risk.

Worker #1
Convert to appropriate units:
((52 ml/kg/min X 100 Kg)/1000) = 5.2 L/min
5.2 L/min X 5 = 26 kcal/min
26 kcal/min X 33% = 8.6 kcal/min through 8 hour day

Worker #2
Convert to appropriate units:
((52 ml/kg/min X 68 Kg)/1000) = 3.536 L/min
3.536 L/min X 5 = 17.68 kcal/min
17.68 kcal/min X 33% = 5.83 kcal/min through 8 hour day

CONTRAINDICATIONS

Prior to testing the evaluator must consider the contraindications for fitness testing and gain consent. Resting blood pressure and resting heart rate are performed as part of the screening process.

The PAR-Q questionnaire has been established as a safe screening protocol to use. A consent form that clinic management finds legally acceptable should be used.

Physical Activity Readiness Questionnaire
PAR-Q

For most people physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check the yes or no opposite the question if it applies to you.

YES	NO	
☐	☒	Has your doctor ever said you have heart trouble?
☐	☒	Do you frequently have pains in your heart and chest?
☐	☒	Do you often feel faint or have spells of severe dizziness?
☐	☒	Has a doctor ever said your blood pressure was too high?
☐	☒	Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?
☐	☒	Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
☐	☒	Are you over age 65 and not accustomed to vigorous exercise?

If you answered YES to one or more questions...
If you have not recently done so, consult with your personal physician by telephone or in person before taking a fitness test.

If you answered NO to all questions...
If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for an exercise test.

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II. Vo_2 SUBMAXIMAL TESTING PROTOCOLS

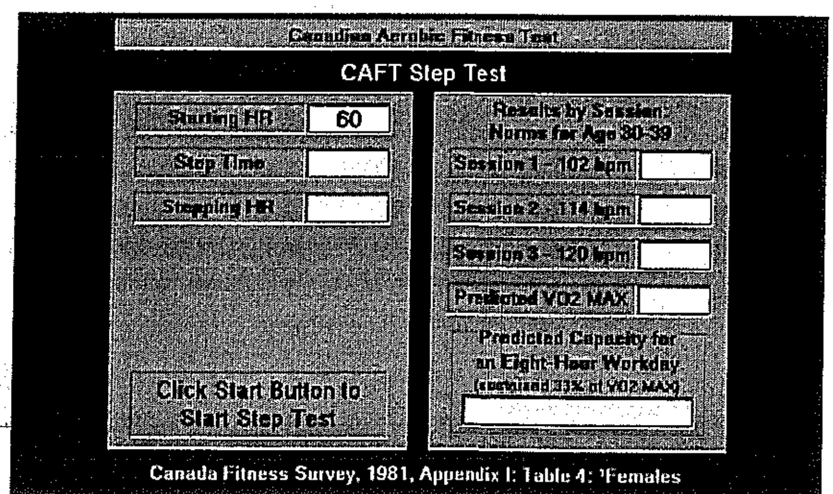
TEST SELECTION

Tests have been developed to meet various sports, recreational and work requirements, and the evaluator should choose the most appropriate test to fit the evaluee. Purpose of the test, muscle groups to be tested, time available for testing and equipment available affect test design. In order to attain Vo_2 max a steady state of metabolic demand needs to be created. This has been accomplished with treadmills, bicycle ergometers, bench stepping equipment and walking courses. General test designs have included steady state designs and graded stages where workload increases as the test progresses. Some tests have a termination point when an evaluee reaches a predetermined heart rate, and others continue until the evaluee can no longer continue or risk signs or symptoms appear.

PROTOCOL FOR DISABILITY EVALUATION

Graded tests with a predetermined termination point are considered the most appropriate for a disability evaluation. Graded testing allows a warm up period that may be as difficult as a deconditioned disability evaluee may be able to handle. Termination points may be reached relatively early in a deconditioned evaluee and serve as a safety measure.

Step tests require the least amount of equipment expenditure and well developed protocols have been established. These protocols are often the test of choice in an evaluation clinic. The stepping requirement could be difficult for an evaluee with a lower body impairment and a bicycle ergometer should be considered for such an evaluation. Treadmill tests have the best predictive validity, based on concurrent validity designs comparing results from the submaximal test with the state of the art gas-exchange methodology. However, considering equipment cost and space requirements versus validity issues, a step test is sufficient for most disability evaluations.



CANADIAN AEROBIC FITNESS TEST (CAFT)

The Canadian Aerobic Fitness Test (CAFT) is a step test appropriate for disability evaluations. The test has stepping cadences graded by age and gender and uses a relatively low 2 step platform (18.4 cm./7.25 in. steps). The evaluee steps to an initial cadence (played on a tape or CD) established by age and gender. The first stage lasts three minutes, and the evaluee continues at an increased pace at stage 2 and subsequently at stage 3, if heart rate has not exceeded the guideline published in the CAFT manual. The CAFT manual has a calculation to convert heart rate after the last stepping stage completed to Vo_2 max using age, weight and gender algorithms. Test results are normed and calculated in ml/kg/min.

STOP THE TEST IF THE EVALUEE HAS SIGNS OR SYMPTOMS OF DISTRESS OR REQUESTS TERMINATION!

The manual and materials for the CAFT can be purchased from:

Canadian Society for Exercise Physiology
185 Somerset Street West, Suite 202
Ottawa, ON
Canada K2P 0J2
tel: (613)234-3755 fax: (613) 234-3565
web site: http://www.csep.ca

CAFT step test calculation

Female, age 29, weight 105 lb (47.7 kg)

Select Factor 1 from last stepping stage completed (from table 1 in CAFT manual - cadence = 114 bpm)	67.3
Determine Factor 2 from evaluee weight and age (from table 2 in CAFT manual)	12.7
Subtract Factor 1 from Factor 2	54.6
Select Factor 4 from post exercise heart rate (from table 3 in CAFT manual)	19.4
Subtract Factor 3 from Factor 4 to get Predicted Vo_2 max	35.2 ml/kg/min

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III. COMPARISON TO WORK REQUIREMENTS

PREDICTION MODELS

Many publications have developed tables of metabolic requirements of occupational tasks. Arun Garg and Don Chaffin are two prominent researchers in this field. Their article "*Prediction of metabolic rates for manual materials handling jobs*" is an excellent resource to determine occupational workload requirements. Garg suggests that a worker can maintain 33% of aerobic capacity over 8 hours, 40 % over 4 hours and 50% for 1 hour. Other authors have published guides specific to an occupational task, but these are less helpful due to the great variation of occupational tasks.

Pragmatically however, the evaluator will not likely have the opportunity to analyze the evaluee's specific occupational workload demands. Most job descriptions will not document this data and reimbursement payments make collection of the data unfeasible. Therefore, general guidelines on occupational metabolic requirements classified by the DOT/CCDO strength requirements have most functionality for the evaluator.

KODAK WORKLOAD GUIDELINES

Workload	whole body	upper body
Light work	2.5 kcal	1.8 kcal
Medium work	3.8 kcal	2.6 kcal
Heavy work	6 kcal	4.2 kcal
Very Heavy work	7 kcal	10 kcal

OCCUPATIONAL DEMANDS

Type of Work	Net Metabolic Rate (kcal/min)
Light Hand Work	0.2
Heavy Hand Work	0.6
Light Work with One Arm	0.[illegible]
Heavy Work with One Arm	[illegible]
Light Work with Both Arms	1.2
Heavy Work with Both Arms	2.2

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RELIABILITY AND VALIDITY

The evaluator must consider if the test was performed reliably. If the test was reliable then the results *might* be valid. Secondly, consider if the Vo_2 max test performed has content validity for the occupational requirements. In most cases the evaluator will compare the results to general classification guidelines, and the content validity has been established in many research studies. However, if the occupational content has extreme heat environmental conditions (e.g., a mining occupation) then the content validity is not present, as other factors affect heat stress. In that case only a heat stress Vo_2 max test has the content validity to be entirely valid. Use of established criteria, such as the Kodak guidelines, or specific gas-exchange analysis of the occupational workload demands will determine the criterion validity.

DETECTING SUBMAXIMAL EFFORT

It is virtually impossible to give feigned effort in a Vo_2 max test. Submaximal effort will lead to the test being discontinued. The test is either performed reliably and produces valid results, or reliability problems exist and the results are invalid.

The most common threat to reliability is use of the hand rails to support some of the body weight, effectively reducing evaluee workload. Hand rails are available on step tests and treadmills as safety devices, and only light touch should be applied. The second most common threat to reliability is not keeping the set pace, effectively reducing the workload that the calculation of Vo_2 max depends on. If the evaluee cannot maintain the pace or uses hand support to reduce effective workload, then reduce the pace, or terminate the test due to reliability concerns.

ISSUES WITH THE DISABILITY EVALUATION POPULATION

Vo_2 max testing has inherent reliability problems for the disability evaluation population. The Vo_2 max test protocol requires the evaluee to perform a cardiovascular workload to their target heart rate. Many disability evaluees are deconditioned plus they have low compliance and motivation due to secondary gain issues. These evaluees have difficulty maintaining the level of exertion required in the Vo_2 max test and the test results are not valid. Those evaluees that successfully perform the Vo_2 max test fatigue from this exertion and are tired for the remainder of the FCE, causing validity problems for the remainder of the tests.

SUMMARY

The learning objective of this section was to:

- ✓ Introduce the purpose and reason for metabolic testing
- ✓ Acquaint the evaluator with submaximal methodologies
- ✓ Outline the major issues in metabolic testing

LEARNING EXERCISE:

The training session will demonstrate a step test. (continued next page)

LEARNING EXERCISE:

VO_2 max according to the test outcomes:

_____ml/kg/min

Calculate the evaluee's aerobic capacity in kcal/min:

((____ml/kg/min X _____ Kg)/1000) = ____L/min

_____L/min X 5 = _____kcal/min

Calculate the evaluee's tolerance for:

8 hours work	_____kcal/min X 33%	_____kcal/min
4 hours work	_____kcal/min X 40%	_____kcal/min
1 hour work	_____kcal/min X 50%	_____kcal/min

What strength classification does this evaluee meet for whole body work through an 8 hour day?

- ☐ Light work 2.5 kcal
- ☐ Medium work 3.8 kcal
- ☐ Heavy work 6 kcal
- ☐ Very Heavy work 7 kcal

Was this test performed reliably?

Are these results a valid representation of this evaluee's aerobic capacity?

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3. Ayoub, M. M., and Dempsey, Patrick G. "The Psychophysical Approach to Manual Materials Handling Task Design". Ergonomics, 1999, Vol 42, No. 1, 17-31.
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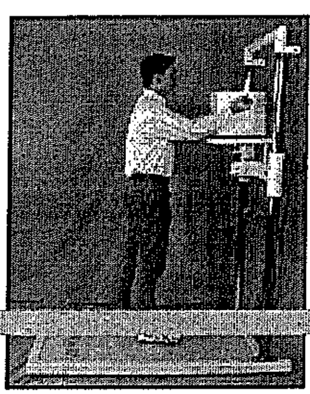
strength

I. Introduction to Strength Testing
II. Biomechanical Model (static and dynamic)
III. Metabolic Predictive Models
IV. Psychophysical Predictive Models
V. Issues in Testing and Interpretation

WHAT YOU NEED TO KNOW

- contraindications
- how to perform the test
- compare results to work requirements



I. STRENGTH TESTING

FITNESS FOR WORK

The objective of strength testing and comparison to work requirements is to ensure that the evaluee can work without undue stress, fatigue or injury. It is a challenging task. Strength testing has to measure and evaluate *multiple* components in order to be a valid predictor of ability to perform strength tasks on the job. Work strength involves diverse functional tasks, usually lifting, carrying, pushing and pulling. Each of these tasks has different biomechanical components, and within each task a number of variations may apply: size of the load, height, coupling (handles), distance from the body, friction coefficients, mechanical aids. Strength testing objectives must be utilitarian; using tests that have maximum utility across functions and biomechanical variances, in as little amount of testing time as possible. Broadly classifying the evaluee according to the DOT/CCDO strength categories is usually not sufficient information for planning a return to a specific job.

DEFINITIONS:

Static Strength Testing is measurement of force applied over time to a load cell (transducer). Force is applied via various handle couplings, placed at various heights, allowing diversified whole body/ upper body measurements.

Dynamic Strength Testing is measurement of force applied through a range of motion. This testing is accomplished with weight boxes and adjustable shelves. Various handle couplings and heights allow diversified whole body/upper body measurements.

Isometric Strength Testing is measurement of instantaneous exertion of force applied to a load cell (transducer).

Isokinetic Strength Testing is measurement of force applied at a constant speed through a range of joint motion. Anatomic stabilization and control over speed allow diversified body joint measurement. Whole body measurement is not possible.

The ***Biomechanical Model*** is the applied science describing patterns of movement and forces causing movement.

The ***Psychophysical Model*** is based on the branch of psychology dealing with the relationship between stimuli and the resultant sensations. It is applied to manual materials handling by a protocol that allows the evaluee to estimate his/her capacity to perform tasks by selecting load, frequency or range through an adjustment time period.

The ***Metabolic Model*** is based on the calculation of workload task requirements and a ratio comparison to the evaluee's maximal aerobic capacity.

MOTION FORCES

Biomechanics is the applied science that seeks to describe and explain the kinematics (patterns of movement) and kinetics (forces causing movement) of living things. The basis for static strength testing comes from research conducted at the Center for Ergonomics at the University of Michigan, under the direction of Donald B. Chaffin, Ph.D. Through this research, Dr. Chaffin and his associates have developed a norm-referenced mathematical model to predict the static rotational forces generated at specific joints for a given body posture and external load applied at the hands. The University of Michigan system is a biomechanical model in that it predicts forces within the human body based upon measurements of body position and external force acting upon the body.

STATIC STRENGTH TESTING

The original static strength model was developed through a grant from NASA to the University of Michigan in the late 1960's. Since that time the model has been revised and upgraded as additional research data has become available.

Numerous studies using this model have been published in scientific and medical journals. The original focus of application was in industrial settings where it was used to determine job safety. The model effectively computed joint rotational force requirements for a broad range of job situations, thus providing engineers and ergonomists quantifiable data with which to make judgments regarding job safety.

The University of Michigan developed a computer program based on this model called **2DSSPP**, or "Two Dimensional Static Strength Prediction Program". Unfortunately, the program itself is not easy to use as it requires tedious manual data entry. Medical professionals have become aware of this model and the potential it offers for standardized strength testing. Consequently, user-friendly software programs have been developed to automate the testing and data input process.

The University of Michigan system is a biomechanical model that predicts forces within the human body based upon measurements of body position and external force acting upon the body.

The University of Michigan program computes rotational forces that occur at each of five major body joints (ankle, knee, hip, shoulder and elbow). For this model, a joint rotational force is a force producing joint flexion or extension in the sagittal plane. Joint force results are compared to population data in order to predict the ***percent*** of the normal population ***capable*** of producing an equivalent force (the ***percent capable*** value) at each of these joints. The ability to compare evaluees to statistically reliable population norms is a key feature of static strength testing. Of particular interest is the *lowest percent capable* value computed for these joints. The assumption is that the load (rotational force) at the joint with the smallest percent capable value will be the limiting factor for a subject in the specified posture. The corresponding joint is referred to as the ***most loaded joint.***

The concept of ***percent capable*** is vital to the correct understanding and application of the results of static strength testing, and yet this term is often misunderstood. Percent capable literally means the percent of the population capable of producing an equivalent force at a given joint. High percent capable values indicate activities that do not require great strength and, therefore, are acceptable to a greater percent of the general population. Conversely, low percent capable values indicate activities that require significant strength and, therefore, cannot be performed by many individuals.

Keep in mind that rotational force is what is being quantified. This explains why the shoulder and elbow will have high percent capable numbers in lifting tasks where the arm is hanging almost straight down. In these postures, the load is being exerted in the tensile direction with little or no rotational component. Understanding this concept will help the evaluator to correlate a given lifting posture with a set of joint percent capable values, and to better interpret the results of the test to the evaluee.

Static strength testing results are compared to normative data based on the subject's height, weight and sex. Age does not affect the prediction model. Since body weight is used in the calculation of joint forces, heavier subjects tend to produce lower percent capable values than lighter subjects when lifting the same load, as lifting effort includes body weight as well as load.

If an individual is 85% capable at his or her most loaded joint, then 85% of the population is strong enough to achieve the same amount of rotational force at this joint while 15% of the population cannot achieve this much rotational force or torque.

DYNAMIC STRENGTH TESTING

Dynamic strength testing allows the evaluee to move through a range of motion while performing the test. This model more closely approximates real human tasks, however there are significant limitations to the test. Foremost is the absence of an officially recognized body of normative data, and thus the inability to compare individual performance to accepted norms. Safety concerns exist, as an acceptable load in one position may become excessive as an evaluee moves to a different position. Finally, dynamic testing equipment often isolates a single body joint, while utilizing an isokinetic (constant velocity) testing modality. Movement that is joint-specific and isokinetic does ***not*** simulate typical real-life tasks.

STATIC VERSUS DYNAMIC TESTING

The advantage of static strength testing is that there is normative data against which to compare an evaluee's performance. When performed correctly it involves the total body, using all major muscle groups to accomplish a lifting task in a similar manner to actual work situations. More importantly, it is safe. Static testing has been used for over fifteen years with an extremely low incidence of testing injury. It is simple to administer, provides consistent and reliable results, and is quite cost effective. The primary disadvantage is that most human exertion is dynamic, and thus the testing procedure does not exactly model the working environment.

To summarize, static testing provides comparisons to reliable normative data, is easy and safe to administer, and is recognized and accepted by NIOSH. Dynamic testing can compliment static testing by yielding job specific data regarding strength through a range of motion. Due to a lack of normative data, it cannot be used as a substitute for static testing and, as currently implemented, is not an inherently superior testing modality.

Static	**Dynamic**
Comparable to normative data	Models the working environment
Involves the total body	Yields job specific data
Safe	
Simple to administer	
Recognized and accepted by NIOSH	

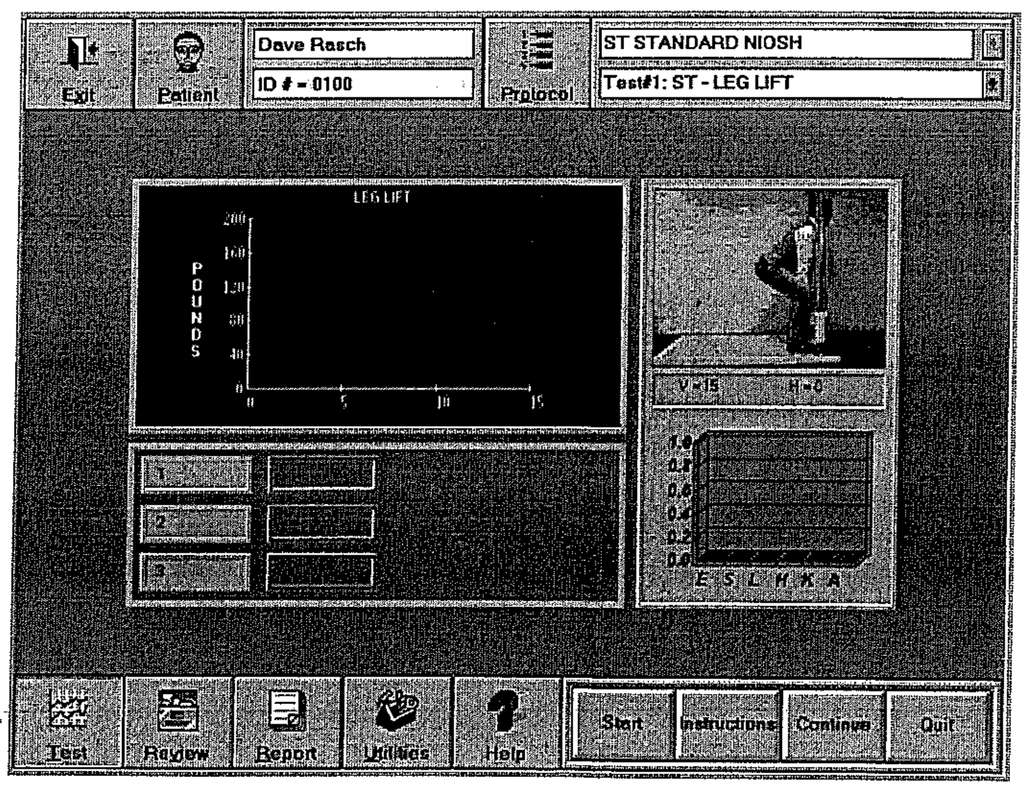
strength

PERFORMING A STATIC STRENGTH TEST

The ARCON Static Strength Test (ARCON ST) simplifies whole-body static strength testing through the use of real-time computer measurement. In addition, ARCON's software provides an automatic link to the University of Michigan's 2DSSPP modeling program to provide the flexibility to perform almost any type of job task simulation with accuracy and speed. The ARCON ST lifting platform adjusts to accommodate posture used for lifting, pushing or pulling. The evaluator can obtain consistent and reliable results which, in the past, may have been difficult to achieve using manual testing methods with cable tensiometers.

The ARCON ST can be used to:

- ☑ Quantify whole-body static strength in any posture.
- ☑ Perform pre-employment strength testing with comparisons to job requirements.
- ☑ Compare an individual's static strength levels to population norms.
- ☑ Analyze specific jobs to determine if they are safe.
- ☑ Objectively chart progress of an evaluee during work hardening and/or rehabilitation.
- ☑ Instruct evaluees in biomechanically safe lifting techniques.



PERFORMING A STATIC STRENGTH TEST

Have the evaluee "practice" the test by assuming the correct posture, grasping the handles, and exerting a ***light*** force for a short period of time. In order to avoid fatigue don't have the evaluee practice at a high level of exertion.

When the evaluee fully understands the instructions for this test, have him or her assume the proper posture on the platform, but do ***not*** have the evaluee grasp the handles yet. When the system is ready have the evaluee should grasp the handles and start lifting. The actual measurement does not start until the system senses force on the handles, so there is no need to have the evaluee rush to start the lifting test.

A standard lifting trial is performed for ***five*** seconds. Have the evaluee ***gradually*** build up force to their ***maximum*** capability over the first ***two*** seconds, and then ***hold*** that force to the best of his/her ability for the next ***three*** seconds. This may require some verbal encouragement on the part of the evaluator, especially for evaluees that are not highly motivated. A "beep" will sound at the end of five seconds, and the evaluee should ***stop lifting*** and relax.

Under no circumstances should an evaluee ever "jerk" the handles, or attempt to exert forces beyond what they can safely sustain. If an evaluee experiences significant pain, they should immediately reduce their exertion force to keep pain at a manageable level.

At the end of each trial the average lifting force will be displayed in the appropriate "trial" box at the bottom of the screen. The computer also starts a count-down timer to allow the evaluee a rest period to recover (muscle recovery from the fatigue of an extended isometric lift).. The computer will "beep" to signal that it is ready to measure the next trial.

When all three trials are completed, the test is complete and the ***coefficient of variation*** for the three trials will be displayed. For static testing, a coefficient of variation of 14% or less is considered a valid test. However, there is an option to repeat any of the three trials if they were performed incorrectly (e.g., the evaluee released the handles too soon).

Once the patient has completed the test a panel showing average force, coefficient of variation, and average ***peak*** force is displayed. Also, a "Norms" button will appear to optionally calculate joint ***percent capable*** values for this evaluee using the University of Michigan's **2DSSPP** program.

PERFORMING A DYNAMIC STRENGTH TEST

The **ARCON LC Dynamic Lifting Capacity Test** is a standardized progressive lifting evaluation designed to determine an evaluee's maximum safe frequent and/or occasional lifting capacity. The LC is based on the PILE (Progressive Isoinertial Lifting Evaluation) functional testing methodology published in SPINE magazine Volume 13, Number 9, 1988.

The **ARCON SPOT Dynamic Functional Capacity Test** is a job-specific work simulation designed to determine an evaluee's capability to perform a specific task. The SPOT protocol involves the expenditure of work at a predetermined rate over an extended period of time utilizing a job-specific posture, load, and pattern of movement. The SPOT test has been designed by Brent Ruiz, Ph.D., of the Professional Prevention Corporation. The abbreviation **SPOT** stands for **S**imulated **P**hysiological **O**ccupational **T**olerance. Because this test is job-specific, there are no norms. The evaluee receives either ***Pass*** or ***Fail*** rating.

Both the LC and the SPOT utilize ARCON's wireless heart rate transmitter to continuously monitor an individual's physiological response to work. This is done both for safety (tests are terminated or suspended if heart rate exceeds safe levels), and for validity (to determine if the individual is working to capacity).

LC DYNAMIC STRENGTH TEST

The LC test consists of one or more lifting tasks, with each task structured as a progressive series of lifts with increasing loads. The goal of the test is to determine an evaluee's maximum safe lifting capacity for each task and, from that data, to predict ***frequent lifting capacity.***

The LC protocol involves lifting a weighted "crate" from a starting level to a shelf at a higher level, then returning it to the starting level.

The three "standard" lifts, in order of increasing difficulty, are:

- ☑ Knuckle to Shoulder (lifting without bending)
- ☑ Floor to Knuckle (lifting with bending)
- ☑ Floor to Shoulder (full vertical work plane)

Each lift is performed repeatedly with increasing weight until a maximum safe limit is reached. The lifts performed at each weight level are called a **cycle**, with a normal increase of 10 pounds per cycle for men and 5 pounds per cycle for women.

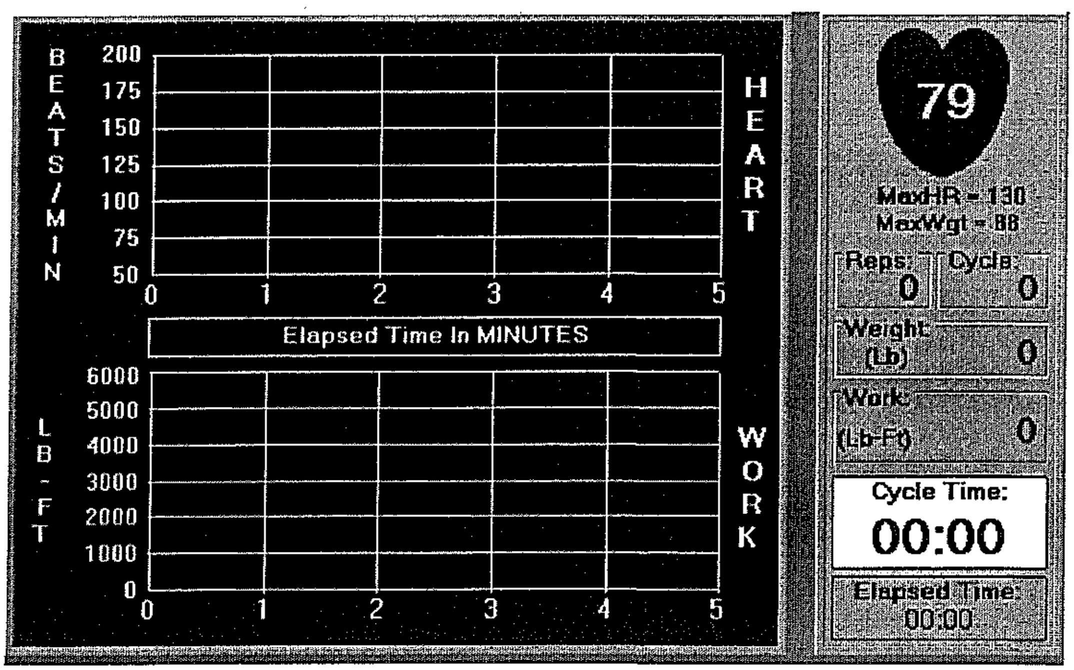
LC DYNAMIC STRENGTH TEST

If the LC is being used as a post-offer placement test, it is recommended that the evaluator attempt to correlate one of the above protocols with the lifting requirements of the job. If the LC is being used for return-to-work testing or impairment evaluations, then the evaluator should correlate the LC protocol to the evaluee's area of injury as follows:

- ☑ Knuckle to shoulder for upper extremity and cervical injuries.
- ☑ Floor to knuckle for lower extremity and lumbar injuries.
- ☑ Floor to shoulder as additional testing sequence for either above.

Safety is of prime importance in the LC test and the test will be terminated if any of these three limiting factors (also called ***endpoint conditions***) are achieved:

- ☑ **Psychophysical** - evaluee perceives load as being too heavy
- ☑ **Physiological** - heart rate exceeds 75% of age-adjusted maximal heart rate for one minute, or exceeds 85% of age-adjusted maximal rate at any point in test
- ☑ **Safety** - load exceeds 101 pounds or 55% of evaluee's adjusted body weight, or intervention by evaluator based on observation of unsafe lifting mechanics



Continuous monitoring of evaluee heart rate is an important feature of the LC test, both as a safety factor and as a reliable indication of physiological response to work. Should heart rate increase significantly at low work loads, the evaluee is alerted to a potential limitation in cardiovascular work capacity. Conversely, if heart rate does not increase significantly, but the evaluee indicates that he/she is unable to continue (e.g., load limit or pain), this may be an indication of symptom magnification.

Prior to starting the test, prepare the evaluee by attaching the wireless heart rate transmitter.

Start with the ***empty*** weight basket at the ***lower*** level of the test (***floor*** for "Floor to Knuckle" and "Floor to Shoulder", and ***lower shelf*** for "Knuckle to Shoulder). Show the evaluee the correct lifting posture (squat rather than bend for floor level lifts), how to grasp the handles, and how to move the basket from the lower level to the upper level and back again. The evaluee should move one foot ***forward*** as the basket is placed on the shelf, and ***back*** as the basket is removed (avoid ***leaning*** forward or ***extending*** the arms - these place high stress on the low back). Proper lifting mechanics are important for the ***safety*** of the test, and to provide the evaluee with the opportunity to lift to his or her maximum ability.

On the ***first*** lift of each cycle the basket is raised to the upper shelf and ***released***. This allows the system time to ***weigh*** the basket. The timer stops during weighing, so that the lifting cycle time is not affected. When the operator has verified that the basket has been weighed correctly (if not, the basket can be ***re-weighed*** by pressing the **Enter** key), the patient is instructed to ***remove*** the basket and to ***complete*** the lifting cycle without stopping. For standard LC tests (4 lifts per cycle) this means lowering the basket, then performing ***three*** more lifts without stopping. To avoid delays, the evaluee's hands should remain close to the handles after releasing the basket.

To prevent ***rushing***, each lift is performed on a ***4-count*** (approximately 4 seconds). On count 1, the evaluee lifts the basket to shelf height, keeping the basket close to the body. On count 2 the evaluee steps forward and places the basket on the shelf. On count 3 the evaluee removes the basket and steps back. On count 4 the evaluee lowers the basket to the starting point. The evaluee should ***practice*** the correct lifting motion and cadence with the empty basket several times. The evaluee should understand that for a frequent test, the goal is to complete exactly ***four*** lifts in the twenty second cycle period, then stop (for an infrequent test the goal is one lift in ten seconds).

At the end of each lifting cycle the system starts a 20-second rest period and displays a dialog box to allow to record the evaluee's response to lifting that amount of weight. The evaluee is asked to rate the **Perceived Load** (how ***heavy*** the basket was). The final step of the rest period is to ***add more weight*** to the basket. The normal weight increase is 10 pounds (5 pounds for women) per cycle. The LC test will continue from cycle to cycle, with the evaluee lifting heavier loads each cycle, until one of the following endpoint conditions occurs.

Psychophysical: Voluntary test termination by the evaluee based on complaints of fatigue, excessive discomfort or an inability to perform lifting movements as required. A psychophysical endpoint is also triggered if the evaluee's ***perceived load*** is **8** (very heavy) or **9** (too heavy).

Physiological: Achievement of an age determined target heart rate (based on an age-adjusted ***maximal*** heart rate of **220 - age**). A physiological endpoint will result if either of these conditions occur:

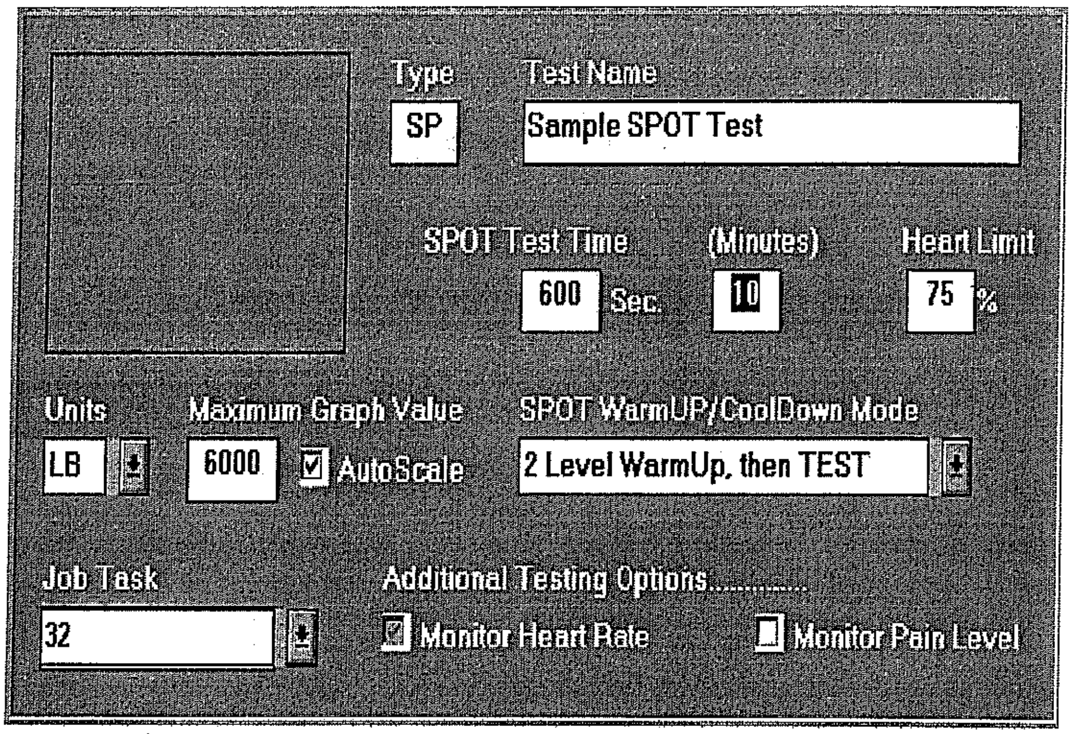
- ☒ If the evaluee's heart rate exceeds 85% of the age-adjusted maximal rate.
- ☒ If the evaluee's heart rate exceeds 75% of maximal during a lifting cycle, the start of the next cycle will be delayed until the heart rate drops below 75%. Test is terminated if rate exceeds 75% for ***one minute.***

Safety: For safety, the test will be limited to approximately 101 pounds or 55% of the evaluee's adjusted body weight, whichever is less. Once an evaluee exceeds 100 pounds, they achieve a ***Very Heavy*** lifting capacity rating (the highest category in the DOT ***physical demand characteristics of work***). There is no point in testing beyond this level. In addition, at any point during the test, the evaluator can stop the test if there is a question about the evaluee's ability to SAFELY continue. This would include uncorrected high-risk lifting mechanics, or overt symptoms of distress.

THE SPOT TEST

The SPOT test is a job-specific dynamic evaluation. The goal of the test is to have an evaluee perform a job simulation by lifting and/or carrying a predetermined load at a predetermined rate for an extended period of time (usually 15 to 20 minutes). There are only two possible results for a SPOT test - the evaluee completes the test (a **Pass** result), or the evaluee cannot complete the test (a **Fail** result). While the test is being performed, it resembles an LC test with one very long lifting cycle.

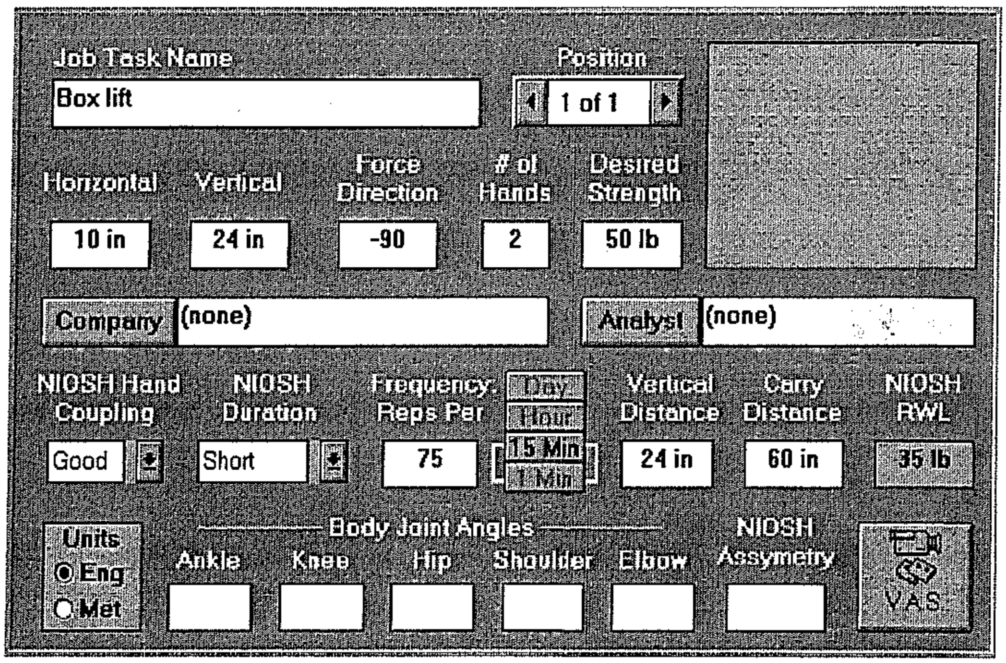
In order to perform a SPOT test, the evaluator must create a job-specific SPOT Test Record (sample below) which is linked to an appropriate Job Task Description



A SPOT test has a **Test Time** that may be specified either in seconds or minutes (entering one will automatically set the other). The **Heart Limit** works the same as in the LC test. In this case, if the evaluee's heart rate exceeds 75% of his or her age-adjusted maximum for more than one minute the test is terminated. **Units** and **Maximum Graph Value** have the same meaning as in all other tests. The **SPOT WarmUP/CoolDown** mode is used to select an appropriate warm-up and cool down cycle for this test. Options include ***no*** warm-up or cool down for light loads, and ***one*** or ***two*** cycles of warm-up with a cool down for heavier loads. Finally there is a **Job Task** link to provide a ***description*** of the job being simulated.

THE SPOT TEST

For a SPOT test, the ***only*** fields that are applicable are as follows: **Horizontal** and **Vertical** indicate the starting position for the lift, measured in inches from the floor, midpoint between the evaluee's ankle bones to the midpoint between the hands. **Desired Strength** is the weight of the load, in pounds, being lifted and/or carried (in this example, 50 pounds). **Frequency** is the rate at which the work task is performed, and is entered as ***repetitions per 15 minutes*** (the evaluator may need to do some calculations for this - in the above example, 75 reps per 15 minutes is the same as 5 reps per minute). **Vertical Distance** is the distance the load is lifted (or lowered) to its final position, and **Carry Distance** is the distance the load is carried to its final position. These are both entered in inches. The other fields are ***not*** used for SPOT tests, but may be used to optionally compute the NIOSH Recommended Weight Limit (RWL) for this job. Be aware that the RWL is a ***guideline*** that applies to a ***job***, not to an ***individual***.



Set the scale shelf at the ***ending*** height for this task, and set up another shelf or table (or area if the test starts at the floor) at the ***starting*** height. Place the object being lifted (should be the same size and weight as required by the job) in the starting position. The evaluator may need to measure and set a carry distance in order to properly place the starting position. If the actual work task involves varying heights and distances, use the ***average*** height and distance for your SPOT test. Each lift will involve moving the object from the ***starting*** position to the ***ending*** position and ***back again***, so use ***half*** the actual carry distance in your SPOT setup. Make sure the evaluee can move in an unobstructed manner.

Attach the heart rate transmitter to the evaluee as explained in the section on the LC test. Have the evaluee practice the lifting and carrying task from the starting position to the scale (ending position) and back again.

As with the LC test, a message will instruct the evaluator to have the evaluee place the object on the scale and to release it so that it can be weighed. If this is a warm-up cycle, the warm-up weight will be indicated, otherwise the actual testing weight will be specified. Once the object is weighed, instruct the evaluee to continue by returning the object to the starting position, and to rest until the next lift is to be performed. When the timer indicates ***NOW***, instruct the evaluee to perform the next lift (to the scale and back to the starting position). The evaluator may want to set the starting position so that the evaluee can observe the screen so as to be able to watch the timer and pace themself.

Each warm-up or cool down cycle lasts for one minute, after which the weight of the object should be adjusted. The actual test cycle lasts for the duration specified in the SPOT Test Record. When all cycles have been completed, the SPOT test is done.

The SPOT test continues for a fixed time unless one of the following occurs:

- ☒ The evaluee cannot continue (**Psychophysical** endpoint).
- ☒ The target heart rate is exceeded (**Physiological** endpoint).
- ☒ The operator stops the test for safety reasons (**Safety** endpoint).

If any of these occur , the test result will be ***Fail***. Otherwise the test will run to completion and the result is ***Pass***.

III. METABOLIC PREDICTIVE MODELS

WORK CAPACITY

The chapter on Work Physiology introduced the metabolic model, which compares an evaluee's aerobic capacity to work requirements. The metabolic model is important for strength testing, and should not be disregarded. Unfortunately, established dynamic or static lift protocols do not use heart rate monitoring beyond safety criteria, for to do so would require calculation of the metabolic workload. Workload calculation is extremely complex and requires computerized calculation to be done efficiently. Metabolic workload calculation has been incorporated into the ABLE (Aerobic Biomechanical Lifting Evaluation) protocol undergoing research at Virginia Commonwealth University.

CALCULATING WORKLOAD DEMANDS

Workload demands of a task are calculated based on the evaluee's body size (weight), the weight, height and horizontal distance of the lift, gender criteria and lift duration and frequency.

(LLiftMD) Low Lift Metabolic Demand = ((0.514*Kg. Body Weight)*(0.81-Lower Lift Height))+((2.19*(Kg. Weight Lifted)+(0.62*Gender Factor)*(Kg. Weight Lifted))*(0.81-Lower Lift Height)))/100

(HLiftMD) High Lift Metabolic Demand = (((0.062*Kg. Body Weight)*(Upper Lift Height-0.81))+((3.19*(Kg. Weight Lifted)+(0.52*Gender Factor)*(Kg. Weight Lifted))*(Upper Lift Height-0.81)))/100

(LLowMD) Low Lower Metabolic Demand =(((0.511*Kg. Body Weight)*(0.81-Lower Height))+((0.701*(Kg. Weight Lifted))*(0.81-Lower Height)))/100

(HLowMD) High Lower Metabolic Demand =(((0.093*Kg. Body Weight)*(Upper Height-0.81))+((1.02*(Kg. Weight Lifted)+(0.37*Gender Factor)*(Kg. Weight Lifted))*(Upper Height-0.81)))/100

(LHMD) Low Horizontal Weight Movement Metabolic Demand = ((0.112*Kg. Body Weight)+(1.15*(16*0.0254))+0.505*Gender Factor *(Kg. Weight Lifted*0.4))/100

(HHMD) High Horizontal Weight Movement Metabolic Demand = (16*0.0254)*((0.086+(0.036*(Kg. Weight Lifted*0.4))))

Lift and Lower Floor to Knuckle Task Metabolic Demand =(1.824*TaskDuration+(Frequency*(*LLiftMD*+*HLiftMD*+*LLowMD*+*HLowMD*+*LHMD*+*HHMD*)))/TaskDuration

strength

IV. PSYCHOPHYSICAL PREDICTIVE MODELS

INTRODUCTION

The psychophysical model of strength testing has been well validated over the past thirty-five years. An evaluee is allowed an adjustment period to alter weight or frequency, and via practice estimate their capacity through an 8 hour workday. Research has demonstrated that the rates or loads estimated in 20-40 minutes can be predictive of ability through an 8 hour day based on concurrent validity studies. Slower rates (< 4.3 lift-lowers/minute) have greater predictive validity than faster rates.

METHODOLOGY

Psychophysics is the relationship between stimuli and the resultant sensations. It is applied to manual materials handling by a protocol that allows the evaluee to estimate his/her capacity to perform tasks by selecting load, frequency or range through an adjustment time period. Snook developed a large database for designing lifting, lowering, pushing, pulling and carrying tasks for men and women. Ayoub developed a database applicable to six ranges of lifts and lowers. Mital published a database of three ranges of lift, three box sizes and frequency ranging from one to 12 lifts per minute for eight hour work shifts.

PROS AND CONS

The advantages of the psychophysical model include the following:

- ☑ psychophysics allows realistic simulation of work
- ☑ there is considerable psychophysical data in the literature
- ☑ psychophysics accounts for biomechanical and metabolic factors

The disadvantages are:

- ☒ psychophysics is subjective method and secondary gain issues may lead to an underestimation of capacity
- ☒ Psychophysical results for high frequency tasks may exceed metabolic criteria
- ☒ Some psychophysical results may exceed biomechanical criteria
- ☒ 20-40 minutes of testing time per criterion is not feasible in a functional capacity evaluation

V. ISSUES IN TESTING AND INTERPRETATION

INTRODUCTION

Strength testing is an important facet of Functional Capacity Evaluation. The evaluator should be sensitive to the advantages and disadvantages of each type of test available on the following traits:

- ☒ One dimensional testing has diminished validity considering the multi-dimensional nature of occupational strength tasks.
- ☒ Empirical research based on static and dynamic testing protocols has only 'occasional' and 'frequent' lift frequency comparisons on limited ranges of motions, reducing the utility of this testing when evaluating specific occupational tasks.
- ☒ Submaximal effort rating has demonstrated equivocal results in research

DETECTING SUBMAXIMAL EFFORT

Static strength testing allows coefficient of variation (CoVar) for detection of maximal effort. Interpretation of the CoVar should be used cautiously as research has both supported the CoVar as identifying submaximal effort and shown CoVar *not* being sensitive to submaximal effort. If the evaluee has any impairment that might affect medical stability of the musculoskeletal system under load then it is not a valid indicator of submaximal effort.

The PILE test has established the ratio of strength based on horizontal distance of the load away from the body. This submaximal effort rating system is a human engineering model, cross validated to the original research data. If the evaluee has any impairment that might affect medical stability of the musculoskeletal system under load then 'horizontal validity' may not be a valid indicator of submaximal effort.

More detailed analysis of submaximal effort is contained in the 'Evaluee Reliability' section.

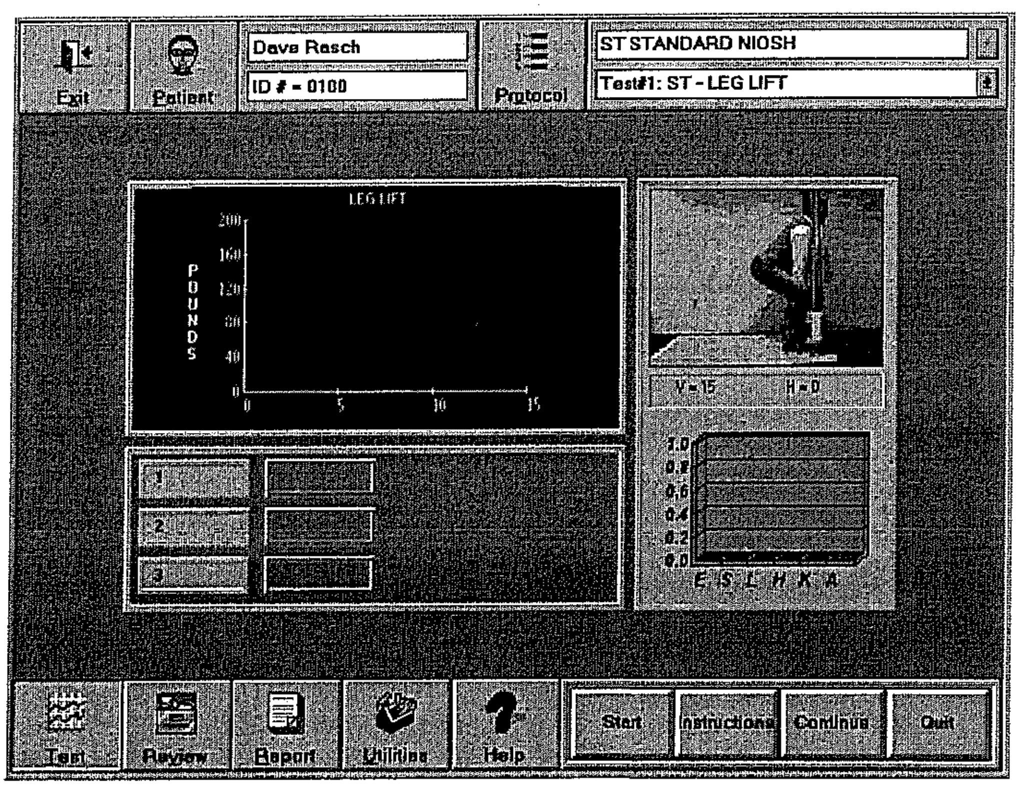
SUMMARY

The learning objective of this section was to:

- ✓ Introduce the purpose and reason for strength testing
- ✓ Acquaint the evaluator with biomechanical, metabolic and psychophysical methodologies
- ✓ Outline the major issues in strength testing

LEARNING EXERCISE:

The ARCON ST strength protocol will be demonstrated.



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