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A RELIABILITY AND VALIDITY STUDY OF THE BALTIMORE THERAPEUTIC EQUIPMENT WORK SIMULATOR AT LIGHT, MEDIUM AND HEAVY WORK INTENSITIES

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "**A RELIABILITY AND VALIDITY STUDY OF THE BALTIMORE THERAPEUTIC EQUIPMENT WORK SIMULATOR AT LIGHT, MEDIUM AND HEAVY WORK INTENSITIES**" submitted by **Lorian Kennedy** in partial fulfillment of the requirements for the degree of **Master of Science.**

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ABSTRACT

Thirty male volunteers (18 - 35 yrs) participated in three laboratory sessions to determine test-retest reliability and criterion validity of the Baltimore Therapeutic Equipment Work Simulator (BTE). Following a preliminary session during which peak oxygen consumption was measured using arm ergometry, the subjects performed three repetitive, upper extremity criterion tasks which were subjectively classified by three experienced physical work evaluators as light (CL), medium (CM), and heavy (CH) levels of intensity and then three corresponding simulated tasks (SL, SM, SH). The criterion tasks and the simulated tasks were performed in the second and third sessions for five minutes each until steady state was obtained. Oxygen consumption ($\dot{V}O_2$), and heart rate (HR) were monitored continuously. The Rating of Perceived Exertion (RPE) was obtained at the end of each criterion task.

Correlations between trials of the same task for $\dot{V}O_2$ ranged from r = 0.74 - 0.87 and for HR from r = 0.59 - 0.78. These were significant and indicated test-retest reliability. Post hoc examination of the analysis of variance of the mean values of these revealed no significant differences between trials for both these variables.

All criterion-simulated correlations were significant. CL-SL correlations for $\dot{V}O_2$ were r = 0.81 and 0.83; for HR r = 0.88 and 0.95, indicating high criterion validity at light work intensity. CM-SM correlations for $\dot{V}O_2$ were r = 0.56 and 0.52; for HR r = 0.91 and 0.92. The lower $\dot{V}O_2$ correlations may be related to the nature of the task which was above the shoulder level. CH-SH correlations for $\dot{V}O_2$ were r = 0.68 and 0.75; for HR r = 0.91 and 0.90. $\dot{V}O_2$ values were significantly different between light, medium and heavy work intensities except for SM and SH. Criterion-simulated post hoc comparisons for $\dot{V}O_2$ revealed a lack of similarity between CH - SH. It appears that the subjects underestimated the amount of resistance required on the BTE to simulate the heavy criterion tasks. Similar comparisons for HR revealed a lack of similarity between both CM - SM and CH - SH. Caution is urged in making judgments about the subject's abilities to do "real" work at medium and heavy intensities based on test results from the BTE.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Growing numbers of disabled individuals require appropriate assessment, treatment and placement in the work force. Statistics Canada (1983) has pointed out that while Canada's population is among the youngest in the industrialized nations, the trend is toward an increasing number of older people, with a predicted increase of 3% in the working age population (15-64 years) between 1976 and 2001. Along with the higher proportion of people reaching old age, more people will be affected by the types of disabilities which cause long-term problems. In order of prevalence these are: arthritis and rheumatism, disorders of back, limbs and joints, hay fever and other allergies, skin allergies and skin disorders and dental trouble. Nearly half a million Canadians (2% of the population) "are so severely disabled that they cannot carry out a major activity such as work, attending school or housework. Of those, over 300,000 are from 15 to 64 years old" (p. 12). Shephard (1987a) has concluded that by the age of 65 years, 25% of the labour force will fall substantially below the supposed population average on physiological test scores due to chronic disease. The cost of lost productivity both to these people in their individual lives and to society as a whole is significant and the cost of providing financial support will fall on insurance companies and taxpayers.

These disabled people will require a variety of health services which must be provided out of limited health care resources. It is essential that these resources be used efficiently and effectively. Occupational therapy has a unique contribution to make in linking medical services and the world of work (Brintnell & Harvey-Krefting, 1986). One of the important roles of occupational therapists is assessing the ability of injured or disabled individuals to return to the work force (Bear-Lehman & McCormick, 1985-6; Harvey-Krefting, 1985; Marshall, 1985a, 1985b). The occupational therapist uses a framework which recognizes the individual's complex nature and his or her interaction with the environment. One model of this process used by many occupational therapists is the Model of Occupational Performance (Health and Welfare Canada, 1983). It outlines the integrated components which comprise the individual (spiritual, physical, sociocultural, and mental) and his or her areas of occupational performance in leisure, self-care and productivity relationships set in the context of a social, cultural and physical environment.

By involving the disabled worker in general activities, the therapist is able to observe basic physical, mental and social skills as well as work habits necessary for the performance of any type of job and to determine such things as manual skills, dexterity, reasoning and judgment, ability to share tools and equipment, punctuality and safety awareness. In specialized work evaluation settings, standardized tests and work samples may be used, and on-site job analysis, work simulations and situational assessments may be done (Brintnell & Harvey-Krefting, 1986). Most of these assessments require the therapist to rely on subjective judgment with observations of objective behavior in poorly standardized situations.

Occupational therapists and others interested in work evaluation in rehabilitation settings frequently use simulated work in order to evaluate physical performance on specific tasks (Beauchamp, Creighton & Summers, 1984; Bettencourt, Carlstrom, Brown, Lindau, & Long, 1986; Birman & Zohman, 1971; Caruso & Chan, 1986; Caruso, Chan, & Chan, 1987; Licter, Hewson, Radke, & Blum, 1984; Matheson, Ogden, Violette, & Schultz, 1985; Wilke & Sheldahl, 1985). Work simulation provides an opportunity to observe the worker performing specifically designated tasks involving both mental and physical processes. Such simulations are useful for both evaluation and therapy to allow the retraining of specific movements, to improve speed and accuracy and to establish endurance, however, they lack many of the basic attributes which would allow the establishment of predictive validity, such as repeatability and inter-rater reliability.

Recently occupational therapists have begun to consider physiological measures such as oxygen consumption ($\dot{V}O_2$), heart rate (HR), blood pressure, and perceived exertion scales, in conjunction with work simulation in order to improve objectivity. While this is a major step towards scientific rigor, the task simulations have still not been standardized (Beauchamps et al., 1984; Shanfield, 1984; Wilke and Sheldahl, 1985). While simulations are useful to test the individual's abilities to perform varied physical tasks, particularly over lengthy periods of time, the lack of standardization has made it difficult to assess the reliability[1] and validity[2] of the data.

The importance of selecting the appropriate means of measuring work load is emphasized in studies comparing arm and leg ergometry, and the many differences between work which primarily involves either the arms or the legs. This is dealt with in more detail in Chapter II.

Valid and reliable measurement instruments are a requirement of scientifically based professional practice (Hopkins & Smith, 1983; Nottrodt & Celentano, 1984; Smith, Cunningham & Weinberg, 1986). Objective, reproducible methods must be used in assessment wherever possible. Yet clinicians face a serious dilemma in the field of work evaluation: although there are numerous tests and countless possible ways of simulating work, very few of these meet the criteria for scientific rigor and utility which is required in measurement tools. As outlined by Law (1987), assignment of a quantifiable value to an attribute or characteristic permits a mathematical evaluation of these attributes in a standard manner and facilitates the comparison of individuals. Yet the careful standardization which is necessary to achieve reliable quantifiable values is lacking. Instruments must be sought out which can simplify this process. Tools which can provide objective measurements of complex movement patterns are particularly valuable as they allow a means of measuring changes in the individual and form a foundation from which predictive validity can eventually be established.

One device which has the potential to provide objective, quantifiable data is the Baltimore Therapeutic Work Simulator™ (BTE). It is a commercially produced device which has been "designed to provide for specific repetitive upper limb motions against measurable resistances over a measurable period of time" (Curtis, Clark, & Snyder, 1984, p.905). The instrument simulates a wide variety of movements in different planes with different attachments. There are two primary components: a controlled resistance assembly with seventeen attachments and multiple positions; and a micro-processor which allows the selection of the desired resistance level and monitors performance. Work is recorded in inch-pounds, and exercise time is measured

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1 Mitchell(1979) describes reliability as follows. "A reliable instrument is one with small errors of measurement, one that shows stability, consistency, and dependability of scores for individuals on the trait, characteristic or behavior being assessed" (p. 136). "Test-retest reliability is the degree to which scores are stable or consistent over time". (Currier, 1984, p.161).

2 Validity "represents the degree to which the instrument measures the intended characteristic, not another related characteristic" (Law, 1987, p. 136.). More specifically, criterion validity is the degree to which the measurements obtained by the instrument agree with another more accurate measure of the same characteristic, that is, a criterion or gold standard measure (Nunnally, 1978).

automatically allowing calculation of power output in watts and in Engals[3]. Isometric strength can be measured and dynamic exercise can be graduated. Theoretically, by setting up tasks which simulate the "real" world, functional disability can be evaluated and the client can be assessed and trained for entry to the work world.

Physical work has been classified according to its intensity to make it easier to describe and to facilitate the fit between the worker and the job. One system familiar to occupational therapists is that used by the Canadian Classification and Dictionary of Occupations (1986) which divides work into five categories (sedentary, light, medium, heavy, and very heavy) according to the strength required for lifting, carrying, pulling and pushing. More detail on this and other systems is given in the "Operational Definitions" section later in this chapter and in Chapter II.

The Problem

Occupational therapists are increasingly recognizing the importance of the use of standardized measurements in their clinical practice (Law, 1987). However, at the present time, there are few measurement tools in the field of physical work assessment and work simulation which have been shown to meet the scientific criteria of reliability and validity. Therapists are forced to create work simulations in order to judge the client's abilities or to use unproven test batteries. While these are useful in providing subjective information and may have good face validity, more scientifically evaluated tools are required. Only with a solid foundation of reliable and valid measurement tools can therapists begin to research the most effective and efficient treatment techniques and attempt to successfully predict which workers can safely handle real work tasks. The BTE has the potential to be such a tool.

Rationale and Objectives of the Study

Many rehabilitation programs are utilizing the BTE for both testing and treatment (Baxter & Fried, 1984, Bear-Lehman & McCormick, 1985; Berlin & Vermette, 1985; Blair, McCormick, Bear-Lehman, Fess, & Rader, 1987; Curtis & Engalitcheff, 1981; Curtis et al., 1984) despite its high initial cost (approximately $35,000). However, its reliability and validity have not yet been established. The limited amount of research

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[3] As the quantities of power produced are small this unit was invented as more appropriate to the human hand. One Engal equals the effort required to move a load of one inch-pound one degree in one second (0.00197 watts).

conducted with the BTE has not addressed this issue (Curtis et al., 1984; Curtis & Engalitcheff, 1981; Berlin and Vermette, 1985; Wolf, Klein and Cauldwell-Klein, 1987). Therefore research to test the assumptions being made about the BTE's test-retest reliability and criterion validity was needed.

The BTE provides useful objective data (force, distance and power); however, the same variables are not easily obtainable on "real" tasks for the purposes of comparison. In order to make comparisons, other reliable and valid measures were required which could be obtained in both the real and simulated tasks. Physiological measurements such as heart rate (HR) and oxygen consumption ($\dot{V}O_2$), both of which have established reliability and validity (Astrand & Rodahl, 1986, pp. 491, 493), can be generated under both conditions providing an indirect method of comparison. If the simulation on the BTE is accurate, these two sets of measurements should be quite similar and therefore, highly correlated.

The objectives of the study were therefore to determine the test-retest reliability and criterion validity of the BTE in simulating repetitive tasks at three levels of work intensity (light, medium, and heavy). The following research questions were posed:

1) Were the measurements of $\dot{V}O_2$ and HR obtained while participants performed criterion tasks reliable at each of the three intensities of work?
2) Were the measurements of $\dot{V}O_2$ and HR obtained while participants performed simulated tasks reliable at each of the three intensities of work?
3) Was there a close correspondence, demonstrating validity, between the measurements of $\dot{V}O_2$ and HR that were obtained on the simulated tasks with the BTE, and those obtained on the criterion tasks, at each of the three levels of work?
4) What was the relationship between work intensity as measured by the RPE, and level of work during the criterion tasks?

Operational Definitions

Work Simulation

An artificial task set up to mimic as closely as possible for the purposes of evaluation or training the physical attributes and demands of a task performed in a productive work setting. The work simulation may be performed in a variety of occupational settings and with a variety of tools, equipment and supplies.

Criterion task

An activity performed by the subject in a standardized manner using weights and/or objects from the work environment.

Simulated task

An activity performed on the BTE by the subject in a standardized manner controlling resistance and direction of movement in order to imitate as closely as possible the physical attributes and demands of a criterion task as judged by an expert judge.

Canadian Classification and Dictionary of Occupations (CCDO)

This dictionary and classification system contains listings of over 7,000 Canadian job titles with their associated task descriptions, worker functions, physical activities, environmental conditions, general educational development, specific vocational preparation, aptitudes, interests and temperaments involved or required (CCDO, 1986). The counterpart of the CCDO in the United States of America is the Dictionary of Occupational Titles (DOT). Further information is given in Chapter II.

Categories of Work

The three categories of work used in this study as defined by the CCDO (1986) were:

> Light Work (L)
> Lifting 20 lbs. maximum and occasionally lifting and/or carrying of objects weighing up to 10 lbs. Even though the weight may be only a negligible amount, an occupation is in this category (a) when it requires walking or standing to significant degree, or (b) when it involves sitting most of the time with a degree of pushing and pulling of arm and/or leg controls.
>
> Medium Work (M)
> Lifting 50 lbs. maximum with frequent lifting and/or carrying of objects weighing up to 20 lbs. Consideration of (b) under "light work" may apply here.
>
> Heavy Work (H)
> Lifting 100 lbs. maximum with frequent lifting and/or carrying of objects weighing up to 50 lbs.

Steady State

Steady state is the physiological condition under which the heart rate, cardiac output and ventilation have achieved relatively constant levels. During steady state work , the oxygen uptake corresponds to the demands of the tissues and no lactate accumulates in the body. This state is generally achieved after two to three minutes of continuous work during which the oxygen transporting system adjusts to the work load (Astrand & Rodahl, 1986, p.299). Higher intensities may require somewhat longer.

Oxygen consumption ($\dot{V}O_2$)

Oxygen consumption in liters per minute measured during the last 60 seconds of performing a criterion or simulated task under steady state conditions.

Peak oxygen uptake ($p\dot{V}O_2$)

Highest rate of oxygen uptake observed during arm exercise, measured in liters per minute.

Heart Rate (HR)

Heart rate measured in beats per minute (bpm) during the last 30 seconds of performing a criterion or simulated task under steady state conditions.

Rating of Perceived Exertion (RPE)

A subjective estimate of the degree of physical strain as indicated on the 15-point interval scale devised by Borg (1982). (See Appendix A.) Further details are in Chapter II.

Resistance Level Selected on the BTE (EX. LEVEL)

The numerical level set on the BTE console which determines the amount of resistance on the tool. These are ordinal units.

Expert judge

A professional who has worked in the field of work evaluation for a minimum of two years.

CHAPTER II

LITERATURE REVIEW

The literature was reviewed to examine ways in which the physical work capacity of the individual has been evaluated in vocational evaluation settings. Types of evaluation can be divided into work simulations and commercial vocational evaluation systems. The use of physiological measurements such as $\dot{V}O_2$ and HR is discussed, as well as psychophysical methodology, such as the RPE scale. Work classification systems which describe the workload rather than the work capacity are reviewed and the importance of the appropriate use of arm ergometry is discussed.

Work Simulation in Rehabilitation Settings

General work simulation is often used in treatment programs as part of larger programs dealing with clients or patients and their rehabilitation. Sometimes it is focused on particular disability groups with more detailed and sophisticated application. The latter kind of work simulation is often used with cardiac patients.

Birman and Zohman (1971) described a work simulation program used in assessing the readiness of coronary patients to return to their regular jobs. Following an assessment of the patient's job "a 'mock' job in the hospital was arranged to simulate the physical requirements, emotional stresses, environmental conditions, and personnel relationships of the patient's former job" (p. 148). Various parts of the hospital were used and when it was not possible to simulate some jobs (such as clothing salesman), at least the physical parts of the job were simulated. Electrocardiographic recordings were monitored closely. Work hours were progressively increased and monitoring was tapered off to accustom patients to working without the reassurance of constant medical supervision. The program was deemed to be more meaningful than the previous test (the Master's Test) for identifying those who could safely return to work and those who could not. The authors commented on some of the problems inherent in this type of simulation: the simulations were not exact duplications of the real job; routine hospital work was interrupted; and the job monitoring was expensive in terms of personnel and equipment. However, some of the benefits of the simulations were: the increased information about specific patients doing specific jobs; the opportunity to evaluate and modify jobs by their component parts; and the potential for avoiding industrial accidents by providing warning of potential sources of difficulty. In particular, patients felt they would again be able to work, understood the basis for the physician's recommendations and more readily complied with them.

A specific example of a cardiac work simulation was reported by Beauchamp et al. (1984). They described their Monitored Task Evaluation program and its application in the case of an elevator mechanic with a cardiac condition. A detailed job evaluation including an on-site visit to an elevator repair shop was performed and the data gathered was analyzed with particular reference to the tasks which had particular risks for a cardiac patient. Two critical job requirements were simulated: stair climbing and electrical wiring at high and low levels. As the other routine job requirements appeared to be within his safe activity level as demonstrated during his convalescence and graded exercise test they were not simulated. Blood pressure, HR and ECG findings were recorded at regular intervals while the patient performed the simulated tasks. The wiring simulation consisted of working on a hand dexterity test board placed on a low shelf and later on a high shelf. Stair climbing was performed on a set of training stairs with the patient wearing his own equipment belt and carrying a two pound weight to simulate the weight of the walkie-talkie that he would normally carry. The evaluation revealed that the wiring tasks were within safe limits for the patient but he was symptomatic and exceeded his safe limits on stair climbing. Specific recommendations were developed for the patient and he was able to return to work full-time by pacing himself and avoiding unnecessary stair climbing.

In a similar case study, Wilke & Sheldahl (1985) outlined a simulated work test of a cardiac patient incorporating job analysis, graded dynamic exercise testing and simulated work testing. The graded dynamic exercise test alone was not deemed to provide sufficient information to determine employability as it evaluated response to dynamic leg effort and the patient's job required considerable upper extremity work (weight lifting and carrying). These are high risk factors for cardiac patients. As in the evaluation by Beauchamp et al. (1984), only the most physically demanding component of the patient's job was simulated - the unloading of building materials from delivery trucks. The weight but not the size of the objects actually lifted on the job was simulated. The test protocol required the patient to lift progressively heavier boxes of 13.6, 18.1 and 22.7 kg. at a self determined pace for 30 minutes. An electrocardiogram, the patient's appearance, and blood pressure were monitored as well as $\dot{V}O_2$. The test

revealed that the patient was working within his safe limits (75% of his peak MET[4] capacity determined by the graded dynamic exercise test). As this was considered an acceptable intensity for work of short duration (ie. 30 minutes) he was successfully returned to employment.

The prevalence of chronic back pain patients has led to the development of many treatment programs (Caruso & Chan, 1986; Caruso et al., 1987). Many of these have a work simulation component which is spread out over a longer period of time than for the cardiac programs.

One example of this type of work simulation is found in the community-based comprehensive rehabilitation facility described by Lichter et al. (1984) where it was one part of a broad program. Evaluation included: strength, flexibility, coordination, and endurance. Treatment consisted of: exercise therapy, a back education program, an aerobic endurance training program, and customized home programs. The work simulation program was preceded by a job evaluation which included analysis of the special movements, stress, work postures and the working environment and an activities of daily living analysis. The simulations used an obstacle-course approach similar to circuit weight training, with equipment and supplies such as cement bags, wheelbarrows, sawhorses, buckets, pipes, luggage, and shovels. Kitchen counters, shopping carts, shelves, and vacuum cleaners were used for patients retraining in activities of daily living. Much of the focus of this program was on counteracting the deconditioning effect of prolonged physical inactivity and restoring the patient's confidence.

Matheson et al. (1985) reviewed the history and current characteristics of work hardening programs in industrial rehabilitation and commented:

> "these programs use work capacity evaluation devices as the primary treatment tools. This is a new class of evaluation equipment that allows the work hardening professional to present the patient with tasks that simulate job tasks and that can be graded in terms of the level of difficulty or the length of time involved... Most of the devices in use are 'homemade,' although a few have recently become commercially available" (p.317).

These authors stressed the benefits of working with the client in a laboratory setting which allowed experimentation with job and tool modifications. Clients who experienced the greatest benefit from the program were typically those who were seriously deconditioned after an impairment caused by injury or disease.

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4 Metabolic equivalents (METs) "A multiple of the resting rate of O_2 consumption ($\dot{V}O_{2rest}$). One MET equals $\dot{V}O_{2rest}$ which is approximately 3.5 ml.kg.min" (ACSM, 1986, p.159).

Several methods of evaluating and simulating work demands were u[illegible] concurrently in a comprehensive program outlined by Bettencourt et al. (19[illegible] simulation aspects of the program included:

1) A "multiwork station" which was a wooden frame structure with four sides. Three sides were designed to simulate construction work in carpentry, plumbing and electrical wiring. The fourth side had a vertical ladder and a stepladder, as well as a staging that provided access to the upper level. Tools and materials were available for a variety of assembly and disassembly projects.

2) A truck simulator which consisted of a 3 m high quarter-truck cab equipped with a steering wheel, foot pedals with graded resistance and a computerized video screen, simulating the driving process.

3) A programmable pneumatic lift platform operated pneumatically on a time sequenced basis, to simulate lifting.

4) An Upper Extremity Work Simulator with an adjustable shaft, accommodating a number of tools which could be adjusted to different heights and angles along with a computerized console displaying the amount of resistance the therapist programmed for each tool. A computer printout of force exerted as well as time spent on the activity was supplied. (This last piece of equipment was custom made and appears to be similar to the BTE but there was no comment by the authors on its commercial availability.)

While work simulation is a component of the majority of vocational rehabilitation programs, one is struck by the diversity of ways in which it is used, and the lack of standardization. An even greater concern is the lack of research on evaluation methods or tools.

Measurement of Physical Capabilities With Commercial Vocational Evaluation Systems

As noted by Botterbusch (1982), commercial vocational evaluation systems have suffered from problems in technical standards. "While some developments of norms, reliability, and validity have occurred in the last 14 years, most work sample systems are technically inadequate" (p.ii).

Measurement of physical capacities is not the focus of Botterbusch's review. However, enough information is provided on 14 systems[5] to determine the limited way

[5] Career Evaluation System (Career Heston); McCarron-Dial Work Evaluation System (McCarron-Dial or MDS); Micro-TOWER; Occupational Assessment / Evaluation System (OA/ES); Philadelphia Jewish Employment and Vocational Service Work Sample System (JEVS); Prep Work Samples; Pre-

in which this aspect of the evaluation has been attempted. These test batteries have tended to focus on tasks which can be conveniently "packaged" in small work areas, thus concentrating more on fine motor tasks or on a very limited range of gross motor tasks which tap mainly light physical abilities of the upper limbs. The ability of the subject to perform heavy physical work is not truly assessed. The evaluations range from tests such as "jumping" and measures of hand strength (grip dynamometer) or lifting strength (standing platform) to tests of physical capacity "assessed by the evaluator" in which no procedures are given.

A) Work Evaluation Systems Technology (WEST)

One system which attempts to provide a more detailed and objective evaluation of work capacity is that developed by Work Evaluation Systems Technology (1985a, 1985b, 1987). The test equipment consists of wall-mounted brackets and a system of weights and tools. Initial assembly and mounting of the brackets is required. Several types of evaluation are carried out with the basic equipment. The WEST Standard Evaluation (WSE), consists of a standardized set of procedures for observing evaluees while they reach to their full limit of motion[6] with either arm and then with both upper extremities, first unburdened and then with progressively increasing loads. An optional section examines the evaluees' "brief tool use". This is a timed test of speed of installing bolts, washers and nuts using a nut driver and a combination wrench at specified heights. The Comprehensive Weight System with the WSE allows further evaluation with heavier loads, finer gradations of weight, heavier lifts unilaterally, and handles of differing diameters and grasps.

An evaluation procedure and record format is provided. The evaluee's height relative to the apparatus is noted although this latter information is not taken into account in the normative data. Qualitative information about lifting styles is gathered in a systematic manner which nevertheless requires considerable judgment on the part of the evaluator. "Next-day" symptoms are collected and recorded before the evaluation is deemed complete. Other than providing an anatomical chart of the front and back of a

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Vocational Readiness Battery (Valpar 17); System for Assessment and Group Evaluation (SAGE); Talent Assessment Programs (TAP); TOWER System; Valpar Component Work Sample Series (Valpar); Vocational Evaluation System by Singer (Singer); Vocational Information and Evaluation Work Samples (VIEWS); Vocational Interest Tempermenț and Aptitude System (VITAS); Vocational Skills Assessment and Development Program (Brodhead-Garrett); Wide Range Employability Test (WREST); Work Skill Development Package (WSD).

6 WEST calls this "whole body range of motion under load", a rather misleading term as some aspects of range of motion are not evaluated. What is measured is functional range and strength in combination.1

man to be used in indicating areas of pain, no guidelines are provided on how this information is to be collected or used. Brief guidelines are provided for adapting the test to evaluate the ability of the evaluee to do frequent lifting at whatever height is deemed appropriate (at 35%-40% of the evaluee's maximum load for this range).

The strength of the WEST is that the evaluee is observed actually lifting, giving it high face validity. However, there are many drawbacks to the system : 1) the normative data provided lacks sufficient information to be useful, 2) no reliability or validity data are provided, 3) references in the manual are inadequate, and 4) the procedure manual is confusing and vague.

The WEST provides an additional evaluation device - the WEST 4 (1987), (utilizing the same bracket system and additional tools) to evaluate and develop the ability to use hand tools and to develop upper extremity work capacity. Originally designed to allow the evaluation of workers engaged in a repetitive torquing task, it is a standardized method of measuring torque in dominant and non-dominant hands in both supination and pronation. The evaluator is cautioned that this "testing must not directly involve an impaired component of the biomechanical system. This sort of testing is not only potentially injurious but it also is unreliable and will produce an uninterpretable result" (p.31). Given this caution it is not clear how residual function in an injured extremity can be evaluated although in the case studies provided with the manual it is obvious the WEST 4 has been used to evaluate "impaired components" with decisions based on this information. The authors state that reliability with a small number of normal subjects has been established based on the coefficient of variation statistic. Validity is stated to be "often unarguable" as "the relationship between the evaluation and the job can be easily demonstrated" (p.6).

B) Available Motions Inventory (AMI)

As described by Malzahn (1984) the AMI is used to evaluate job-related physical abilities primarily in the hands and arms of neurologically impaired individuals. It consists of 71 subtests in which the seated client activates controls of various types and in a variety of positions. Strength (torque, applied force, pinch and grip, measured in pounds or inch-pounds), reach, reaction time, and time to reach the target control are recorded. The tasks in the AMI were chosen because of their relationships to repetitive, light bench work - similar to that found in the sheltered workshop of the test developers.

The AMI is designed to measure a selected range of physical abilities which are the basis of skilled movement. Careful attention has been paid to obtaining objective information in a standard format. A microcomputer program prompts data acquisition and produces the final reports which include raw scores, and scores normalized against a small (25 males, 25 females) non-disabled sample with similar age distribution to the client population. These latter scores allow intra-individual comparisons. Scores are further analyzed with respect to the fine to gross motor motions required and the number of planes of movement involved. The final report provides an analysis of the relative ability of 14 components (progressing from the fingers to hand, forearm , and arm) of the left and right sides. These scores are again stated in z scores. The reports highlight specific motions which require modification and make it possible to set realistic goals and to measure progress.

The bench tasks available to the developers were analyzed so that client performance on the AMI could be matched with these tasks providing a small but important link between test scores and real job performance. These scores give an indication of how close a client is to being physically able to work at a level suitable for industrial placement. The test makes no attempt to measure endurance or lower limb abilities. The AMI is a carefully considered and developed measurement tool which is useful for a narrow spectrum of clients. Apparently reliability and validity have been tested (AMI brochure - further literature not available).

C) Vocational Evaluation System (VES)

This set of work samples by the Singer Company is one example of a structured work sample system that not only measures worker traits but also replicates job tasks. Through a series of 25 work sampling stations (for example, bench assembly, welding, cooking and baking), the client is both evaluated and given an opportunity for occupational exploration. Scores are based on time to complete the assigned projects and judgments made by the evaluator. The tests measure motor processes as well as thought processes (Russell, 1980). Limited norms are provided. VES reports moderately high test-retest reliability and validity (VES brochure- further literature unavailable). Advantages of the VES are high face validity and the hands-on nature of the work samples which provide opportunity for performance appraisals. However, each work sample requires its own space, many stations are required, testing is time consuming and the test materials have to be restocked. Nevertheless, because of the standardized administration, and preselected materials it is far superior to informal work simulations at least for the lighter occupational groupings.

D) Microcomputer Evaluation and Screening Assessment (MESA)

VALPAR introduced the MESA in 1982 as a vocational screening assessment. It is a broadly based assessment of perceptual -motor skills, academic skills and problem solving abilities with a component which addresses manual skills, tool usage and physical capacities (VALPAR, 1984). Scores on the MESA are both criterion referenced and norm referenced although the limited norming group makes this latter category weak.

All MESA subtests have been analyzed with the same procedures used by the U.S.A. Department of Labor in the Dictionary of Occupational Titles (DOT). Eleven exercises are combined to form the physical aptitudes score.The physical capacities tested include: strength; fine finger dexterity and fine assembley; manual dexterity and tool use. As is commonly a limitation of vocational test batteries, very little knowledge is gained about the client's physical endurance or abilities to carry out moderate to heavy work.

The MESA test apparatus includes standardized test devices and computer software which is used to do parts of the testing and which tabulates and integrates the final scoring, producing the final report. The test reportedly has good face validity (Bordieri, & Musgrave, undated). No data on reliability or validity are available, however the test is carefully structured with specific instructions and scoring guidelines designed to minimize error. It is nevertheless a complex test and confusing to administer. The DOT itself, while widely used, is open to challenge, underlining the importance of further attention to studies of validity. Unfortunately the MESA is not linked to the CCDO.

E) Baltimore Therapeutic Equipment Work Simulator (BTE)

The BTE is a relatively new and expensive piece of equipment. There are few references to its use in the literature and even fewer examples of research based on it. It appears that its use has largely been in clinical treatment programs.

In two articles (Curtis and Engalitcheff,1981; and Curtis et al., 1984) the authors, who were associated with its development, described the BTE and gave brief case histories of patients with whom it had been used in treatment regimes. While these authors felt the BTE was a very useful device for the treatment of upper extremity disorders, information necessary to subject the BTE to scientific scrutiny was not included.

Berlin and Vermette (1985) performed an exploratory study of isometric and dynamic grip and wrist flexion in a group of 30 subjects (15 females, 15 males) to establish initial norms for two attachments of the BTE. They stressed the importance of measuring dynamic power, which is more closely linked to function, rather than measuring only the strength of maximum isometric contraction, which has more commonly been used. They repeated the protocol over three test sessions. This was not done to establish the reliability of the the test equipment and procedure but was intended to determine the amount of fluctuation which could be expected within subjects. Reliability of the equipment and the procedure was not discussed. They reported a wide range of performance among the subjects with high standard deviations and female scores 42 -57% lower than male scores. Statistical test procedures were not used to establish the sex differences. They reported a relatively low "average" fluctuation rate of 6-14% between test sessions for males and females. How they performed these calculations is unclear. They concluded that "the consistency of scores can be evaluated when there is a question concerning sincerity of effort during the testing process" (p. 64). They also reasoned that hand dominance had little effect on power or strength. They advised the calculation of the ratio of the injured to the non-injured hand. This is meaningful only when one hand can be assumed to be normal and the other injured or disabled.

Wolf et al., (1987), studied 30 males comparing torque strength measures on the BTE and the WEST 4. This study represented "the first documented comparison of two devices commonly used to measure torque strength in clinical practice" (p. 26). They used the BTE in the static mode which caused the subject to use an isometric contraction while the WEST required dynamic contraction. They found significant differences between the two measures reinforcing the concept that static and dynamic strength are different although clinicians may have tended to ignore this difference. No reliability statistics for either device were included.

Baxter and Fried (1984) briefly mentioned the use of the BTE along with other modalities to provide appropriate job simulation in their work tolerance program of the Hand Rehabilitation Center in Philadelphia. Patients performed simulated tasks at progressively greater amounts of resistance and for increasing periods of time. Performance was plotted on a graph.

Blair, et al. (1987) described the BTE as "a useful instrument in clinics and hospitals that deal with upper extremity injuries" (p.52). They included specific tasks on the BTE (pushing and pulling with four different attachments) as an "observation tool" as part of their Physical Capacity Evaluation but they cautioned "that the BTE does not have reliability and validity statements at this time and should not be relied on as the only assessment instrument for work output" (p.55).

No single assessment tool will resolve all the difficulties of assessing the varied and complex movements of work done in the "real world". However, as noted by

Curtis & Engalitcheff (1981), Curtis et al. (1984), Berlin & Vermette (1985), and Blair et al. (1987) the BTE has many potential benefits for rehabilitation facilities and their clients.

1) It allows quantitative measurement and documentation of the client's output. This gives therapists objective information on which to base decisions about the client's ability to work.
2) It allows the therapist to increase the difficulty level of tasks in graded increments thereby minimizing the risk of injuring the client by starting a task at a level above his or her safe ability.
3) It allows the simulation of a movement with resistance in both directions (for example, forward and backward or up and down) or in one direction only.
4) It allows the simulation of a much broader range of tasks in a small amount of space than is possible by using specific tools such as lathes and drill presses. It therefore reduces the costs associated with providing a wide variety of tools and equipment.
5) It provides clear feedback to clients which can help to motivate them.
6) It permits the assessment of strength and function in the performance of static and dynamic movements as opposed to measurement of only isometric contractions.
7) The automatic recording of measurements makes it possible for clients to work on their programs with minimal therapist supervision.

There are also some drawbacks of the BTE which will make it important to continue to supplement it with other evaluation methodologies.

1) Tasks must be broken down into small components in order to simulate each component serially. This differs from the "real" work pattern which frequently requires complex integrated movements.
2) The BTE is primarily designed for upper extremity use. Tasks which combine upper and lower extremities (such as carrying a load over a distance) cannot be fully simulated.
3) The individual must stand or sit in a small area when performing tasks. This is not always the case in the "real world" situation where walking and carrying are often a part of the task.

However, despite these limitations the BTE has potential to add considerable objective information to the evaluation process and to be an extremely useful treatment tool once its reliability and validity have been ascertained.

Physiological Measures

The energy cost of aerobic work can be measured by the amount of O_2 consumed. In the physiological system, O_2 is used to liberate energy from substrates stored within the body. For each litre of O_2 consumed, about 20 kJ of energy will be delivered; hence the higher the oxygen uptake, the higher the aerobic energy output. Oxygen uptake during exercise or work may be measured with an accuracy of ± 0.04 litres/min (Astrand & Rodahl,1986, p.299) with the use of proper instrumentation.

Two methods for assessing energy expenditure are possible; the direct method of oxygen uptake during the work activity and the indirect method of estimation of oxygen uptake based on heart rate during the activity. The validity of using oxygen uptake as a basis for measuring energy expenditure has been well established producing a wide variety of methods for collecting expired air under laboratory and field conditions and a vast amount of information on the energy cost of physical work. (Astrand & Rodahl, 1986, p.491).

In many types of exercise the HR, unless disturbed by environmental conditions, increases linearly with the rate of exercise. During maximal lower extremity exercise, Astrand & Rodahl cited a standard deviation of only $\pm$ 10 beats per minute. This relationship makes HR a useful and easily obtained measure which is used extensively in fitness training and testing (Astrand & Rodahl, 1986, p. 189; ACSM1986, p.34). The linear relationship of HR to $\dot{V}O_2$ under standardized conditions makes the estimation of workload possible. The HR can be used to estimate the workload provided the workload-HR relationship has been established for the individual, the work involves similar large muscle groups in both cases, and environmental temperature, emotional stress, etc are the same. Rodahl (as cited in Astrand & Rodahl, 1986, p.495) found very good reproducibility of HR in field studies with fishermen repeating the same work over three days.

The Rating of Perceived Exertion (RPE) Scale

The 15-point Rating of Perceived Exertion Scale (Appendix A) is not a physical capacity test but is a means of measuring the individual's subjectively perceived level of physical exertion. It was developed by Gunnar Borg in 1970 (Pandolf, 1983) and consists of numbers from 6 to 20 with accompanying verbal descriptions ranging from "7 - very, very light" to "19 - very, very, hard". This simple appearing ordinal scale was developed on the basis of research on the bicycle ergometer and was found with median age groups to have a linear relationship to intensity of exercise and to HR so that the HR at a given exercise intensity roughly corresponds to 10 times the RPE value. The numerical ratings are given additional meaning by the attached category expressions (Borg, 1982). Borg (1982, p. 377) stated that:

> "the overall perceived exertion rating integrates various information, including the many signals elicited from the peripheral working muscles and joints, from the central cardiovascular and respiratory functions, and from the central nervous system. All these signals, perceptions, and experiences are integrated into a configuration or 'Gestalt' of perceived exertion."

A) Laboratory Controlled Studies

Gamberale (1985) cited the RPE scale as the most frequently used scale for measuring the degree of perceived exertion during physical work. The scale has been well validated against physiological variables such as HR, $\dot{V}O_2$, respiration rate, ventilation and blood lactate (Pandolf, 1983). Reliability coefficients reported by Skinner et al. (1973, as cited in Pandolf, 1983) and Stamford (1976) ranged from r = 0.71-0.90 with the higher coefficients found in progressive rather than random presentation of exercise intensities. Purvis & Cureton (1981) established the relationship between the anaerobic threshold and ratings of perceived exertion. On load-incremented bicycle ergometer stress tests the mean RPE at the anaerobic threshold was 13.1 ± 0.9 for females and 14.2 ± 0.9 for males. The RPE for the combined group was 13.6 ± 1.2, implying that the effort was perceived as "somewhat hard". They concluded that the similar perception of exercise intensity corresponding to anaerobic threshold by different individuals makes it possible to prescribe an exercise intensity equivalent to the anaerobic threshold using RPE.

Burke (1979) used percent $\dot{V}O_{2max}$[7] rather than HR as a criterion for validating the RPE in several studies, finding the RPE as good as or better than HR in predicting percent $\dot{V}O_{2max}$. In findings later supported by Purvis & Cureton (1981), he found that an RPE of 13 equated in most individuals to between 65 and 80% of $\dot{V}O_{2max}$. This level was both a psychologically pleasing and an effective intensity for increasing

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[7] Highest rate of oxygen uptake observed during exercise; indicated by the failure of oxygen uptake to increase with increase in external work" (ACSM, 1986, P.16), measured in liters per minute.

aerobic power. He recommended using RPE along with HR to provide the most complete information.

The RPE does not always have a linear relationship with HR. Heart rate can be affected by many factors such as age, type of exercise, environment, certain drugs and anxiety (Borg, 1982; Ekblom, Lövgren, Alderin, Fridström, & Sätterström, 1974; and Pandolf, 1972 as cited in Pandolf, 1983). Burke (1979) found that cigarette smokers found it difficult to work at a training level below an RPE of 14. Despite such limitations, Gamberale (1985, p. 307) suggested that rating scales can "have clear advantages compared with magnitude estimation or other techniques"... in "practical settings where absolute comparisons between different work situations are needed or when interest is focused on interindividual or intraindividual comparisons".

B) The Rating of Perceived Exertion Related to Occupations

Several researchers in occupational therapy have used the RPE scale as an anchor point in studies of motivation and the effect of the purposefulness of tasks (Kircher, 1984; Steinbeck, 1986; Thibodeaux & Ludwig, 1988). Although different points on the RPE scale were selected, in each study subjects were asked to work up to a specific RPE on a purposeful or non-purposeful task and then to repeat the same amount of exertion with the corresponding non-purposeful or purposeful task. As RPE correlates highly with $\dot{V}O_2$, HR, ventilation, and blood lactate concentration, it is considered a "valid and reliable indicator of the level of physical exertion during constant intensity exercise" (ACSM 1986, p.36) and it can be used to establish an exercise intensity.

Noble (1982) stressed the important applications of perceived exertion in occupational and other settings. The Borg RPE Scale has been use in occupational settings to evaluate the effort perceived by workers under many conditions. Khaleque (1981) measured HR , RPE, and job satisfaction in light industrial work in a cigar factory. He found significant correlations between HR and job satisfaction but not between RPE and job satisfaction. He postulated that while RPE is related to HR in heavy physical work, in light work psychological factors such as emotional stress or tension might have an important role to play in influencing HR.

Goslin & Rorke (1986) found correlations between RPE and cardio-respiratory measures indicating a reasonably high degree of relationship ($\dot{V}O_2$, $r = 0.75$; HR, $r = 0.47$; VI, $r = 0.58$) in studies of backpack load carriage with three increasing loads and two increasing speeds on a motorized treadmill. RPE, ventilatory and cardio-respiratory responses increased linearly with increases in load carried and speed.

RPE is sometimes constant over different tasks. Nicholson & Legg (1986) found non-significant differences in RPE values over three repetitive lifting task conditions in which the subjects were able to adjust the load or the lifting frequency or a combination of both variables to select a workload which they considered to be a maximum acceptable workload (MAWL). The mean MAWL per minute was highest when frequency was adjusted. They suggested that factors other than physiological measurements and subjective assessments may influence an individual's perception of MAWL.

Garg & Banaag (1988), conducted a laboratory study to determine the effects of repetitive asymmetric lifting on psychophysically determined maximum acceptable weights and resulting HR's and RPE's. The maximum acceptable weights and static strengths were significantly lower and HR and RPE were significantly higher for asymmetric lifting than those for symmetric lifting in the sagittal plane ($p < 0.01$). They used a variation of the RPE which requested subjects to respond with RPE values for localized parts of the body (eg. wrist, shoulder, lower back, lower body) as well as the whole body.

The RPE was found by Eston & Williams (1988) to be useful as a perceptual frame of reference in the regulation of high levels of exercise intensity for healthy men and women. Subjects regulated the resistance of the cycle ergometer without reference to the instrument display panel to attempt to cycle at constant loads based on their perception of ratings 9, 13, and 17 of the RPE scale. Correlations between the three trials ranged from $r = 0.83$ to $r = 0.94$.

Bjurö, Fugl-Meyer, Grimby, Höök, & Lundgren (1975), in ergonomic studies of domestic work in varying patient groups, recorded time consumption, HR and RPE during a 4.5 - 5 hour domestic work program. Compared with the control group, the RPE and HR in the two patient groups were found to be higher despite a slightly lower submaximal workload. In the two patient groups there was a considerably higher RPE in relation to HR than in the control group and in relation to HR, RPE showed more variation than found in healthy subjects. As subjects could select the pace of their work, RPE was seen to have a decisive function. Methods to reduce the high RPE in patient groups were proposed, such as training of motor function and circulatory capacity, improvement in work techniques, and improvement in environmental design and equipment.

Shanfield (1984) proposed the use of the RPE as part of a Physiological Monitored Evaluation (PME) which also included HR, blood pressure and a Shortness of Breath (SOB) Index. She provided a case example of a PME used to evaluate a hemiparetic patient and to plan and monitor his progress.

Work Classification Systems

Many occupational therapists and vocational evaluators use the CCDO (1986) classification of work into five categories (sedentary, light, medium, heavy, and very heavy) according to the strength required for lifting, carrying, pulling and pushing. In addition the work is classified by the need for climbing or balancing; stooping, kneeling, crouching and/or crawling; reaching, handling, fingering and/or feeling; talking; hearing; seeing; and the use of differing types of controls. The advantage of this system has been that many jobs could be quickly and easily categorised without recourse to extensive detailed analysis. The disadvantage is that the definitions are very general and do not define the rate, frequency or duration of effort required.

Bearing in mind the many physiological and psychological variables that affect individual responses, Astrand & Rodahl (1986, p.502), provide the following classification system for $\dot{V}O_2$ and HR respectively, refering to males twenty to thirty year of age:

Light - up to 0.5 L/min; and 90 beats/min;
Moderate - 0.5 to 1.0 L/min, 90 to 110 beats/min;
Heavy - 1.0 to 1.5 L/min, 110 to 130 beats/min;
Very Heavy - 1.5 to 2.0 L/min, 130 to 150 beats/min;
Extremely Heavy - over 2.0 L/min, 150 to 170 beats/min.

Industrial physicians use a well standardized system of classifying the intensity of aerobic work according to the amount of energy required (Brown & Crowden, 1963). These authors also included overlapping ranges to take into account the variations in physical demands in the work cycle. As reported by Shephard (1987a) and with the conversion to litres per minute of $\dot{V}O_2$, this system has the following classification: light work demands an energy expenditure of up to 14 kJ/min. (0.67 L/min.), moderate work 14 to 23 kJ/min. (0.67 to 1.10 L/min.), heavy work 23 to 38 kJ/min. (1.10 to 1.82 L/min.), and very heavy work more than 38 kJ /min. (over 1.82 L/min.). With this kind of classification system it is possible to make a connection between workers and their abilities to carry out heavy industrial work by measuring their $\dot{V}O_{2max}$ and calculating the corresponding energy expenditure of which they are capable.

The duration of effort must also be considered in relationship to the intensity of work as the heavier the intensity the shorter the interval at which the worker can perform it without fatigue. Thirty to 40% of $\dot{V}O_{2max}$ is considered to be the reasonable upper limit for physical work performed over a regular 8-hour workday (Astrand & Rodahl, 1986, p.501; Shephard, 1987a) with 63 to 76% an acceptable upper limit for work of short (one hour) duration.

A five level classification system of exercise intensity based on work of Durnin and Passmore (1967, as cited in McArdle, Katch, & Katch, 1986, p.139) gives the following categories for men : light - 0.40 to 0.99 L/min.; moderate - 1.00 to 1.49 L/min.; heavy - 1.50 to 1.99 L/min.; very heavy - 2.00 to 2.40 L/min.; unduly heavy - 2.50 l/min. and over. It can be seen that this system is slightly different from that suggested by Shephard (1987a).

Another frequently used system expresses the volume of O_2 consumed per minute relative to the subjects body weight (ml/kg) and relative to the resting metabolic rate (MET). Many tasks have been expressed in terms of METs and this system is often used with cardiac patients (Wilke & Sheldahl, 1985; ACSM, 1986; Astrand & Rodahl, 1986, p.362; McArdle et al., 1986, p.139).

Arm Versus Leg Ergometry

The physiological responses to exercise have most frequently been measured by the use of tests that require leg work such as stationary cycling, treadmill walking and step tests but, as outlined in a review by Franklin (1985), "alternative methods involving arm exercise appear to be more appropriate for selected subjects such as paraplegics, amputees, and those with peripheral vascular disease or lower extremity disabilities, as well as those whose occupational or recreational activity is dominated by arm work".

Several researchers (Bar-Or & Zwiren, 1975; Franklin, 1985) have demonstrated that estimates of leg $\dot{V}O_{2max}$ from experiments with arm work and vice versa have a relatively weak correlation. In order to more accurately predict performance capacity, arm exercise testing appears to be the functional evaluation of choice for persons whose physical activity is dominated by upper extremity efforts (for example, occupations such as sewing machine operation, manual labouring, construction, carpentry, ditch digging; recreation and training such as swimming, canoeing, cross-country skiing, tennis, kayaking, raquetball; and clinical conditions such as arteriosclerosis in the lower extremities, spinal cord injury, orthopaedic/arthritic limitations, and amputees).

At a given submaximal workload, arm exercise is performed at greater physiological cost (ie. less efficiently, with higher $\dot{V}O_2$ and HR) than leg exercise (Astrand & Rodahl, 1986, p.192; Davis, Vodak, Wilmore, Vodak, & Kurtz, 1976; Franklin, 1985). The reasons suggested for this are the use of smaller muscle groups and the static effort required with arm work which increases $\dot{V}O_2$ but does not increase external work output. $\dot{V}O_{2max}$ during arm exercise in men is 72% of leg $\dot{V}O_{2max}$ (the mean value from seven separate studies), while HR is comparable (Franklin, 1985).

Arm ergometry is now being used for evaluation and training of both able-bodied and disabled males and females (Bhambani, Clarkson, & Gomes,1988; Davis et al., 1976; Pollock, Miller, Linnerud, Laughridge, Coleman, & Alexander, 1974; Washburn, & Seals, 1983; 1984; Vander, Franklin, Wrisley, & Rubenfire, 1984).

Summary

The review of the literature points out the serious lack of standardization in the evaluation of work which makes validation of our techniques an almost impossible endeavor. Even the "standardized" tests and systems have technical flaws and inadequate scientific foundation. The BTE has potential to provide some objective information, but there is little published literature on it and even more disturbingly, little recognition (except by Blair et al, 1987) that the issue of reliability and validity require attention.

Physiological and psychophysical measures can provide objectivity and hopefully these will be used more by therapists. However, these types of measures do not always answer the questions related to specific types of work. The work classification systems tend to be too general to be more than just guidelines for groups of jobs rather than giving full information on specific jobs.

It can be seen that valid assessment tools are seriously lacking in this field. It was for this reason that one potentially useful tool, the BTE, was selected to begin the slow process of developing reliable and valid methods for therapists to assess and make decisions about clients and their abilities to perform specific tasks.

CHAPTER III

METHODS AND PROCEDURES

Study Participants

Thirty healthy, male subjects, 18 - 35 years, volunteered to participate in the study. Volunteers were solicited at informal and formal sporting activities such as softball games, running races, from among the researcher's social contacts and through poster advertisements. Subjects were not remunerated. The subjects were informed of the testing procedures involved and gave written consent for participation (Appendix B). All participants met the screening criteria of the Physical Activities Readiness Questionnaire (PAR-Q, Appendix C). No subjects with any known physical disability or who were on any medication affecting metabolic or cardiovascular responses were included. Anthropometric information (age, weight, and height) was collected on each participant.

Equipment and Instruments

1) BTE Work Simulator™. Model number 101A (Baltimore Therapeutic Equipment Co., Maryland, USA). At the beginning of each session the simulator was calibrated according to the manufacturer's instructions.
2) MMC Horizon™ Systems Metabolic Measurement Cart (MMC), SensorMedics Corporation, Anaheim, California. This is an automated system which permits the assessment of respiratory and metabolic parameters, performs all the required calculations and provides a printout. Although reliability coefficients were not stated, Wilmore, Davis, & Norton (1976) have established reliability and validity. At the beginning of each session the MMC was calibrated according to the manufacturer's instructions.
3) Sport Tester™ PE 3000 Heart Rate Meter. (Polar Electro, Kempele, Finland). The Sport Tester consists of a wireless, lightweight electrode belt and transmitter worn on the chest and a small receiver which registers the heart beat frequency of the user in beats per minute. Karvonen, Chwalbinska-Moneta, Saynajakangas (1984) concluded that

the device was as valuable for recording heart rate during exercise as the ECG. Leger & Thiverge (1988) found correlation coefficients between the device and ECG of r = 0.95 to 0.97 on three exercise tests, r = 0.95 on low intensity exercise and r = 0.71 on high intensity exercise.

4) Arm ergometer (Monark Rehab Trainer 881, Varberg, Sweden). This is a mechanically braked system mounted on an adjustable height table.

5) Electrocardiogram (ECG) monitor (Hewlett Packard, Model 1500B) The use of this monitor allows direct measurement and recording of HR on the MMC printout where automatic calculations are performed. However, as noted by Franklin (1985), satisfactory ECG recordings were more difficult to obtain due to motion artifact in arm ergometry, particularly at the heavier loads, and therefore the Sport Tester™ was used concurrently.

6) Borg Rating of Perceived Exertion (RPE) Scale (Appendix A). The RPE is a 15-point category rating scale which has been well validated in correlation with other physiological and psychological variables as a measure of degree of physical strain. (Gamberale, 1985; Pandolf,1983; Stamford, 1976).

Procedures

Prior to preliminary testing each subject was provided with written instructions (Appendix B) asking him to refrain from ingesting a heavy meal or engaging in vigorous physical activity for at least three hours prior to the testing periods. The three test sessions were all scheduled at approximately the same time of day for each subject in order to account for diurnal variations in the physiological variables being monitored (Shephard, 1984).

The Tasks

As the BTE was designed to be used with repetitive upper limb motions, repetitive criterion tasks which utilized primarily the upper limbs were set up in the laboratory. The tasks were at three levels of work described by the CCDO (light, medium, and heavy) and were within the guidelines established by Snook (1978) for maximum acceptable weights of repetitive lifts for males.

Tasks were selected based on the following requirements:

1) the movements could be simulated on the BTE (for example, were within the height restrictions of the equipment),
2) the movements were repetitive, and primarily involved the upper body,
3) the movements were in a single plane,
4) the task would be consistent throughout each trial and on repeated trials,
5) the equipment and/or supplies for the criterion task could be readily obtained.

Three expert judges independently observed and briefly performed each of the tasks in both the criterion and simulated forms. These were modified or changed until each judge subjectively felt that the criterion tasks met the operational definitions of light, medium and heavy work and that the simulations corresponded well with the respective criterion tasks.

The criterion tasks were designated CL, CM, CH for the light, medium, and heavy tasks respectively, illustrated in the following Figures 1-3.

Using appropriate combinations of the variable height, angles and attachments, each of the three criterion tasks was simulated on the BTE. These were designated SL, SM, SH for the light, medium, and heavy tasks respectively. These are also illustrated in Figures 1-3.

The participants were given pacing instructions which were similar to the procedures used by Snook (1978) and Legg & Myles (1981): "Do this task at a comfortable intensity which you feel you could keep up for a regular eight-hour work day." All tasks were performed in the standing position. Details of the tasks were as follows.

CL (Criterion Light)
Loading six filled, glass soft drink bottles (0.28 litres) into and out of the nearest 6 slots of a plastic soft drink carton. Bottles were gripped by the caps one at a time using the dominant hand. (The tops were covered with masking tape to protect the participant from the rough edges.) Bottle height was 94 cm from the floor. The total height of lift of each bottle was a minimum of 118 cm (measured from the floor) to clear the edge of the carton placed 23 cm from the front edge of the table. Bottles were placed on the table in marked locations so that the lateral distance moved was 44 cm for each bottle. This unilateral activity was performed in the coronal plane in front of the body.

SL (Simulated Light)
With the shaft in a horizontal position, BTE tool #701 ("medium crank handle") was used, set in the position providing the longest radius (22 cm). With the top of the face of the BTE as a 0° reference point, two range-of-motion limiters (#001) were attached at 105° and 255° so that the handle moving across the top of this arc covered a distance of 180°. The BTE was moved to its lowest position so that the height of the knob at the end of the handle was a minimum of 94 cm from the floor at the extreme of its arc. The participant stood in front of the BTE, 23 cm back from the front edge of the handle, held the small knob with the same hand as in CL, and moved the knob in an arc from side to side in the coronal plane.

Figure 1A. C L Task

1B. S L Task

CM (Criterion Medium)
Lifting a 2.6 kg. pan 23 x 23 x 4.5 cm from the front of a counter, at a height of 92 cm, to a shelf, 66 cm above the counter, set back 48 cm from the front edge of the counter. This bilateral arm activity was performed in the sagittal plane directly in front of the body.

SM (Simulated Medium)
BTE tool #181 ("multiple handle crossbar") was used, with the shaft set at a height of 64 cm from the floor so that the highest position of the tool was equal to that of the CM task. The rope portions were taped to the crossbars to prevent them from swinging around. Standing to the side of the BTE the subject grasped one set of handles at the lower position (92 cm from the floor) and moved the handles upwards to the highest position of the tool, then returned to the original position. This bilateral arm activity was performed in the sagittal plane directly in front of the body.

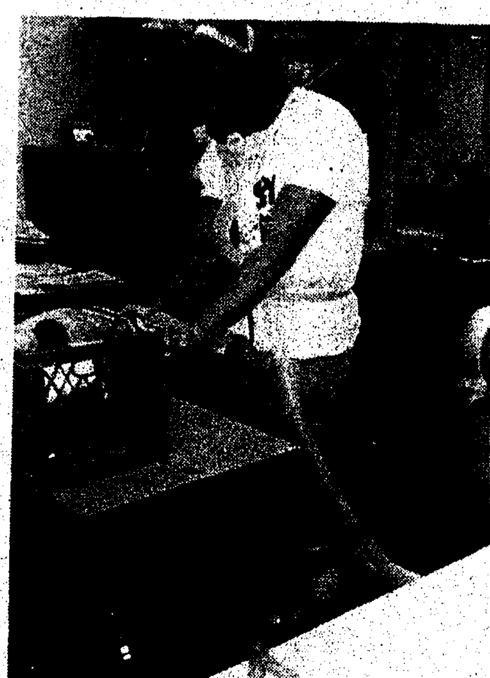
Figure 2A. C M Task

2B. S M Task

CH (Criterion Heavy)
Pushing a weighted 45 kg. plastic carton backward and forward 27 cm on an arborite covered table using a horizontal wooden handle 20 x 3 x 2 cm. The height of the handle from the floor was one meter. This bilateral activity was performed primarily in the sagittal plane directly in front of the body.

SH (Simulated Heavy)
With the shaft in a horizontal position, BTE tool #901 ("one or two handed grasp") was used. Two range-of-motion limiters were attached at 135° and at 225° to give a 27 cm range of motion. The shovel handle was replaced by a wooden handle 20 x 3 x 2 cm to allow placement of both hands side by side. (The handle projecting at right angles was not used.) The BTE shaft was adjusted so that the height from the floor to the handle in the horizontal position was one meter. The participant, standing to the side of the BTE, pushed and pulled. This bilateral activity was performed primarily in the sagittal plane directly in front of the body.

Figure 3A. C H Task



3B. S H Task

Orientation and Preliminary Testing

Participants were given a familiarization session in the laboratory to orient them to the equipment and the six tasks. The three criterion and three simulated tasks were explained to the participants who then performed each task until it was understood.

Following this orientation a graded arm ergometer exercise test following the protocol established by Davis, et al. (1976) was performed. This test was used to determine the p$\dot{V}O_2$ for each subject and was the basis for calculations of intensity of work on the tasks relative to the subject's fitness level. Guidelines of the American College of Sports Medicine (1986) which allow for maximal capacity testing in the absence of a physician were followed.

The participant was seated in front of an arm ergometer, adjusted so that the midpoint of the sprocket wheel was at shoulder level. Electrodes and the Sport Tester™ were attached so that the participant's heart rate could be monitored continuously. Respiratory gas exchange variables were monitored by the MMC using a face mask connected to the free end of the MMC. (Two subjects with beards were fitted with mouth pieces and nose clips in place of the face mask to ensure proper fit.) The participant, aided by audiovisual feedback from a metronome (Franz, Model LM-FR-4), started turning the arm cranks at 50 rpm and zero resistance for a period of four minutes. The metabolic cart, programmed to perform calculations every 30 seconds, was started at the beginning of this four minute period. Thereafter the resistance was increased by 0.25 kg every two minutes until the participant reached his maximum exercise capacity. This was considered to be the exercise intensity at which the subject consumed the maximum amount of oxygen, and/or was unable to continue cranking at the prescribed rate. In the latter case the p$\dot{V}O_2$ was considered to be the $\dot{V}O_{2max}$. Towards the end of the test the "shout" method of motivation was used to obtain the maximal performance by the subject. The participant was asked to indicate his RPE on the Borg scale during the last 15 seconds at each power output.

Trial One

On a subsequent day a minimum of 24 hours after the orientation session, the participant was appropriately prepared for metabolic measurements using the MMC. HR was monitored with the Sport Tester™. Once connected to the apparatus each participant stood at ease for four minutes to allow measurement of resting $\dot{V}O_2$ and HR. Following the pacing instructions previously described, the participant worked for a minimum of five minutes at each task in order to obtain a steady state of the physiological variables being monitored. During the last 30 seconds of each of the tasks RPE and HR were recorded. The $\dot{V}O_2$ was obtained from the MMC for the latest two 30 second intervals. After the task was completed, HR and $\dot{V}O_2$ were monitored using the MMC until these variables returned to their standing values. Then the participant was instructed to perform the second and third criterion tasks in a similar fashion, each followed by a similar recovery period. The three tasks (CL, CM, CH) were presented in random order (determined previously by picking from a hat).

Using the same metabolic apparatus and the same protocol, the participant was instructed to perform the three simulated tasks on the BTE. The resistance level for each task on the BTE was gradually increased until the participant indicated he was working at the same RPE score reported on the corresponding criterion task. It was necessary for criterion tasks to be performed prior to simulated tasks so that the subjects could determine this. This method of setting the resistance level on the BTE was chosen because of its similarity to clinical use of the BTE, where specific forces are seldom known and the therapist or client estimate the required resistance. The three tasks (SL, SM, SH) were again presented in random order.

Trial Two

The second trial took place a minimum of 48 hours following the first trial. Each participant was retested in both the criterion and simulated tasks in the same manner and at the same time of day. During simulated tasks the resistance level was set at the level determined for each task by that subjec[illegible]al one. A new random order of tasks was selected.

Limitations

This study investigated only three tasks; therefore, findings cannot be generalized to infer that similar results will be found when other tasks or attachments of the BTE are studied.

No attempt was made in this study to measure specific muscle activity (for example, throught the use of EMG) or to analyse the mechanical forces acting on the bones, muscles, or joints.

Much of the accuracy of the BTE is dependent on the therapist's judgement. The analysis of the "real" task and the choice of attachments, positions, and resistance levels to provide the simulation could vary between therapists. Expert judges were utilized to minimize the effects of this limitation.

Real tasks usually involve patterns of movements in more than one plane rather than isolated movements in a single plane. While the BTE allows a wide variety of movements, it is seldom possible to simulate a complete task involving several planes of movement with one attachment. Several attachments may be required in succession to provide all the movement patterns. Therefore somewhat artificial tasks in a single plane were chosen for this study to avoid this problem.

Although the BTE is used mainly with clients who have disabilities it would be extremely difficult to establish initial reliability and validity by using this population of subjects. There are so many types of disabilities, many of which fluctuate in their course, that a very large study would be required. Thus, in this study, able-bodied subjects were used with the rationale that if reliability and validity were not present with this sample they would be even less likely to be evident with a more varied sample. Reliability and validity established with able-bodied subjects provides a foundation for further research with disabled subjects.

Another limitation of the study was that simulated tasks were always performed after criterion tasks. This may have introduced an element of fatigue although subjects were allowed to rest between tasks until resting $\dot{V}O_2$ and HR values were obtained.

Diet, sleeping and smoking patterns, educational level, and type of employment were not controlled.

Delimitations

Subjects were a convenience sample of healthy males 18-35 years of age who took part in physical recreational activities equivalent to a minimum of 5 METs for thirty minutes at least three times per week.

Experimental Design

The study was a three factor design (2 x 3 x 2): in which Factor A had two levels ("Type" - criterion and simulated); Factor B had three levels ("Task" - light, medium, and heavy); and Factor C had two levels ("Time" - trials one and two), with repeated measures on all factors. (Appendix D).

Data Analysis

Pearson product moment correlations (Keppel, 1982; Currier, 1984) for $\dot{V}O_2$ and HR were calculated between trials to examine reliability and between criterion and simulated conditions to examine validity. The critical "r" value for significance on these tests (n=30) was 0.306 (df = 28, 1-tailed alpha equal to 0.05).

Intraclass correlation coefficients were also computed for each type and task between trials to produce reliability estimates (Krebs, 1984).

In order to examine whether there were any significant differences between the mean values of the criterion and simulated tasks under the different conditions, the data was also subjected to a three-way analysis of variance with repeated measures followed by the Greenhouse-Geiser conservative test (Keppel, 1982). Significant "F" ratios were then investigated using a post hoc Scheffé test (Keppel, 1982) to locate the differences between task types, levels and trials. Alpha equal to 0.05 level of significance was selected.

As recommended by Keppel (1982), the triple interaction term in the summary of analysis of variance was examined first. If this was significant the post hoc analysis was examined to determine the location of significant differences. Where the three-way interaction was not significant, then the two-way interactions were examined, pooling or collapsing the data from the third factor not included in the interaction term in each analysis.

The SPSSx statistical software program (SPSSx ,1986) was used for the following: descriptive statistics, correlations, analysis of variance with repeated measures (UANOVA), the Greenhouse-Geiser adjustment, and Scheffé multiple comparisons.

CHAPTER IV

RESULTS

Section A

Characteristics of Participants

The characteristics of the participants are given in Table 1. Data from an additional five subjects were not included: two were considered pilot studies, and three did not complete the study. Of these, one fell ill from unrelated causes, one was discovered to be ineligible due to diabetes, and one did not return for the second and third sessions and could not be contacted. (Raw data are in Appendix E). The subjects came from a wide variety of backgrounds - stockbrokers, bankers, administrators, technicians, graduate and undergraduate students, and unemployed manual workers. The majority of participants were actively involved in recreational physical activity equivalent to a minimum of 5 METS for thirty minutes at least three times per week. For many subjects these activities included running and /or weight lifting.

TABLE 1
Means, Standard Deviations and Ranges of Selected Variables for Study Participants (n=30)

Variable	Mean	SD	Min	Max
Age (years)	28.6	4.8	19	35
Height (cm)	177.4	5.7	165.3	189.5
Weight (kg)	74.7	9.5	56.8	96
$p\dot{V}O_2$ (L/min)	2.33	.57	1.17	3.4
$p\dot{V}O_2$ /kg (ml/min/kg)	31.1	7.0	17.8	47.6
HR max (bpm)	167	15	141	187

Section B

Oxygen Consumption and Heart Rate during Light, Medium and Heavy Tasks under Criterion and Simulated Conditions

a) Oxygen Consumption

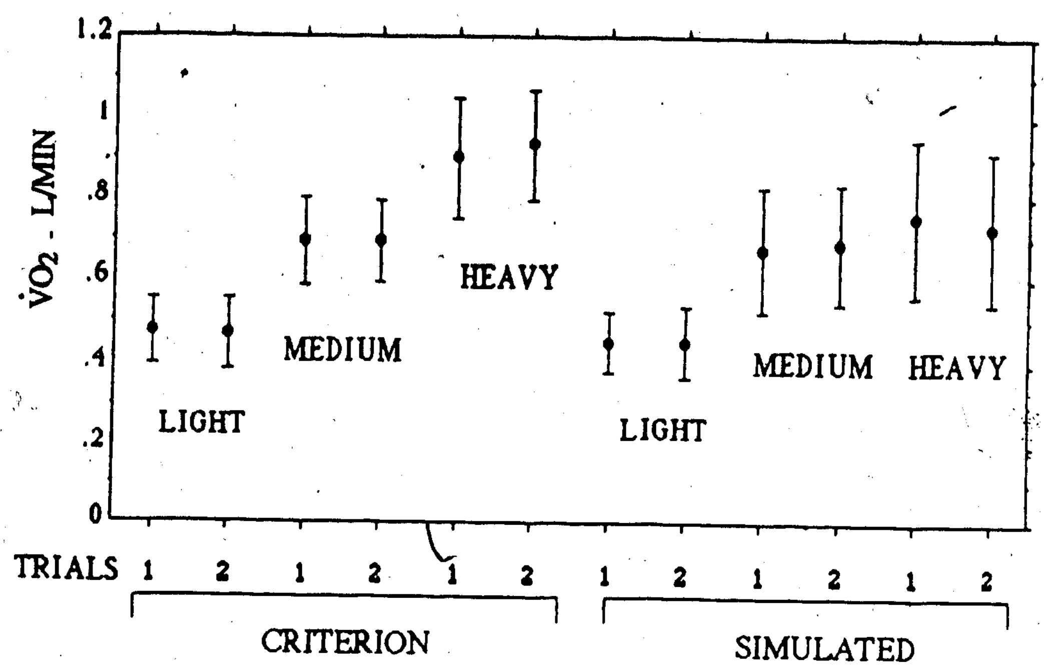
Oxygen consumption as presented in Table 2 and Figure 4 increased during both trials of the criterion and the simulated tasks as the level of intensity increased but the increase was less marked in the SH levels.

TABLE 2

Means, Standard Deviations and Ranges of Oxygen Consumption (L/min) for Criterion and Simulated Types during Light, Medium and Heavy Tasks for Trials One and Two

TASKS	TRIAL ONE				TRIAL TWO			
	Mean	SD	Min	Max	Mean	SD	Min	Max
CL	.477	.077	.338	.635	.472	.084	.336	.664
SL	.449	.073	.325	.624	.450	.086	.341	.683
CM	.697	.103	.474	.871	.694	.098	.498	.859
SM	.674	.149	.428	1.095	.689	.145	.372	.981
CH	.898	.152	.623	1.229	.932	.136	.677	1.282
SH	.756	.189	.481	1.358	.730	.180	.474	1.430

FIGURE 4
Mean Oxygen Consumption for Criterion and Simulated Types Comparing Trials One and Two during Light, Medium and Heavy Tasks



The same trends were present when $\dot{V}O_2$ was examined relative to the subject's body weight, as seen in Table 3 and Figure 5, and were repeated again when the percentage of $p\dot{V}O_2$ was calculated in Table 4 and Figure 6 which follow.

TABLE 3
Means, Standard Deviations and Ranges of Oxygen Consumption per Kilogram of Subject's Body Weight (ml/kg/min) for Criterion and Simulated Types during Light, Medium and Heavy Tasks for Trials One and Two

	TRIAL ONE				TRIAL TWO			
TASKS	Mean	SD	Min	Max	Mean	SD	Min	Max
CL	6.4	.8	5.1	8.4	6.3	.9	4.2	8.3
SL	6.1	.9	3.6	7.8	6.0	1.0	4.1	7.7
CM	9.4	1.4	6.7	12.2	9.3	1.3	6.3	12.0
SM	9.1	2.3	5.4	15.3	9.3	2.2	5.3	13.8
CH	12.1	2.3	8.3	17.3	12.6	2.0	7.9	16.0
SH	10.2	2.4	5.0	15.2	9.8	2.1	6.2	14.9

FIGURE 5
Mean Oxygen Consumption per Kilogram of Subject's Body Weight for Criterion and Simulated Types Comparing Trials One and Two during Light, Medium and Heavy Tasks

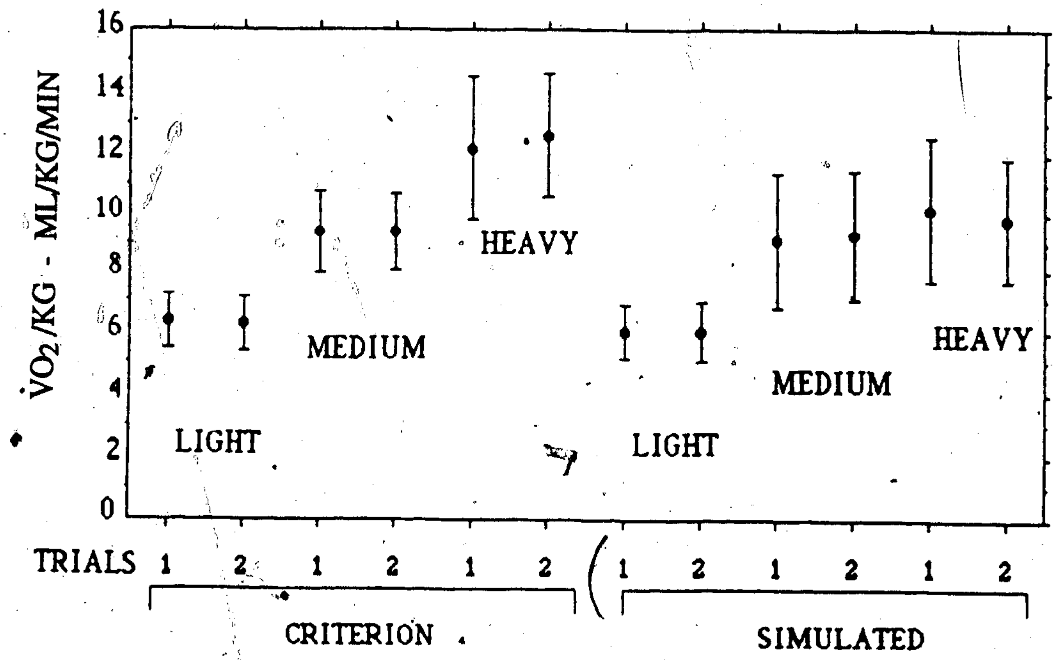
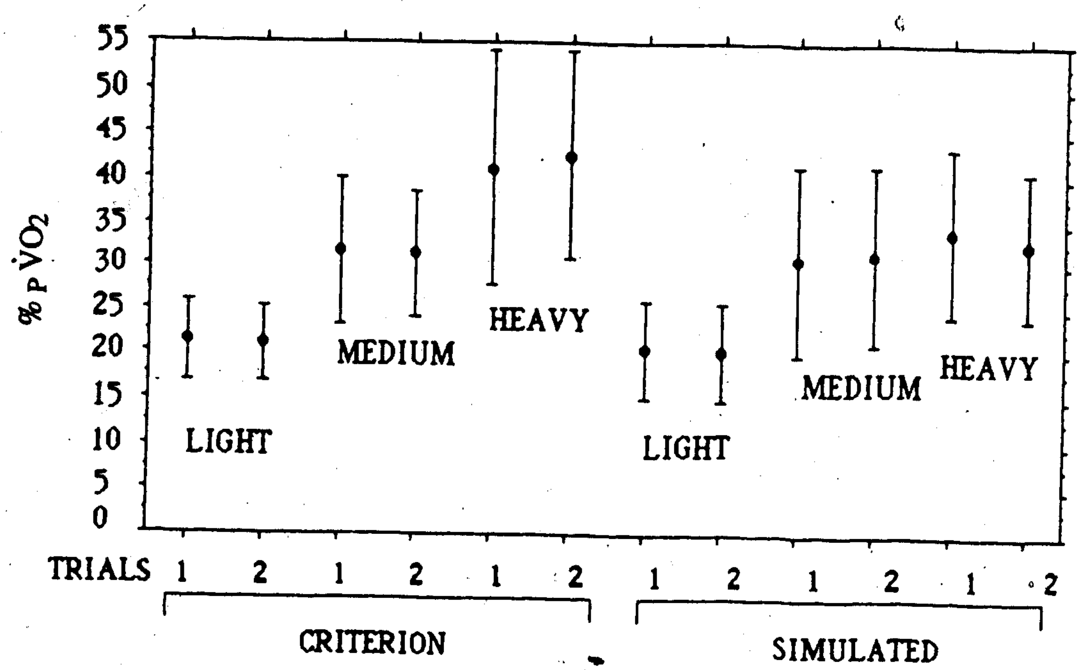


TABLE 4
Means, Standard Deviations and Ranges of Percentage of Peak Oxygen Consumption for Criterion and Simulated Types during Light, Medium and Heavy Tasks for Trials One and Two

	TRIAL ONE				TRIAL TWO			
TASKS	Mean	SD	Min	Max	Mean	SD	Min	Max
CL	21.4	4.5	11.7	35.1	21.1	4.3	14.4	32.5
SL	20.3	5.3	12.5	35.3	20.2	5.3	13.9	41.5
CM	31.5	8.4	20.5	65.2	31.2	7.3	22.4	59.9
SM	30.8	10.8	17.3	63.4	31.3	10.4	18.3	63.9
CH	40.9	13.3	18.9	93.2	42.3	11.8	29.2	85.4
SH	33.9	9.7	20.9	58.1	32.6	8.4	23.0	57.3

FIGURE 6
Percentage of Peak Oxygen Consumption for Criterion and Simulated Types Comparing Trials One and Two during Light, Medium and Heavy Tasks



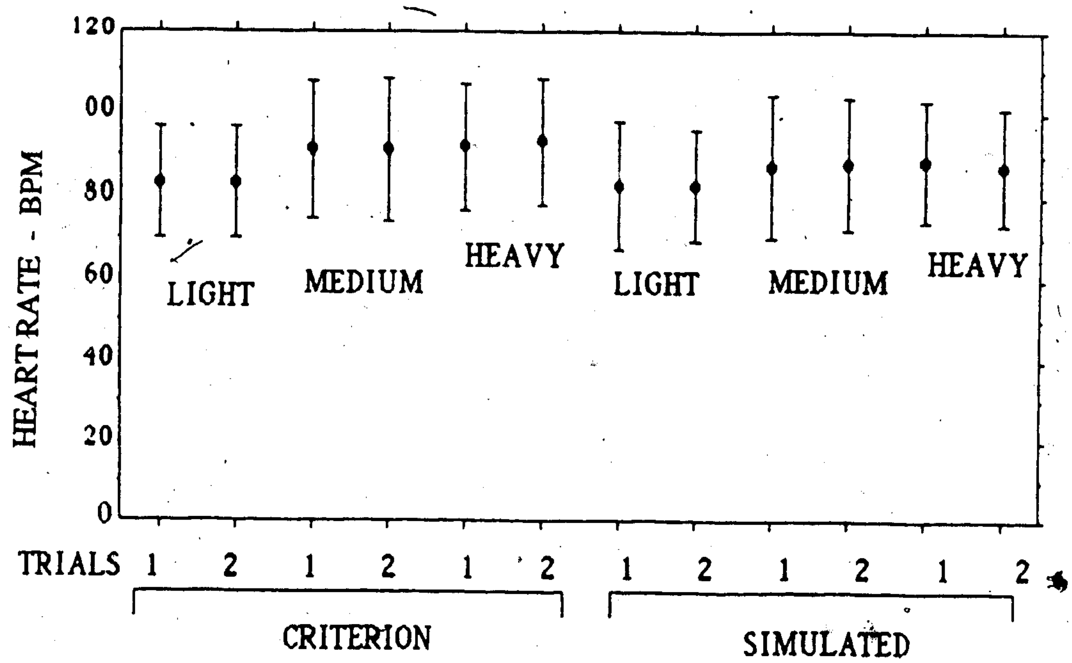
b) Heart Rate

As seen in Table 5 and Figure 7, heart rate increased moderately as work intensity increased from light to moderate, but did not show much change as the intensity increased from moderate to heavy during both the criterion and simulated tasks. The overall trend observed as the work intensity increased from light to heavy was parallel to that observed for $\dot{V}O_2$.

TABLE 5
Means, Standard Deviations and Ranges of Heart Rate (beats per minute) for Criterion and Simulated Types during Light, Medium and Heavy Tasks for Trials One and Two

	TRIAL ONE				TRIAL TWO				
TASKS		Mean	SD	Min	Max	Mean	SD	Min	Max
CL	84	13.1	66	117	84	13.2	59	112	
SL	83	15.0	62	123	83	13.0	54	112	
CM	91	16.5	69	141	91	17.1	66	141	
SM	87	16.7	67	145	88	15.5	59	138	
CH	92	14.8	71	141	93	15.0	65	125	
SH	88	14.6	67	134	87	13.8	59	117	

FIGURE 7
Mean Heart Rate for Criterion and Simulated Types Comparing Trials One and Two during Light, Medium and Heavy Tasks



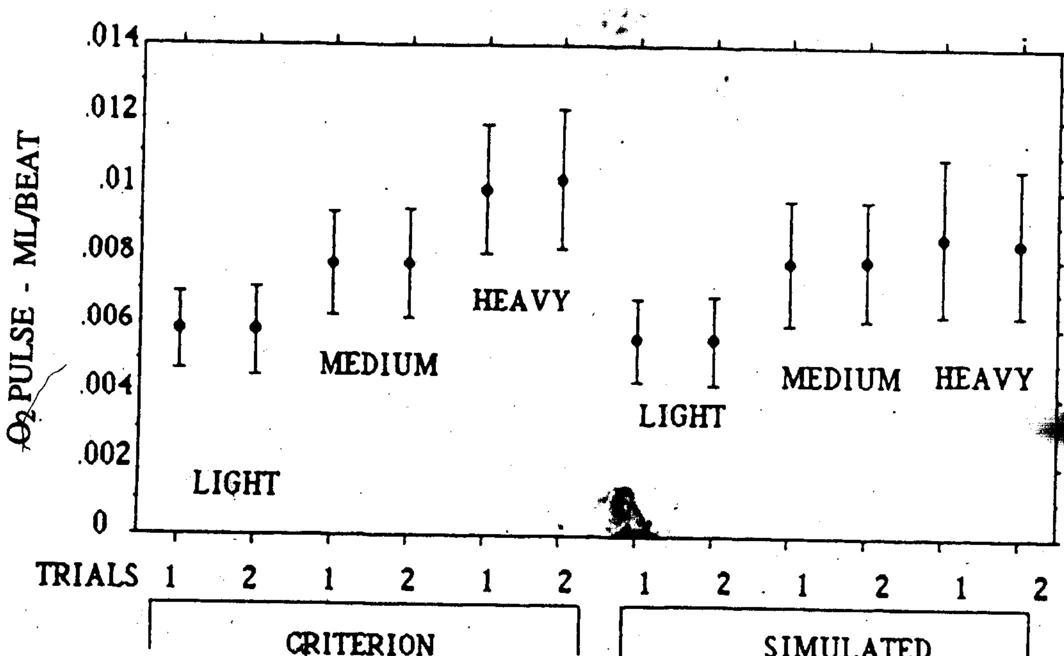
c) Oxygen Pulse

As shown in Table 6 and Figure 8, when oxygen pulse (the amount of oxygen consumed per heart beat), was considered there was a distinctive increase with increasing workload.

TABLE 6
Means, Standard Deviations and Ranges of Oxygen Pulse (millilitres per beat) for Criterion and Simulated Types during Light, Medium and Heavy Tasks for Trials One and Two

	TRIAL ONE				TRIAL TWO			
TASKS	Mean	SD	Min	Max	Mean	SD	Min	Max
CL	5.8	1.1	3.5	9.1	5.8	1.3	3.4	8.5
SL	5.6	1.2	3.4	9.0	5.6	1.3	3.4	8.7
CM	7.8	1.5	4.9	12.0	7.8	1.6	4.5	11.8
SM	7.9	1.9	5.2	11.7	8.0	1.8	5.0	11.5
CH	9.9	1.9	7.4	14.2	10.2	2.0	6.3	14.5
SH	8.7	2.3	5.5	15.3	8.5	2.1	5.0	14.6

FIGURE 8
Oxygen Pulse for Criterion and Simulated Types Comparing Trials One and Two during Light, Medium and Heavy Tasks



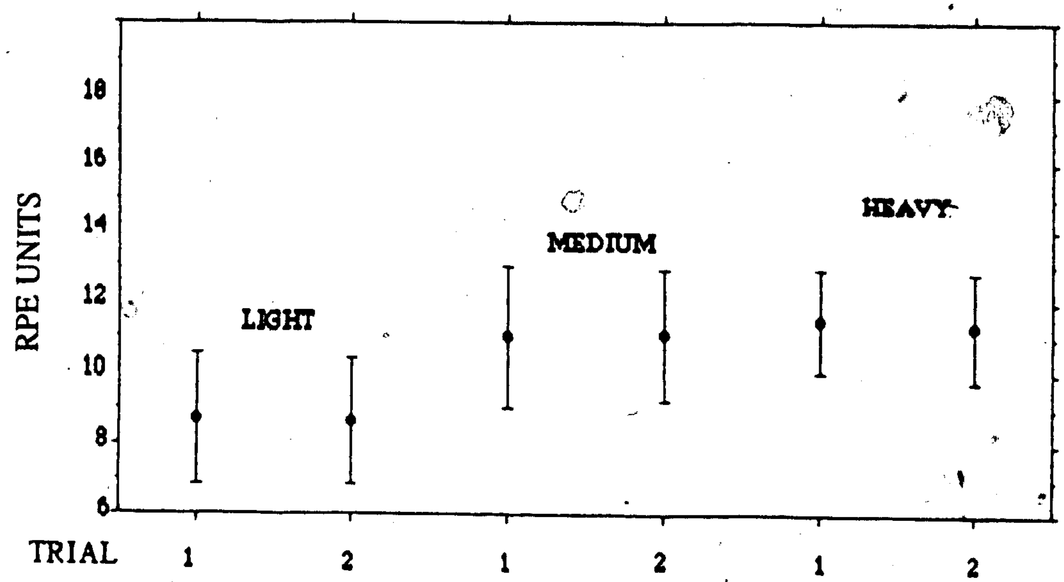
Ratings of Perceived Exertion

Summary data of the RPE reported by subjects at the end of the criterion tasks are presented in Table 7 and Figure 9. RPE's increased from 8.6 (very light) at the CL level to 11 (fairly light) at CM and 11.4 (fairly light) at CH. There was little difference between CM and CH. The values selected by the subjects varied widely at each task level and the highest values were at the medium task levels.

TABLE 7
Means, Standard Deviations and Ranges of Ratings of Perceived Exertion for Trials One and Two

	TRIAL ONE				TRIAL TWO			
TASKS	Mean	SD	Min	Max	Mean	SD	Min	Max
CL	8.7	[illegible]	6	13	8.6	1.7	6	15
CM	11.0	[illegible]	8	17	11.0	1.8	8	16
CH	11.4	[illegible]	8	14	11.2	1.6	9	14

FIGURE 9
Ratings of Perceived Exertion for Criterion Types Comparing Trials One and Two during Light, Medium and Heavy Tasks



Section C

Test-Retest Reliability

a) Oxygen Consumption

The correlation coefficients between trials one and two for CL, CM, and CH (Table 8) indicated high test-retest reliability.

TABLE 8
Correlations of Oxygen Consumption between Trials One and Two during Light, Medium and Heavy Tasks at Criterion and Simulated Levels. †

		TRIAL ONE - TRIAL TWO		
TYPE	TASK	LIGHT	MEDIUM	HEAVY
CRITERION	LIGHT	.85	.74	.67
	MEDIUM	.58	.84	.71
	HEAVY	.45	.53	.74
SIMULATED	LIGHT	.81	.44	.67
	MEDIUM	.57	.85	.52
	HEAVY	.71	.46	.87

† All correlations were significant at the alpha = 0.01 level. n = 30.

The intraclass correlation coefficient was also calculated to estimate the test-retest reliability of the BTE (Table 9). The values were very similar to those found in Table 8, supporting test-retest reliability.

TABLE 9
Intraclass Correlation Coefficients between Trials for Oxygen Consumption for Criterion and Simulated Tasks at Light, Medium and Heavy Levels. n = 30.

CRITERION	LIGHT	.85
	MEDIUM	.85
	HEAVY	.72
SIMULATED	LIGHT	.81
	MEDIUM	.85
	HEAVY	.87

Mean values obtained during testing and retesting (Table 2 and Figure 4) for criterion and simulated tasks were almost identical within each of the three task categories. As the three-way interaction term in the analysis of variance for $\dot{V}O_2$ was significant (Appendix F) post hoc results were examined to determine the location of significant differences (Table 10). No significant differences were found between trials one and two at any level, substantiating high test-retest reliablility. Expressing the $\dot{V}O_2$ relative to the subject's p$\dot{V}O_2$ (Table 11) produced an identical pattern.

TABLE 10

Mean Oxygen Consumption (l / min) during Light, Medium and Heavy Tasks at Trials One and Two for Criterion and Simulated Tasks. n = 30

TYPE	TASK	TIME	
		TRIAL ONE	TRIAL TWO
CRITERION	LIGHT	.477	.472
	MEDIUM	.697[1]	.694[1]
	HEAVY	.898[2]	.932[2]
SIMULATED	LIGHT	.449	.450
	MEDIUM	.674[1]	.689[1]
	HEAVY	.756[a]	.730[a]

1 = Light - Medium)
2 = Medium - Heavy) F values significant
a = Criterion - Simulated for the same intensity) at the 0.05 level.

TYPE*TASK*TIME: p= < 0.01

TABLE 11
Mean Percentage of Peak Oxygen Consumption during Light, Medium and Heavy Tasks at Trials One and Two for Criterion and Simulated Tasks. n = 30

TYPE	TASK	TIME	
		TRIAL ONE	TRIAL TWO
CRITERION	LIGHT	21.4	21.1
	MEDIUM	31.5[1]	31.2[1]
	HEAVY	40.9[2]	42.3[2]
SIMULATED	LIGHT	20.3	20.2
	MEDIUM	30.8[1]	31.3[1]
	HEAVY	33.9[a]	32.6[a]

1 = Light - Medium)
2 = Medium - Heavy) F values significant
a = Criterion - Simulated for the same intensity) at the 0.05 level.

TYPE*TASK*TIME: p= < 0.01

b) Heart Rate

All correlation coefficients between trials for HR were significant (Table 12). These were moderately high for CL, CM, and CH respectively, although somewhat lower than for VO_2. Moderately high correlation coefficients were also observed for SL, SM,and SH, indicating good test-retest reliability of these measurements under these conditions.

TABLE 12

Correlations of Heart Rate between Trials One and Two during Light, Medium and Heavy Tasks at Criterion and Simulated Levels. †

		TRIAL ONE - TRIAL TWO		
TYPE	TASK	LIGHT	MEDIUM	HEAVY
CRITERION	LIGHT	.59	.64	.56
	MEDIUM	.65	.74	.90
	HEAVY	.60	.69	.74
SIMULATED	LIGHT	.64	.63	.57
	MEDIUM	.70	.78	.63
	HEAVY	.70	.69	.70

† All correlations were significant at the alpha = 0.01 level. n = 30.

As with $\dot{V}O_2$, the intraclass correlation coefficient for HR was calculated (Table 13) and the values were similar to those in Table 12, supporting test-retest reliability.

TABLE 13

Intraclass Correlation Coefficients between Trials for Heart Rate for Criterion and Simulated Tasks at Light, Medium and Heavy Levels. n = 30.

CRITERION	LIGHT	.60
	MEDIUM	.75
	HEAVY	.75
SIMULATED	LIGHT	.64
	MEDIUM	.79
	HEAVY	.71

Mean values of HR during criterion and simulated tasks (Table 5 and Figure 7) were almost identical within each of the three task categories. As the three-way interaction term in the analysis of variance for HR was not significant (Appendix F) the two-way interactions (Type and Time) were examined to determine whether there was a significant effect over time, pooling the data from the third factor (Task: light, medium and heavy) as shown in Table 14. There were no significant differences in the means between trials for either criterion or simulated tasks.

TABLE 14
Mean Heart Rate (bpm) for Criterion and Simulated Tasks At Trials One and Two. (Light, Medium and Heavy Levels Collapsed.) †

TYPE	TIME	
	TRIAL ONE	TRIAL TWO
CRITERION	88.8	89.3
SIMULATED	86.2	85.9

TYPE*TIME: p= > 0.01   TYPE: p= < 0.01   TIME: p= > 0.01

† There were no significant differences between trials at the alpha 0.05 level. n = 90

Section D

Criterion Validity

a) Oxygen Consumption

All correlations between criterion and simulated tasks were significant (Table 15). These varied from highs of r = 0.81 and 0.83 for the light tasks, for trials one and two respectively, and r = 0.68 and 0.75 for the heavy tasks, to lower but still significant r = 0.56 and 0.52 for the medium tasks indicating varying degrees of validity.

TABLE 15

Correlations of Oxygen Consumption between Criterion and Simulated Tasks during Light, Medium and Heavy Tasks at Trials One and Two. †

		CRITERION-SIMULATED		
TYPE	TASK	LIGHT	MEDIUM	HEAVY
TRIAL ONE	LIGHT	.81	.47	.58
	MEDIUM	.66	.56	.59
	HEAVY	.63	.62	.68
TRIAL TWO	LIGHT	.83	.55	.71
	MEDIUM	.84	.52	.69
	HEAVY	.81	.50	.75

† All correlations were significant at the alpha = 0.01 level. n = 30.

Mean values (Table 2) for CL and CM were very similar to SL and SM respectively, but SH was notably lower than CH for both trials as illustrated in Figure 10. The same pattern was observed when % p$\dot{V}O_2$ was examined (Figure 11).

FIGURE 10
Mean Oxygen Consumption Comparing Criterion and Simulated Types during Light, Medium and Heavy Tasks for Trials One and Two

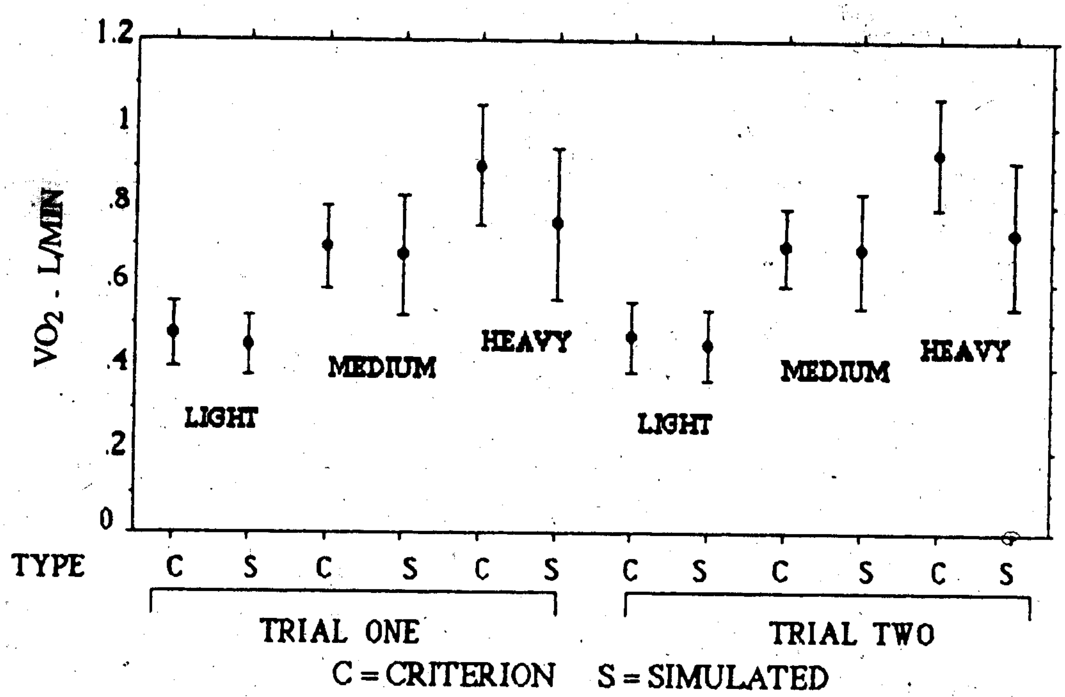
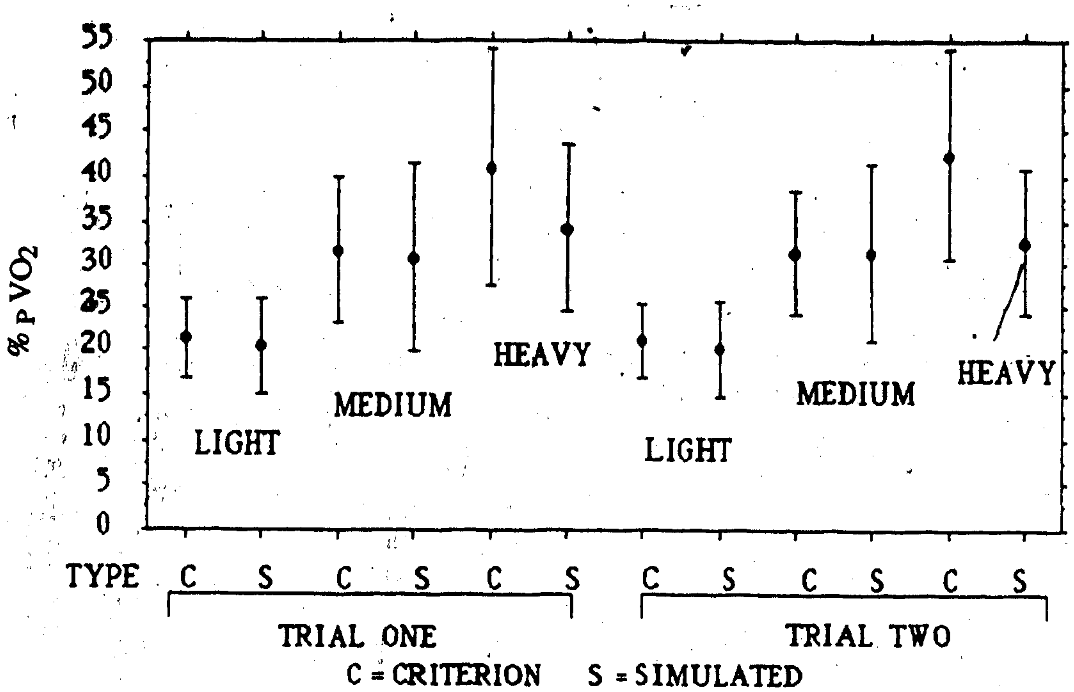


FIGURE 11

Percentage of Peak Oxygen Consumption Comparing Criterion and Simulated Types during Light, Medium and Heavy Tasks for Trials One and Two



The post hoc analysis of $\dot{V}O_2$ values indicated that there were no significant differences between criterion and simulated tasks at the light and medium levels, however, there were significant differences between criterion and simulated tasks at the heavy level (see note [a], Table 10). These results suggest that the BTE was accurately simulating only light and medium tasks.

b) Heart Rate

All correlation coefficients were significant between criterion and simulated tasks ranging from r = 0.88 to r = 0.95 (Table 16) indicating very high validity.

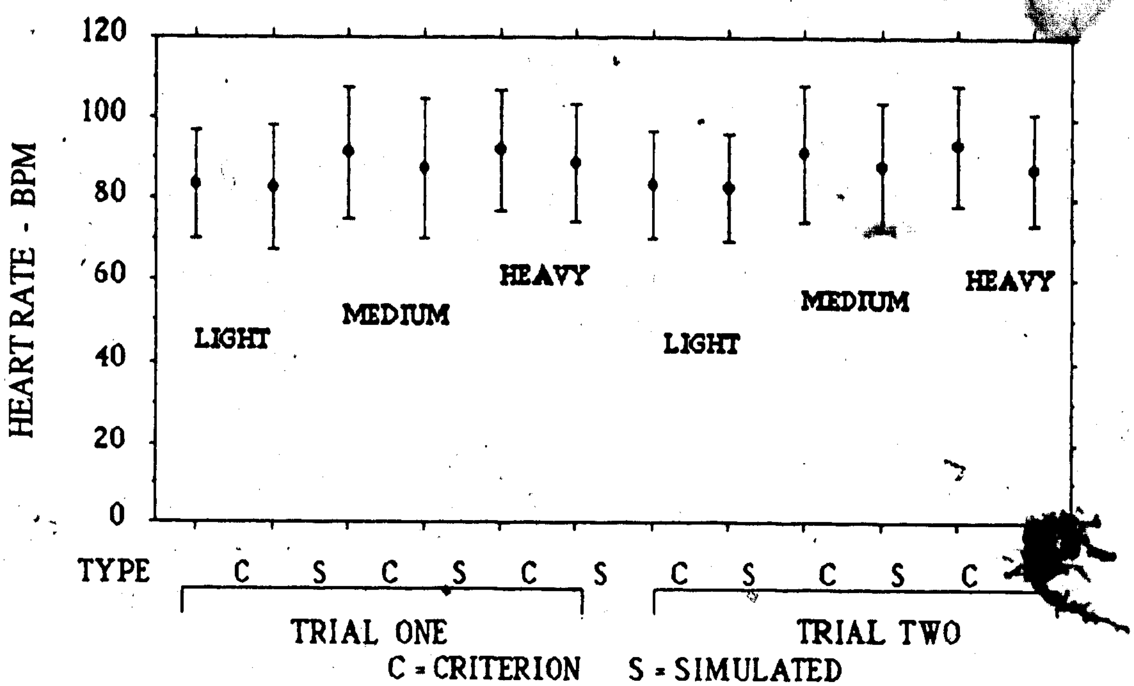
TABLE 16
Correlations of Heart Rate between Criterion and Simulated Tasks during Light, Medium and Heavy Tasks at Trials One and Two. †

		CRITERION-SIMULATED		
TYPE	TASK	LIGHT	MEDIUM	HEAVY
TRIAL ONE	LIGHT	.88	.85	.77
	MEDIUM	.88	.91	.84
	HEAVY	.85	.87	.91
TRIAL TWO	LIGHT	.95	.84	.89
	MEDIUM	.93	.92	.89
	HEAVY	.92	.83	.90

† All correlations were significant at the alpha = 0.01 level. n = 30.

Mean HR values (Table 5 and Figure 11) were very similar for CL and SL but both SM and SH were lower than CM and CH respectively.

FIGURE 12
Mean Heart Rate Comparing Criterion and Simulated Types during Light, Medium and Heavy Tasks for Trials One and Two



As the difference between trials was not significant, data from this factor was pooled so that the differences between the criterion and simulated tasks could be examined at each level of work intensity. Analysis of variance found significant differences between simulated and criterion mean values at the medium and heavy level (Table 17) with lower simulated HR values. This suggests that although subjects' paire HR scores tended to vary in a consistent manner, there were differences between the simulated and criterion tasks at medium and heavy task levels.

TABLE 17

Mean Heart Rate (bpm) for Criterion and Simulated Tasks at Light, Medium and Heav Levels. Trials One and Two Collapsed. n =60

TYPE	TASK		
	LIGHT	MEDIUM	HEAVY
CRITERION	83.5	91.2	92.4
SIMULATED	82.7	87.6†	87.9†

TYPE*TASK: p= < 0.01 TYPE: p= < 0.01 TASK: p= < 0.01

† Criterion -Simulated F values at the alpha = 0.05 level.

Intercorrelations Between Oxygen Consumption and Heart Rate

Intercorrelations between $\dot{V}O_2$ and HR were not significant in most categories (Table 18). When this was calcluated with $\dot{V}O_2$ expressed as a percentage of the individual's p$\dot{V}O_2$ (Table 19) the correlation coefficients were significant in all but two categories (light and heavy simulated tasks).

TABLE 18
Intercorrelations between Oxygen Consumption and Heart Rate for Criterion and Simulated Tasks for Light, Medium and Heavy Tasks At Trials One and Two.

		VO_2 - HR	
TYPE	TASK	TRIAL ONE	TRIAL TWO
CRITERION	LIGHT	.19	.04
	MEDIUM	.25	.11
	HEAVY	.41†	.19
SIMULATED	LIGHT	.20	.10
	MEDIUM	.31	.33†
	HEAVY	.22	.23

† Correlations were significant at the alpha 0.05 level. n = 30.

TABLE 19

Intercorrelations between Oxygen Consumption as a percentage of the subject's $p\dot{V}O_2$ and Heart Rate for Criterion and Simulated Tasks for Light, Medium and Heavy Tasks At Trials One and Two.

		PVO_2 - HR	
TYPE	TASK	TRIAL ONE	TRIAL TWO
CRITERION	LIGHT	.33†	.51†
	MEDIUM	.45†	.61†
	HEAVY	.43†	.43†
SIMULATED	LIGHT	.26	.57†
	MEDIUM	.46†	.58†
	HEAVY	.27	.44†

† Correlations were significant at the alpha 0.05 level. n = 30.

CHAPTER V

DISCUSSION

Characteristics of Participants

The absolute and relative $\dot{V}O_2$ and HR values of the subjects in this study were compared with those of previous researchers in Table 20. It is evident from the table that the mean p$\dot{V}O_2$ was within one standard deviation of the values reported by all the researchers indicated, except the values reported by Falkel , Sawka, Levine, Pimental, & Pandolf (1986).

The mean maximum HR (167 bpm, S.D.15) was also within one standard deviation of that reported by Washburn & Seals (1983,1984) but was lower than the mean HR reported by Davis, et al. (1976), and Pollock et al. (1974) as presented in Table 20.

TABLE 20
Peak Oxygen Uptake and Heart Rate Values in Arm Ergometry with Males

Investigators	Subjects	Age Yrs	pVO2 L/min	pVO2 ml/kg/min	HR bpm
Present study	30 volunteers	26 ± 4.8	2.33 ± 0.57	31.1 ± 7	167 ± 15
Falkel et al. 1986	9 volunteers	26 ± 2	3.07 ± 0.14	39.9 ± 1.4	176 ± 3
Washburn & Seals 1984	20 phys. ed. students	36 ± 6	2.55 ± 0.45	34.2 ± 5.3	174 ± 14
Washburn & Seals 1983	20 aerobic trained	31.1 ± 5.6	2.53 ± 0.61	33.8 ± 5.7	171 ± 13.2
Davis et al. 1976	30 students	22.5 ± 2.6	2.34 ± 0.39	31.0 ± 4.2	184 ± 12.4
Pollock et al. 1974	11	38			
	sedentary - untrained		1.93 ± 0.4	23.3 ± 3.6	176 ± 12
	sedentary - trained		2.65 ± 0.5	32.5 ± 4	179 ± 7.5
	11	38			
	controls - untrained		2.17 ± 0.3	26.0 ± 4.1	186 ± 17.3
	8	38			
	L. E. disabled - untrained		1.88 ± 0.3	20.5 ± 4	181 ± 17.2
	L. E. disabled - trained		2.23 ± 0.4	24.4 ± 4.3	180 ± 22.9

Test-Retest Reliability and Criterion Validity

Since no similar studies on the BTE have been done, it is not possible to compare the present observations with related research on this instrument.

The evidence provided in this study indicated that both $\dot{V}O_2$ and HR measurements at the three work intensities on the BTE were reliable. The somewhat lower between trial correlation values found with HR measures (Table 12) can be explained by the many extraneous factors which affect HR such as food intake, caffeine, nicotine, medications, the size of the exercising muscle group, room temperature, and anxiety levels. In this study subjects were given prior written and verbal instructions regarding food intake and activity levels in order to control for this. Despite this there were large differences between and within individuals, as found by other authors (Borg, 1982; Pandolf, 1983; Shanfield, 1984; Shephard, 1987b, p.16).

The correlation coefficient, Pearson's r, can tell us whether a relationship exists between two variables and the strength of that relationship. By squaring the coefficient we find out the proportion of total variability of one variable which can be accounted for by the other variable (the coefficient of determination). Even through correlation coefficients such as $r = 0.50$ or 0.60 are considered fairly high, correlations of this magnitude account for only 25 to 36% of the variability (Pagano, 1986, p.121). Clinicians must always keep this in mind in interpreting the results of correlational studies as such correlations indicate many other factors must also be important.

The validity of the BTE was consistently demonstrated at the light work intensity by both $\dot{V}O_2$ (Tables 10 and 15) and HR (Tables 16 and 17). However, results were conflicting at the medium work intensity level. The somewhat lower correlations for $\dot{V}O_2$ may be due to the fact that upper extremity work was being performed at shoulder height. This involved the use of small muscle groups, which fatigue more quickly when working above shoulder level. Work at this elevation significantly increases physiological stress (Astrand & Rodahl, 1986, p.192). Under this already more stressful condition subjects may have varied their pacing contributing to greater variation in obtained $\dot{V}O_2$ values.

There were no significant differences between mean criterion and simulated $\dot{V}O_2$ values at the medium work intensity, supporting criterion validity. It should be noted that HR correlations between criterion and simulated tasks remained very high at this level ($r = 0.91$ and $r = 0.92$ on trials one and two respectively) indicating that subjects were successfully maintaining a constant heart rate despite differing rates of energy utilization. However, there were significant differences between mean CM and SM HR values. It may be that the SM task allowed the subject to utilize some trunk and leg musculature as well as arm and shoulder muscles (in other words, sway forward and backward to help push the tool) whereas in the CM task, swaying of this type would not have been particularly helpful and the subjects were more likely to use only arm and shoulder movements, which would be reflected in a higher HR in the criterion task. Although statistically significant, the mean difference was very small (3.5 beats per min., with standard deviations ranging from 15.5 to 17.1).

Criterion validity was not demonstrated at the heavy work intensity where subjects consistently had significantly lower $\dot{V}O_2$ (Tables 3 and 10) and HR (Tables 5 and 17) values while performing on the BTE. The restricted movement patterns of the simulated tasks due to the equipment guiding the movements may have tended to minimize extraneous postural adjustments and thus reduced the overall workload for the subject. This effect could be expected to be most pronounced at the highest workload where the involvement of trunk and upper arm muscles was greatest.

It may be that subjects had more difficulty judging the amount of resistance required to match heavy tasks and may have tended to overestimate the amount of work they were doing in the simulated condition. In a study of males estimating their lifting capacity, Mital (1983) found that males had difficulty estimating in a 25 minute period how much they could lift for an 8 hour period. Their 8-hour amount lifted was only 65 % of the amount they had estimated after a 25 minute trial.

Another explanation may come from the work of Astrand & Rodahl (1986, p. 188) who found that HR tended to increase linearly with the increase in rate of exercise but exceptions were most common in untrained subjects. Particularly when carrying out heavy work, the a-$\dot{V}O_2$ difference (the extraction of oxygen from the blood) may increase so that the oxygen uptake increases relatively more than the cardiac output. The subjects in this study were of average fitness as indicated by their p$\dot{V}O_2$ values during arm ergometry, and they had only a brief opportunity to become accustomed to the materials handling tasks that they were required to perform in this study.

Although HR increased from the light to heavy tasks in both criterion and simulated conditions this was not a linear increase with both medium and heavy tasks having very similar values (Table 5). This can be explained by the fact that the three tasks were quite different from each other and were not, as in many experiments which have found linear HR increases, the same task (eg. bicycle ergometry) with increasing amounts of resistance.

Although RPE values increased with increasing workloads (Table 7), there was not the separation between medium and heavy that was expected and both medium and heavy tasks were perceived as "fairly light". This indicates that the expert judges were not in fact able to classify the tasks appropriately strictly on the basis of their brief trials and observations, and emphasizes the need for more objective information.

Another complementary explanation is that the subjects had been instructed to chose a pace they could continue for a full work day. As mentioned previously, the work by Mital (1983) indicates that this may be quite difficult for subjects to judge (and maybe as difficult for the experts). However, if the expert judges had been allowed to determine an appropriate pace for each of the tasks, this problem might have been avoided.

Work Classification

As indicated earlier, the three way interaction of the analysis of variance for $\dot{V}O_2$ was significant, indicating that there were differences between the three task levels (light, medium, and heavy) for criterion and simulated tasks on both trials (see notes 1 and 2, Table 10) with the exception of the SM and SH categories on both trials. The SH tasks appear to have been consistently lighter than their counterpart criterion tasks.

Oxygen consumption increased as work intensity increased with the CL,SL, CM, and SM tasks falling within the respective "light" and "medium" categories suggested by Shephard's (1987a) work classification system. None of the highest $\dot{V}O_2$ values for the light and medium tasks were above these categories. However, oxygen consumption during the CH and SH tasks was below the "heavy" categories in both these systems, falling on average, in the "medium" category. Some of the maximum values were in the "heavy" category according to Shephard's system.

Using the classification system suggested by Durnin (1967, as cited in McArdle et al., 1986) all values were in the "light" category, with some of the maximum values for heavy tasks in the "medium" category. This classification system does not specifically distinguish between arm and leg work.

When $\dot{V}O_2$ relative to body weight was examined (Table 3), all categories were within the "light" category according to Durnin's classification system (1967) which is the only one which gives values for this variable. Only the maximum values for the CH tasks were above this, being in the "medium" category.

Percentage $p\dot{V}O_2$ (Table 4) increased as work intensity increased. Subjects had been instructed to work at a pace they could continue for a full work day. According to Astrand & Rodahl (1986, p.487) and Shephard (1987a) this would be between 30 to 40 % of the subject's $\dot{V}O_{2max}$. The mean values for all tasks approximated this guideline. The same authors gave 63 to 76% as acceptable upper limits for work of one hour's duration. When the maximum values were examined it could be seen that at the CH level this guideline was exceeded and some subjects reached 85.4 and 93.2 % $p\dot{V}O_2$ - a pace they could not likely have maintained even for an hour. Conversely, in the light tasks subjects were working well below the 30% guideline underestimating their fatigue levels.

As shown in Table 6 and Figure 8, when oxygen pulse (the amount of oxygen consumed per heart beat) was considered, there was a distinctive increase with increasing workload. This increase did not show up when HR was examined alone as the increasing oxygen transport could have been accomplished with larger stroke volumes or improved efficiency of oxygen utilization in the muscles (Astrand & Rodahl, 1986, p. [illegible]87).

Intercorrelations Between Oxygen Consumption and Heart Rate

There is generally a linear relationship between relative $\dot{V}O_2$ and HR in situations utilizing large muscle groups such as the legs (Astrand & Rodahl, 1986, p.493). The use of the upper extremities in the tasks chosen for the study may explain the relatively low correlations, because of the use of small muscle groups and the one task (medium) in which subjects worked above shoulder level.

An additional explanation is provided by Shephard (1987b) who noted that with leg exercise this relationship departs from linearity if the effort is less than 50% of $\dot{V}O_{2max}$. The mean percentage of $p\dot{V}O_2$ in this study ranged from a low of 20% on simulated light tasks to a high of 42% on criterion heavy tasks (Table 4) indicating that the subjects were not working at a high enough percentage of their maximum capacity to be in the range where linearity between $\dot{V}O_2$ and HR could be expected. This would likely be even more pronounced with arm exercise.

SUMMARY AND CONCLUSIONS

Thirty male volunteers participated in three laboratory sessions to determine the test-retest reliability and criterion validity of the BTE. This was done by having subjects perform three repetitive upper extremity tasks on the BTE which simulated three criterion tasks. The tasks were subjectively classified by expert judges into light, medium and heavy categories. As no direct method of comparing the tasks was available, measures of $\dot{V}O_2$ and HR, both valid measures, were observed during both criterion and simulated conditions. RPE was also obtained at the end of each task. In addition, in a preliminary session, subjects performed an arm ergometry test to determine their p$\dot{V}O_2$. This made it possible to calculate and examine %p$\dot{V}O_2$ under all task conditions and to compare the subjects to other studies.

Correlations between trials of the same task for $\dot{V}O_2$ ranged from r = 0.74 - 0.87 and for HR from r = 0.59 - 0.78. These were significant and indicated test-retest reliability. Post hoc examination of the analysis of variance of the mean values of types of tasks at each level of intensity revealed no significant differences between trials for both these variables.

Criterion validity varied according to factors such as the type of work (eg. height above the shoulder), the pace of work, and the ability of humans to accurately judge the resistance required on the BTE. These factors appeared to have had the least effect at the light task level. All criterion-simulated correlations were significant. CL-SL correlations for $\dot{V}O_2$ were r = 0.81 and 0.83; for HR r = 0..88 and 0.95, indicating high criterion validity at light work intensity. CM-SM correlations for $\dot{V}O_2$ were r = 0.56 and 0.52; for HR r = 0.91 and 0.92. The lower $\dot{V}O_2$ correlations may be related to the nature of the task which was above the shoulder level. CH-SH correlations for $\dot{V}O_2$ were r = 0.68 and 0.75; for HR r = 0.91 and 0.90. The $\dot{V}O_2$ values were significantly different between light, medium and heavy work intensities except for SM and SH. Criterion-simulated post hoc comparisons for $\dot{V}O_2$ revealed a lack of similarity between CH - SH. It appears that the subjects underestimated the amount of resistance required on the BTE to simulate the criterion tasks. Similar comparisons for HR revealed a lack of similarity between both CM - SM and CH - SH.

Clinical Implications

In using the BTE to simulate and thereby predict an individual's ability to carry out work tasks, therapists must keep several factors in mind.

1) The BTE can seldom be set up to simulate a whole task with one attachment. Most tasks can be simulated only by piecing together the various elements with separate attachments. This changes the pacing and the physiological demands of the task.

2) In light tasks individuals were quite accurate in judging the amount of resistance needed to replicate the criterion task but as the tasks became heavier they increasingly underestimated the required resistance. Therapists can compensate by increasing the resistance at heavier levels, however the best solution would be to obtain actual measurements of the force required in the specific tasks. While therapists seldom have this information readily available, with collaborative efforts, it may be possible over time to build up a data base of force requirements for typical tasks.

3) Subjective estimates of the intensity of work are difficult for even expert judges to make. Classification systems which do not give specific information about the height of tasks and the pace of work are of only limited use. Therapists must take these factors into account in evaluating the individual's abilities.

4) Occupational therapists are increasingly being called upon to testify in civil courts of law as "expert witnesses" (Demaio-Feldman, 1987). Numerical findings, such as those produced by the client with the BTE, are attractive in such settings and certainly have a place in the evaluation process, but the therapist must make a clear delineation between the findings which are truly objective and those which can only be called subjective. Several more stages of research are required before predictive validity of the BTE can be established with non-disabled subjects. Extending that validity to disabled subjects will obviously be an even longer process.

5) This study has not examined the use of the BTE to improve strength, endurance, and co-ordination, where its adaptability and objective feedback could be particularly valuable.

Future Studies

In future studies, it would be useful to assess the BTE's validity by directly measuring the work and power required by tasks in the work place and comparing them with the same measures obtained from the BTE data. In order to simulate the real tasks, the pace of work would also need to be replicated.

The numerous other attachments of the BTE also require study. The type of attachment may have a significant effect on both reliability of the measurements and validity.

Finally, research needs to be extended to study the disabled populations for which the BTE was primarily designed.

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APPENDICES

Appendix A

The RPE Scale[8]

The 15 point scale for ratings of perceived exertion.

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

8 Borg, G.A. (1982). Psychophysical bases of perceived exertion. Medicine and Science in Sports and Exercise, 14 (5):377-381.

Appendix B

Department of Occupational Therapy
Faculty of Rehabilitation Medicine
University of Alberta
April 1988

INFORMED CONSENT FOR RESEARCH STUDY:

"A Reliability and Validity Study of the BTE Work Simulator™"
Investigator: L.E. Kennedy

Outline of procedures

The purpose of the study is to determine the reliability and validity of the BTE in simulating real tasks. The study will involve attending three separate sessions of approximately one hour each within a two week period. Your height and weight will be recorded. Your heart rate will be recorded using surface electrodes and your oxygen consumption will be measured by sampling the air you breathe out through a face mask.

In the first session you will be shown six tasks which you will be performing in the subsequent sessions. Three of these tasks will involve repetitive movements such as pushing or pulling objects. Three of the tasks will be performed on the BTE work simulator. Some of the tasks will be harder than others. You will have a chance to try each of the tasks to become familiar with them. You will also perform a graded maximal exercise test on the arm ergometer during which your heart rate, oxygen consumption and level of perceived exertion will be measured. You will be monitored by the researcher who is familiar with the American College of Sports Medicine guidelines for terminating a graded maximal exercise test.

On the second session, a minimum of 48 hours after the first, you will be asked to perform the six tasks (for approximately five minutes each) and be given a rest interval between each task. Your heart rate, oxygen consumption and level of perceived exertion will be measured. The third session, a minimum of 48 hours later, will be the same as the second. The total time involved for all three sessions will be approximately three hours.

You are asked not to eat a heavy meal or engage in vigorous physical activity three hours prior to the testing periods.

The data collected will belong to the Department of Occupational Therapy and will be utilized in a manner that does not reveal your identity.

You will complete the Physical Activities Readiness Questionnaire (PAR-Q) providing information that is accurate to the best of your knowledge. If at any time during the tests you experience any unusual discomfort you will be allowed to discontinue the activity or opt out of the study without any obligation to offer an explanation.

An effort will be made to answer any questions you may have concerning the test procedures or any other aspects of the project.

Subject consent

I consent to participate as a subject in a study entitled " A Reliability and Validity Study of the BTE Work Simulator™" to be conducted by Lorian Kennedy. I acknowledge that the research procedures described above and of which I have a copy have been explained to me and that any questions I have asked have been answered to my satisfaction. I have been advised that I may withdraw from participation at any time without offering any explanation to the investigator. By agreeing to participate in this study, I hereby waive any legal recourse against the University of Alberta or its representatives now and in the future.

Name (please print): ______________ Subject's signature: ______________

Date: ______________ Witness' signature: ______________

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)[9]

PARTICIPANT IDENTIFICATION

PAR-Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

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	
☐	☐	1. Has your doctor ever said you have heart trouble?
☐	☐	2. Do you frequently have pains in your heart and chest?
☐	☐	3. Do you often feel faint or have spells of severe dizziness?
☐	☐	4. Has a doctor ever said your blood pressure was too high?
☐	☐	5. 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?
☐	☐	6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
☐	☐	7. 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 increasing your physical activity and/or taking a fitness test. Tell him what questions you answered YES on PAR-Q, or show him your copy.

programs

After medical evaluation, seek advice from your physician as to your suitability for:

- unrestricted physical activity, probably on a gradually increasing basis.
- restricted or supervised activity to meet your specific needs, at least on an initial basis. Check in your community for special programs or services.

NO to all questions

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

- A GRADUATED EXERCISE PROGRAM - A gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort.
- AN EXERCISE TEST - Simple tests of fitness (such as the Canadian Home Fitness Test) or more complex types may be undertaken if you so desire.

postpone

If you have a temporary minor illness, such as a common cold.

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Reference: PAR-Q Validation Report, British Columbia Ministry of Health, 1978.
Produced by the British Columbia Ministry of Health and the Department of National Health & Welfare.

[9] PAR-Q Validation Report,(1978). British Columbia Ministry of Health.

Appendix D

EXPERIMENTAL DESIGN *

A-TYPE	B-TASK	C-TIME	
		TRIAL ONE	TRIAL TWO
CRITERION	LIGHT		
	MEDIUM		
	HEAVY		
SIMULATED	LIGHT		
	MEDIUM		
	HEAVY		

* 2 x 3 x 2 factorial design.
Dependent variables to be measured: HR, VO_2.

Appendix E

RAW DATA

Participant Characterisitcs

I.D	AGE	HEIGHT	WEIGHT	pVO2	pVO2/KG	MAX HR	ST HR
[illegible]	32	181	66	1.174	17.8	160	102
5	19	173.5	58.25	2.09	35.8	184	75
7	[illegible]	171	69	1.434	20.7	160	[illegible]
8	27	176.5	71.5	2.778	38.8	187	76
9	[illegible]	188.5	81	2.244	27.6	164	76
10	22	175.5	72	2.523	35	165	69
11	35	173	70.5	2.49	35.2	145	54
12	[illegible]	179	73	2.474	33.8	184	109
13	27	175	76.75	2.307	30	169	[illegible]
14	[illegible]	180.25	75.5	2.957	39.1	184	[illegible]
15	[illegible]	170	59.5	1.484	24.9	161	79
16	[illegible]	177	72.5	1.969	27.1	186	84
17	32	183.5	88.75	2.779	31.2	153	48
18	30	173.25	79.5	1.881	23.6	158	67
19	24	176.5	71.25	2.716	38	180	64
20	19	189.5	84.5	2.635	31.1	172	97
21	34	[illegible]	68.25	3.252	47.6	173	75
22	35	178.5	80	2.361	29.5	152	94
23	28	176	75.5	2.571	34	181	71
24	23	175.75	78.25	2.592	33.1	182	82
25	27	179.75	80.5	2.228	28.4	156	70
26	31	170	56.75	1.485	26.1	143	[illegible]
28	24	175	72	3.416	47.3	183	70
29	26	178.5	83	3.121	37.5	167	93
30	35	182.75	60	1.45	24.1	148	71
31	31	186.5	96	3.092	32.1	141	60
32	31	183.5	88	2.12	24	142	70
33	27	170	73	2.087	28.9	163	79
34	30	176	90	2.192	24.3	182	74
35	27	181	70.5	1.871	26.5	184	72

CRITERION LIGHT TASKS

	TRIAL ONE				TRIAL TWO			
I.D.	RPE	HR	VO2	VO2/KG	RPE	HR	VO2	VO2/KG
3	10	116.5	.412	6.25	10	111.5	.381	5.75
5	10	75	.4[illegible]5	7.25	8	97.5	.461	7.9
7	10	79	.4335	[illegible]25	9	92.5	.409	5.95
8	7	81.5	.5375	7.5	7	82.5	.4895	6.8
9	7	77	.608	7.5	8	95	.6255	7.7
10	7	71	.474	6.6	7	67	.503	6.95
11	6	79	.544	7.7	6	60.5	.459	6.5
12	7	113.5	.5795	7.95	8	94.5	.5065	6.9
13	7	91	.4625	6	7	85	.462	6
14	7	90	.6355	8.4	8	82	.624	8.25
15	13	88	.361	6.05	11	106.5	.373	6.25
16	9	92.5	.444	6.1	10	81	.41	5.65
17	8	73.5	.504	5.65	8	58.5	.45	5.05
18	7	66	.4015	5.05	7	78.5	.407	5.1
19	9	75	.479	6,7	9	67.5	.5005	7
20	8	105.5	.602	7.1	9	105	.6395	7.55
21	8	80	.4475	6.5	8	89	.487	7.15
22	10	92	.509	6.35	9	94	.496	6.15
23	10	83.5	.4595	6.05	9	79.5	.4425	5.85
24	8	85.5	.4945	6.3	7	86.5	.4645	5.95
25	7	67.5	.4885	6.05	7	74	.461	5.7
26	10	87	.378	6.65	10	96.5	.3365	5.9
28	9	75.5	.4	5.55	9	83.5	.492	6.85
29	8	100	.4735	5.7	8	78	.4755	5.7
30	7	66.5	.3375	5.6	7	61.5	.3725	6.2
31	8	69	.6255	6.5	8	78	.664	6.9
32	8	78	.479	5.4	8	83.5	.562	6.35
33	13	74	.4385	6	15	80.5	.4585	6.25
34	12	94.5	.454	5.05	9	75.5	.3735	4.15
35	11	76	.4165	5.9	11	81	.3775	5.35

CRITERION MEDIUM TASKS

I.D.	TRIAL ONE RPE	HR	V̇O2	V̇O2/KG	TRIAL TWO RPE	HR	V̇O2	V̇O2/KG
3	12	141	.766	11.6	12	141	.703	10.6
5	13	87.5	.636	10,9	12	104	.699	12
7	10	96	.62	8.95	12	107	.666	9.65
8	13	95.5	.87	12.15	13	86	.7855	11
9	8	80	.7145	8.8	11	95	.7105	8.75
10	10	78.5	.648	9	10	68	.639	8.85
11	9	78.5	.8475	12	12	70	.826	11.7
12	12	129	.8685	11.9	14	116	.79	10.8
13	10	105.5	.741	9.6	8	87	.7105	9,25
14	10	92.5	.7845	10.35	12	92	.8105	10.7
15	13	96	.4735	7.95	13	112	.4985	8.35
16	12	92	.5555	7.65	11	[illegible]	.581	8.05
17	9	86	.7725	8.65	9	[illegible]	.6595	7.45
18	8	69	.6095	7.65	10	[illegible]	[illegible]	7.9
19	9	80.5	.671	9.4	9	72.5	.697	9.75
20	9	124	.7005	8.25	10	113.5	.824	9.75
21	10	87.5	.725	10.6	11	104	.784	11.45
22	12	94	.7765	9.7	10	99.5	.727	9.1
23	12	95.5	.6075	8.05	10	79.5	.67	8.9
24	11	81	.666	8.5	8	88.5	.682	8.7
25	9	78.5	.672	8.35	9	76.5	.7035	8.75
26	13	95	.5675	10	12	109	.514	9
28	11	85	.6995	9.7	11	97	.766	10.65
29	12	104	.802	9.65	13	85	.784	9.45
30	9	72	.6345	10.55	8	66	.5185	8.65
31	10	72.5	.8715	9.05	10	81.5	.8585	8.95
32	12	89	.7185	8.15	12	95	.7505	8.55
33	17	87.5	.742	10.3	16	91.5	.6915	9.45
34	12	83	.602	6.65	11	78.5	.5665	6.25
35	13	77.5	.533	7.55	12	81.5	.562	7.95

CRITERION HEAVY TASKS

	TRIAL ONE				TRIAL TWO			
I.D.	RPE	HR	VO2	VO2/KG	RPE	HR	VO2	VO2/KG
3	10	125.5	1.0945	16.55	11	121	1.003	15.2
5	12	89.5	.7865	13.5	12	113.5	.9325	15.95
7	9	96.5	.751	10.85	10	112	.905	13.1
8	13	92	1.0235	14.3	11	90.5	.9855	13.75
9	11	88	.9835	12.1	13	101	1.1195	13.8
10	12	86.5	.9885	13.7	13	79	1.029	14.25
11	11	70.5	.983	13.9	11	69.5	.948	13.45
12	12	141	1.2285	16.8	10	124.5	1.085	14.8
13	11	98.5	.836	10.9	12	92.5	.816	10.6
14	11	95.5	1.0095	13.35	13	96	1.135	15
15	14	88.5	.703	11.8	14	107	.6765	11.35
16	13	105.5	.775	10.8	12	90.5	.831	11.4
17	10	77	.987	11.1	10	65	.883	9.95
18	8	78	.773	9.7	9	81.5	.821	10.3
19	11	81.5	1.0035	14.05	11	79	.985	13.75
20	11	111.5	.9235	10.9	9	112	1.047	12.35
21	11	95	.965	14.15	12	100	.9495	13.9
22	11	97.5	.9095	11.35	9	95.5	.899	11.2
23	13	91.5	.8715	11.55	13	87.5	.8175	10.8
24	9	88	.894	11.4	9	93	.873	11.15
25	11	84.5	.929	11.55	11	84	.9685	12
26	14	97	.715	12.55	13	108.5	.818	14.4
28	11	88	.6465	[illegible].95	11	103	1.0205	14.15
29	11	101.5	1.0295	12.[illegible]5	12	85.5	1.0635	12.8
30	12	87.5	1.0415	17.3	9	74	.93	15.45
31	11	82	1.1655	12.1	10	88.5	1.282	13.35
32	11	76.5	.7405	8.4	10	84.5	.8135	9.25
33	14	86.5	.8105	11.1	14	95	.9225	12.6
34	11	78.5	.746	8.25	[illegible]	[illegible]	[illegible]	7.9
35	13	73	.623	8.8	13	87	.702	9.95

SIMULATED LIGHT TASKS

I.D.	TRIAL ONE BTE	TRIAL ONE HR	TRIAL ONE VO2	TRIAL ONE VO2/KG	TRIAL TWO HR	TRIAL TWO VO2	TRIAL TWO VO2/KG
3	9	123	.4145	6.25	111.5	.4875	7.35
5	12	76.5	.355	6.05	94	.4055	6.95
7	11	85.5	.4155	6	101.5	.367	5.3
8	15	89.5	.546	7.65	77.5	.513	7.15
9	14	82	.569	7	87.5	.577	7.1
10	12	70.5	.4303	5.95	70	.4315	6
11	18	61.5	.455	6.45	64	.5355	7.6
12	13	115	.564	7.75	100	.531	7.25
13	12	89	.4085	5.3	82	.3965	5.2
14	15	86.5	.5575	7.35	83	.51	6.7
15	16	66.5	.337	6	99.5	.3405	5.7
16	15	89	.436	6	80	.3515	4.85
17	14	73.5	.4245	4.75	53.5	.4355	4.7
18	10	76	.424	5.3	77.5	.4025	5.25
19	10	73.5	.4055	5.7	76	.422	5.9
20	16	117	.5585	6.6	104	.648	7.65
21	9	88.5	.415	6.05	90	.4805	7.05
22	13	85.5	.4725	5.9	86.5	.462	5.75
[illegible]	10	87	.382	5.05	77	.402	5.3
24	10	80.5	.4435	5.65	86	.389	4.95
25	12	72.5	.53	6.6	74	.4545	5.65
26	13	88.5	.3975	7	97	.3585	6.3
28	14	69.5	.426	5.9	78	.475	6.6
29	13	96	.446	5.35	71	.487	5.85
30	16	64.5	.445	7.4	63	.343	5.7
31	14	69.5	.624	6.5	78.5	.683	7.1
32	12	76.5	.456	5.15	84	.4485	5.1
33	13	68	.423	5.8	76	.4275	5.85
34	13	89	.325	3.6	76	.3625	4.05
35	12	74.5	.392	5.55	81	.3695	5.25

SIMULATED MEDIUM TASKS

		TRIAL ONE			TRIAL TWO		
I.D.	BTE	HR	$\dot{V}O2$	$\dot{V}O2$/KG	HR	$\dot{V}O2$	$\dot{V}O2$/KG
3	35	144.5	.7445	11.25	138	.7505	11.35
5	38	85	.5645	9.65	90	.606	10.4
7	32	90.5	.5875	8.5	102.5	.536	7.75
8	46	103.5	1.095	15.25	92.5	.9055	12.65
9	42	86	.907	11.15	95	.8365	10.3
10	37	76	.6625	9.2	70	.6275	8.7
11	42	67	.7125	10.05	71.5	.824	11.65
12	36	128.5	.814	11.1	104	.745	10.2
13	28	88.5	.5235	6.8	85.5	.5845	7.6
14	38	90	.718	9.5	85.5	.724	9.55
15	49	87	.615	10.35	102	.7045	11.8
16	40	87	.632	8.7	82.5	.581	7.95
17	33	66.5	.5305	5.95	58.5	.512	5.75
18	41	77.5	.592	7.45	86	.7175	9
19	44	82.5	.867	12.3	88	.981	13.75
20	45	104.5	.8105	9.6	110.5	.8635	10.2
21	39	90.5	.6635	9.7	102.5	.7975	11.65
22	40	91	.754	9.4	88	.649	8.05
23	39	84	.54	7.1	78	.636	8.4
24	32	79.5	.531	6.75	85	.496	6.3
25	32	74.5	.59	7.3	77	.5485	6.8
26	31	91.5	.509	8.95	94	.4915	8.65
28	39	72.5	.5915	8.2	84	.6235	8.65
29	35	105	.6635	8	78.5	.719	8.65
30	49	73	.856	14.25	70.5	.784	13.05
31	35	70.5	.808	8.4	84.5	.8625	8.95
32	51	85	.8025	9.1	97.5	.9005	10.2
33	39	81	.6095	8.35	91.5	.6805	9.3
34	40	80.5	.486	5.4	65.5	.5975	6.6
35	28	78.5	.428	6.1	74.5	.3715	5.25

SIMULATED HEAVY TASKS

	TRIAL ONE				TRIAL TWO		
I.D.	BTE	HR	$\dot{V}O2$	$\dot{V}O2/KG$	HR	$\dot{V}O2$	$\dot{V}O2/KG$
3	28	119.5	.6555	9.9	117	.673	10.15
5	40	85	.6385	10.95	94	.65	11.1
7	37	102.5	.7305	10.55	107	.623	9
8	51	95.5	1.0035	14	84.5	.8685	12.1
9	45	89	.9695	11.95	97	.839	10.35
10	47	89	.9145	12.65	79	.839	11.6
11	46	67	.869	12.3	66.5	.8455	12
12	37	134	1.0395	14.2	102	.7665	10.45
13	30	96	.576	7.75	89	.5805	7.55
14	40	87.5	.814	10.75	87	.729	9.6
15	53	81.5	.62	10.4	102	.615	10.3
16	47	93	.602	8.3	81	.535	7.35
17	42	74.5	.645	7.25	58.5	.641	7.2
18	41	83	.741	9.3	77.5	.6455	8.1
19	31	75	.6175	8.65	76.5	.6505	9.15
20	43	116	.7615	9	112	.907	10.7
21	46	94	1.0355	15.15	106.5	1.006	14.7
22	43	91	.6805	8.5	87.5	.6575	8.2
23	45	83.5	.6215	8.2	79	.672	8.9
24	39	82.5	.7475	9.55	89	.6175	7.85
25	44	81	.867	10.75	79.5	.7645	9.5
26	30	88	.4805	8.45	94	.4735	8.3
28	43	76	.7145	9.9	91.5	.786	10.9
29	37	95	.737	8.85	75.5	.7795	9.35
30	45	69.5	.8425	14	68.5	.73	12.15
31	58	88.5	1.358	14.1	98	1.43	14.85
32	43	80	.6545	7.4	84.5	.7615	8.65
33	43	76.5	.604	8.3	86	.749	10.25
34	40	81.5	.5055	5.6	72.5	.556	6.15
35	40	77	.6255	8.85	79	.513	7.25

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR OXYGEN CONSUMPTION

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		31.91	0.07	31.91	0.2487E-2	12827.02	1.0	29.0	.616E-39
UNIV	TYPE		0.09	0.07	0.09	0.2487E-2	36.67	1.0	29.0	0.136E-5
ERROR TERM:	TYPE*CASES									
UNIV	TASK		1.70	0.30	0.85	0.5154E-2	164.95	2.0	58.0	.116E-23
GREENHOUSE-GEISER ADJ:			EPSILON:	0.75	0.85	0.5154E-2	164.95	1.5	43.5	.425E-18
ERROR TERM:	TASK*CASES									
UNIV	TIME		0.7246E-5	0.04	0.7246E-5	0.1369E-2	0.5292E-2	1.0	29.0	0.94251
ERROR TERM:	TIME*CASES									
UNIV	TYPE*TASK		0.12	0.16	0.06	0.2841E-2	21.23	2.0	58.0	0.120E-6
GREENHOUSE-GEISER ADJ:			EPSILON:	0.81	0.06	0.2841E-2	21.23	1.8	47.2	0.143E-5
ERROR TERM:	TYPE*TASK*CASES									
UNIV	TYPE*TIME		0.7008E-3	0.03	0.7008E-3	0.8923E-3	0.79	1.0	29.0	0.38278
ERROR TERM:	TYPE*TIME*CASES									
UNIV	TASK*TIME		0.1910E-3	0.02	0.9554E-4	0.3650E-3	0.26	2.0	58.0	0.77063
GREENHOUSE-GEISER ADJ:			EPSILON:	0.90	0.9554E-4	0.3650E-3	0.26	1.8	52.3	0.74805
ERROR TERM:	TASK*TIME*CASES									
UNIV	TYPE*TASK*TIME		0.5248E-2	0.02	0.2624E-2	0.2590E-3	10.13	2.0	58.0	0.00017
GREENHOUSE-GEISER ADJ:			EPSILON:	0.86	0.2624E-2	0.2590E-3	10.13	1.7	50.1	0.00038
UNIV	CASES	*	2.04	0.02	0.07	0.2590E-3	270.86	29.0	58.0	0.0
UNIV	TYPE*CASES	*	0.07	0.02	0.2487E-2	0.2590E-3	9.60	29.0	58.0	.277E-12
UNIV	TASK*CASES	*	0.30	0.02	0.5154E-2	0.2590E-3	19.89	58.0	58.0	.209E-22
UNIV	TIME*CASES	*	0.04	0.02	0.1369E-2	0.2590E-3	5.29	29.0	58.0	0.371E-7
UNIV	TYPE*TASK*CASES	*	0.16	0.02	0.2841E-2	0.2590E-3	10.97	58.0	58.0	.776E-16
UNIV	TYPE*TIME*CASES	*	0.08	0.02	0.8923E-3	0.2590E-3	3.44	29.0	58.0	0.00003
UNIV	TASK*TIME*CASES	*	0.02	0.02	0.3650E-3	0.2590E-3	1.41	58.0	58.0	0.09731
UNIV	TYPE*TASK*TIME*CASES	*	0.02	****	0.2590E-3	****	****	58.0	****	****
ERROR TERM:	TYPE*TASK*TIME*CASES									

AN ASTERICK (*) INDICATES IF APPROPRIATE ERROR TERM CANNOT BE FOUND. IF SO, RESIDUAL IS USED.

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR RELATIVE OXYGEN CONSUMPTION

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		156.68	0.33	156.68	0.01	13831.90	1.0	29.0	.207E-39
UNIV	TYPE		0.45	0.33	0.45	0.01	39.34	1.0	29.0	0.757E-6
ERROR TERM:	TYPE*CASES									
UNIV	TASK		8.23	0.90	4.11	0.02	266.07	2.0	58.0	.604E-29
GREENHOUSE-GEISER ADJ:			EPSILON:	0.87	4.11	0.02	266.07	1.7	50.3	.277E-25
ERROR TERM:	TASK*CASES									
UNIV	TIME		0.7159E-3	0.22	0.7159E-3	0.7645E-2	0.09	1.0	29.0	0.76177
ERROR TERM:	TIME*CASES									
UNIV	TYPE*TASK		0.47	0.52	0.23	0.8999E-2	26.05	2.0	58.0	0.847E-8
GREENHOUSE-GEISER ADJ:			EPSILON:	0.84	0.23	0.8999E-2	26.05	1.7	48.7	0.260E-6
ERROR TERM:	TYPE*TASK*CASES									
UNIV	TYPE*TIME		0.3418E-2	0.10	0.3418E-2	0.3618E-2	0.94	1.0	29.0	0.33911
ERROR TERM:	TYPE*TIME*CASES									
UNIV	TASK*TIME		0.1092E-2	0.10	0.5464E-3	0.1791E-2	0.31	2.0	58.0	0.73823
GREENHOUSE-GEISER ADJ:			EPSILON:	0.84	0.5464E-3	0.1791E-2	0.31	1.7	48.7	0.70038
ERROR TERM:	TASK*TIME*CASES									
UNIV	TYPE*TASK*TIME		0.03	0.06	0.01	0.1049E-2	12.54	2.0	58.0	0.00003
GREENHOUSE-GEISER ADJ:			EPSILON:	0.87	0.01	0.1049E-2	12.54	1.7	50.7	0.00008
UNIV	CASES	*	3.53	0.06	0.12	0.1049E-2	115.86	29.0	58.0	.164E-40
UNIV	TYPE*CASES	*	0.33	0.06	0.01	0.1049E-2	10.79	29.0	58.0	.210E-13
UNIV	TASK*CASES	*	0.90	0.06	0.02	0.1049E-2	14.73	58.0	58.0	.504E-19
UNIV	TIME*CASES	*	0.22	0.06	0.7645E-2	0.1049E-2	7.28	29.0	58.0	.899E-10
UNIV	TYPE*TASK*CASES	*	0.52	0.06	0.8999E-2	0.1049E-2	8.57	58.0	58.0	.272E-13
UNIV	TYPE*TIME*CASES	*	0.10	0.06	0.3618E-2	0.1049E-2	3.45	29.0	58.0	0.00003
UNIV	TASK*TIME*CASES	*	0.10	0.06	0.1791E-2	0.1049E-2	1.71	58.0	58.0	0.02202
UNIV	TYPE*TASK*TIME*CASES	*	0.06	****	0.1049E-2	****	****	58.0	****	****
ERROR TERM:	TYPE*TASK*TIME*CASES									

AN ASTERICK (*) INDICATES IF APPROPRIATE ERROR
TERM CANNOT BE FOUND. IF SO, RESIDUAL IS USED.

HIERARCHICAL SUMMARY TABLE OF F-RATIOS FOR HEART RATE

TYPE	PART OF MODEL		SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
UNIV	GRAND MEAN		0.27597E7	1282.08	0.27597E7	44.21	62424.14	1.0	29.0	.686E-49
UNIV	TYPE		798.04	1282.08	798.04	44.21	18.05	1.0	29.0	0.00020
ERROR TERM:	TYPE*CASES									
UNIV	TASK		3570.97	3769.49	1785.49	64.99	27.47	2.0	58.0	0.403E-8
GREENHOUSE-GEISER ADJ:			EPSILON:	0.98	1785.49	64.99	27.47	2.0	56.8	0.110E-6
ERROR TERM:	TASK*CASES									
UNIV	TIME		1.34	9416.28	1.34	324.70	0.4140E-2	1.0	29.0	0.94914
ERROR TERM:	TIME*CASES									
UNIV	TYPE*TASK		230.24	1061.39	115.12	18.30	6.29	2.0	58.0	0.00337
GREENHOUSE-GEISER ADJ:			EPSILON:	0.98	115.12	18.30	6.29	2.0	56.6	0.00365
ERROR TERM:	TYPE*TASK*CASES									
UNIV	TYPE*TIME		13.61	641.10	13.61	22.11	0.62	1.0	29.0	0.43901
ERROR TERM:	TYPE*TIME*CASES									
UNIV	TASK*TIME		1.67	658.45	0.84	11.35	0.07	2.0	58.0	0.92908
GREENHOUSE-GEISER ADJ:			EPSILON:	1.00	0.84	11.35	0.07	2.0	58.0	0.92904
ERROR TERM:	TASK*TIME*CASES									
UNIV	TYPE*TASK*TIME		30.42	614.87	15.21	10.60	1.43	2.0	58.0	0.24648
GREENHOUSE-GEISER ADJ:			EPSILON:	0.91	15.21	10.60	1.43	1.8	52.9	0.24714
UNIV	CASES	*	59970.93	614.87	2067.96	10.60	195.07	29.0	58.0	.604E-47
UNIV	TYPE*CASES	*	1282.08	614.87	44.21	10.60	4.17	29.0	58.0	0.186E-5
UNIV	TASK*CASES	*	3769.49	614.87	64.99	10.60	6.13	58.0	58.0	.467E-10
UNIV	TIME*CASES	*	9416.28	614.87	324.70	10.60	30.63	29.0	58.0	.135E-24
UNIV	TYPE*TASK*CASES	*	1061.39	614.87	18.30	10.60	1.73	58.0	58.0	0.01983
UNIV	TYPE*TIME*CASES	*	641.10	614.87	22.11	10.60	2.09	29.0	58.0	0.00871
UNIV	TASK*TIME*CASES	*	658.45	614.87	11.35	10.60	1.07	58.0	58.0	0.39758
UNIV	TYPE*TASK*TIME*CASES	*	614.87	****	10.60	****	****	58.0	****	****
ERROR TERM:	TYPE*TASK*TIME*CASES									

AN ASTERICK (*) INDICATES IF APPROPRIATE ERROR
TERM CANNOT BE FOUND. IF SO, RESIDUAL IS USED

Appendix G

RELIABILITY AND VALIDITY STUDY OF THE BTE WORK SIMULATOR

PARTICIPANT DATA COLLECTION

NAME ____________________ ID NO. ________ DATE ____________________

PHONE NUMBER ____________ AGE ______ BIRTH DATE ________________

HEIGHT ____ WEIGHT _____ DOMINANT HAND R L CONSENT SIGNED ___

GRADED ARM ERGOMETER p$\dot{V}O_2$ TEST

LOAD	RPE	HR (MMC)	HR(ST)
0.00			
0.25			
0.50			
0.75			
1.00			
1.25			
1.50			
1.75			
2.00			
2.25			
2.50			
2.75			
3.00			

p$\dot{V}O_2$ __________

p$\dot{V}O_2$ /KG ______

MAX HR __________

TRIAL 1						TRIAL 2					
DATE			TIME			DATE			TIME		
STANDING HR											
ORDER	TASK	RPE	HR	VO_2	VO_2/KG	ORDER	TASK	RPE	HR	VO_2	VO_2/KG
	CL						CL				
	CM						CM				
	CH						CH				
***		BTE				***		BTE			
	SL						SL				
	SM						SM				
	SH						SH				

COMMENTS: