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LA THÈSE A ÉTÉ  
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A Relationship Between Percentage of Body Fat, Exercise  
and Fine Motor Performance as Evaluated on a  
Step-Input Subject-Paced Pursuit Tracking Task

by

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B.Sc., University of Ottawa, 1982

B.A., Psychology, University of Ottawa, 1983

Thesis submitted to the School of Graduate Studies in  
partial fulfillment of the Degree of Master of Science  
in Kinesiology

University of Ottawa  
Ottawa, Ontario

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ABSTRACT

## A RELATIONSHIP BETWEEN PERCENTAGE OF BODY FAT, EXERCISE AND FINE MOTOR PERFORMANCE

There is a paucity of empirical evidence to determine whether or not percentage of body fat can actually impair fine motor performance after a period of physical exertion. In the present study, a self-paced step-input pursuit tracking task measuring speed of movement through four performance parameters (total response time, correct reaction time, non-overshoot movement time and overshoot movement time) was utilized. The physical exertion consisted of two ten minute walks against a grade, the first exercise performed at a light intensity (3 mph, 7.5% grade), the second at a heavy intensity (3.5 mph, 12% grade). Fifty healthy sedentary males (30-39 years of age) covering a range of body fat from 14.2% to 31.7% volunteered for the study. They were divided for analyses, into five equal groups of increasing percentage of body fat. Subjects were tested over a two day period. Sixteen practice trials were given, eight on day 1 and eight on day 2. On day 2, the eighth trial was followed by the light intensity exercise which was itself followed by four more trials. After a 15 minute rest, the heavy intensity exercise took place followed immediately by four more trials. Results indicate that after each exercise period there were no significant differences between the five groups for any of the performance parameters. No difference was observed even if the groups with the higher percentage of body fat had to

work more strenuously during exercise. However, the heavy intensity exercise did significantly affect post-exercise performance for all five groups. The correct reaction time was significantly shorter compared to pre-exercise values while non-overshoot movement time and overshoot movement time were both significantly longer. Overall, total response time was significantly longer following the heavy intensity exercise. No relationship was found between post-exercise heart rate and performance parameters for each exercise session. These observations suggest that body fat seems to have little effect on the performance parameter as measured on the tracometer immediately following a light or a heavy intensity graded walk on a treadmill.

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## Chapter I

## Introduction

Carrying an excess of body fat while involved in day to day activities is an experience shared by a growing number of adults in Canada and in the United States. In the U.S., the 1971-74 Nutrition Examination Survey conducted by the National Center for Health Statistics showed that in the 20 to 74 years of age range, 14% of the men and 24% of the women were 20% or more overweight (Bray 1979). In Canada, a recent analysis of two previous surveys showed that in the 20 to 69 years of age range, 14% of the men and 20.6% of the women were 20% or more overweight (Millar and Neilson 1985). Whatever the causes, an excess of body weight can have major effects on health. For example, the results of the 1979 Build Study on insured lives and the American Cancer Society study (Lew and Garfinkel 1978) suggest that beyond a 20% increase in body weight, male life expectancy is reduced by approximately 2 years at age 30. Furthermore, this excess becomes clinically significant in absence of hypertension, hyperlipidemia and diabetes at about 30% over ideal weight for sex and height (Build Study 1979). According to several epidemiological studies, an excess of body fat or body weight is considered a possible mediator of some of the known risk factors for atherosclerosis (Brunzell 1984); other medical complications associated with an excess of body fat may include hypertension, diabetes mellitus, gall bladder disease, arthritis of weight bearing joints and respiratory insufficiency (Rossner 1984).

In addition to the pathophysiological effects of excess body fat which have been extensively investigated, other studies underline the fact that it may also affect the functional status of the individual in areas such as his social behavior, his general perception of himself, his motor capacity, etc. For example, Steward and Brook (1983) mentioned that out of 5,817 people between 14 and 61 years of age, 28% of the moderately overweight individuals had limitations in personal functioning such as pain, worries, restrictions in activities, psychological handicaps and others as opposed to 19% of the normal weight people. These authors and others go on to suggest that researchers should broaden this field of study as the effects of the overweight state on the behavior and general well-being of the individual have not been fully explored.

Beyond the medical complications and the social and psychological limitations associated with an excess of body fat, there is a growing interest in the exploration of a possible relationship between excess body fat and work performance. Both in the military establishment and in the industrial community there is a growing concern pertaining to the impact of an excess of body fat on work capacity and work security. The possibility of a link between excess body fat and work performance raises some interesting questions. For example, a naval radar operator called to his station in a sudden emergency may have to dash up a couple of flights of stairs or run in order to reach his station. What are the immediate effects of these types of physical

exertion on eye-hand coordination, on reaction time and movement time? Under the same circumstances, if we were to compare the fine motor performance values of individuals possessing different amounts of body fat would there be any difference among them? More specifically, would there be differences among the levels of performance of the leanest, the average and the overfat individuals and if so, to what extent? As far as it is known, there is no empirical evidence found in the literature to determine whether or not excess body fat can actually impair the performance of a fine motor task when it is preceded by a period of general physical exertion (GPE). In the present context, the GPE is defined as an aerobic type of exercise involving the leg musculature as during treadmill walking or running, cycling and bench stepping. This study will investigate whether or not there is a difference in the fine motor performance of individuals classified according to their percentage of body fat, immediately after two 10 minute walks on a treadmill, the first at a light intensity and the second at a heavier intensity.

### 1.1 Rationale of the Study

Since 1940 (Elbel 1940) a number of studies have strived to determine the effects of various intensities of leg induced aerobic exercise, on the performance of skilled work. In a majority of these studies the preferred skill tasks were generally simple, of short duration, involving discreet movement, necessitating no special skills and using mostly gross muscles.

However, the need to assess the effects on fine skilled performance of factors such as medical drugs, alcohol and physiological conditions such as cold temperature, fatigue and time of day has lead to the development of instruments capable of responding to small changes in the individual and capable of monitoring a large number of discrete parameters. The National Research Council (NRC) tracometer is one such instrument. It can monitor the following speed parameters: total response time, correct reaction time, non overshoot and overshoot movement time as well as accuracy parameters. This instrument incorporates a four choice reaction time task within a pursuit tracking task. Combining both tasks results in a complex task necessitating eye-hand coordination, the ability to make decisions and error corrections in order to control the speed and the accuracy of short, discrete movements. It is well suited for the purpose of the present research since it allows the continuous precise monitoring of the previously mentioned parameters. It can also provide an enormous quantity of data in a short period of time on the effects of physical exertion on the post-exercise motor performance. (For more information on the tracometer see Appendix C).

With regard to the exercise - motor performance relationship, it appears that the performance of a complex task may be more susceptible to disruption following a bout of physical activity than a simpler task. For example, the results of a study by Hammerton and Tickner (1968) suggests that as the

degree of complexity of a task increases, the performance of a group of males possessing an ordinary level of fitness is detrimentally affected following a burst of violent exercise. Furthermore, research studies on the impact of exercise on reaction time and on movement time indicate the following. First of all, as the intensity of the exercise increases reaction time may be affected (Levitt and Gutin 1971; Gutin 1973; Sjoberg 1975; Bender and McGlynn 1976; Sjoberg 1977) or may not be affected (Phillips 1963; Meyers et al. 1969; Lulofs et al. 1981) whereas movement time tends to become shorter (Phillips 1963; Levitt and Gutin 1971; Gutin 1973). The previous observations suggest that some of the parameters recorded by the tracometer may be affected by physical exertion depending on its intensity.

Sedentary individuals who carry extra weight as a result of excess fat will work at a higher energy cost (Mahadeva, Passmore and Woolf 1953) than individuals whose weight is normal. They will also expend more energy than sedentary individuals who carry less fat than average while walking on a motor driven treadmill at a same absolute work load, meaning same speed and grade (Miller and Blyth 1955; Auchincloss, Sipple and Gilbert 1962; Turel, Austin and Alexander 1964; Hanson 1973). The higher exercise intensity for the overfat subjects may produce a marked increase in post-exercise physical discomfort (Foss 1981), in exercise-induced activation level (Gutin 1973) and in arm-hand unsteadiness (Gutin, Fogle, Meyer and Jaeger 1974) all of which possibly affecting the speed variables on the tracometer.

6.

In summary, the higher physiological cost for the same work load for subjects carrying an excess amount of body fat and its post-exercise consequences may result in a significant difference in the fine motor performance level of overfat subjects as compared to leaner or average subjects.

### 1.2 Hypothesis

The purpose of this study was to assess the impact of different levels of body fat on the ability to perform a fine motor task following a leg induced physical exertion. The research hypothesis was:

The percentage of body fat affects differentially fine motor performance following a period of physical exertion.

There were two separate physical exertions each performed at a different level of intensity. In this respect, the impact of each physical exertion level on performance was studied separately to decrease the bias due to expected practice effect. In between trial 16 (pre-exercise for the light intensity exercise) and trial 20 (pre-exercise for the heavy intensity exercise) four post-exercise trials were performed and a practice effect is likely to take place. Thus the initial hypothesis was further broken down into the two following sub-hypotheses:

Sub-hypothesis A: The percentage of body fat affects differentially fine motor performance following a period of light physical exertion.

Sub-hypothesis B: The percentage of body fat affects differentially fine motor performance following a period of heavy physical exertion.

### 1.3 Limitations

This study must be considered within the following limitations:

1. The subject sample consisted of 50 healthy male volunteers who participated because they were interested to a certain extent in the fitness evaluation and the detailed analysis of their results which were provided with their participation as advertised on the publicity sheet (see appendix B).

2. The sum of the four skinfolds (biceps, triceps, subscapular and suprailiac) and the equations derived from Durnin and Womersley's 1974 study were used to estimate the percentage of body fat of the subjects. However, the determination of body density by skinfold thickness is less reliable when measuring extreme fatness. Nevertheless, even hydrostatically determined body density is not without limitations and source of errors.

3. The predicted maximum aerobic power ( $\dot{V}O_2 \text{ max}$ ) was assessed through the use of the Canadian Aerobic Fitness Test. It is an indirect procedure that use heart rate frequency in order to predict oxygen consumption. In this respect, the results of this procedure are sensitive to any factors that can affect the heart rate.

4. The fine motor performance task was undertaken after each two exercise period and not during as in other studies.

#### 1.4 Lexicon

The present terms define mostly the performance parameters measured with the pursuit tracking task with their respective abbreviations.

Activation (arousal): It is the degree of release of potential energy stored in the organism. In the context of exercise-induced activation it is defined as the degree of metabolic activity in the tissues of the organism at any moment.

Correct reaction time (CRT): It is the reaction time for correct responses that is the time interval between target presentation and the pointer crossing the boundary of the starting position moving in the correct direction, toward the new target.

General physical exertion (GPE): It is defined in the present study as an aerobic type of exercise involving only the leg musculature as during treadmill walking or running and bench stepping.

Movement time (MVT): It is the time taken from the initiation of the movement when the pointer crosses the boundary of the starting position to the initiation of the 200 milliseconds (ms) uninterrupted alignment with the new target.

Non-overshoot movement time (NOMT): A movement time for responses made without overshoot. It is a movement time where the subject hits the target light without going beyond it before achieving a correct 200 ms alignment.

Overshoot movement time (OMT): A movement time with an overshoot, that is when the response is perceived as excessive in magnitude, going beyond the target boundary and necessitating a reversal in direction back toward the starting position in order to achieve the 200 ms uninterrupted alignment with the target.

Sedentary (or occasional exerciser): They are subjects who did not undergo three or more regular sessions of aerobic types of exercise (such as jogging, racquetball, squash, basketball, rope skipping, aerobic dancing, soccer, ice hockey, swimming in a pool) per week during the 2 months preceding the study.

Total response time (TRT): It is the time in ms required to complete a successful movement from one target to the next. This TRT value includes reaction time, movement time and time taken for correction of errors and overshoots if they occur.



## Chapter II

### Review of Literature

#### 2.1 The Relationship Between General Physical Exertion and Motor Performance

Researchers, in trying to predict or explain the effects of prior exercise on subsequent motor performance, initially referred to the activation theory presented by Duffy (1962). This theory will be elaborated upon as well as subsequent approaches derived from it in the following study of the relationship between activation induced by physical exertion and motor performance. In addition, the two-factor theory of the warm-up effect of exercise will be covered as well as the condition known as fatigue and its effects on motor performance.

##### 2.1.1 Activation theory

The most prominent conception of activation has been conveyed by Duffy (1962) and Malmo (1959). The construct of activation, which is used interchangeably with other terms such as tension or arousal, refers to the intensity dimension of behavior as compared to the direction of behavior. It was defined by Duffy (1962) as the degree of release of potential energy stored in the organism as exemplified during activity or response. Because the level of activation of the whole organism, described as the degree of metabolic activity in the tissues of the organism at any moment (Gutin 1973), varies from time to time, it was classified on a continuum from a low point in deep sleep or coma to a high point in extreme excitement, covering

intermediate states such as drowsiness, relaxation, alertness and excitation. Furthermore, as far as day to day activities are concerned, fluctuations may be caused by both internal and external sources. In this respect, it is considered a non specific response to numerous independent variables including cognitive ones and it can be measured by a number of dependent variables. Because activation level refers mainly to a central brain event (Hennessey and Levine 1979) responses can be measured centrally through electrocortical responses recorded with an electroencephalogram, the technique considered the most direct measure of activation (Landers 1980). It can also be measured peripherally through the recording of autonomic responses such as reactions which are under the immediate control of the autonomic nervous system. These reactions can be expressed by the somatic nervous system and/or by the endocrine system as changes in muscular tension, heart rate, skin temperature and blood catecholamines to name a few. A third way of assessing arousal is through behavioral response (Marten 1974) which consists of questionnaires, direct observations or self-observations. Despite these ways of measuring arousal, accurate assessment of such an intangible concept remains a problem. Within a single individual the correlation between physiological measurements is low (Grings and Dawson 1978). In addition, it appears that some individuals respond primarily with one specific physiological system whereas others react with a different one (Landers 1980) challenging the notion of the undifferentiated nature of arousal.

To add confusion to the issue, other researchers such as Hennessy and Levine (1979) have presented in their psychoendocrine hypothesis, evidence of an integrated system, the pituitary-adrenal system, which can be considered a component of a unified system of arousal.

#### 2.1.2 The arousal performance relationship

In the context of perceptuo-motor performance a number of investigations have shown that the degree of activation is probably of considerable importance in determining the quality of performance. For example, Oxendine (1980) studying the skills involved in sports from archery to football blocking, devised a table of optimal arousal levels for various sports skills, suggesting different levels of arousal from normal to extremely excited and the appropriate level to optimally perform each sport. In this respect, the relationship between activation level and performance has been described mainly by the inverted-U curve hypothesis and the drive theory hypothesis. In Martens' (1974) literature review on arousal and motor performance, the inverted-U curve hypothesis is considered the most popular. It stipulates that as activation level increases, performance improves up to an optimal point and then deteriorates with further increases in activation. The optimal arousal point is assumed to coincide with the best level of performance, too little or too much arousal resulting in a poor performance. This hypothesis is supported by considerable experimental evidence and it also is

intuitively appealing and describes what the drive theory with its linear relationship cannot describe (Martens 1974). Landers (1980), in his literature review, suggests that the drive theory which indicates a linear relationship between arousal and performance should not be abandoned when describing the relationship between activation level and motor performance. This theory indicates that increased drive raises the probability that the dominant response will be made. This response is the most likely when one is aroused and may interfere with newly learned skills. However, with practice, it is believed that a new habit is formed and performance is enhanced by increased drive. Singer (1980) suggested that both theories are applicable in different contexts, the inverted-U curve hypothesis being more adequate to describe activities that involve complexity in sequential coordination movement and drive theory best describing performance where extreme effort and persistence are necessary. This suggests that the inverted-U curve which relates arousal to performance may adequately describe some types of performance and not others depending on mediating factors such as the type of work, personality characteristics and others. In fact, numerous factors which can modify the arousal motor performance relationship have been identified. Among them there is the nature of the task itself particularly its degree of complexity, the energy required to execute it and the level of mastery of the task. In terms of complexity, Yerkes and Dodson (1908) demonstrated that complex tasks are best performed when one's

activation level is low while simple tasks are best performed when activation level is high. Therefore, an activation level which is either too high or too low for a particular task may result in impaired performance. This supports Oxendine's (1980) comments which stipulate that the optimal level of arousal varies with the particular motor task suggesting that different tasks require different levels of arousal for most effective performance. In that respect, he concluded from research evidence that gross motor activities involving muscular strength, endurance and speed are optimally performed at a high level of arousal while the same level of arousal will interfere with the performance of a task involving complex skills, fine muscle movements, coordination, steadiness and general concentration. A slightly above average level of arousal seems to be preferable to a normal or subnormal arousal state for all motor tasks (Duffy 1962). In terms of mastering a task, it is suggested that an overlearned task is far more resistant to high arousal or disrupting situations than a newer task thus modifying the relationship between level of arousal and performance of a task (Landers 1980).

Another set of factors which can affect the arousal-performance relationship are individual differences. Among those which have been investigated let us mention personality disposition of tract anxiety (Landers 1980), introversion and extroversion (Corcoran 1965), differences in the degree of excitability of the nervous system (Duffy 1972), age differences

(Duffy 1972), experience and lack of experience (Martens 1974), resistance to distraction (Oxendine 1984) and recovery capacity (Duffy 1972).

Other factors may include unknown elements which can affect the arousal state, attentional process and stimulus sensitivity in relation to past history (Landers 1980); they may also include the way in which the organism accommodates repeated exposure to arousing situations (Martens 1974).

#### 2.1.3 B. Gutin and the relationship between exercise induced activation and motor performance

Just as numerous factors can mediate the arousal-motor performance relationship, a number of factors have been used to induce changes in the activation level in order to investigate the nature of the relationship between activation and motor performance. Physical exercise, which will be investigated here, is one such factor. Because of the diversity in types of physical exercise only the ones involving the leg musculature in activities such as walking, running, cycling and stepping will be considered. The motor tasks executed during or after the exercise induced activation (EIA) will consist only of arm-hand tasks requiring skill performance and decision making.

Dynamic physical exercises using the legs as described above produce, depending on the type, intensity and duration, acute physiological and biochemical effects on the organism. Some of the major changes involve a marked increase in heart rate and

systolic blood pressure, regional shifts in blood flow, increased ventilation, increased oxygen consumption, changes in the muscle metabolism as well as increases in catecholamine excretion (Alexanders 1984). The effects of exercise on central nervous system functions are however not very well understood (Carlow and Appenzella 1978, Spirduso 1980). Hebb (1955) suggested that biochemical changes in blood brought on by heavy exercise could interfere with the precise and delicate timing of cortical activity. Cooper (1973) suggested that exercise affects the reticular formation and as a result affects arousal. Gutin (1973) mentions a research which found an increase in flicker fusion frequency, a measure of excitability of the visual and central nervous system, following light exercise and diminution following strenuous exercise. Spirduso (1980) presented evidence which lends support to the concept that exercise can acutely and chronically alter variables that influence synaptic transmission. Forrester (1978) suggested that there is enough ATP released while exercising skeletal muscles to alter cerebral blood flow and increase brain metabolism. All these points support the relevance of physical exercise as a way to raise the activation level of the organism.

In the context of this literature review, in order to raise subjects' activation level, researchers have used motor-driven treadmills, bicycle ergometers and stepping tasks. Because the relationship between heart rate increase and oxygen consumption is linear until near maximal effort (Davies 1968), it was favored



by Gutin (1973) as an indicator of metabolic activity or degree of arousal. Indeed, in a majority of articles, the sole indicator of activation level has been heart rate.

The various results of all these related researches investigating the relationship between EIA and gross or fine motor performance are in conflict. Some investigators have reported that exercise has a facilitative effect on performance while some observed that it impairs performance and others observed a null effect. Gutin (1973) confronted by this diversity came up with a theoretical framework in order to explain the relationship between physical exertion and a wide variety of tasks. He used Duffy's (1962) idea of the inverted-U curve and came up with a continuum to classify tasks in terms of the degree of inhibition required by the task. According to this classification, each task has a place within a continuum ranging from high inhibition to low inhibition; for example, steadiness tasks which required high inhibition of movement could be at one end of the continuum while a straight speed task where no inhibition is required could be at the other. Following this construct, a task involving high inhibition or a great deal of restraint of movement would necessitate a low level of EIA for optimal performance compared to a low inhibition task which would be facilitated by high EIA. Tasks situated close to the centre of the inhibition continuum should be performed optimally at an intermediate level of EIA.

The inhibition based theory has helped to clarify and

account for part of the diversity in findings produced by research on the effects of physical exertion and performance of motor skills. It has been shown that the effects of physical exertion on motor performance depend among other things on the type of motor task and the level of physical exertion induced in the subject. Gutin's (1973) observations and those of others tend to show that there is an optimal EIA level for different tasks and therefore lend indirect support to the inverted-U curve hypothesis as a way of describing the relationship between physical exertion and motor performance. However, the inhibition construct does have an internal problem as there is no clear-cut quantification of the inhibition demand of a task thus resulting in inadequate parameters for classifying tasks according to inhibition level. In addition, there may be more effective ways of classifying motor tasks which would explain why no significant differences were found between performance at rest and following strenuous exercise for tasks such as pursuit motor, styles maze and simple reaction time, all located near the middle of the inhibition continuum (Gutin 1973). The 2 following researches are examples of modifications that have been brought to the existing inverted-U curve theory and to the field of motor task classification in order to find new ways of accounting for the diversity of findings generated by the study of the relationship between EIA and motor performance.

Thomas, Cotten, Spieth and Abraham (1975) suggested that during prolonged exertion, the inverted J model could be more

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appropriate than the inverted-U curve theory to explain the relationship between EIA and motor performance. They postulated that as activation increases, performance results should follow the usual inverted-U curve shape until severe fatigue levels are reached and maintained. At this point, performance should continue to deteriorate until the long side of the inverted J eventually drops down beneath the initial resting baseline. This model holds only for research necessitating long periods of heavy physical exertion which results in high levels of exhaustion.

Williams et al. (1976), while testing the specificity hypothesis which suggests that practice of a motor task under heavy exercise conditions should lead to better learning and performance under similar criterion conditions, introduced two considerations related to the classification of motor tasks. First of all, it is important to distinguish between short duration, discrete tasks and continuous or long duration tasks because the latter are less resistant to external and internal changes. For example, it is similar to comparing the sigma test which is a simple arm movement executed in less than 2 seconds to the ladder climbing task which necessitates a continuous dynamic stepping movement involving coordination of the hands and legs. Secondly, it is suggested that the relative proportion of perceptual process involved in a motor task compared to the proportion of physical process may affect performance following a high level of physical exertion. Since perceptual processes are more resistant to physical exertion, high intensity exercise

should not greatly affect the performance of a task where the proportion of the physical versus the perceptual component is low.

#### 2.1.4 D.K. Richard's two-factor theory of the warm-up effect

Another theory that has been used to explain the inverted-U curve relationship between physical exertion and motor performance is the two-factor theory of the effects of prior exercise on performance. Richards (1968) postulated from research findings that the amount of preliminary exercise generates both a beneficial and a detrimental effect on performance. The first effect, being an improvement in the performance of a motor task is associated to a warm-up of the body and muscles; the second, the deterioration of the same performance is caused by the fatigue induced by the initial exercise. The interaction of these two components produces an inverted-U curve relationship between the amount of preliminary exercise and performance. More specifically, this means that minimal exercise should have minimal influence or no influence at all on motor performance. As exercise intensity increases facilitative effects on performance results, the beneficial effects overriding the detrimental ones, the net result being an improved performance. As intensity and duration of the exercise increase, the facilitating performance effect should increase proportionally until the accumulation of biochemical by-products negates it. At this point, the two effects should cancel each

other out following which the favorable effect should be overwhelmed by fatigue, the net effect being a gradual deterioration in performance. Furthermore, at extreme levels of physical exertion the exhausted state of the subject should result in ineffective performance. Richard's theory, also named the arousal-plus-fatigue hypothesis following Cooper's (1973) suggestion that exercise is likely to influence arousal, was tested by Dickinson et al. (1979). The results of their experiment lend support to the idea that prior exercise increases the level of arousal and, depending on the amount of preliminary exercise, sufficient fatigue can build up and offset the beneficial effect of prior exercise.

#### 2.1.5 Fatigue and motor performance

Because the concept of fatigue remains difficult to define, no theories explaining the detrimental effects on motor performance have been formulated. Nevertheless, it has been manipulated in order to investigate the extent of its effects on performance. In the context of the present review, the aspect of fatigue that is involved is defined as general physical fatigue as opposed to local physical fatigue. It is artificially induced by the use of a fatigue task involving the entire body rather than only the muscle being used for the motor task as with local physical fatigue. Because there is no interdisciplinary definition of fatigue (Eidelman 1980) it is operationally defined in most related articles as a consequence of a work load on a

subsequent motor performance such as when a reduction in motor performance occurs immediately after muscle exertion.

Most researchers use a predetermined criterion of fatigue such as a heart rate of 180 bpm (Williams, McEwen, Watkins, Gillespie and Boyd 1979), a state of exhaustion or discomfort where subjects voluntarily stop the exercise (Bard and Fleury 1978), or work loads of different intensities and durations (Spano and Burke 1976). The fatigue inducing activities which they usually employ are treadmill running, cycling on a bicycle ergometer and bench stepping. In most of the articles, the main goal is to assess the effects of physical fatigue, induced as mentioned above, on motor performance; and since there is no integrated theoretical framework specific to the fatigue, condition only assumptions exist. One of these, suggested by Carron and Ferchuk (1971), stipulates that if the intensity and duration of the physically fatiguing activity is increased a point should be reached where it will have a detrimental effect on motor performance because the subject can no longer adequately do the task. Two of the reasons given for the impairment of the subject's motor performance are 1) the accumulation of the usual by-products from biochemical reactions (Carron 1972) such as lactate (Fleury et al. 1981) and 2) the production of neural noise created by the wide variety of physiological responses induced by the heavy exercise which enterferes with the timing and coordination of motor skills (Hebb 1955).

Investigations of the effects of physical fatigue on motor

A performance artificially induced by physical exertion, have been plagued by numerous problems such as 1) confusion about the nature of fatigue; 2) problems related to the measure of the level of fatigue (Pack, Cotten and Biasiotto 1974) and associated with the production of a specific amount of fatigue (Evans 1966); 3) the accurate assessment of the recuperation capacity of the subjects; 4) the evaluation of the effects of practice on the lowering of the fatigue effect on performance (Schmidt 1968); 5) the impact of subjects' motivation upon resistance to physical fatigue (Asmussen 1979) and 6) the type of motor task used and the fact that fatigue can improve the performance of certain types of motor tasks (Carron and Ferchuk 1971).

#### 2.1.6 Summary

In summary, the field of research investigating the relationship between physical exertion and human motor performance is still without a unifying theory that can integrate the differing experimental observations and account for the variability seen in experiments.

## 2.2 General Physical Exertion and Gross Motor Skill

Part of the literature covering the effects of prior physical exertion on motor skills involves a study of general body fatigue and its effects on gross motor tasks, simple gross coordination tasks involving whole body movement. Holding (1981) looking at skill classification, defined gross skills as those which are less complex than fine skills-(weight lifting as opposed to violin playing for example) and which necessitate whole body movement. The 2 principal tasks categorized as gross motor in the literature and studied in research on physical exertion are ladder climbing (Bachman ladder task) and balance maintenance (stabilometer). The Bachman ladder task, where the subject must climb and balance on a free-standing ladder, is a dynamic task, evaluated in terms of rungs-per-attempt score. It has a considerable physical component and involves the movement and coordination of several large body segments. The stabilometer, consisting in a platform supported by a fulcrum which is free to tilt in any direction, necessitates that the subject keeps his balance while having his feet positioned on either side of the fulcrum. Compared to the Bachman ladder task it is less physically demanding since the legs are not as stressed and because it does not involve the coordination of large body segments.

Schmidt (1968), Carron (1972), Pack et al. (1974) and Williams et al. (1976) investigated the effects of prior GPE on the Bachman ladder performance. These studies seem to indicate

that even when heart rate is initially increased to 180 bpm for an experimental group prior to any motor trial there is no significant difference in the first trial between it and the control group. However, if the initial exercise intensity is maintained through a number of short exercise periods interpolated between repeated motor trials, preventing subjects' recuperation, then motor performance becomes detrimentally affected. In order to negatively affect performance on the Bachman ladder task the intensity of the initial exercise period and of the following interpolated bouts must be heavy, subjects achieving a heart rate of 150 bpm or more (Pack et al. 1974). Other factors such as an increase in the duration of both the initial and the interpolated exercise periods, as well as the number of interpolated exercise bouts, will diminish the rungs-per-attempt score.

Studies using the stabilometer, Bartz and Smith (1970), Carron and Ferchuk (1971), Thomas et al. (1975) and Williams et al. (1979), indicate that an initial exercise intensity sufficient to generate a heart rate ranging from 160 to 180 bpm, followed by a number of interpolated bouts of exercise is necessary to impair performance on the balance task. However, one study (Cochran 1975) found an improvement in subjects' performance when they were tested once a week for 4 consecutive weeks; the GPE consisting of 8 minutes of bicycle ergometer at a load sufficient to increase heart rate to an average of 172.8 bpm and 1 interpolated 3 minute bout of exercise at the same

intensity. The fact that subjects' physical fatigue had a positive effect on performance of the task is difficult to explain according to Cochran. He suggested that the exercise could have served as a warm-up period even though it was a heavy work load for female subjects. A possible explanation not mentioned in his article could be the fact that he used only 1 interpolated bout of exercise instead of several as in all the other studies where deterioration in performance, following a long period of alternating bouts of exercise and task performance at a high heart rate was found, probably due to cumulative fatigue.

In summary, the researches dealing with the Bachman ladder task and the stabilometer suggest that high intensity, long duration aerobic exercise performed on a treadmill, bicycle ergometer or by means of a stepping test, is necessary to trigger a small but non significant decrement in motor performance. Subsequent bouts of exercise, depending on their intensity, duration and number can however significantly affect performance in a detrimental fashion. Furthermore, the type of motor task performed is an important factor. For example, the stabilometer only requires minimal movement in the upright position while the Bachman ladder task is in itself a physically demanding task. Subjects involved in a balance task on the stabilometer could possibly succeed better after heavy physical exertion than those involved in the Bachman ladder task because the skills, coordination and physical demands required for balancing on the

stabilometer are less than for the Bachman ladder climbing task. In this respect, it can be said that the type of task performed and the level of fatigue induced prior to performance and during interpolated bouts are 2 important factors when assessing the effects of GPE on the performance of gross motor tasks.

### 2.3 General Physical Exertion and Visual Capacity

Williams et al. (1976) examining the effects of high levels of fatigue on motor tasks were concerned about the relative proportions of perceptual and physical components involved in a task. According to them the physical components are less resistant to high levels of physical fatigue than perceptual components. In this respect, Vlahov (1977) observed an increase in resolution acuity following a Harvard step test session compared to a non exercise session; these results were arrived at using only five subjects of unknown physical condition, the number of individuals being too low to allow for any statistically valid generalizations. Bard and Fleury (1978) used 16 undergraduate males of unknown levels of fitness to investigate the effects of a progressive bicycle ergometer test on the three following visuo-perceptual tasks: a visual search task, a visual field task and an anticipation/coincidence task. The exercise task was performed until subjects were so discomforted that they had to stop. Their results did not lend support to the hypothesis that a high level of physical fatigue derived from physical exertion carried to exhaustion impairs certain constituents of the above mentioned perceptual tasks. In fact, none of the visual measures changed significantly. In another research, Vlahov (1979) used 3 work load intensities (300, 700 and 1100 kpm) on a bicycle ergometer at 2 lengths of duration (3 and 6 minutes) in order to test the effects of different work loads on resolution acuity. No information about

the 21 male undergraduates' level of physical condition was given. A non exercise control session was also given to these same subjects. It was found that an increase in intensity or in duration of exertion improved resolution acuity significantly for all subjects compared to their performance during the non exercise control session. Fleury et al. (1981) investigated the independent effects of 3 energy systems: anaerobic alactacid, anaerobic lactacid and aerobic on a visual detection task. Following the evaluation of the  $VO_2$  max of 31 male athletes, they submitted them to 3 treadmill sessions within a week, each session involving the utilization of a different source of energy. The first, involving the anaerobic alactacid system, consisted of a sprint type of exercise, 20 seconds at a 10% grade at 7 to 10 mph; the second, involving the anaerobic lactacid system, consisted of 5 bouts of 1.5 minutes of exercise at 150% of the  $VO_2$  max; the last was a partially aerobic exercise where subjects walked at 3.4 mph during 4 minutes followed by an increase to 6 mph with a 1% slope added every minute until subjects decided to stop. The order for experimental conditions involving these various systems was counterbalanced between subjects. The authors observed that by mobilizing the different sources of energy they did not differentially affect perceptual performance as measured on the visual task. Nor the lactate increase, nor the fatigue level had any significant effect on the perceptual performance of the 31 male athletes. The authors suggest that sedentary individuals would probably not handle the

exercise intensity as well and that further research should be carried out on sedentary or normally fit individuals.

In summary, most of the investigations tend to suggest that physical exertion, performed even to exhaustion, has no depressing effect on the above mentioned visual tasks. On one hand, Vlahov (1977, 1979) observed an improvement in resolution acuity following a step test and following an increase in work load or duration of exercise on a bicycle ergometer; on the other, Bard and Fleury (1978) and Fleury et al. (1981) found no significant changes in the performance of different visual tasks following 2 types of exercise at various intensities, some carried out until exhaustion. Only this final research gives an indication of the level of fitness of subjects suggesting that in the other researches the results cannot be generalized since we do not know to which type of population, sedentary, normally fit or very fit, the experimental procedure was applied. Nevertheless, their observations give partial credibility to Williams et al. (1976) by suggesting that perceptual components, vision in this case, involved with performance of a task can be more resistant to high levels of physical exertion than motor components.

#### 2.4 General Physical exertion and perceptual-motor tasks

Perceptual-motor tasks imply a perceptual as well as a motor component. Since these two components were covered individually in the 2 preceding sections, the next step will be to look at their integration during the execution of more complex tasks. These tasks will be classified as fine motor tasks because they require manual dexterity, eye-hand coordination and are more complex than gross motor tasks (Holding 1981). Two approaches exist to the study of the relationship between aerobic exercise and fine motor skills; the first looks at the effects of local aerobic exercise, mainly arm exertion, on arm-hand movement tasks and the other examines the effects of whole body aerobic exercise on arm-hand movements. Because of the orientation of this research, only the second approach involving various aerobic exercises using the legs and their effects on arm-hand tasks, will be studied.

Evans (1966), looking at the effects of heavy physical work on pistol shooting, found that fatigue quantified as a percentage decrement (0, 10, 20 and 30%) in maximum walking speed on a treadmill having a 5% angle, caused no change in pistol shooting accuracy. However, he did observe an increase in latency to fire that is the time taken to step off the treadmill, pick up the pistol and fire the first shot. It was therefore suggested that fatigue may have slowed the fine motor movements and adjustments necessary to acquire the firing stance. It must be noted that accuracy was not affected despite the fact that 2 different sets

of instructions were given to the subjects during the different experimental sessions, one emphasizing speed of execution and the other accuracy. This can be explained by the fact that pistol firing is mainly an accuracy task regardless of instructions. The walking speed and the time needed to reach the different percent decrements for each subject was not given nor was their initial level of training, if any.

Hammerton and Tickner (1968) investigated the performance of twelve moderately fit military men on a portable control simulator using a screen and a thumb joystick. The results obtained following a violent 400 seconds burst of step-ups on a twelve inch bench showed no decrement in performance even for the subjects complaining of extreme exhaustion. In a second experiment, they modified the sensitivity of the control joystick in order to achieve a more complex and difficult task known as second order or acceleration control (Hammerton 1981) where the spot across the screen changes velocity proportionally to the deflection of the stick. Using one normally fit and one very fit group of men, they observed that the same violent exercise had a detrimental effect upon the performance of the difficult task for the normally fit men but not for the very fit men. They concluded that the moderate task difficulty can be handled adequately by subjects who are moderately fit even after 400 seconds of violent exertion. The fact that the very fit group was trained for field gun competition could explain part of their ability to perform well following heavy exercise. Their low

heart rate following this exercise compared to the moderately fit men's could also indicate that exercise was not as disruptive for them as for the moderately fit group. This suggests that the initial physical condition of subjects can be an important factor mediating the relationship between physical exertion and motor performance.

Welch (1969) investigated the amount of fatigue transfer from a 10 minute heavy step-up exercise to three motor coordination tasks designed to measure speed (rho test, rho test with a friction load) and accuracy (pursuit motor apparatus). A transfer of fatigue occurs if the execution of a preceding fatigue task causes impairment in a subsequent different task. Seventy college undergraduate male volunteers from physical education activity classes were used in this experiment. No significant decrements in performance were observed, suggesting that the heavy leg exercise did not have a significant effect upon arm movement. Welch concluded that fatigue resulting from bench stepping at a high intensity has no effect on arm performance. Welch's results are in disagreement with the 2 previous studies which showed diminution of some arm skill performance following leg exertion. In her research, there was no estimate of the heart rate of the subjects at the end of the 10 minute exercise period nor do we know their level of physical fitness prior to the experiment. Recuperation could have played a major role but she offers no information on the time taken to administer the motor tests following exercise. Her results

promote the idea of the non transferability of fatigue from one limb to the other or what could be called the specificity of fatigue.

In trying to find parameters that could explain the variability observed between the intensity of exercise and the performance of skills, Gutin, Fogle, Meyer and Jaeger (1974) investigated the effects of cycling on hand steadiness. In their first experiment they asked 18 male students in physical education to perform a 3 minute exercise at a steady state on a bicycle ergometer set at 3 different heart rate intensities, 100, 130 and 160 bpm preceded by 2 to 3 minutes of progressive loading. All treatments were rotated and given on the same day. The steadiness task was given pre- and post-exercise. When comparing pre-exercise values they found that unsteadiness was significantly greater at 160 bpm than at 130 or 100 bpm, the first being 181% over baseline values, the second 53% over and the last 35% over baseline values. In their second experiment, they monitored the effects of recuperation on the performance of a steadiness task following 90 to 120 seconds of cycling designed to produce a heart rate of 160 bpm that was maintained for 5 minutes. Results showed that steadiness was recovered slightly faster than heart rate in the direction of pre-exercise levels. However, even 4 minutes after exercise, unsteadiness was still 27% greater than before exercise, suggesting that even low exercise heart rate can have a measurable influence on arm and hand steadiness and that steadiness recovery does not follow

heart rate recovery.

How perceptual-motor skill is affected during steady-state exercise was investigated by Spano and Burke (1976). Fifteen young male students performed 3 different 10 minute bicycle ergometer rides at 60, 75 and 90% of their maximum heart rate. During the sixth through to the tenth minute of steady-state exercise they had to do five 30 second pursuit motor trials. Results indicate that as intensity increases there is significant differences between results at 60 and 75% and between 75% and 90% of maximum heart rate. The authors suggest that fine motor performance is more easily affected by exercise intensity because of greater nervous involvement. They mention that good aerobic capacity should enable the performer to work at a lower heart rate and overall stress, enabling him to execute the required movement with a higher accuracy than someone who does not have good aerobic capacity. This statement is confirmed by Hammerton and Tickner's (1968) observation that a violent burst of activity has only a slightly detrimental effect on the perceptual-motor performance of highly trained individuals compared to that of normally fit men. In this case, low exercise heart rate and fast recuperation were probable components associated with the efficiency of the highly trained group. In most of these researches the authors do not specify the level of aerobic capacity of subjects nor do they compare the performance of unfit and fit subjects.

Davies and Ward (1978) looked at the effect of physical work

produced by 5 minutes of cycling on a bicycle ergometer adjusted for a load of 900 Kpm/min, on a modified Purdue Pegboard task. The fine manipulative task involved picking up pins by the leading edge with a pair of tweezers and inserting them into holes on a board with 2 parallel rows of 25 holes each. The authors hypothesized that an increase in tremor level induced by hard physical exertion, which was equated in intensity to heavy manual work, would be detrimental to the performance of the fine manipulative task. The Purdue Pegboard task was practiced prior to execution by 6 male students until a required level of performance was maintained. The execution of the above mentioned physical exercise was immediately followed by 1 trial; 2 other trials followed one 5 minutes and the other 30 minutes after completion of exercise. They observed no significant difference between the pre trial time and the 3 testing times preceded by the hard work with the legs. It was suggested that the physical work was not intense enough to cause any tremor side effects on the fine manipulative task. This research goes a step further than Gutin et al's (1974) because beyond simply measuring hand tremor, a fine manipulative task using the hands is involved. However, it does not offer definite conclusions on the effects of GPE induced hand tremors on a fine manipulative task. Davies and Ward's experiment suffers from the following flaws: first, since heart rate was not measured there is no information on each subject's individual adaptation to the work load; secondly, their fitness level is unknown; third, the single 900 Kpm/min load

provides only partial information about the effects of task exertion on task performance where the use of a range of work loads would have provided more information in task sensitivity to physical exertion; and finally, the number of subjects is too low to indicate any statistically significant relationship between physical exertion and a fine manipulative task.

Dickinson et al. (1979) used 7 female and 15 male first class long-distance runners for a 15 minute warm-up run followed by a rest than a voluntary run to exhaustion. The perceptual-motor task involved was Fitt's reciprocal task done twice with the preferred hand within 10 to 15 seconds after completion of both the 15 minute warm-up run and the run to exhaustion.

Results indicated a significant facilitatory effect of exercise on the level of performance of a tapping task done following the warm-up and the exhaustive run. This research did not control for the fitness effect by comparing its results to those of a sedentary group.

In summary, 7 studies have been covered in the context of the effects of prior exercise on the subsequent performance of a perceptual-motor task. Among the 7, one suggests a facilitatory effect (Dickinson et al. 1979); two indicate that physical exercise has no effect (Davies and Ward 1978; Welch 1969), these results being supported by Hammerton and Tickner's (1968) first experiment; the 3 remaining experiments indicating that there is a detrimental effect induced by physical exercise on perceptual-motor performance. Faced with such contradictions in

results, Williams et al's (1979) statement that: "...the literature is characterized by a diversity of findings which seem to have resulted from the use of many different motor tasks under a variety of experimental conditions", is also applicable in this context.

Following are some of the critical factors which affected both results and the generalizations which can be drawn. The first factor concerns the number of subjects which varied from 6 to 70 depending on the research. The second concerns the type of subjects as they were males and females drawn mostly from physical education courses and varying from 18 to 35 years of age. The third factor concerns subjects' level of physical fitness which was generally unknown in most researches. However, since most of them were physical education students they may have been more fit than members of the general population, therefore not representative of average sedentary subjects. In this case, before making any generalizations, knowing the role played by physical fitness in 2 of the researches (Hammerton and Tickner 1968; Dickinson et al. 1979) it is important to be aware of subjects' level of fitness prior to exercise. The fourth factor was exercise intensity and duration. Researchers used either target heart rates, fixed work loads or the percentage of maximal heart rate as ways of quantifying their intensities. In general, the higher the exercise intensity the more likely it was that a threshold would be reached following which performance was negatively affected. However, the use of multiple work loads

provided more information on task performance level under a range of exercise intensities. Therefore, with this approach it was possible to observe that some tasks were more easily disrupted by exercise than others. Exercise duration, when given, varied from between 5 and 15 minutes of continuous exercise.

The next factor was the methodology used. Most researchers used pre and post exercise testing periods where the effects of exercise on five motor tasks were measured after exercise and compared to pre-exercise results. Spano and Burke (1976) employed a methodology where the effects of exercise on fine motor performance were measured during the exercise period rather than at the end. The sixth factor was the type of motor task used as each research had a different perceptual-motor task varying in complexity, in perceptual or motor input and in coordination; some were more vulnerable than others to the effects of physical exertion. The final factor concerns the number of practice trials of the perceptual-motor task given prior to the testing session. A greater number of trials led to better learning and less vulnerability to disrupting events.

Each experiment was unique as a result of varying combinations of these factors, making comparisons difficult. Despite the lack of information about the level of physical fitness of the subjects, their recuperation time, their heart rate and blood pressure during exercise, it can be suggested that the level of physical fitness of the subjects was one of the key factors in limiting the disruptive effects of exercise on

perceptual-motor tasks, and therefore it should be assessed using one of several standardized testing protocols (Shephard 1984).

In addition, there was an array of different tasks, each one calling for a mix of specific skills to successfully complete the task. Once again, when faced with such diversity, it is difficult to make comparisons and arrive at any type of substantial conclusions.

## 2.5 General Physical Exertion and Reaction Time, Movement Time

### 2.5.1 Reaction time

Reaction time (RT) has been a well known simple indicator of the status of the nervous system for over a century. Initially, it was considered as the measurable time lag between the presentation of a stimulus and the initiation of a response. Recently, Weiss (1965) fractionated RT or what is called total reaction time (TRT) into premotor (PMT) and motor time (MT) components. He describes PMT as the time interval between the onset of a visual stimulus and the appearance of a muscle action potential; MT representing the time interval between muscle firing and the actual muscle contraction, the total relationship being expressed as  $TRT = PMT + MT$ . Kroll and Clarkson (1977), monitoring changes in brain waves activity (electro-encephalograph, EEG), further subdivided the PMT into 1) reception time or the time between the apparition of a visual stimulus and an EEG wave in the visual cortex; 2) opto-motor integration time or the time between the reception of the stimulus at the visual cortex and a second wave (EEG) at the level of the motor cortex; and 3) the motor outflow time or the time taken to convey an efferent signal down to the motor nerve. Reaction time is affected among other things by the following (Holding 1981): the presence of a prior warning signal, the sense modality which will convey the stimulus, the part of the body used for response and the age, sex, state of arousal or fatigue of the subject. It is also affected by the level of physical fitness of the subject as

well as by the amount of information presented or the number of possible alternatives offered (simple compare to choice RT) during performance of the task and by the strategy used (speed versus accuracy).

The preceding three factors as well as the state of arousal or fatigue will now be covered more extensively for the purpose of the present experiment.

The origin of fatigue or specifically the site of degradation of performance has been part of a lengthy controversy in research. The central or neural failure theory suggests that fatigue has a central origin and is related to an alteration at the central nervous system level or within the motor neurons responsible for innervating the involved muscles. The peripheral (muscular) theory of fatigue suggests that degradation of performance is due to a contractile failure of the muscle rather than a command failure (Stull and Kearney 1978). Both theories have used PMT and MT as ways of gaining information about the actual site of fatigue mainly because PMT is a measure of central nervous system processing time and MT a measure of the time involved in the translation of the electrical signal into a mechanical contraction at the level of the muscle. An increase in one or both would suggest what site(s) is involved in the fatigue process. Researchers studying the effects of physical exertion used as a means of inducing fatigue, defined as a decrement in performance, and its relationship to RT have been particularly interested in locally induced muscular fatigue. In

order to induce fatigue some of the following strategies have been employed: added weight to the performing arm and wrist (Stelmach 1969), isotonic and isometric exercises on the knee extensors (Kroll 1973; Viitasalo and Komi 1980), a hand-gripping device (Stull and Kearney 1978; Hanson and Klimovitch Lofthus 1978), a hand ergometer (Carron 1969; Godwin and Schmidt 1971), a vertical two-handed low friction arm crank (Phillips 1963). Their investigations have not yielded a consistent picture of the effects of local exertion on PMT and MT. Some indicate an increase in TRT, some an increase in MT or PMT, others indicate no increase at all in any factor or to the contrary, a facilitatory effect on all. In order to explain the discrepancies in the literature, Kroll and Clarkson (1977) mentioned that the strength loss ~~induced in some experiments~~ was not of sufficient intensity to produce changes in the PMT and MT components; Stull and Kearney (1978) also believed that the level of fatigue experienced by subjects was not of sufficient intensity to effect these same components. Wood (1981) also observed that the range of types of physical exertion used in these studies was too wide and that the response times were often measured by a motor act totally divorced from that of the fatiguing activity. Hanson and Klimovitch Lofthus (1978) suggested that the diversity in subjects' characteristics may also affect performance. They mentioned that higher-skilled and/or better trained athletes may have developed compensatory mechanisms which can take certain motor-integrating functions

over at the apparition of fatigue. Viitasalo and Komi (1980) stated that the fiber type distribution in the muscle used, the type of contraction executed and muscle temperature elevation are factors which affect the motor performance following fatigue exercise. Kroll and Clarkson (1977) following a review of articles discussing specific training regimen effects on the neuromuscular system, suggested that the fast RT of athletes in some sports activities may be partially derived from the training regimens and not entirely from a superior genetic make-up.

With regard to training regimens, some researchers have indicated a relationship between physical fitness, aging and psychomotor speed. Clarkson (1978) comparing young individuals (18-28 years of age) that were classified as active or inactive depending on whether or not they were involved in regular physical activity for at least three hours a week to older individuals (55 to 79 years of age) also classified as active or inactive according to the same criteria, found that the deterioration in speed of movement according to age had almost disappeared with participation in regular physical activity throughout life. Their results suggest a possible beneficial effect of physical activity on motor performance. However, Spirduso (1980) in his review of the literature stated that the relationship between life-long physical activity and improved speed of movement is not confirmed since some researchers have not found the relationship; because the individual evaluation of each subject's level of physical activity was not well controlled

in some researches; because aerobic capacity was never directly measured in conjunction with motor performance; and finally because several unknown variables such as health, motivation, medication, genetic profile and others, all having possible effects in psychomotor speed, were not taken into consideration.

A relationship between an aerobic conditioning program and psychomotor speed was suggested by Spirduso (1980) but is far from being clearly demonstrated. Powell (1983) looked at the effects of 7 weeks of aerobic conditioning, 1 hour per day, 5 mornings per week, 5 mets minimum, on 36 sedentary male adults (20-45 years of age). Their maximum oxygen consumption was measured at the beginning of the experiment and showed a positive improvement with a mean difference of 5.06 ml/kg/min after the 7 weeks. The results of the 2 psychomotor tests, the first consisting of a simple RT and the second a 4 choice RT, both administered before and after the 7 weeks indicated that in both cases changes were not significant. However, a trend toward a faster choice RT following aerobic conditioning was noted. In the light of Powell's experiment, further research into the effects of conditioning programs on PT are needed.

Another factor modifying the RT during choice RT tasks is the number of probable alternatives with which the operator is confronted during each task. As the operator moves from a 2 choice RT task to a 4 choice RT task, his RT will increase linearly in proportion to the amount of information presented, meaning according to Hick's Law, that the time it takes to make a

decision about a response is linearly related to the amount of information that must be processed (Schmidt 1982). This law will be exemplified in researches using multiple choice RT designs and the tracometer task where RT is affected by the directional probability associated to target positioning.

Fitts (1966) arrived at a modified version of Hick's Law by introducing among other factors, the speed or accuracy requirement where depending on an individual's strategy and task conditions, the individual may opt for either speed or accuracy, thus affecting his RT. As speed increases, the operator takes less time to process information and the number of errors increases, diminishing accuracy; if on the other hand he takes more time, accuracy improves. This relationship between speed of response and number of errors is called the speed-accuracy trade-off.

#### 2.5.2 Movement time

Movement time (MVT) is defined as the time taken from the initiation of a movement (the end of RT) to the termination of the required movement. It is a function, as defined by Fitts and Peterson (1964), of both the distance moved and the accuracy required at the terminal point. The mathematical combination of these 2 factors gives the index of difficulty<sup>or</sup> of a movement from which a linear relationship is drawn between the index and MVT. This relationship is referred to as Fitt's Law and the sum of RT and MVT is called response time.

### 2.5.3 Literature

Several researchers have investigated the effects of strenuous physical exercise on RT and MVT but only studies involving dynamic leg exercises will be taken into consideration here. Phillips (1963) used a heavy but non related general body warm-up exercise involving 10 minutes of step-up exercises at 60 mounts/min. in order to look at the influence of fatiguing warm-up exercise on an arm criterion performance task which involved a circular movement ending with a forward movement in the horizontal plane. Sixty trials fractionated into 4 blocks of 15 trials were given following the exercise. Results indicated that RT values were not influenced by the heavy warm-up but MVT values improved significantly compared to those of a control group. It was therefore concluded that heavy global warm-up exercise can improve MVT but not RT.

Meyers, Zimmerli, Farr and Baschnagel (1969) following the inconclusive results arrived at in previous researches on the relationship between RT and strenuous exercise, used 116 men, students in an undergraduate physical education program, 80 of which were randomly assigned to the experimental group, in an experiment designed to investigate the relationship between 5 minutes of bench stepping, 30 steps per minute and 2 RT tests, finger and foot RT. The values of both foot and finger RT measured immediately after exercise indicated that there was no significant difference with pre-exercise values. No relationship was found between the measure of recovery which consisted of

pulse counts taken at the first, second and third minute following the end of the bench stepping, and the values for foot and finger RT. The heart rate values were not published in this article. In conclusion, no difference was observed in foot or finger RT following 5 minutes of bench stepping at a rhythm of 30 steps per minute compared to the values of the control group.

Noting that one of the weaknesses of previous studies was their lack of testing of RT over a wide enough range of exercise intensities, Levitt and Gutin (1971) used 4 levels of heart rate intensity in random order, rest, 115, 145 and 175 bpm in their experiment. Their 20 male subjects were given 25 practice trials on a 5 choice RT task before physical exertion in order to become familiar with the task. There was no control group. The exercise, given on a motor driven treadmill, consisted of 6 minutes of walking at the target heart rate followed by 6 minutes of walking during which 30 RT-MVT trials were administered. After 3 minutes of rest on a chair and at a heart rate below 90 bpm, subjects were given another treatment at a different heart rate level. No information was given on the state of physical fitness of the subjects. During exercise, MVT increased with the increase in heart rate; RT, on the other hand, followed an inverted-U curve, being optimal at 115 bpm. At 175 bpm, RT performance worsened significantly. This observation seems to give credit to the idea that tasks involving greater information processing are best performed at a low level of exercise induced activation. Because the 3 treadmill tests were given one after



the other in random order, it is possible that subjects were not fully deactivated between each therefore affecting motor performance to a greater extent. However, Levitt (Gutin 1973), in his doctoral dissertation, using the same procedure with the exception that each treatment was given on a separate day, found RT to be optimal between 115 and 145 bpm as compared to at rest or 175 bpm. Once again, MVT improved linearly with the increase in the level of exercise induced activation. The use of a target heart rate rather than an absolute work load as a measure of activation level has one particular drawback since it does not take the level of cardiorespiratory efficiency of each subject into consideration. Indeed, the individual who is very fit will have to work at a far higher work load to reach the target heart rate compared to the poorly fit individual who reacts with greater magnitude to different work loads. In summary, it seems that RT and MVT in these two studies are affected quite differently during exercises of varying intensities when evaluated on a 5 choice RT task.

Also using multiple work loads, Sjoberg (1975) looked at the variation between activation level and behavioral efficiency during a bicycle ergometer test. He used a range of 5 work loads that were rotated following a latin square design. Each load was maintained for 7 minutes during which time the subjects had to go through a sequence of 30 signals for the last 100 seconds. A new work period was started whenever the resting heart rate level was reached. Heart rate served as an indicator of activation level

and a visual 2 choice reaction task was used to measure the number of reactions per second. An inverted-U curve describes the relation between the number of reactions per second and the heart rate range (95 to 145 bpm). The optimal reaction speed was at 120 bpm which is close to Levitt and Gutin's (1971) optimal level. The same criticisms directed to Levitt and Gutin's (1971) experiment are applicable here.

Bender and McGlynn (1976) controlled the preceding methodological errors by comparing every individual to each other in terms of percentage of maximum heart rate (MHR) across four varying exercise levels. They also determined the cardiovascular condition of their 10 male student subjects by using the Kasch step-test which indicated that they were all in very good cardiovascular condition. The test consisted of a simple sound RT pre-test followed by tests of similar nature given during each of the four 3 minute continuous treadmill stages. Speed and grade were increased at each of the 4 stages, the fourth one being 5.0 mph at an 18% grade. The last RT was taken 2 minutes after the fourth stage. This procedure was repeated once a week for 3 consecutive weeks. During this 3 week period results indicated that RT was least detrimentally affected at 40% MHR (113 bpm) or at 3.4 mph at a 14% grade and that it increased, meaning that RT became slower, as MHR percentage increased. However, during the last 2 weeks, at the stage 3 and 4 levels, a progressive reduction in RT was noted suggesting that subjects were less affected by exercise. Furthermore, post-exercise RT

was not significantly different from pre-test RT even after 12 minutes of work and a recovery heart rate equal to 80% of MHR levels after 2 minutes. This signifies that even after strenuous exercise, individuals can perform almost the same way they do during the rested state. The fact that the heart rate level was still high suggests that it is not a reliable indicator of activation level during recovery. Because of the reduction in RT values with repetition of exercise, it would be interesting to look at research using, as some gross motor task researches do, interpolated exercises at the same intensity in order to assess the effects of repetitive bouts of exercise on RT.

Sjoberg (1977) looked at reaction speed in tasks presenting 3 levels of difficulty (simple RT, 2 choice RT and 4 choice RT) performed at 5 different levels of activation on a bicycle ergometer (150 to 750 kpm/min). He obtained results that support the Yerkes-Dodson Law. The 4 choice RT task was performed optimally at a lower heart rate (107 bpm) than the 2 choice RT task (118 bpm) which was lower than for the simple RT task (128 bpm). This suggests that lower activation, measured in terms of heart rate, gives optimal results for a more difficult task while higher activation does so for an easier task. Unfortunately, the motor part of the task did not involve the necessity of having greatly skilled or coordinated movements and the fact that the maximum heart rate was 143 bpm suggests that the maximal work load intensity was in the moderate to low range.

Lulofs, Wennekens and Van Houtem (1981) manipulated the

level of effort of 20 male amateur cyclist subjects giving them work loads equivalent to 20, 50, 70 and 90% of their maximum bicycle ergometer work load. The authors modified their binary choice reaction task by adding a complex condition where subjects had to react only when they heard 2 successive similar tones compared to the simple condition where they reacted to every tone. In order to control the amount of effort needed to perform the task they divided the group into 5 subgroups, each having different mean interstimulus intervals during the reaction task, adding a time-pressure condition. During the experiment subjects had to cycle for 2 minutes at a specific work load then they received 1.5 minutes of choice RT task while pedaling. This was followed by 0.5 minutes of cycling at the same work loads as before, then moving on to another work load. A total of 16 minutes were spent cycling. Even with very large differences in activating level, meaning a heart rate varying from around 120 bpm at 20% of maximum to 170 bpm at 90% of maximum work load, no correlation was found between work load and RT or the number of correct responses. The assumption of a direct causal relationship between activation and performance was questioned by the authors. The fact that subjects were well trained, active, amateur cyclists used to competition and high intensity exercise, could have biased the results.

#### 2.5.4 Summary

In the 8 preceding researches on RT, 3 indicate that RT is

not affected by GPE (Phillips 1963; Meyers et al. 1969; Lulofs et al. 1981), the first 2 using a pre-post design while for the last one, exercise and RT tasks were done at the same time. A fourth research (Bender and McGlynn 1976) indicates that pre- and post-RT values were almost identical while RT values recorded during the exercise period showed a significant increase, therefore slower RT. Five out of the 8 studies suggest that RT is affected by physical exercise (Levitt and Gutin 1971; Levitt (Gutin 1973); Sjoberg 1975; Bender and McGlynn 1976; Sjoberg 1977) during the exertion period. These 5 studies used multiple work loads, each load being given one after the other in a counter balance order or as with Levitt (Gutin 1973) on separate days in order to establish which exercise intensity was detrimental according to the EIA and the inverted-U curve model. Sjoberg's researches (1975, 1977) suggest that from a heart rate at rest to a maximal heart rate of approximately 150 bpm, RT diminishes up to an optimal point which varies with the number of choices associated with the RT task. Following this optimal point, RT values increase to pre-exercise levels but now at a work load generating a heart rate of approximately 150 bpm. Levitt and Gutin (1971) and Levitt (Gutin 1973) found that RT values on the 5 choice RT tasks were lower at a heart rate of 175 bpm than at rest. Bender and McGlynn (1976) observed a detrimental effect on simple RT at an exercise intensity equivalent to 40, 55, 75 and 90% of maximal heart rate on a treadmill. However, Lulofs et al. (1981) found no significant

effects of physical exertion at 20, 50, 70 and 90% of maximum work load on a bicycle ergometer; these values corresponding to heart rate levels of approximately 120, 130, 160 and 175 bpm.

It is to be noted that in 4 researches where RT task was performed during exercise and where multiple work loads were used, 3 out of 4 had a change in RT performance. Only the research by Lulofs et al. (1981) found no significant change in RT performance. In 3 other researches which tested RT before and after exercise, difference in RT performance was found.

Movement time was modified in the 3 researches which also studied that variable. In Phillips's (1963) research the heavy warm-up improved speed on the criterion arm movement for the experimental group as compared to the control group and in Levitt and Gutin (1971) and Levitt (Gutin 1973) MVT was faster as the heart rate increased, being the fastest at 175 bpm.

## 2.6 General Physical Exertion, Excess Body Fat and Motor Performance

### 2.6.1 The estimation of body fat through anthropometric measurements

The human body can be partitioned into several components in order to determine its composition. These components may include body fat and fat-free weight (FFW) or muscle, bone and fat or water, protein, mineral and fat depending on the technology used (Lohman 1984). In studies assessing body fatness, the 2 component model has been used extensively. In this model the total body mass is subdivided into 2 compartments, the body fat compartment which includes the entire content of chemical fat or lipids and the fat-free compartment which excludes all lipids (Durnin and Womersley 1974). This subdivision was arrived at through basic assumptions about patterns of distribution of fat and the relative densities of the elements in the 2 compartments. Because the density of body fat in human adults is relatively constant within and between individuals independently of age, sex or location within the body (Wilmore 1983) researchers have been inclined to use body density to estimate the relative body fat. In fact, the use of body density in order to estimate body composition has become the gold standard against which the precision of other more indirect methods is validated (Wilmore 1983). Among these other methods, one of the most widely used in field study or in a clinical setting is the anthropometric method. It includes measures of height, weight, height/weight indices, body

circumferences, skeletal diameter and skinfold measures. All these measurements predict with various degrees of precision, body density and body fatness. For example, from the Metropolitan Life Insurance Build and Blood Pressure Study (Metropolitan Life Insurance 1959) arose the notion of ideal weight also known as optimal or desirable weight. This ideal weight represents the optimal average weight for adult men and women; it is arrived at by comparing the relative mortality rate of individuals of different height-weight combinations and is expressed in terms of weight for the given height and sex of applicants for insurance policies. In Pollock, Schmidt and Jackson (1980) the correlation between weight and body density in 308 men is -0.62. When the relative body weight index is used meaning the ratio of percentage of actual weight to ideal body weight, the correlation with body density measures is -0.67. This means that relative body weight accounts for only 45% of the variance of the best measure of body fatness (Keys 1981). Numerous epidemiological studies have used index or ratios of weight to various powers of height in order to predict the percentage of body fat (Rogers, Mahoney, Mahoney, Straw and Kenigsberg 1980). From at least a dozen of these ratios, the best index is the Body Mass Index (BMI) also known as the Quetelet Index, calculated by dividing the weight by the height square ( $Wt/(Ht)^2$ ). However, the BMI in Pollock, Schmidt & Jackson's study (1980) gives only a slightly better correlation for men,  $r = -0.69$  than body weight alone when compared to

hydrostatically determined body density. When the relative BMI is compared to the mean skinfold thickness in studies done in different countries, the average coefficient of correlation is 0.78 (Keys 1981). For Bray (1980) this index has the highest correlation with body fat. Keys' (1981) conclusion is that the BMI and all other measures of relative weight give poor estimates of obesity or excess fat and are only useful at the far extremities of the fat distribution. Circumferences are excellent to analyze body size and physique (Jette 1981) and can be a powerful tool to assess body composition when integrated into a regression equation, combining one or a number of independent variables (height, girths, skinfolds, diameters) in order to predict body density, body fat or lean body mass (Katch and Katch 1980). Lean body mass (LBM) is a concept that takes into account the essential lipids used in cell membranes, nerves etc., while FFW excludes all lipids. Some confusion exists in the literature concerning the proper use of these terms (Buskirk and Mendez 1984).

Among all the various indirect methods of prediction, the best predictor of body density and body fat is skinfold thickness (Womersly and Durnin 1977, Pollock and Jackson 1984). The correlation between hydrostatically determined body density and the sum of 7 skinfold sites in Pollock, Schmidt and Jackson (1980) is -0.88. The rationale behind the fatfold measurement is based on a number of assumptions, one being that subcutaneous fat comprises a constant or at least a predictable proportion of

total body fat, another being that compressibility and fat content are relatively constant (Womersley and Durnin 1977). As such, by measuring in millimeters at specific sites the thickness of the double layer of skin and subcutaneous tissue with a skinfold caliper, it is possible, using a regression equation, to predict body density and in turn apply one of the common equations (Siri 1961, Brozek, Grande, Anderson and Keys 1963) to determine body fat from body density.

The use of skinfold thickness and densiometry in order to predict the fat content of the body is limited by biological and technical sources of variation. Under ideal conditions this method produces a standard error of estimate for percent body fat in the order of 3.5 to 3.9% of fat (Lohman 1981, Lohman 1982, Pollock and Jackson 1984). The breakdown of the source of variations is as follows. The first source is linked to biological variability (Lohman 1981), meaning that even though subcutaneous fat represents some of the major fat deposits in the human body there are nevertheless several other fat deposits distributed in the body such as inter and intra muscular fat, fat deposits in the thorax and in the abdominal cavity to name a few. There is therefore considerable chance for biological variations in the distribution of fat in the body. Another source of biological variability is the amount of subcutaneous fat which has been estimated mostly from indirect evidence. Katch and Katch (1984) assumed that about one half of total body fat content is located beneath the skin while Lohman (1981),

referring to Allen, Peng, Chan, Huang, Chang and Fang's (1956) reference man and woman, talked about one third of total body fat being stored subcutaneously. According to Lohman's (1981) review of the literature on skinfold, body density and body fat, the amount of subcutaneous fat described as percent of total fat can range from 20 to 70% depending on factors such differences in measurement techniques, sex, age, degree of fatness and genetic differences among individuals.

The second major source of variation is associated with the measurement of skinfold thickness. Possible sources of measurement error are according to Pollock and Jackson (1984), the equipment, the tester and the fact that measurement procedures have not been standardized. In the first case, several types of calipers are used and furthermore, variations exist in the pressure exerted by the caliper jaw. In the second, the use of experienced technicians is recommended in order to diminish the measurement error in skinfold determination because of high inter and intra observer variability. Finally, measurement standardization should include a precise definition of the skinfold sites of measurement, the control of the size of the skinfold grasp, the control of the time delay in reading the skinfold measurement, the measurement to the nearest 0.1 or 0.5 mm, the repetition of measurement on each site a minimum of 2 to 5 times and the application of all measures on the right side of the body. Another possible source of measurement error lies with the estimation of fat content from skinfold thickness. Only a

finite number of sites are used to approximate the average thickness of the total subcutaneous tissue and they vary in compressibility, fat content and distribution over the body surface (Despres, Bouchard, Tremblay, Savard and Marcotte 1985). In addition, the variation between subcutaneous fatness and the total fat mass is not well known in the human population. In as such, for a given skinfold measurement the content of body fat will vary from one individual to another (Womersley and Durnin 1977).

Beyond biological and measurement variations, there is the error associated to the prediction of body density from anthropometric measures. Initially, the assumption was that in all populations studied the LBM composition and density could be relatively stable between individuals in terms of water, proteins, minerals, muscle and bone content. However, this is not the case because density of the LBM is highly variable introducing potential errors in the evaluation of body composition (Wilmore 1983). Lean body mass (LBM) is specific to a population evaluated according to factors such as age, social background, sex, degree of physical activity (Lohman 1981) and degree of fatness (Pollock and Jackson 1984). In order to predict body density from anthropometric measures, over 100 population specific anthropometric regression equations were produced during the last 30 years (Ward, Johnson and Stager 1984) but because they are specific to the population from which they were derived, they are limited in the extent to which they can be

applied to populations in general. However, Durmin and Womersley (1974) initiated a new trend by developing an equation based on 4 skinfold sites which is more applicable to a general population, taking their age and sex into consideration. More recently, Jackson and Pollock (1978) and Jackson, Pollock and Ward (1980) have produced generalized equations for men and women. These have several advantages over the specialized equations because they can be applied to a wider range of subjects, taking fatness and age differences into consideration; they also minimize large prediction errors for lean subjects and fatter-than-average subjects.

In addition to the errors in determining body density from skinfold thickness there are the errors in estimating the percent of body fat from body density prediction equations which are mostly derived from underwater methods (Jackson 1984). The equations developed by Siri (1961) and Brozek et al. (1963) to convert body density into body fatness also have errors associated to the density and composition of LBM; furthermore, these equations were drawn from a population of young adult men (Lohman 1981) but they are applied to the entire population without proof of their applicability (Lohmen 1984).

Following this enumeration it is important to recognize that none of the techniques used to assess whole body density in order to determine relative body fat are without limitations or sources of error. Pollock and Jackson (1984) mentioned that the standard error of estimation for the gold standard method, hydrostatic

densiometry, is around 2.7% fat; Lohmen (1982) suggested 2 to 4% depending on the population under study, compared to the error associated with skinfold measurements which ranges from 3.3 to 3.9% for middle-aged adults (Lohman 1982). Womersley and Durnin (1977) suggested that both techniques are in the same order of accuracy for the estimation of body fat however, skinfold measurement is less reliable for measuring extreme obesity or extreme paucity of body fat (Rogers, Mahoney, Mahoney, Straw and Kenigsberg 1980).

#### 2.6.2 The classification of male subjects according to their estimated percentage of body fat

The use of the sum of skinfold in conjunction with linear regression equations in order to estimate body density and to further convert it into body fat values, remains a practical method currently employed as a standard procedure in Canada and in the United States (Pollock and Jackson 1984). In Canada it is a part of the regular anthropometric measurement techniques used in the Standardized Test of Fitness (STF) which in turn is integrated into the Canadian Fitness Survey (CFS). This survey is designed to provide reliable statistics on physical activity patterns and fitness levels for the Canadian population. The most recent CFS, 1981, was carried out on a total of 15,519 Canadians (CFS 1982). It yielded, from the sum of 4 skinfolds (triceps, biceps, subscapular and suprailiac) norms and percentiles tables by age group and sex and further tables for

the estimated percentage of body fat based on Durnin and Womersley's (1974) regression equations (CFS 1984). With regard to the need to classify the different percentages of body fat into categories and to therefore define who has an excess of body fat, selected percentile scores and their assigned nomenclature, drawn from the 1981 CFS values expressed in percentage of body fat, will be used. The CFS nomenclature is based on a subdivision of the percentile distribution into 5 categories of fatness, the twentieth, the fortieth, sixtieth and eightieth percentile. For each of these percentile range the following nomenclature is applied: lean, less than average, average, more than average and overfat (see Appendix A). The sample of men in this study will be classified according to these percentiles and nomenclature.

In the general population, body fat content for males ranges from 3.7% for track and field athletes up to 50% in the case of very obese individuals. According to Bray (1980) the average fat content in a 18 year old male is approximately 15 to 18% of his body weight. According to Pollock, Schmidt and Jackson (1980) the ideal standard upper limit of body fat for men should be 16 to 19% while for Lohman (1982) the minimum fat content should be 3 to 7% of body weight. However, as an individual grows older his percentage of fat has a tendency to increase gradually which may not be necessary nor desirable in Bray's opinion (1980). For example, in the 1981 CFS (Appendix A) at the 50 percentile, for the 20 to 29, 30 to 39 and 40 to 49 years of age groups the

respective values for the estimated percentage of body fat are 16, 21 and 24%. Age related percentage of body fat has further complicated the operational definition of what should be considered an acceptable or normal amount of body fat for a population as well as what should be considered an excessive amount of body fat. In this respect, obesity, a condition that can be described as an excessive accumulation of body fat (Build Study 1979), is operationally defined by only a few arbitrary criteria which are mostly index based on epidemiological studies and actuarial analyses concerned with mortality and morbidity (Berger et al. 1981).

Some of these criteria have been derived from different anthropometric techniques. For example, according to the Metropolitan Life Insurance ideal weight tables, excess weight of above 35 to 40 percent of ideal weight standard tables is considered a pathological disorder which requires medical intervention (Build Study 1979). A more articulated definition of the excess weight range is given by Hanna, Loro and Power (1981) who equated obesity and overweight, as defined in relation to tables of ideal weight, into the 6 following categories: 10-20% over ideal weight, defined as slightly overweight; 21-30% mild; 31-50% moderate; 51-75% severe; 76-100% massive and 101% or more, morbid overweight. According to the BMI index, a value between 24 to 25 and 35 kg/m<sup>2</sup> defines overweight. Obesity is a BMI value greater than 30 kg/m<sup>2</sup> and considered a state of serious mortality risk, is a value above 42 kg/m<sup>2</sup> (Bray 1980). In the

U.S., Garn, Bailey, Solomon and Hopkins (1981), in the Ten State Study, used the 85th percentile of skinfold thickness in each age category to define the upper limit of the normal range while Bray (1980) defined obesity as an amount of body fat greater than 25% of total body weight.

Beyond these various operational definitions and classifications of excess weight or body fat defined in relation to morbidity and mortality, there is no operational definition of excess body fat based upon performance capacity, a measure which indicates when excess fat may lead to physical or psychological or social incapacity or impairment (Berger et al. 1981). However, the military establishment is aware of the detrimental effects of an excess of body fat on the physical fitness level, work capacity and combat readiness of its active men and has defined body fat criteria in relation to military duties. In this respect, the U.S. Army has determined that the body composition standards for men, 17 to 35 years of age, entering U.S. Army Basic Training will have a 20% body fat goal for all age groups but they will tolerate up to 24% (Knapik, Burse and Vogel 1983).

Because there is no operational definition of how much body fat an individual must carry before it significantly affects his motor performance after GPE, if ever it is the case, the present research will use a large number of subjects (N=50) all in the same age category, from 30 to 39 years of age, in order to cover as best as possible the range of percentage of body fat

possibilities from lean to overfat.

### 2.6.3 The cardiovascular and respiratory cost of weight-bearing aerobic exercises in subjects having an excess body fat

Whenever physical activity is continued for more than a few minutes, oxygen must be supplied in appropriate amounts by the blood to the mitochondrias in the working muscles in order to generate the energy to do work (Shephard 1984). This process is referred to as aerobic exercise where oxygen is absorbed from the atmosphere by the pulmonary system, transported to the periphery through the cardiovascular system where it is delivered to the active tissue and utilized for the combustion of nutrients, the end product being a release of heat, carbon dioxide, water and energy. In this respect, there is a direct relationship between oxygen consumption and energy expenditure. Oxygen consumption or oxygen uptake, expressed in litre(s) per minute ( $\dot{V}O_2$ ), is a measure of the difference between the volume of oxygen inspired and the volume of oxygen expired. It reflects the rate of utilization of oxygen by the active components of the organism for the aerobic metabolism. When expressed as the maximum  $\dot{V}O_2$  ( $\dot{V}O_{2\text{ max}}$ ) it represents the highest rate at which oxygen can be utilized by the individual to produce energy during work.

Furthermore, it is considered to be the most important determinant of individual performance in physical activity of an aerobic nature (Lamb 1978).

In light of the above, numerous studies have explored the

effects of carrying excess fat on the  $\text{VO}_2$  of overweight individuals during weight-bearing aerobic exercises such as stepping, running or walking as opposed to weight supported tasks such as bicycling or rowing.

Excess fat is associated with numerous cardiovascular and respiratory changes which will be covered in relation to the physiological cost of performing external work on a motor-driven treadmill or during similar weight-bearing tasks.

Mahadeva, Passmore and Woolf (1953) measured the energy expenditure of a group of 50 subjects varying in age, sex, race, weight, height and resting metabolism, during a walk around an indoor track and during a stepping task. They observed in both instances that energy expenditure was directly proportional to body weight and that the predictability of this relationship was not significantly affected in terms of precision, by taking the other factors into consideration. Thereby, in any physical activity where the body has to be moved or lifted, the metabolic cost varies proportionally to body weight.

Miller and Blyth (1955) compared the percentage of body fat of 30 healthy males varying in fat content from 0.0 to 33.9%, with an average of 14.5%, to the metabolic cost ( $\text{VO}_2$ ) of lifting the body during a 15 minute walk at 5 mph, 10% grade on a motor-driven treadmill. They observed, as Mahadeva et al. (1953) had, that the metabolic cost of work involving the transport of the body was directly proportional to gross body weight and that the correlation remained highly significant even when the

individual influence of fat content, lean body mass and height was eliminated. By taking Buskirk and Taylor's (1954) observation that  $\text{VO}_2$  max is limited by the size of the lean body mass into account, they observed that the oxygen requirement per unit of lean body mass increased during exercise as the content in body fat increased. It therefore seems that excess body fat, which represents extra weight, increases the metabolic cost of work when the body has to be lifted through space without increasing the  $\text{VO}_2$  max resulting in a limitation in work capacity.

Buskirk and Taylor (1957) found that following the determination of  $\text{VO}_2$  max in 59 young men covering a range of body fat content up to 34% (average 13.7%) that the best indicators of cardiovascular and respiratory performance were the fat-free body mass (FFM) ( $r: 0.85$ ) and the active tissue ( $r: 0.91$ ) because they allowed for the best approximation of the working mass. On the other hand,  $\text{VO}_2$  max expressed per kilogram of body weight (KgBW) and defined as a measure of the oxydative energy available for moving a kilogram of body weight from one point to the other, best describes the capacity of an individual to perform endurance running. This was well demonstrated in an experiment by Cureton, Sparling, Evans, Johnson, Kong and Purvis (1978). After subdividing their subjects into 3 classes according to their percentage of body fat (10% or less, 10 to 25% and greater than 25% fat), Buskirk and Taylor (1957) observed no significant difference between the  $\text{VO}_2$  max expressed in KgFFM. This was also

observed by Welch, Riendeau, Crisp and Isenstein's (1958) experiment on 28 young men with a range of 5.6 to 25.9% body fat. This may indicate that excess fat, within the limits of these authors' samples, has no significant detrimental effect on the capacity of the cardiovascular and respiratory systems to deliver oxygen to the muscles under maximal performance conditions. In their article, Binkhorst, Heevel and Noordeloos (1984) draw a similar conclusion by stating that  $\dot{V}O_2$  max values expressed in KgFFM for healthy obese subjects are no different from those of healthy normal subjects of comparable height, age and FFM. However, Welch et al. (1958) found that the  $\dot{V}O_2$  max expressed in KgBW is affected by the percentage of body fat, probably because of the extra weight to be carried which increases the oxygen requirement without improving the  $\dot{V}O_2$  max capacity, as mentioned previously.

Auchincloss, Sipple and Gilbert (1963) compared unsteady and steady-state ventilatory performance during a 10 minute treadmill exercise at 1.7 mph, 10% grade in 14 healthy obese subjects who were at least 42% over ideal weight as compared to 25 normal subjects. During the first 2 minutes of exercise, the ventilation of the obese subjects was characterized by a more pronounced hypoventilation as compared to normal subjects. For the rest of the exercise the obese maintained a normal alveolar carbon dioxide partial pressure by increasing the minute ventilation ( $\dot{V}_E$ ). The  $\dot{V}_E$  is the product of the tidal volume, i.e. the volume of air entering or leaving the lungs during a

single breath, multiplied by the ventilatory frequency. When this value is compared to their maximum ventilatory capacity, the results suggest that the rate of breathing of the obese is close to their maximum. Dempsey, Reddan, Rankin and Balke (1966) have shown that healthy sedentary obese males with 32 to 50% body fat readjust their breathing pattern during exercise because of their elevated  $V_E$  and in order to minimize the rising metabolic cost of breathing. This increased cost is associated in the obese to the increased work necessary to move the chest which is explained by a decrease of the chest wall compliance (Suratt, Wilhoit, Hsiao, Atkinson and Rochester 1984) due to the accumulation of fat at the level of the chest, the diaphragm and the abdomen and to a possible inefficiency of the respiratory muscles (Luce 1980, Ray, Sue, Bray, Hansen and Wasserman 1983). The breathing readjustment is usually accomplished by hyperventilating. This results in a shallow and rapid breathing pattern with an elevated  $V_E$  as observed by Dempsey et al. (1966). In fact the authors mention that many of their overweight subjects were breathing heavily during exercise but without complaining of labored breathing (dyspnea) which is a common problem in the obese. Finally their  $VO_2$  and their carbon dioxide production correlate closely with weight, suggesting a higher energy expenditure in the overweight group as compared to normal subjects.

The same parameters,  $V_E$ ,  $VO_2$  and respiratory frequency, were studied by Turell, Austin and Alexander (1964) on 12 normal and 15 very obese subjects (on average 194% of predicted ideal

weight) during an exercise period of 6 minutes carried out at 4 different grades (0, 5, 10 and 15%) on a treadmill functioning at a constant speed of 1.6 mph. Results for the obese group indicate that at each level of exertion their  $V_E$ ,  $VO_2$  and respiratory frequency were almost twice the level of those of the normal subjects. However, when the  $VO_2$  was equalized between the 2 groups by letting the obese walk on the treadmill at ground level while the normal subjects climbed at a 15% grade, the only variable which was significantly different during exercise was the higher respiratory frequency of the very obese. When looking at the mechanical efficiency of each subject they found no difference between the 2 groups. This supports the observations of several other contemporary studies which have looked at the efficiency of exercising muscles in obese subjects by mostly using the bicycle ergometer (Bray 1983, Anton-Kuchly, Roger and Varenne 1984). The principal causes of increased metabolic cost in obese subjects are factors such as lower muscular coordination, increased cost of breathing, increased energy used to maintain posture and stability, increased body mass, all of which increase the energy cost of performing external work. Bray (1983) concluded in 1982 that there is no evidence of abnormality in the relationship between energy production and muscular contraction in moderately and massively obese subjects.

Alexander (1964) looked more closely at the cardiac performance of 40 grossly obese men and women (between 50 to 110 kg above predicted ideal weight) during exercise. At rest he found

that they had an increase in cardiac output (volume of blood pumped by each ventricle per minute) probably in order to supply extra blood to the enlarged vascular bed stemming from the added adipose tissue depots (Alexander 1965, Grommet 1980). This increase was produced mainly by an increase in the stroke volume (volume of blood ejected by the ventricle during one beat of the heart) since the heart rate at rest was within normal range. More recent studies have shown that the  $\dot{V}O_2$ , the cardiac output and the stroke volume are elevated in normal healthy obese individuals and correlate positively at rest with weight and the importance of the overweight state (Kaltman and Goldring 1976, Divitiis et al. 1981, Reisin and Frohlich 1981). During exercise at varying grades (0, 5, 10 and 15%), the circulatory adjustment expressed as the increment in cardiac output per unit, per increment in  $\dot{V}O_2$  was within normal limits compared to that of normal subjects. This observation was confirmed by Backman, Freyschuss, Hallberg and Melcher (1973) study. However, in Alexander's (1964) study, the cardiac work load was significantly greater for the grossly obese than for the normal subjects at the same absolute intensity. This suggests that for the very obese any movement involving the transport of excess weight will produce a greater cardiac work load.

Hanson (1973) using 4 healthy male volunteers subjected them to a one month standardized diet period followed by 4 months of high-caloric feeding which increased their weight by 18 to 20%, from an average of 73.6 kg up to an average of 87.8 kg. They

were tested a total of 4 times during the experiment on a bicycle ergometer and on a motor-driven treadmill where they had to walk at 3 mph at a 7, 14 and 25% grade. A mean 15% gain in basal body weight significantly increased the  $\text{VO}_2$  value at the 14 and 25% grades. After a 19% weight gain the  $\text{VO}_2$  values were significantly different at all grades compared to values at basal weight. In fact, above basal values the increment in percentage of  $\text{VO}_2$  closely followed the increase in percentage of weight gain. This suggests that as weight increases there is a proportional increase in energy expenditure and that the heart rate for each grade is not statistically different from one gain to another. Minute ventilation and carbon dioxide production are significantly different as compared to basal weight values. As seen before, these last 2 exercise parameters are also affected in studies using subjects already possessing an excess of weight.

Gitin, Olerud and Carrol (1974) criticized the use of the term  $\text{VO}_2$  max expressed in relation to lean body mass (LBM) when employed in order to assess the level of physical fitness of an individual. In fact, using 18 very young men varying in body fat content, from 4.3 to 35.4%, they showed that percentage of body fat is negatively correlated with the United States Marine Corps Physical Fitness Test scores ( $r: -0.686, p < .005$ ) and positively correlated with the time it takes to run 3 miles ( $r: 0.405, p < .05 < .01$ ). From these tests they observed that subjects carrying excess fat appear less fit according to all criteria except for the  $\text{VO}_2$  max expressed per unit of LBM. From their

results they concluded that this final measure can be misleading when used to evaluate the capacity to do exhaustive work. They further suggested that adipose tissue is not an inert weight as believed before (Miller and Blyth 1955). Indeed, it is a well vascularized tissue (Bulow 1982) and the blood flowing through it increases with exercise. Jens Bulow (1982), in his thesis on adipose tissue blood flow during exercise, confirmed that the flow increased in all major adipose tissue depots during exercise in order to facilitate free fatty acid mobilization in human subjects. Furthermore, in vitro research on rats' adipose tissue (Orth, O'Dellan and Williams 1960) has shown that this tissue increases its  $VO_2$  in response to hormones and catecholamines. This suggests, according to Gitin, Olerud and Carroll (1974), that during exercise part of the increase in  $VO_2$  may be due to the metabolism of the adipose tissue itself and they therefore estimate that 8 to 10% of the total  $VO_2$  max can be accounted for in this way.

Bray, Whipp, Koyal and Wasserman (1977) assessed the effects of exercise on 10 moderately overweight males (20 to 40% overweight) and 10 normal weight males. Subjects were initially evaluated at 3 different work rates on a bicycle ergometer. Their  $VO_2$  values at these 3 levels were reproduced during a walk on a treadmill at a speed and/or grade which could produce a similar level of  $VO_2$  between the 2 groups. A reduction in speed and/or grade on the treadmill was required for the overweight group in order to equate their  $VO_2$  with that of the normal weight

group suggesting that even a moderate excess of weight can impair work capacity. It can be seen here that the amount of work done on the treadmill at comparable  $\text{VO}_2$  levels was significantly lower for the overweight men than for the normal weight ones. At rest neither group had a significant difference in blood pressure and heart rate but at an intensity of work of 50 watts, both systolic and diastolic blood pressure were significantly higher for the obese men. At 100 watts only the systolic pressure was significantly higher and at 150 watts there was no significant difference in heart rate, systolic and diastolic blood pressure between the 2 groups.

Freyachuss and Melcher (1978) assessed the  $\text{VO}_2$  of a group of 14 male and female patients suffering from extreme obesity by using a motor-driven treadmill before a jejuno-ileostomy and on 8 of the patients afterwards. Before the surgical operation patients'  $\text{VO}_2$  values for a given work load were considerably higher than the values of a healthy control group. Following an average weight loss of 62 kgs for the 8 subjects studied after surgery, their  $\text{VO}_2$  values on an identical work load dropped significantly from 2,388 ml per min to 1,334 ml per min. This phenomenon can be partly explained by a reduced metabolic rate and by a diminution of the weight that must be moved during grade walking. Results suggest that by reducing body weight the oxygen transport system is relieved.

Devore and Nemiro (1979), using a modified Balke protocol, tested 190 overweight men subdivided in 3 groups, less than 30lb

over ideal weight, between 30 and 100 lb over ideal weight and greater than 100 lb over ideal weight. The testing procedure was stopped when a subject's heart rate reached 85% of his age-adjusted maximal heart rate as predicted by standard tables. Using this protocol, they found that the 3 groups had a mean met level below 7 which is comparable to the level achieved during an activity such as walking at 5 mph at ground level. A met, equal to approximately 3.5 ml of  $O_2$ /kg/min, represents the average amount of oxygen consumed while sitting quietly in a chair. A value below 7 mets is representative of a low cardiorespiratory fitness level. Furthermore, the authors observed that their subjects could not perform strenuous exercise without experiencing discomfort.

With the reference value of 7 mets used as an approximation of the maximum work capacity of the overweight and following a review of the previous studies using overweight subjects in researches employing different absolute work loads (Miller and Blyth 1955, Auchincloss et al. 1963, Turett et al. 1964, Hanson 1973), it was decided that the light exercise intensity for the present study would be set at approximately 6 mets and the heavy exercise intensity at approximately 9 mets. A 6 mets work load can be induced by walking on a motor driven treadmill functioning at 3 mph and at a 7.5% grade while a 9 mets work load can be induced by a walking speed of 3.5 mph at a 12% grade. For example, during motor treadmill fitness testing at the above mentioned intensities at the University of Ottawa, using a

modified Balke protocol and involving over 200 sedentary adult males, the average heart rate and  $\text{VO}_2$  were (Jette 1981):

|                                               | Light work load<br>(6 mets or 3mph at 7.5% grade) | Heavy work load<br>(9 mets or 3.5mph at 12% grade) |
|-----------------------------------------------|---------------------------------------------------|----------------------------------------------------|
| average heart<br>rate (bpm)                   | $130 \pm 14$                                      | $160 \pm 17$                                       |
| average oxygen<br>consumption (ml/kg/<br>min) | $20.5 \pm 1.8$                                    | $32.3 \pm 2.9$                                     |

These value ranges give an approximation of the physiological effects of the 2 absolute work loads.

In summary, sedentary individuals possessing varying degrees of excess body fat will see the metabolic cost of their weight-bearing activities increase in direct relationship with their weight. In this respect, the obese subject will expend significantly more energy at a definite work load than the lean subject because of the load of fat he carries as excess weight to be moved, implying a high energy cost for a low external output. However, the excess fat per se does not significantly influence the capacity of the cardiovascular and respiratory systems to deliver oxygen to the muscles during maximal performance. In fact, the  $\text{VO}_2$  max expressed in liters per minute or per kg FFM for healthy obese individuals is no different than that of healthy individuals of normal weight and of similar age, FFM and height. As a result, it can be said that obesity limits the capacity for prolonged strenuous exertion by increasing the oxygen cost of exercise without increasing the  $\text{VO}_2$  max. At rest,

the overweight individual depending on his degree of body fatness, may exhibit some cardiovascular anomalies such as increased cardiac output and increased blood volume probably in order to supply his large vascular bed. During exercise, the circulatory adjustments appear to be within normal limits while the oxygen cost of muscular work is increased even in moderately overweight subjects. The increased  $\dot{V}O_2$  necessitates an increase in  $\dot{V}_E$  to compensate for the higher production of carbon dioxide. This may lead to hyperventilation at which point, depending on the degree of fat on the thorax, the metabolic cost of breathing may bring on dyspnea and discomfort. In general, the overweight sedentary individual has a poor degree of cardiovascular fitness but the same mechanical efficiency as a healthy individual of normal weight.

#### 2.6.4 Excess fat and motor performance

Beyond the cardiovascular and respiratory burdens associated with excess body fat as carried during weight-bearing tasks, this added body fat may also have significant effects on the performance of motor tasks. Malina (1975) reviewed the literature dealing with the relationship between selected anthropometric measurements and motor performance and strength in subjects ranging from 6 to 21 years of age. He arrived at the conclusion that excess body weight, fatness or endomorphy have a negative effect on tasks involving movements when the entire body must be projected or moved as during running, jumping and pulling up. In

these situations an excess of fat is considered to be a handicap.

Boileau and Lohman's (1977) conclusion in their article on body physique measurements and physical performance, lend support to Malina's (1975) conclusion. Cureton et al. (1978), by adding different external weights to the bodies of 6 young adults, found a systematic decrease in both treadmill running time and in the 12 minute run distance as weights were added on. In 1979, Cureton, Hensley and Tiburzi observed that the difference between men and women in percent of body fat could possibly account for an average mean difference of 30% in performance when the body had to be moved either vertically (pull up, vertical jump) or horizontally (50 yard dash, 12 minute run test). Wilmore (1983) in a direction paper for the American College of Sports Medicine mentioned that there is a high negative correlation between percentage of body fat and performance when the body mass is translocated either vertically or horizontally. However, he cautioned that consideration must be given to exceptions such as the successful middle distance runner whose amount of body fat was over 17% although the usual value is below 12%.

Factors other than excess weight generated by an excess of body fat can also limit motor performance and the exercise tolerance of obese individuals. They may include heat intolerance, movement restrictions and orthopaedic pain (Foss 1981). It has been suggested that obese men may be handicapped during heat generating activities because 1) their amount of adipose tissue diminishes their capacity to dissipate heat, 2)

their ratio of body surface area to body mass is diminished, resulting in a low area volume ratio for heat dissipation and 3) the density of their sweat glands is lower than in normal individuals (Bar-or, Lundegren, Magnusson and Buskirk 1968, Bar-or, Lundegren and Buskirk 1969). In addition, because of the increased metabolic cost of work for the obese, they may develop a higher level of heat generation which is poorly dissipated leading to increased core body temperature which in turn modifies a number of physiological parameters and increases discomfort. When considering movement restrictions, it is believed that large fat depots are a factor which can hinder or restrict the performance of a particular skill. Whipp and Davis (1984) mentioned that the low mechanical skills of the obese are a result of their increased body mass which impedes limb motion in certain directions and of the extra energy required to overcome limb inertia. Finally, orthopaedic pain can occur as a result of high intensity weight-bearing activities because of the stress placed by the extra pounds on the knees, ankles, low back and hips. In this respect, obese individuals have an increased susceptibility to osteoarthritis of the knees but also of non weight-bearing joints (Silberberg 1979).

Very few studies have assessed how body fatness affects reaction time (RT) and other types of perceptual-motor parameters. Smith and Boyarsky (1943) tested Sheldon's relationship between the 3 primary structural components used to describe the human physique, endomorphy, mesomorphy and

ectomorphy and speed of reaction. The index of height over the cube root of weight was used to assess the 3 different somatotypes and it was observed in a group of 50 undergraduate males that the smaller the index, suggesting high endomorphy, the longer the RT and vice versa.

Janoff, Beck and Child (1950) using the 3 same somatotypes as Sheldon, correlated them with 4 measures of RT and found no satisfactory evidence of a significant correlation between somatotype and RT in a group of 51 undergraduate males. They suggested that Smith and Boyarsky's results were affected by a sampling error and that somatotype is not an important factor for predicting RT.

Kitagawa, Usui and Miyashita (1979) observed that there was no difference in electromyographic RT between non obese and obese young men whose percentage of fat was measured by densiometry.

Pierson (1961), after dividing 21 untrained subjects into 4 types of body build, measured their RT to a visual stimulus and their time on a sprint start, the latter defined as over-all body speed. He found no significant correlation between weight, height and RT.

Beunch et al. (1983) looked at the relationship between body fatness and motor fitness in a nationwide sample of Belgian boys 12 to 20 years of age. They found no significant difference in the performance of the stick balance test, an eye-hand coordination test, and in the plate tapping test used to assess the speed of limb movement, between the fattest (75th to 97th

centiles) and the leanest body (10th centile). The authors suggested that there is little association between fatness and selected aspects of motor fitness which do not involve movement or projection of the entire body.

In summary, during physical activities, where the entire body mass must be moved horizontally or vertically, an excess of body fat will limit physical performance and the extent of these limitations will be in proportion to the excess in body fat. They are partially exemplified by the increased energy cost of work as well as by the low heat dissipation of the obese, their breathing difficulties, movement restrictions and the orthopaedic stress put on the articulations, all of which combine to create discomfort and lower exercise tolerance. During non weight-bearing static perceptual-motor tests such as RT, an excess in body fatness does not appear to be a limitation in the few studies covered except for Kitagawa et al. (1979) who suggested that movement time may be longer. In this respect, it seems that more studies are required to clarify whether or not there is a significant difference between the RT and the MVT of individuals carrying excess fat as opposed to those with no excess fat. These studies should focus both on individuals at rest and following exertion.

## CHAPTER III

## METHODOLOGY

3.1 Subjects

Fifty healthy sedentary male volunteers were recruited after they responded to an ad (see appendix B) posted on University of Ottawa campus and in buildings in the surrounding community. The ad offered a full fitness evaluation followed by a debriefing on the results for those willing to participate in a research experiment. The subjects were between 30 and 39 years of age and were sedentary or occasional exercisers. No aerobically trained subjects were accepted which meant that any individual undergoing three or more regular sessions of aerobic type exercise per week, for a duration of 20 minutes or more per session during the two months preceding the experiment was considered a regular exerciser and was refused as a subject for this research.

3.2 Apparatus

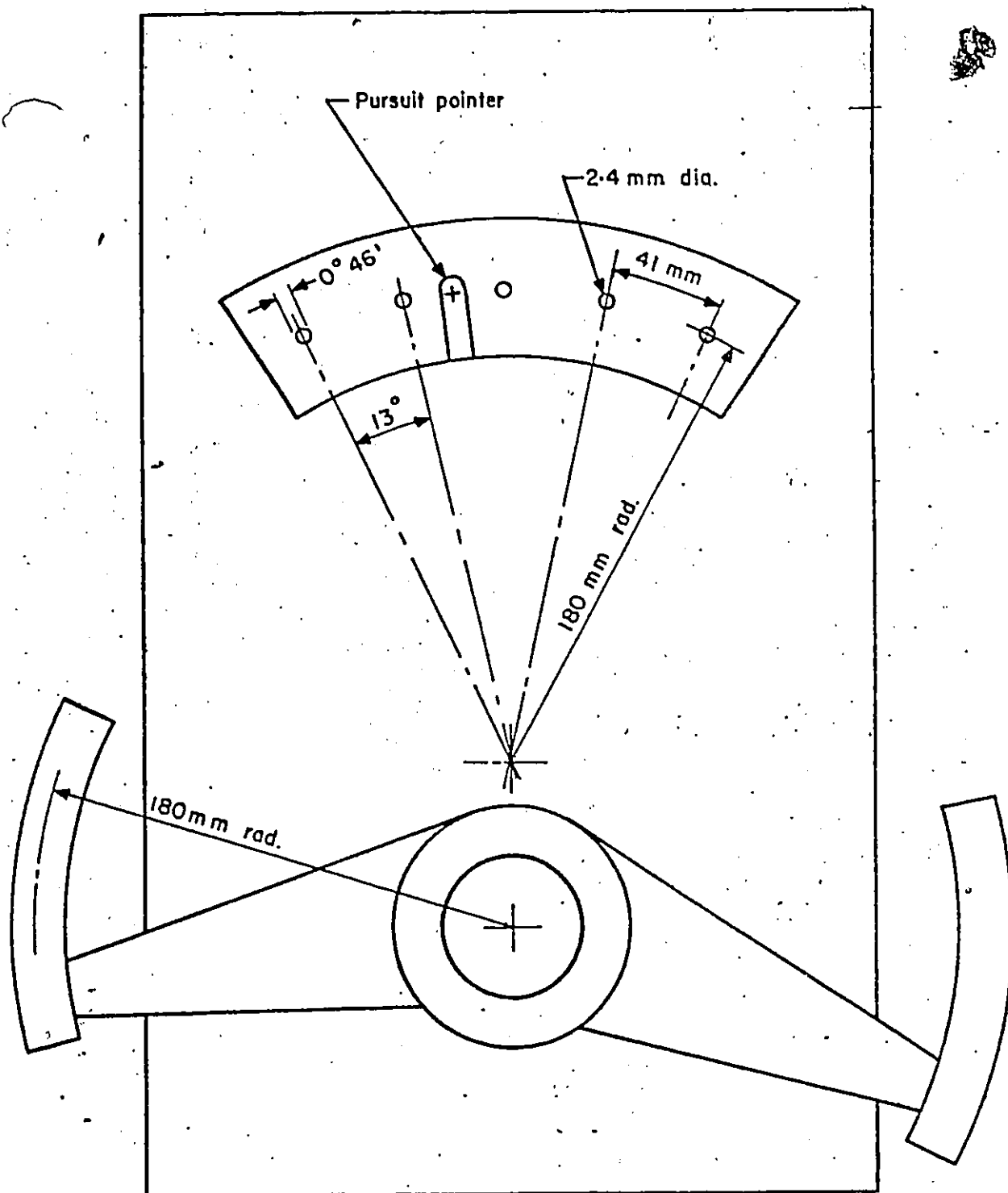
The apparatus used to measure the fine motor performance was the National Research Council (NRC) tracometer (unit type: mark 6A). It is a step-input, subject-paced pursuit tracking task used to detect the effects of various extrinsic factors on skilled performance. Each trial on the tracometer is perceived by the subjects as a random sequence of 100 successive target presentations. For each target presentation the subject has to align a pursuit pointer moved by a control steering wheel set up at a 1:1 ratio to one of the five illuminated targets sit in

semicircular fashion on the tracking unit display (see Figure 1). Once the pointer is in the target area which has a diameter of 2.4 mm, it must stay in that area for a period of 200 ms before the next target is illuminated. As the subject pursues the target, the information is recorded onto magnetic tapes (TDK cassettes, AD60) for future decoding at the NRC facilities. With regard to the speed component of the task the following variables were measured: total response time, total response time by intervals, correct reaction time, non-overshoot movement time and overshoot movement time. For the purpose of the present experiment in order to assess skill baseline, 16 training trials broken down into four blocks of four trials each were given before introducing the subjects to their first bout of physical exertion. These initial trials were given in two sessions of eight trials each. The first session was given on the first day of the experiment and the other on the second day of experimentation just before the first bout of exercise took place. During both the practice and the testing sessions subjects were instructed to track as quickly and accurately as possible. In order to maintain the motivation of subjects, knowledge of results (total time taken for the trial) was provided at the end of each trial. (For more information on the tracometer see Appendix C).

### 3.3 Procedure

Each subject was tested on two different days either

## The Pursuit Tracking Unit



successive or separated by an interval varying from one to five days. Testing sessions were conducted from 8:00 a.m. to 9:00 p.m. at the convenience of the subjects.

On the first day of testing each subject was introduced to the different pieces of equipment in the laboratory. Subsequently he was given a consent form, a lifestyle questionnaire and a physical activity screening questionnaire (see appendices D, E and F). His height, weight, circumferences, skinfold thickness (measured with a harpender caliper), heart rate and blood pressure were all taken in accordance with procedures established in the Canadian Standardized Test of Fitness for Adults (1983) and the values were recorded on a personal data sheet (see appendix G).

Following these procedures the subject was seated directly in front of the tracometer which was positioned on a table. The height of the chair was adjusted so that the target display was below the subject's line of sight. Precautions were taken in order to remove all glare on the target display. The subject was then asked to firmly maintain both hands on the vertical hand grips throughout the trials while guarding against the tendency to hold on too tightly. The subject then was instructed to move the pointer to a position between target four and five defined as the starting position for each trial. He was told that 100 targets would be presented per trial and that eight trials (from trial 1 to 8) were scheduled for day 1 with a two minute break after the first four trials. The subject was asked to track the

targets as fast as possible while being as accurate as possible. At the end of each trial subject was informed of his total time in milliseconds required to complete the task. This value was also recorded on the tracometer test record sheet (see appendix H).

After completion of the eight trial, the cardiorespiratory fitness level (aerobic power) of the subject was measured through the use of the Canadian Aerobic Fitness Test which is a standardized stepping test (CSTFA 1983). At the end of the session for day 1 the subject was initiated to the procedure involved on day 2: treadmill walking and disembarking in order to reach the chair in front of the tracometer. The treadmill used in this research was portable, manufactured by Quinton Instruments (Cardio Exercise Treadmill, model 18-54, Seattle, Washington). Before leaving, the subject was finally reminded to avoid all strenuous physical activity, the use of alcohol, tobacco and caffeine-containing beverages a few hours before testing. These guidelines were described to every subject and each received a written copy (see appendix I).

On day 2, upon arrival the subject was seated on a chair and asked to sign a second consent form (see appendix J) and complete another lifestyle questionnaire (II) (see appendix K). His heart rate and blood pressure were measured and recorded on a second data sheet (see appendix L). In the sequel, resting heart rates were recorded through a three leads portable electrocardiogram manufactured by Cambridge (VS 4 type). The subject was then

instructed on the procedure relative to moving with the attached electrodes from the treadmill to the chair in front of the tracometer. Once seated in front of the tracometer he executed eight trials (from trials 9 to 16). Then, the subject was invited to the treadmill which was right next to the tracometer for a 10 minute walk at a speed of 3 mph with a 7.5% grade. Forty seconds before the end of the 10 minute walk the perceived level of exertion of the subject was measured using the 15 grade Borg's Rate of Perceived Exertion (RPE) scale (Borg 1982) (see appendix M). The RPE was obtained by asking the subject to state the appropriate rating on a large reproduction of the rating scale displayed in front of him. At the 10 minute mark the treadmill was stopped and the subject walked to the tracometer where he was presented with four trials, called post-exercise trials (from trials 17 to 20). In addition, during the subject's 10 minute walk on the treadmill, his heart rate was measured with the portable ECG for two 10 second periods: the last 10 seconds preceding the five minute mark and 10 other seconds at the 20 second mark before the end of the 10 minute walk. Furthermore, the heart rate was also measured for 10 seconds at the beginning of the first post-exercise pursuit tracking trial (trial 17) and 10 seconds before the end of every minute for the next five minutes.

Following the fourth post-exercise trial, a 15 minute rest period was provided before the next treadmill walk. During this period the subject was informed of his fitness results obtained

from the preceding day. After 14 minutes of rest, heart rate and blood pressure were measured and if their values were close to pre-exercise values the subject was allowed back on the treadmill set at a speed of 3.5 mph with a 12% grade for another 10 minute walk. At the end of this 10 minutes the subject was immediately transferred to the tracometer for another four tracometer trials (from trials 21 to 24). This time before initiating the first post-exercise trial (trial 21) the subject had the opportunity to remove the sweat from his hands and his face before beginning the pursuit tracking task. This procedure helped maintain proper steering wheel control and prevent sweat from getting into the eyes during post-exercise trials. Heart rate and the RPE were measured as in the preceding procedure.

During the walk on the treadmill the subject was supervised in order to prevent any accidents. Furthermore, he was asked not to use the bar in front of the treadmill for support during the walk unless he lost his balance.

### 3.4 Design and Analysis

The analysis of the results was divided into two parts. the first part focuses on an analysis of antecedents to independent variables. Results from the two lifestyle questionnaires and the results of the anthropometric and physiological evaluations were analyzed. The data were further analyzed for two selected key parameters: percentage of body fat and predicted maximum oxygen consumption. The following statistical procedures were utilized:

descriptive statistics, one-way analysis of variance, Tukey HSD test and Pearson product moment correlations. The second part focusses on an analysis of the dependent variables. Results for heart rate and rate of perceived exertion were described and analyzed with the following procedures: descriptive statistics, Pearson product moment correlation procedure,  $FGR(5) \times Conditions(2)$  ANOVA with repeated measures on Conditions and Scheffe's post-hoc test. Motor performance values for each FGR recorded before and after the light intensity exercise (trial 16 before and 17 after exercise) and before and after the heavy intensity exercise (trial 20 before and 21 after exercise) were described and analyzed in terms of total response time, correct reaction time, non-overshoot movement time and overshoot movement time. Each pre-exercise trial (trials 16 and 20) was analyzed for all four fine motor parameters using a one-way ANOVA on the five FGRs. The pre- and post-exercise trials were compared separately at each level of intensity: light and heavy. Since the fine motor parameters were measured at five successive intervals or four levels of probabilities or four target distances, these data were analyzed through a  $FGRs(5) \times Trials(2) \times Intervals(5)$  (or Probabilities (4) or Target distances(4)) ANOVA with repeated measures on Trials and Intervals (or Probabilities or Target Distances). Each motor parameter was analyzed through univariate analysis since only this type of analyses were available at the NRC where the entire data had to be analyzed. In the case of missing data due to mechanical failures, specific levels of

performance were dropped or scores were averaged.

For each fine motor performance parameters, the distribution scores were analyzed specifically to identify possible atypical scores (outliers). High values (e.g. over 10 s in duration) could presumably be caused by a break in attention while low values could be caused by minute movements of the steering wheel.

Performance scores for all analyses were averaged. For each trial, the performance parameter values were recorded for each of the 100 targets and averaged in order to produce a score which represents the average time in milliseconds (ms) per target over the trial. One subject provided no fine motor performance data for trial 17 because of a technical error. Since the program used at the NRC to perform the analysis of variance with repeated measures cannot operate without an equal number of subjects in each FGR, the analyses for trials 16 and 17 were performed on 45 subjects instead of 50 by removing the performance values of every third subject in each of the five FGRs.

## CHAPTER IV

## RESULTS

Data analysis was undertaken at Systems Laboratory, a division of the Mechanical Engineering Department of the National Research Council of Canada (NRC), where a special computer program is set up to process the scores of the step-input, subject-paced pursuit tracking task known as the NRC tracometer. For the purpose of this analysis the 50 subjects were ranked according to their percentage of body fat and afterwards subdivided into five groups of 10 subjects each representing increasing levels of percentage of body fat. As such FGR 1 represented the 10 leanest subjects of the sample and FGR 5 the 10 fattest subjects. The average percentage of body fat for each of these groups will be computed. These FGRs will be compared to the 1981 Canadian Fitness Survey (CFS) body fat classification.

#### 4.1 ANALYSIS OF THE SAMPLE

Subjects health, level of physical activity, physical activity prior to testing on day 2 and anthropometric and physiological characteristics were described from data taken from two lifestyle questionnaires (I and II) and from tests performed on subjects during day 1.

##### 4.1.1 Questionnaire

On both testing days prior to any physical testing all

subjects responded to a questionnaire assessing their lifestyle. The first lifestyle questionnaire (I) was meant to reflect their health and exercise habits and was administered at the beginning of the first meeting. A second standardized assessment, the PAR-Q, designed to evaluate their physical activity readiness was also administered. The second lifestyle questionnaire (II) provided information on the consumption of cigarettes, coffee, tea and alcohol by subjects as well as possible involvement in any type of exercise prior to the second testing session. All answers provided by subjects were recorded by the investigator.

#### 4.1.1.1 Health of subjects: questionnaire I

The first question in lifestyle questionnaire I (see appendix E) was "When did you last receive a medical examination?". Forty subjects (80% of the sample) had received a medical examination during the last five years while 24 (48%) of them had undergone one examination during the preceding 18 months. Six subjects (12%) had received their last examination seven or eight years prior to the study and four subjects (8%) did not remember or had never had one.

The second question, which is related to the first one was: "Were you advised of any potential medical problem during this examination?". In the case of a yes answer the subject was asked to specify the medical problem. The breakdown of answers appears in Table 1.

**TABLE 1:** Responses of FGRs to the health portion of the  
lifestyle questionnaire I.

| FGR | No of<br>subjects | Medical Problem |     | Type                                                                    | Medication? |     | Type                                                        |
|-----|-------------------|-----------------|-----|-------------------------------------------------------------------------|-------------|-----|-------------------------------------------------------------|
|     |                   | yes             | no  |                                                                         | yes         | no  |                                                             |
| 1   | 10                | 1               | 9   | .palpitations                                                           | 0           | 10  |                                                             |
| 2   | 10                | 4               | 6   | .cholitis<br>.under stress<br>.liver problem<br>.high blood<br>pressure | 2           | 8   | .cortisone<br>.sleeping<br>pills and<br>muscle<br>relaxants |
| 3   | 10                | 1               | 9   | .high blood<br>pressure                                                 | 0           | 10  |                                                             |
| 4   | 10                | 3               | 7   | .pneumonia<br>.foot surgery<br>.burn out                                | 2           | 8   | .antibiotic<br>.tagamet and<br>a relaxant<br>(ativan)       |
| 5   | 10                | 2               | 8   | .high blood<br>pressure<br>.high blood<br>cholesterol                   | 1           | 9   | .diuretics                                                  |
| T   | 50                | 11              | 39  |                                                                         | 5           | 45  |                                                             |
|     | 100%              | 22%             | 78% |                                                                         | 10%         | 90% |                                                             |

Thirty nine subjects (78% of the sample) answered that they had no known medical problem while 11 (22% of the sample) said they did. The type of medical problems encountered by individuals is given by FGR in Table 1. None of these problems prevented the subjects from undergoing the testing protocol. Of the 11 subjects who had known medical problems, five (10%) mentioned that they were taking medication. The type of medication appears in the far right column of Table 1. Following the health questionnaire, subjects had to answer the physical activity readiness questionnaire (PAR-Q) (see appendix F) designed to identify those individuals for whom physical activity may be unsuitable, particularly those with ailments which can be aggravated by exercise. However, from the results of this last questionnaire all subjects were considered healthy enough to undergo the exercise protocol.

According to these two questionnaires, all subjects were healthy and fit for the testing procedure.

#### 4.1.1.2 Recent level of physical activity: questionnaire I

Relative to the physical activity pattern and the non regular aerobic exercise criteria, subjects were asked the following two questions. The first question was: "In relation to physical activity, did you exercise in the past two months, a little if any, occasionally or regularly?". The second question, when appropriate, was: "List the type, number of sessions per week, duration and intensity of your exercise sessions over the

past two months" (see appendix E). The answers by FGRs to the first question appear in Table 2.

In response to the first question, 31 subjects (62%) answered that they had done little if any exercise. From this group 15 did not answer the second question, the reason being that they felt they had done no specific exercise during this two months period. The remaining sixteen (32%) subjects exercised occasionally and three (6%) exercised regularly. Of the three regular exercisers, one in FGR 1 mentioned that he practiced Hatha Yoga three times a week, one in FGR 3 did home calisthenics four times a week and the last one, in FGR 5, followed a television work out in the morning five times a week.

With regard to the second question subjects could list a maximum of four different types of activities with their respective frequency (weekly frequency), time duration in minutes and intensity level (light, medium or heavy). A total of 56 answers were recorded, see Table 3. Thirty subjects (60%) identified at least one activity, 15 (30%) mentioned two activities, five (10%) listed three activities and one (2%) listed four.

The 13 (23.2%) activities appearing only once were: home calisthenics, following an exercise class on television, Hatha Yoga, rope skipping, golf with a cart, basketball, soccer, weight lifting, hiking, rockclimbing, light housework, gardening, mowing the lawn with a push mower.

**TABLE 2:** Classification of subjects into FGRs according to their level of physical activity in the past two months (N=50).

| FGR | No of subjects | Level of physical activity |               |              |           |
|-----|----------------|----------------------------|---------------|--------------|-----------|
|     |                | None                       | Little if any | Occasionally | Regularly |
| 1   | 10             | 2                          | 2             | 5            | 1         |
| 2   | 10             | 2                          | 5             | 3            | 0         |
| 3   | 10             | 3                          | 3             | 3            | 1         |
| 4   | 10             | 6                          | 3             | 0            | 1         |
| 5   | 10             | 2                          | 3             | 5            | 0         |
| T   | 50             | 15                         | 16            | 16           | 3         |
|     | 100%           | 30%                        | 32%           | 32%          | 6%        |

**TABLE 3:** Type of physical activities done by the 50 subjects in the two months preceding the study.

| Type                             | No of individuals <sup>a</sup> | Percentage <sup>b</sup> |
|----------------------------------|--------------------------------|-------------------------|
| Bicycling                        | 8                              | 14.3                    |
| Tennis                           | 6                              | 10.7                    |
| Walking as an exercise           | 6                              | 10.7                    |
| Windsurfing                      | 4                              | 7.1                     |
| Jogging                          | 3                              | 5.4                     |
| Racquetball                      | 3                              | 5.4                     |
| Softball                         | 3                              | 5.4                     |
| Ice hockey                       | 3                              | 5.4                     |
| Swimming in a pool               | 3                              | 5.4                     |
| Golf, walking and carrying clubs | 2                              | 3.5                     |
| Motocycling                      | 2                              | 3.5                     |
| Activities appearing only once   | 13                             | 23.2                    |
| T                                | 56                             | 100.00                  |

a One individual can be involved in up to four different activities.

b This percentage reflects the relative frequency of occurrence of the activity out of a total number of 56.

Those individuals performing aerobic types of exercise such as jogging, racquetball, ice hockey, swimming in a pool, following an exercise class on television, rope skipping, basketball and soccer were questioned more closely about their involvement over the last two months. Frequency, duration and intensity of exercise were the parameters used to assess the extent of their physical training during this period. Any individual undergoing three sessions or more a week of aerobic type of exercise for a duration of 20 or more minutes non stop during the two months preceding testing was not accepted as a subject for this study.

Of the total of 14 individuals (28% of the sample) involved in the aerobic types of exercise mentioned above, 11 stated that they were involved once a week or only occasionally. Of the three remaining subjects, one mentioned that he played ice hockey twice a week over the two months while another swam three times a week and the last one followed a 30 minute exercise class presented on television five days a week. However, none of the last two subjects was exercising continuously during his period of physical exercise and the intensity of their exercise was not high enough to produce any training effect. In this respect, they were not considered as aerobically trained. The distribution of the 14 subjects involved in aerobic types of exercise is as follows: four subjects in FGR 1, two in FGR 2, three in FGR 3, one in FGR 4 and four in FGR 5. All five FGRs are represented.

Overall, the sample of subjects met the sedentary or occasional exercise requirements since all but two were not involved in a regular aerobic type of training during the two months period preceding evaluation. The two subjects who exercised regularly were not considered as aerobically trained following a closer assessment of their physical activity level.

#### 4.1.1.3 Physical activity prior to testing session: questionnaire II

All subjects were given an explanatory sheet (see appendix I) at the end of day one asking them to refrain from a number of stimulants (exercise, smoking, coffee, tea and alcohol) during the six hour period preceding testing on the second day and to only ingest a light meal, if desired, a minimum of two hours before the testing session. To control these variables a second lifestyle questionnaire (II) (see appendix K) was administered prior to testing on day 2. However, only information pertaining to physical activity prior to testing was retained for analysis.

Subjects were asked before undergoing testing on day 2 if they had done any vigorous physical activity in the hours preceding their coming to the testing facility. All 50 subjects answered no to this question.

#### 4.1.2 Anthropometric and Physiological Parameters

As mentioned earlier this sample of 50 male subjects was divided into five groups (FGR 1 - FGR 5) of 10 subjects each

after they were ranked by increasing percentage of body fat FGR 1 represents the 10 leanest subjects and FGR 5, the 10 fattest subjects. This categorization is presented in Table 4 where the anthropometric and physiological characteristics, as measured on day 1, are presented for the total group and each FGR.

**TABLE 4:** Means (M) and standard deviations (SD) of anthropometric and physiological characteristics for the five FGRs (N=50).

| Variable                      |    | Total group | FGR 1 | FGR 2 | FGR 3 | FGR 4 | FGR 5 |
|-------------------------------|----|-------------|-------|-------|-------|-------|-------|
| No of subjects                | N  | 50          | 10    | 10    | 10    | 10    | 10    |
| Age (years)                   | M  | 34.0        | 34.0  | 34.0  | 33.0  | 36.0  | 36.0  |
|                               | SD | 3.1         | 3.2   | 2.8   | 3.3   | 2.4   | 3.4   |
| Height (cm)                   | M  | 177.9       | 177.9 | 179.0 | 179.3 | 177.8 | 174.2 |
|                               | SD | 7.5         | 5.3   | 6.4   | 6.4   | 9.9   | 7.1   |
| Weight (kg)                   | M  | 77.6        | 70.9  | 71.8  | 76.7  | 80.5  | 88.2  |
|                               | SD | 11.1        | 8.4   | 8.5   | 6.4   | 9.6   | 13.0  |
| Skinfolds (mm)                | M  | 62.5        | 29.8  | 45.9  | 61.6  | 76.6  | 98.7  |
|                               | SD | 24.9        | 3.6   | 4.6   | 5.7   | 3.8   | 11.6  |
| % Body fat                    | M  | 23.0        | 16.0  | 20.6  | 23.7  | 26.1  | 28.8  |
|                               | SD | 4.6         | 1.3   | 1.1   | 1.0   | 0.5   | 1.2   |
| Systolic BP (mmHg)            | M  | 114.6       | 107.7 | 114.2 | 115.9 | 119.2 | 116.2 |
|                               | SD | 11.6        | 10.5  | 14.3  | 11.2  | 9.9   | 10.4  |
| Diastolic BP (mmHg)           | M  | 82.9        | 78.8  | 82.4  | 83.6  | 83.6  | 86.2  |
|                               | SD | 8.6         | 9.8   | 9.0   | 9.5   | 7.4   | 6.8   |
| Predicted V02 max (ml/kg/min) | M  | 42.3        | 45.0  | 44.8  | 42.3  | 39.5  | 39.9  |
|                               | SD | 3.7         | 2.6   | 3.2   | 3.1   | 1.4   | 3.9   |

The average age of subjects in this sample was 34.0 (SD=3.1) years. Their average height, 177.9 cm (SD=7.5) was slightly larger than the average for Canadian males between 30 and 39 years of age according to the 1981 CFS. The same observation applies for weight, 77.6 kg (SD=11.1) versus 76.7. From FGR 1 to FGR 5 the weight of subjects increased in similar pattern as their percentage of body fat. The correlation coefficient between weight and predicted percentage of body fat measured with a caliper was (N=50)  $r = .57$  ( $p < .05$ ).

The mean percentage of body fat for the 50 subjects (Table 4) was 23.0 (SD=4.6) with a range of 14.2 to 31.7%. The two extreme groups, FGR 1 and FGR 5, had mean percentage of body fat of 16.0% (SD=1.3) and 28.8% (SD=1.2), respectively. A one-way analysis of variance on the percentage of body fat indicated that there was a significant difference among the five FGRs ( $F(4,45)=223.0$ ,  $p < .01$ ). The Tukey HSD technique applied to all pairwise comparisons lead to the conclusion that the five FGRs were significantly different from one another ( $p < .01$ ) on the percentage of body fat variable.

Subjects in the five FGRs were compared to the 1981 CFS classification of percentage of body fat (1981, unpublished data; see appendix A) for the Canadian male population between 30 and 39 years of age. The results appear in Table 5.

TABLE 5: Comparison of percentage of body fat between the sample of 50 subjects and the 1981 CFS norms.

| Percentile range | Classification (1981 CFS) | No of subjects (N=50) | RESEARCH GROUPS (RE:FAT) |       |       |       |       |
|------------------|---------------------------|-----------------------|--------------------------|-------|-------|-------|-------|
|                  |                           |                       | FGR 1                    | FGR 2 | FGR 3 | FGR 4 | FGR 5 |
| 01.0-22.5        | LEAN                      | 8                     | 8                        |       |       |       |       |
| 22.6-42.5        | LESS FAT THAN AVERAGE     | 5                     | 2                        | 3     |       |       |       |
| 42.6-62.5        | AVERAGE                   | 7                     |                          | 7     |       |       |       |
| 62.6-82.5        | MORE FAT THAN AVERAGE     | 10                    |                          |       | 10    |       |       |
| 82.6-            | OVERFAT                   | 20                    |                          |       |       | 10    | 10    |
| Total            |                           | 50                    | 10                       | 10    | 10    | 10    | 10    |

According to the CFS classification FGR 1 was comprised mostly of lean subjects, eight out of 10, with two from the less fat than average category. In FGR 2 there were seven subjects classified as average and three classified as less fat than average. The third FGR 3 consisted of subjects in the more fat than average category and FGRs 4 and FGR 5 were made up of subjects in the overfat category. In this study, FGR 1, made up of the leanest subjects, was defined as LEAN; FGR 2 was renamed AVERAGE and FGR 3 kept its original classification MORE FAT THAN AVERAGE. However, to differentiate FGR 4 from FGR 5, the 95th percentile was used as a criteria. In this respect the OVERFAT classification applied to subjects with a percentage of body fat between 82.6 and the 95th percentile (FGR 4) while those beyond the 95th percentile were classified FATTEST (FGR 5).

In Table 4 the systolic and diastolic blood pressure values are all considered normal according to medical norms.

The average predicted V02 max of the sample (Table 4), 42.3 ml/kg/min (SD=3.7) measured from the CAFT, is classified as average according to the 1981 CFS for males 30-39 years of age. It is in fact in the lower end of the range which goes from 42 to 45 ml/kg/min. This suggests that the predicted V02 max of the total group was very similar to the average value of a sample of 1,402 Canadian males of the same age tested in 1981. The predicted V02 max was calculated according to a regression equation proposed by Jette et al. (1976) where the body mass (kg) of subjects is subtracted from their initial oxygen consumption

value. As the body mass increases as a result of increased amount of fat tissue, the  $\text{VO}_2$  max expressed in ml/kg/min diminishes. This explains why the  $\text{VO}_2$  max in Table 4 diminishes as the weight and the percentage of body fat of the different FGRs increase.

This is further exemplified by the negative correlation coefficient, ( $N=50$ )  $r = -.63$  ( $p < .05$ ), between the predicted  $\text{VO}_2$  max and the predicted percentage of body fat. When the  $\text{VO}_2$  max of the five FGRs (Table 4) is compared to the 1981 CFS classification, the results for FGRs 4 and FGR 5 place them into the below average category while the three other FGRs (1, 2 and 3) are considered as being in the average category. The predicted  $\text{VO}_2$  max of the five FGRs was submitted to a one-way analysis of variance which indicated that there was a significant difference between the five FGRs ( $F(4,45) = 7.69$ ,  $p < .01$ ). A Tuckey HSD technique indicates that four pairwise comparisons exceeded the critical difference and hence were declared significant at the .01 level. The significant pairwise comparisons were FGR 1 and FGR 4, FGR 1 and FGR 5, FGR 2 and FGR 4, and FGR 2 and FGR 5.

In summary, in terms of percentage of body fat, results of the skinfold measurements indicate that FGRs 3, 4 and 5 respectively possessed significantly more body fat than the lean group (FGR 1). The results of the CAFT indicate that the predicted  $\text{VO}_2$  max for the excess fat groups (FGRs 4 and 5) were significantly lower than the ones for the lean and the average

groups (FGRs 1 and 2).

#### 4.1.3 Assessment of FGRs' level of physical exertion

##### 4.1.3.1 Heart rate

The mean heart rate values at rest, on day 2, were within normal limits (Table 6).

The mean heart rate value for the light intensity exercise (Table 6) was 132.0 bpm (SD=14.6) and was similar to the one reported by Jette (1981). The minimum heart rate was 100 bpm and the maximum one was 173.6 bpm.

The mean heart rate value for the heavy intensity exercise (Table 6) was 177 bpm (SD=17.3) and was similar to the one reported by Jette (1981). The minimum value being 134 bpm and the maximum value 209 bpm. During this work load four subjects ended up with a heart rate value equal to or over 200 bpm. The minimum value of 134 bpm is considered suspect because it was recorded from a subject in FGR 5 with a percentage of body fat of 28.5%. The average heart rate for the group was 182 bpm. This one low heart rate value in FGR 5 explains why subjects in FGR 4 had a higher mean heart rate (186 bpm) than the heavier subjects in FGR 5 (182 bpm). There was no mention on this individual's questionnaire, nor on the PAR-Q, of any known medical problem or whether or not he was on medication or if he had followed a rigorous type of aerobic training before the study. It could be a case of exercise bradycardia, an experimental error or inaccurate reporting by the subject.

TABLE 6: Means (M) and standard deviations (SD) for heart rate (HR, bpm) and rate of perceived exertion (RPE), recorded on day 2, at rest, during and following light and heavy intensity exercises (N=50).

| Variable                    |    | Total group | FGR 1 | FGR 2 | FGR 3 | FGR 4 | FGR 5 |
|-----------------------------|----|-------------|-------|-------|-------|-------|-------|
| HR-rest                     | M  | 73.0        | 67.0  | 75.0  | 73.0  | 74.0  | 77.0  |
|                             | SD | 11.3        | 7.6   | 9.5   | 8.0   | 12.1  | 16.7  |
| Light intensity exercise    |    |             |       |       |       |       |       |
| HR-light exer               | M  | 132.0       | 119.0 | 127.0 | 136.0 | 137.0 | 141.0 |
|                             | SD | 14.6        | 8.2   | 14.1  | 11.5  | 8.0   | 18.4  |
| RPE-light exer              | M  | 11.2        | 10.8  | 10.9  | 11.4  | 11.5  | 11.4  |
|                             | SD | 1.4         | 0.9   | 2.0   | 0.9   | 0.9   | 2.1   |
| HR-post-exer-1 <sup>a</sup> | M  | 122.0       | 107.0 | 117.0 | 126.0 | 128.0 | 131.0 |
|                             | SD | 18.0        | 15.4  | 16.9  | 16.3  | 13.0  | 19.2  |
| HR-post-exer-2 <sup>b</sup> | M  | 99.0        | 85.0  | 99.0  | 105.0 | 103.0 | 107.0 |
|                             | SD | 17.9        | 9.2   | 20.2  | 16.7  | 12.9  | 21.7  |
| HR-post-exer-3 <sup>c</sup> | M  | 93.0        | 80.0  | 94.0  | 97.0  | 94.0  | 98.0  |
|                             | SD | 17.1        | 10.7  | 21.0  | 13.3  | 14.2  | 20.8  |
| Heavy intensity exercise    |    |             |       |       |       |       |       |
| HR                          | M  | 177.0       | 162.0 | 171.0 | 182.0 | 186.0 | 182.0 |
|                             | SD | 17.3        | 14.6  | 13.6  | 14.7  | 9.5   | 21.2  |
| RPE                         | M  | 15.2        | 14.5  | 14.5  | 15.3  | 16.1  | 15.7  |
|                             | SD | 1.6         | 1.7   | 1.7   | 1.1   | 1.0   | 1.8   |
| HR-post-exer-1 <sup>a</sup> | M  | 159.0       | 146.0 | 150.0 | 163.0 | 172.0 | 166.0 |
|                             | SD | 20.0        | 13.9  | 17.6  | 22.0  | 13.2  | 22.1  |
| HR-post-exer-2 <sup>b</sup> | M  | 136.0       | 117.0 | 127.0 | 144.0 | 149.0 | 143.0 |
|                             | SD | 21.5        | 12.3  | 21.0  | 19.6  | 11.0  | 24.4  |
| HR-post-exer-3 <sup>c</sup> | M  | 118.0       | 100.0 | 115.0 | 121.0 | 129.0 | 125.0 |
|                             | SD | 19.2        | 10.3  | 20.0  | 16.8  | 10.5  | 23.7  |

a Post-exercise-1: heart rate measured over the first 10 seconds of the first post-exercise pursuit tracking trial.

b Post-exercise-2: heart rate measured over the last 10 seconds of the first minute of the first post-exercise pursuit tracking trial.

c Post-exercise-3: heart rate measured over the last 10 seconds of the second minute of the first post-exercise pursuit tracking trial.

The mean heart rate for the total group at rest was 73 (SD=11.3) bpm. During the light intensity and the heavy intensity exercises the mean heart rates were respectively 132 (SD=14.6) bpm and 177 (SD=17.3) bpm (Table 6). Each exercise intensity affected the heart rate of each FGR differently. The heart rates at both exercise intensities rose from FGR 1 through to FGR 5 as the percentage of body fat increased (Table 6). This point is confirmed by the positive correlation coefficient between percentage of body fat and heart rate for the light (N=50) ( $r = .57, p < .05$ ) and the heavy (N=50) ( $r = .53, p < .05$ ) intensity exercises.

To study heart rate during light and heavy intensity exercise a FGRs(5) x Conditions(2) analysis of variance, with repeated measures on Conditions, was used. Results indicated (Table 7) that there was a significant difference (within-subjects factor) in heart rate intensities between the two exercise conditions. The heart rate values during the heavy exercise condition being significantly higher than the one during the light exercise condition. The between-subjects factor in Table 7 indicates that there was a significant difference in heart rates among the five FGRs. The fact that the FGRs x Conditions interaction was not significant indicates that the pattern of change in heart rate between the light and the heavy intensity exercise was similar across the five GFRs. A Scheffe post-hoc test was applied to pairwise comparisons in order to locate significant difference in heart rate among FGRs.

Significant differences were observed ( $p < .05$ ) between the heart rates of FGR 1 and FGR 3, FGR 1 and FGR 4, and FGR 1 and FGR 5.

It suggested that the physiological cost of the light and the heavy intensity exercise were markedly higher for the FGRs carrying excess weight (FGRs 3, 4 and 5) in body fat as compared to the lean FGR (FGR 1).

**TABLE 7:** Summary of the analysis of variance with repeated measures for the heart rate values measured during light and heavy intensity exercise conditions (N=50).

| Source            | SS       | DF | MS       | F        |
|-------------------|----------|----|----------|----------|
| Between-subjects  |          |    |          |          |
| FGRs              | 8443.76  | 4  | 2110.94  | 6.13**   |
| residual          | 15504.05 | 45 | 344.53   |          |
| Within-subjects   |          |    |          |          |
| Conditions        | 51483.61 | 1  | 51483.61 | 641.79** |
| FGRs x Conditions | 192.04   | 4  | 48.01    | 0.60     |
| residual          | 3609.85  | 45 | 80.22    |          |

\*\*  $p < .01$

#### 4.1.3.2 Rate of perceived exertion (RPE)

The Borg 15-point category scale for determining rated perceived exertion (RPE) during exercise was used during the last 20 seconds of each exercise period to assess individual's subjective rating of effort. The scale is numbered from 6 to 20 with every odd number anchored by expressions such as very, very light (7) to very, very hard (19) (see appendix M). The RPE scores for the 50 subjects were 11.2 (SD=1.4) for the light and 15.2 (SD=1.6) for the heavy intensity exercise (Table 6). In this respect, the light intensity exercise was perceived by the total group as "fairly light" and the heavy intensity exercise as "hard".

The RPE scores shown in Table 6 increased for both exercise intensities from the lean group (FGR 1) to the fattest group (FGR 5). However, the mean value for FGR 5 was lower for both exercise intensities than the one for FGR 4. This was caused by one subject in FGR 5 who had RPE values of nine for the light intensity and 12 for the heavy intensity exercise as compared to 11.4 and 15.7 for FGR 5. Furthermore, the RPE score for the fattest subject in FGR 5 was missing for the heavy intensity exercise. His score was replaced by the mean of the fifth FGR because of the need for equal cells when performing ANOVAS with repeated measures on the NRC computer. Nevertheless, FGRs 4 and FGR 5 rated their perceived level of exertion for the heavy intensity exercise as ranging from hard to very hard while the lean (FGR 1) and the average (FGR 2) group rated it as close to

hard.

The results were analyzed using an FGRs(5) x Condition(2) analysis of variance with repeated measures on Conditions (light and heavy) (Table 8). Results suggest that there was a significant difference in terms of rating of effort (within-subjects factor) between the light and heavy intensity exercise. The results of the between-subjects factor indicates that there was no significant difference among the five FGRs. Furthermore, there is no significant FGRs x Conditions interaction which suggest that the pattern of change for the RPE scores from the light to the heavy intensity exercise was similar for the five FGRs. These results suggest that even if the RPE scores increase as the percentage of body fat increases there is no statistically significant difference in the perception of effort among the five FGRs under each exercise condition. The correlation coefficients between RPE during the light and RPE during the heavy intensity exercises and the percentage of body fat were respectively (N=49)  $r = .25$  and (N=50)  $r = .41$ , the last value being significant ( $p < .05$ ).

**TABLE 8:** Summary of the analysis of variance with repeated measures for the RPE values measured during light and heavy intensity exercise conditions (N=50).

| Source            | SS       | df | MS       | F        |
|-------------------|----------|----|----------|----------|
| Between-subjects  |          |    |          |          |
| FGRs              | 2160.36  | 4  | 540.09   | 1.73     |
| residual          | 14011.05 | 45 | 311.36   |          |
| Within-subjects   |          |    |          |          |
| Conditions        | 40280.49 | 1  | 40280.49 | 317.33** |
| FGRs x Conditions | 376.96   | 4  | 94.24    | 0.74     |
| residual          | 5712.05  | 45 | 126.93   |          |

\*\* p < .01

\* The RPE values suggest that subjects did perceive that they had to work harder during the heavy intensity exercise compared to the light intensity one. However there was a tendency (non significant) for subjects in FGRs 4 and 5 to perceive both GPE as more strenuous than those in FGR 1. This tendency was more marked during the heavy intensity exercise as indicated by a higher positive correlation coefficient between the RPE and the percentage of body fat.

In summary, under both exercise intensities, FGRs 3, 4 and 5 experienced significantly faster heart rates than the lean group (FGR 1). However, there was no statistically significant difference among the perceived level of exertion of the five FGRs even if the RPE scores increased from FGR 1 to FGR 4 with a slight reduction for FGR 5. These observations indicate that during the two exercise sessions the excess fat groups (FGRs 4 and 5) did work more vigorously than the lean group (FGR 1) due to the extra weight they carried.

#### 4.2 ANALYSIS OF FINE MOTOR PERFORMANCE

The pursuit tracking task was initiated by the subject following the short transit time between the treadmill and the chair in front of the tracometer. The transit took an average of 18 seconds (SD=4.29) for trial 17 and 21.2 seconds (SD=6.02) for trial 21. The longer period of transition on trial 21 is explained by the fact that subjects could wipe the sweat from their hands and/or face before starting the trial.

The mean values for the total group and for each FGR for the four fine motor parameters measured during trials 16, 17, 20 and 21 are shown in Tables 9, 11, 13, 15, 17 and graphically illustrated in Figures 2, 3, 4, 5, 6 and 7. In the Figures, the lines do not represent a continuous change between two trials since an exercise treatment was inserted in between these two trials. Furthermore, since only part of the y-axis is represented graphically, the scale for pre- and post-exercise values is amplified. Nonetheless, the lines are useful because they indicate in a simple and clear fashion the magnitude and the direction of changes in fine motor performance.

##### 4.2.1 Total Response Time (TRT)

Total response time provides an overview of the entire fine motor performance as assessed by the tracometer. The distribution of scores for TRT was normal. Data were submitted to an FGRs(5) x Trials(2) x Intervals(5) analysis of variance with repeated measures on Trials and Intervals.

In Table 9, the values for trial 16 indicate that FGR 1 had the shortest TRT at rest (1042 ms) followed in order of increasingly longer TRT by FGRs 4, 5, 2 and 3 (1153 ms). A difference of 111 ms was observed between the two extreme groups, FGR 1 and FGR 3. For trial 20, FGR 4 and FGR 5 had the two shortest TRT, 1001 ms and 1013 ms, followed in order of increasingly longer TRT by FGRs 1, 2 and 3 (1096 ms). A difference of 95 ms was observed between the two extreme groups, FGR 4 and FGR 3. The scores for each trial were submitted to a one-way analysis of variance on the FGRs. Results indicate that -- there was no significant difference among the five FGRs for trial 16 ( $N=45$ ) ( $F(4, 40) = 1.23, p > .05$ ) and for trial 20 ( $N=50$ ) ( $F(4,45) = 1.49, p > .05$ ). This suggests that before both exercise periods the TRT performance was similar for the five FGRs regardless of the level of body fat.

The means, standard errors and the difference between the means for TRT performance recorded before and after the light and the heavy intensity exercises appear in Table 9 and the mean values are illustrated in Figure 2.

**TABLE 9:** Means (M), standard errors (SE) and difference between the means (DBM) in ms for total response time (TRT) for the total group and by FGRs for trials 16 and 17 and for trials 20 and 21.

| Trial                           |    | Total group | Fat groups |       |       |       |       |
|---------------------------------|----|-------------|------------|-------|-------|-------|-------|
|                                 |    |             | FGR 1      | FGR 2 | FGR 3 | FGR 4 | FGR 5 |
| Light intensity exercise (N=45) |    |             |            |       |       |       |       |
| 16 (ms)                         | M  | 1078        | 1042       | 1070  | 1153  | 1057  | 1066  |
|                                 | SE | 17.7        | 40.1       | 22.9  | 48.7  | 37.7  | 41.9  |
| 17 (ms)                         | M  | 1074        | 1046       | 1105  | 1141  | 1027  | 1050  |
|                                 | SE | 16.2        | 41.9       | 22.7  | 28.1  | 32.1  | 44.6  |
| DBM (ms)                        |    | -4          | 4          | 35    | -12   | -30   | -16   |
| -----                           |    |             |            |       |       |       |       |
| Heavy intensity exercise (N=50) |    |             |            |       |       |       |       |
| 20 (ms)                         | M  | 1045        | 1041       | 1072  | 1096  | 1001  | 1013  |
|                                 | SE | 07.6        | 36.9       | 21.4  | 36.3  | 30.3  | 34.7  |
| 21 (ms)                         | M  | 1087        | 1088       | 1115  | 1125  | 1032  | 1073  |
|                                 | SE | 09.4        | 61.3       | 23.2  | 31.9  | 34.4  | 43.5  |
| DBM (ms)                        |    | 42          | 47         | 43    | 29    | 31    | 60    |

Note. DBM = Post-exercise TRT - Pre-exercise TRT where post-exercise trials correspond to trials 17 and 21 and pre-exercise trials correspond to trials 16 and 20.

Note. A negative sign attached to the DBM indicates a shorter TRT for the post-exercise trial as compared to the pre-exercise trial while an absence of a sign indicates a longer TRT following exercise.

## TRT MEASURED PRE- AND POST-EXERCISE

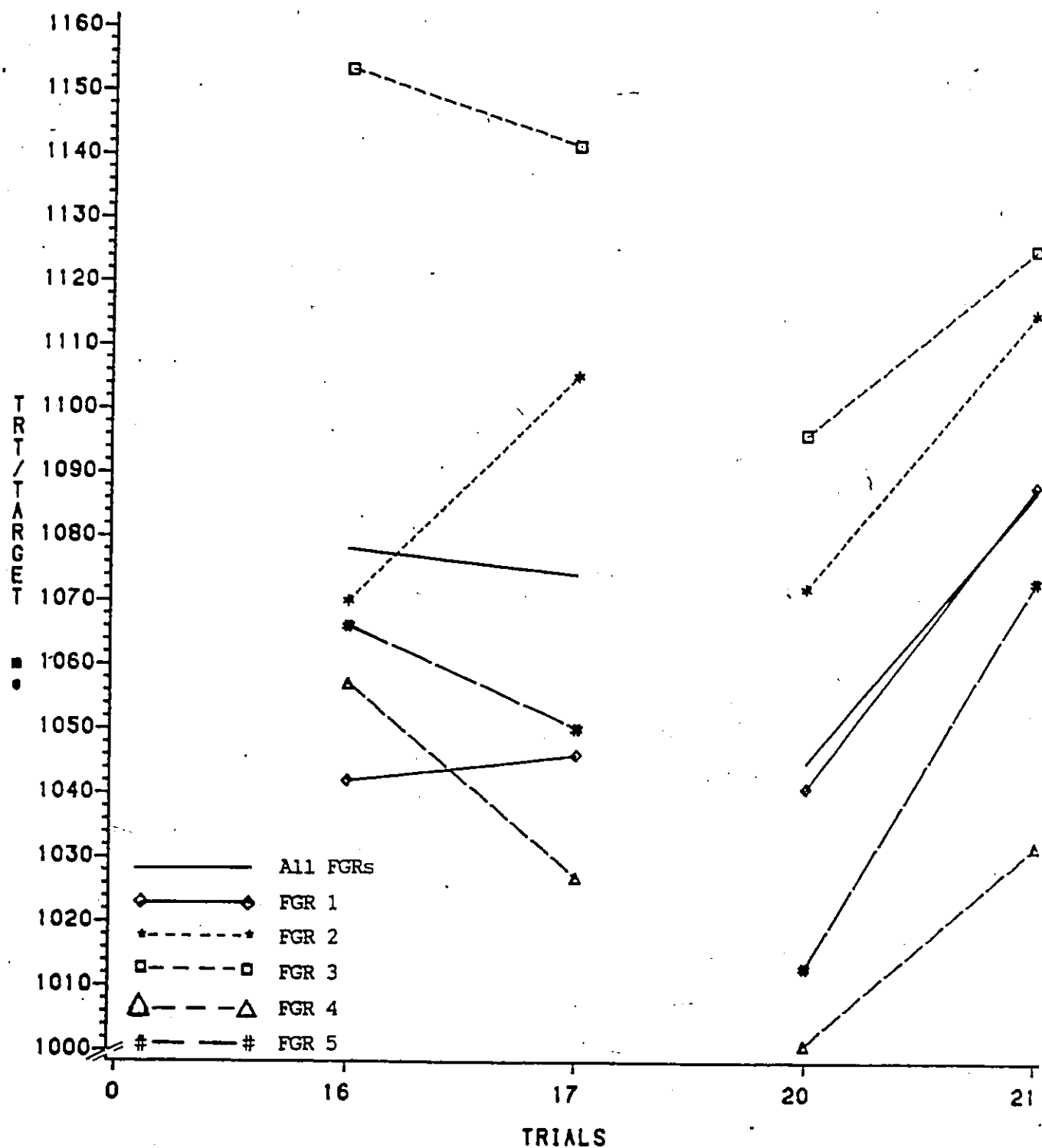


Figure 2- CHANGE IN TRT MEASURED BEFORE AND AFTER 2 BOUTS OF EXERCISE  
IN A GROUP OF 50 SUBJECTS (30 to 39 years) CLASSIFIED  
IN INCREASING LEVELS OF BODY FAT

Following the light intensity exercise the difference between the means of trials 17 (post-exercise) and 16 (pre-exercise) (Table 9) indicates that the TRT for trial 17 was shorter by 12, 16 and 30 ms for the three excess FGRs, FGRs 3, FGR 5 and FGR 4, respectively. However, TRT was for FGR 1 and FGR 2 respectively four and 35 ms longer on trial 17. For the total group (N=45), the performance in trial 17 was four ms shorter than in trial 16. The correlation coefficient between the percentage of body fat and the difference in TRT (trial 17 - trial 16) (N=49) was  $r = -.18$  (not significant  $p > .05$ ). The results of the ANOVA (Table 10) for trials 16 and 17 suggest that there was no significant difference among the TRT of the five FGRs, no FGRs x Trials interaction and no significant difference in the TRT performance between trials 16 and 17.

Following the heavy intensity exercise the difference between the means of trials 21 (post-exercise) and trial 20 (pre-exercise) (Table 9) indicates that the TRT for trial 21 was longer for the five FGRs. FGR 3 had the smallest change (29 ms longer) for trial 21 and FGR 5 the largest change in TRT (60 ms longer). Following the heavy intensity exercise the changes of the TRT parameter for the fattest and the lean group (FGRs 5 and 1) were similar in direction (longer) and close in magnitude, 60 ms versus 47 ms respectively. For the total group (N=50) the performance in trial 21 was 42 ms longer than in trial 20. The correlation coefficient between the percentage of body fat and the difference in TRT (trials 21 - trial 20) (N=50) was

$r = -.01$  (not significant  $p > .05$ ). The results of the ANOVA (Table 10) suggest that there was no significant difference among the TRT performance of the five FGRs and no FGRs x Trials interaction. However, there was a significant difference in the TRT performance between trials 20 and 21.

In summary, the difference between the means for each of the five FGRs for trials 16 and 17 and for trials 20 and 21 indicate that the excess fat groups (FGRs 3, 4 and 5) had a shorter TRT following the light intensity exercise when compared to the lean and the average fat groups (FGRs 1 and 2). Following the heavy intensity exercise the fattest group (FGR 5) had the largest performance slow down followed by the lean group (FGR 1) while the more fat than average group (FGR 3) showed the smallest slow down in performance. The correlation coefficients suggest that there is no significant interrelationship between changes in TRT performance as measured by the difference between pre- and post-exercise trial values and percentage of body fat for each exercise intensity. The ANOVAS suggest that following each of the two exercise intensities the TRT was similar across the five FGRs. These observations suggest that the percentage of body fat does not significantly affect TRT following a GPE of both a light and a heavy intensity.

In terms of exercise intensities, the light intensity had no significant effect on the post-exercise performance, while following the heavy intensity exercise the TRT was significantly longer.

TABLE 10: Summary of analyses of variance with repeated measures for the total response time (TRT) between trials 16 and 17 and between trials 20 and 21 using all five FGRs.

| Source                                            | SS         | df  | MS         | F       |
|---------------------------------------------------|------------|-----|------------|---------|
| Light intensity exercise (trials 16 and 17; N=45) |            |     |            |         |
| Between-subjects                                  |            |     |            |         |
| FGRs                                              | 690358.25  | 4   | 1172589.56 | 1.52    |
| residual                                          | 4539653.69 | 40  | 113491.34  |         |
| Within-subjects                                   |            |     |            |         |
| Trials                                            | 1852.38    | 1   | 1852.38    | 0.18    |
| FGRs x Trials                                     | 54389.93   | 4   | 13597.48   | 1.30    |
| residual                                          | 418911.38  | 40  | 10472.78   |         |
| Intervals                                         | 88105.90   | 4   | 22026.47   | 4.59**  |
| FGRs x Intervals                                  | 74461.13   | 16  | 4653.82    | 0.97    |
| residual                                          | 767363.75  | 160 | 4796.02    |         |
| Trials x Inter.                                   | 149919.56  | 4   | 37479.89   | 6.54**  |
| FGRs x Tri. x Int.                                | 74196.75   | 16  | 4637.30    | 0.81    |
| residual                                          | 917138.55  | 160 | 5732.12    |         |
| Heavy intensity exercise (trials 20 and 21; N=50) |            |     |            |         |
| Between-subjects                                  |            |     |            |         |
| FGRs                                              | 570396.06  | 4   | 142599.02  | 1.15    |
| residual                                          | 5601237.94 | 45  | 124471.95  |         |
| Within-subjects                                   |            |     |            |         |
| Trials                                            | 220332.03  | 1   | 220332.03  | 18.19** |
| FGRs x Trials                                     | 15780.10   | 4   | 3945.02    | 0.33    |
| residual                                          | 545210.23  | 45  | 12115.78   |         |
| Intervals                                         | 48709.75   | 4   | 12177.44   | 2.20    |
| FGRs x Intervals                                  | 68592.73   | 16  | 4287.05    | 0.77    |
| residual                                          | 996724.09  | 180 | 5537.36    |         |
| Trials x Inter.                                   | 236309.89  | 4   | 59077.47   | 11.68** |
| FGRs x Tri. x Int.                                | 92988.18   | 16  | 5811.76    | 1.15    |
| residual                                          | 910064.55  | 180 | 5055.91    |         |

\*\* p < .01

#### 4.2.2 TOTAL RESPONSE TIME PER INTERVALS

There are 20 possible between target movements using the 5 positions on the tracking unit display. These movements recur 5 times within a random sequence of 100 movements. The first occurrence is designated as the first interval (I-1), the second occurrence as the second interval (I-2) and so on. For example, the TRT for the first interval (I-1) represents the average TRT per target for the first occurrence of the 20 possible movements. By comparing the first post-exercise interval to the first pre-exercise one, it is possible to observe the post-treatment effect of exercise on TRT during the first interval. This can be repeated for all five intervals.

Furthermore, with this parameter it is also possible to look at the post-exercise performance versus the pre-exercise performance with regard to a time reference. Indeed, since the first occurrence of the 20 possible movements is at the beginning of the trial while the other occurrence tends to appear later in the trial, it is possible to compare the impact of the exercise bout with regard to a general time frame.

The results of the ANOVAS shown in Table 10, suggest that there were no statistically significant FGRs x Intervals interaction for either exercise intensity which indicates that the five FGRs had similar TRT performance patterns for each of the five intervals independent of percentage of body fat. As a result, the TRT performance was analysed for the total group for all pre- and post-exercise trials (Table 11) in order to explore

the immediate impact of prior exercise on TRT.

The means, standard errors and the difference between the means for the TRT per interval recorded before and after the light and the heavy intensity exercise appear in Table 11 and the mean values are illustrated in Figures 3 and 4, respectively.

TABLE 11: Means (M), standard errors (SE) and difference between the means (DBM) in ms for total response time (TRT) for intervals of trials.

| Trial                           |    | TRT per interval |      |      |      |       |
|---------------------------------|----|------------------|------|------|------|-------|
|                                 |    | I-1              | I-2  | I-3  | I-4  | I-5   |
| Light intensity exercise (N=45) |    |                  |      |      |      |       |
| 16 (ms)                         | M  | 1055             | 1074 | 1105 | 1080 | 1075  |
|                                 | SE | 17.8             | 19.9 | 24.7 | 20.1 | 18.2  |
| 17 (ms)                         | M  | 1115             | 1068 | 1078 | 1081 | 1027  |
|                                 | SE | 17.9             | 19.5 | 18.9 | 18.5 | 18.6  |
| DBM (ms)                        |    | 60**             | -6   | -27  | -1   | -48** |
| Heavy intensity exercise (N=50) |    |                  |      |      |      |       |
| 20 (ms)                         | M  | 1021             | 1029 | 1045 | 1075 | 1054  |
|                                 | SE | 18.0             | 14.5 | 15.0 | 17.5 | 19.0  |
| 21 (ms)                         | M  | 1123             | 1100 | 1096 | 1075 | 1040  |
|                                 | SE | 26.9             | 20.7 | 20.5 | 19.0 | 15.2  |
| DBM (ms)                        |    | 102**            | 71** | 51** | 00   | -14   |

Note. DBM = Post-exercise interval - Pre-exercise interval where post-exercise interval correspond to trials 17 and 21 and pre-exercise intervals correspond to trials 16 and 20.

Note. A negative sign attached to the DBM indicates a shorter TRT for that specific post-exercise interval as compared to the pre-exercise interval while an absence of a sign indicates a longer TRT following exercise.

\*\*  $p < .01$

## TRT. PER INTERVALS

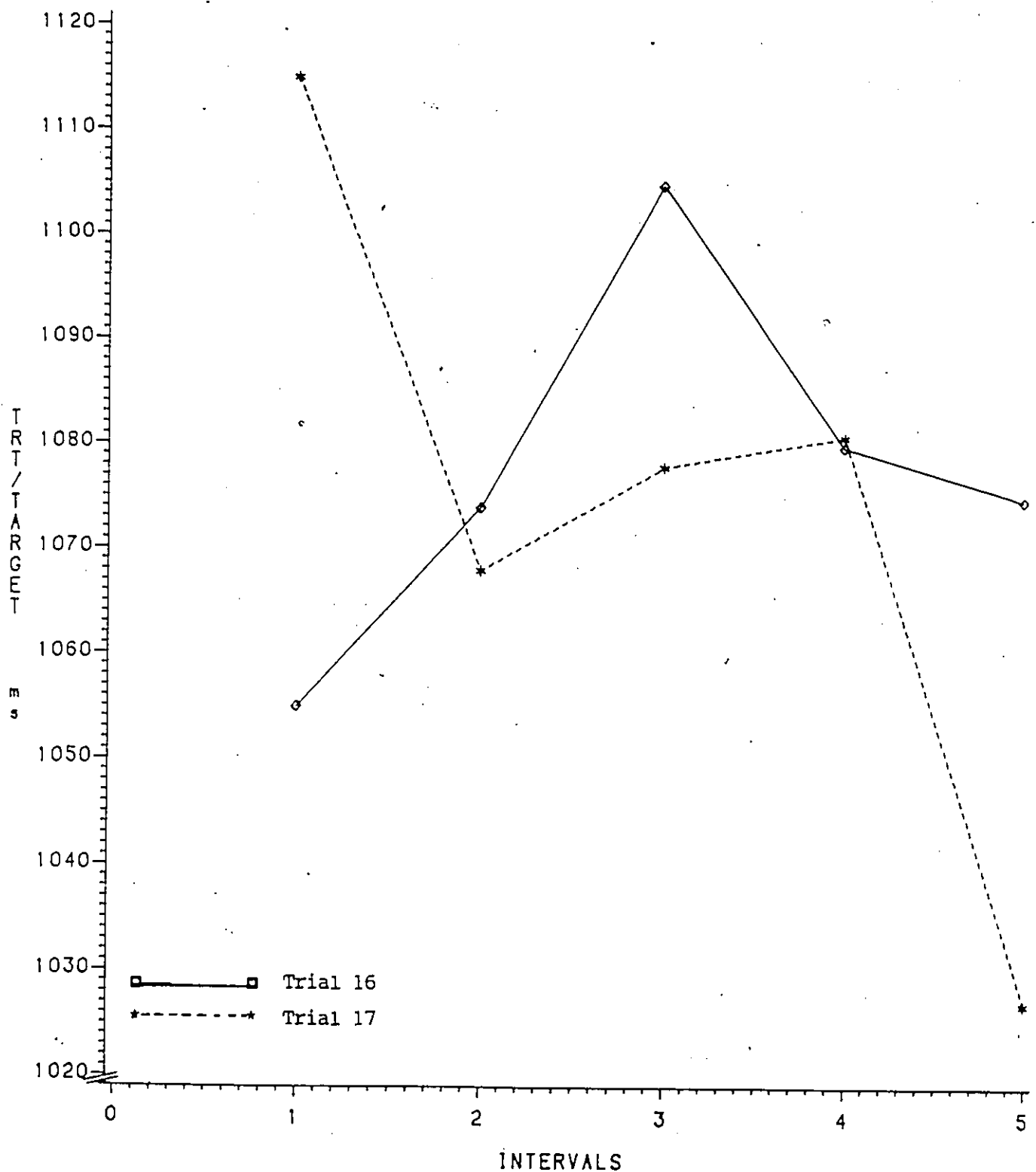


Figure 3-TRT MEASURED BEFORE AND AFTER THE LIGHT INTENSITY EXERCISE  
IN A GROUP OF 50 SUBJECTS (30 to 39 years)

# TRT PER INTERVALS

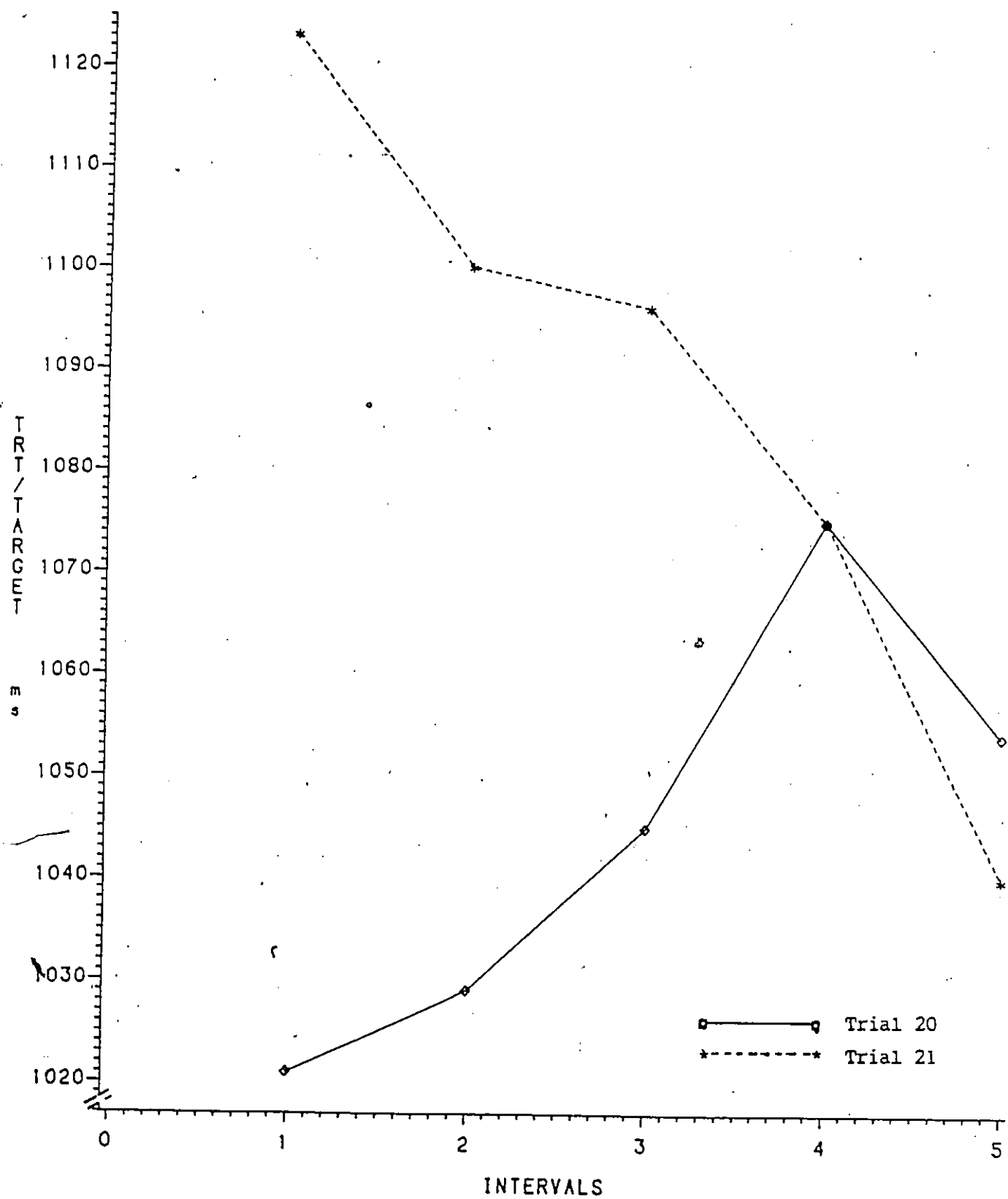


Figure 4-TRT MEASURED BEFORE AND AFTER THE HEAVY INTENSITY EXERCISE  
IN A GROUP OF 50 SUBJECTS (30 to 39 years)

Following the light intensity exercise, the difference between the means (Table 11) indicates that the TRT for the total group during the first interval was 60 ms longer on trial 17 as compared to trial 16. The TRT scores for each interval were analysed using a FGRs (5) x Trials (2) x Intervals (1) analysis of variance with repeated measures on the Trial factor. In this respect the 60 ms difference between the two trials for the first interval was statistically significant ( $p < .01$ ); this is the only occurrence where the performance was longer in trial 17. For the four intervals the TRT in trial 17 was shorter than on trial 16. For I-5, there was a significant difference, the TRT in trial 17 being shorter than in trial 16. The significant difference between trials 16 and 17 for I-1 and I-5 explains the significant Trials x Intervals interaction in Table 10. For ease of interpretation, Figure 3 shows the interaction. The between-subjects factor did indicate that there was no significant difference among FGRs under each of the five intervals.

Following the heavy intensity exercise, the difference between the means (Table 11) indicates that the TRT was 102 ms longer in trial 21 for the I-1 when compared to trial 20. For the two following intervals I-2 and I-3, the TRT per interval remained longer for trial 21 than for trial 20. For I-4, TRT performance score was the same for both trials and for I-5 the TRT was 14 ms shorter for trial 21. There was a statistically significant difference between the TRT values for trials 20 and 21 only for I-1, I-2 and I-3 where the TRT was longer.

The pattern of TRT in trial 21 was different for the first three intervals (longer) than the ones in trial 20 (shorter) than being null for I-4 and diverging in I-5 suggesting some kind of recuperation pattern following exercise. The significant difference between trials 20 and 21 for I-1, I-2 and I-3 explains the significant Trials x Intervals interaction shown in Table 10. For ease of interpretation Figure 4 displays the interaction. As mentioned previously the FGRs x Intervals interaction was not statistically significant. Furthermore, the between-subjects factor analysis indicates that there was no significant difference among the TRT performance for the five FGRs for the five intervals. This suggests that irrespective of exercise intensity level the percentage of body fat had no significant effect on TRT when the pursuit tracking task was performed immediately after exercise, FGR 1 behaving similarly as FGR 5.

Although the percentage of body fat carried does not produce any significant effect on TRT, the exercise intensity does. Furthermore, the results of the TRT per interval suggest that the heavy intensity exercise had a longer lasting effect on TRT than the light intensity exercise. A longer TRT was observed over the first three intervals (I-1, I-2 and I-3) during trial 21 while it was observed only over the first interval (I-1) during trial 17.

A Pearson product moment correlation procedure was used to assess the degree of interrelationship between TRT and : percentage of body fat; heart rate under both exercise

conditions; heart rate during recuperation. None of these correlations were significant at the .05 level of significance (Table 12).

TABLE 12: Pearson product moment correlation coefficients between percentage of body fat, heart rate and TRT (N=50).

| Parameter                                | TRT                   |          | Change in TRT <sup>b</sup><br>(I-1) - (I-3) |          |
|------------------------------------------|-----------------------|----------|---------------------------------------------|----------|
|                                          | trial 17 <sup>a</sup> | trial 21 | trial 17 <sup>a</sup>                       | trial 21 |
| Percentage of body fat                   | 0.177                 | -0.055   | 0.071                                       | -0.100   |
| Heart rate                               |                       |          |                                             |          |
| .Light intensity                         | 0.086                 | ----     | -0.025                                      | ----     |
| .Heavy intensity                         | ----                  | -0.025   | ----                                        | -0.084   |
| Changes in post-exercise HR <sup>c</sup> |                       |          |                                             |          |
| .Light intensity                         | ----                  | ----     | 0.160                                       | ----     |
| .Heavy intensity                         | ----                  | ----     | ----                                        | 0.217    |

a For trial 17, N=49

b Defines as: (TRT for I-1) - (TRT for I-3)

c Heart rate difference between the first and the last 10 s of the first minute of post-exercise trials 17 or 21.

\*  $p < .05$

As observed in Table 6 following the light intensity exercise (trial 17) the average heart rate for the 50 subjects dropped during the transition from the treadmill to the tracometer from its exercise value of 132 (SD=14.6) bpm to 122 (SD=18) bpm then dropped to 99 (SD=18) bpm at the end of the first minute of the trial. After the heavy intensity exercise (trial 21), these same variables were 177 (SD=17.3) bpm, 159 (SD=20) bpm and 136 (SD=21.5) bpm, respectively. In Table 12, the lack of significant correlation between heart rate and all TRT parameters suggest that there was no interrelationship between heart rate and TRT performance measured after exercise.

#### 4.2.3 Correct reaction time (CRT)

The distribution for CRT was manipulated in order to remove atypical scores. In this regard, Buck, Leonardo and Hyde (1981) established an error criteria of 11 msec which was used in order to define the present distribution. Furthermore, from an analysis of the scores distribution a lower magnitude criteria was set at 11 ms and an upper magnitude criteria at 600 ms. This last value is slightly lower than four times the standard deviation (98.4) plus the mean (249). With these criteria 410 (0.4% of the 98,383 CRT recorded) atypical scores were excluded 361, at the low end and 49 at the upper end. The distribution of the scores was normal. The scores were submitted to a FGRs (5) x Trials (2) x Probability (5) analysis of variance with repeated measures on Trials and Probability factor.

In Table 13, the values for trial 16 indicate that FGR 2 had the shortest CRT at rest (242 ms) followed in order of increasingly longer CRT by FGRs 1, 4, 3 and 5, the last two FGRs had both the same CRT (261 ms). A difference of 21 ms was observed between the extreme groups, FGR 2 and both FGRs 3 and 5. For trial 20, both FGR 2 and FGR 5 had the same CRT (230 ms) which was the shortest followed in order of increasingly longer CRT by FGRs 1, 4 and 3 (253 ms). A difference of 23 ms was observed between the extremes groups that is the CRT of both FGRs 2 and 5 and the one of FGR 3. The CRT for FGR 3 was far longer in trial 20 than for the one of the four other FGRs. The scores for each trial were submitted to a one-way analysis of variance

on the FGRs. Results indicate that there was no significant difference among the five FGRs ( $N=45$ ) for trial 16 ( $F(4,40) = 0.25, p > .05$ ) and for trial 20 ( $N=50$ ) ( $F(4,45) = 0.43, p > .05$ ). This suggests that before both exercise periods the CRT for all five FGRs was similar regardless of their percentage of body fat.

The means, standard errors and the difference between the means for the CRT performance recorded before and after the light and the heavy intensity exercises appear in Table 13 and the mean values are illustrated in Figure 5.

TABLE 13: Means (M), standard errors (SE) and difference between the means (DBM) in ms for correct reaction time (CRT) for the total group and by FGRs for trials 16 and 17 and for trials 20 and 21.

| Trial                                        |    | Total group | Fat groups |       |       |       |       |
|----------------------------------------------|----|-------------|------------|-------|-------|-------|-------|
|                                              |    |             | FGR 1      | FGR 2 | FGR 3 | FGR 4 | FGR 5 |
| Light intensity exercise (N=45)              |    |             |            |       |       |       |       |
| 16 (ms)                                      | M  | 256         | 255        | 242   | 261   | 260   | 261   |
|                                              | SE | 05.0        | 0.98       | 10.3  | 11.0  | 12.3  | 12.2  |
| 17 (ms)                                      | M  | 256         | 259        | 238   | 263   | 261   | 259   |
|                                              | SE | 04.5        | 10.0       | 08.6  | 10.6  | 11.1  | 09.7  |
| DBM (ms)                                     |    | 0           | 4          | -4    | 2     | 1     | -2    |
| Heavy intensity exercise (N=50) <sup>a</sup> |    |             |            |       |       |       |       |
| 20 (ms)                                      | M  | 237         | 235        | 230   | 253   | 237   | 230   |
|                                              | SE | 04.6        | 10.2       | 08.1  | 10.2  | 12.2  | 09.9  |
| 21 (ms)                                      | M  | 230         | 236        | 226   | 228   | 233   | 224   |
|                                              | SE | 04.3        | 09.7       | 08.7  | 08.9  | 11.5  | 10.0  |
| DBM (ms)                                     |    | -7          | 1          | -4    | -25   | -4    | -6    |

Note. DBM = Post-exercise CRT - Pre-exercise CRT where post-exercise trials correspond to trials 17 and 21 and pre-exercise trials correspond to trials 16 and 20.

Note. A negative sign attached to the DBM indicates a shorter CRT for the post-exercise trial as compared to the pre-exercise trial while an absence of a sign indicates a longer CRT following exercise.

<sup>a</sup> The values for both trials 20 and 21 represent CRT averaged across 3 probability levels instead of 4. The fourth probability level was dropped because of missing data.

# CRT MEASURED PRE- AND POST-EXERCISE

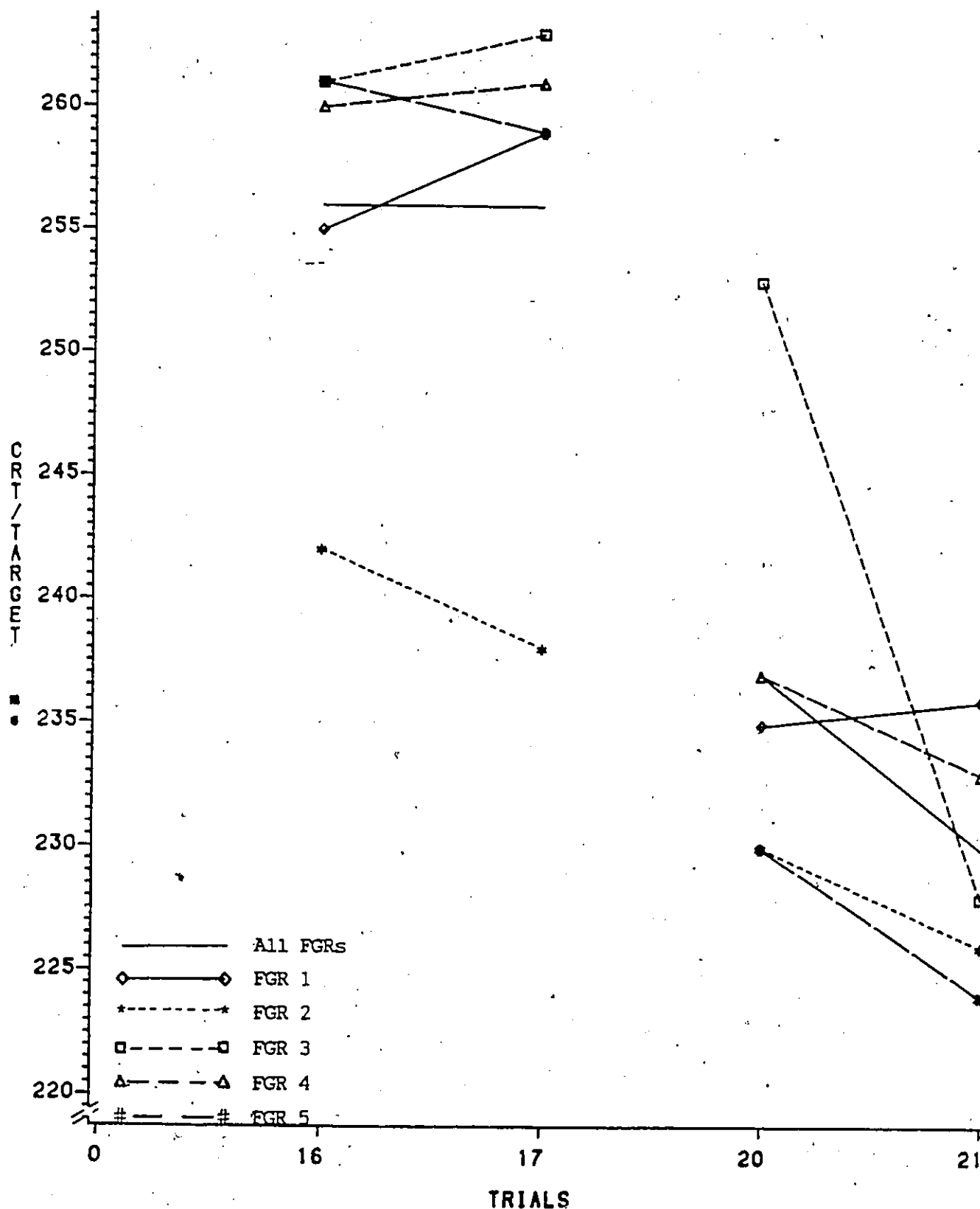


Figure 5-CHANGE IN CRT MEASURED BEFORE AND AFTER 2 BOUTS OF EXERCISE  
IN A GROUP OF 50 SUBJECTS (30 to 39 years) CLASSIFIED  
IN INCREASING LEVELS OF BODY FAT

Following the light intensity exercise, the difference between the means of trials 17 (post-exercise) and 16 (pre-exercise) (Table 13) indicates that the quantitative changes in performance level were relatively minor. Two FGRs had a shorter CRT on trial 17, FGR 5 (2 ms) and FGR 2 (4 ms) while the CRT was increasingly longer for FGR 4 (1 ms), FGR 3 (2 ms), FGR 1 (4 ms). For the total group (N=45) the performance value in trial 17 was the same as in trial 16. The correlation coefficient between the percentage of body fat and the difference in CRT (trial 17 - trial 16) (N=49) was  $r = -.04$  (not significant  $p > .05$ ). The results of the ANOVA (Table 14) suggest that there was no significant difference among the CRT of the five FGRs, no significant FGRs x Trials interaction and no significant difference in the CRT performance between trials 16 and 17.

Following the heavy intensity exercise the difference between the means of trials 21 (post-exercise) and 20 (pre-exercise) (Table 13) indicates that the CRT for trial 21 was shorter for 4 out of the five FGRs. The performance of the FGRs was, in order of increasing time, shorter by four ms for both FGRs 2 and FGR 4, by six ms for FGR 5 and by 25 ms for FGR 3. However, performance was one ms slower for FGR 1. FGR 3 had the most important change in CRT of the five FGRs, however it had the longest pre-exercise CRT value of all five FGRs. For the total group (N=50) the performance in trial 21 was 7 ms shorter than in trial 20. The correlation coefficient between the percentage of body fat and the difference in CRT (trial 21 - trial 20) (N=50)

was  $r = -.06$  (not significant  $p > .05$ ). The results of the ANOVA (Table 14) using three probability levels suggests that there was no significant difference among the CRT performance of the five FGRs and no significant FGRs x Trials interaction. However, there was a significant difference in the CRT performance between trials 20 and 21. The fourth (25%) probability level which happened 10 times per trial was dropped because of missing scores.

In summary, the results of the ANOVAS suggest that following each of the two exercise intensities the CRT performance of the fattest group (FGR 5) was not significantly different from the one of the lean group (FGR 1) nor from any of the other FGRs. The correlation coefficients indicate that there is no significant interrelationship between changes in CRT performance, as measured by the difference between pre- and post-exercise trial scores and percentage of body fat for each exercise intensity.

In terms of exercise intensities, the light intensity had no significant effect on the post-exercise performance while following the heavy exercise intensity the CRT was significantly shorter.

TABLE 14: Summary of analyses of variance with repeated measures for the correct reaction time (CRT) between trials 16 and 17 and between trials 20 and 21 using all five FGRs.

| Source                                                         | SS        | df  | MS        | F        |
|----------------------------------------------------------------|-----------|-----|-----------|----------|
| Light intensity exercise (trials 16 and 17; N=45)              |           |     |           |          |
| Between-subjects                                               |           |     |           |          |
| FGRs                                                           | 23094.29  | 4   | 5773.57   | 0.41     |
| residual                                                       | 569682.28 | 40  | 14242.06  |          |
| Within-subjects                                                |           |     |           |          |
| Trials                                                         | 0.40      | 1   | 0.40      | 0.00     |
| FGRs x Trials                                                  | 693.46    | 4   | 173.37    | 0.09     |
| residual                                                       | 78954.89  | 40  | 1973.87   |          |
| Probabilities                                                  | 432969.66 | 3   | 144323.22 | 87.01**  |
| FGRs x Prob                                                    | 8230.43   | 12  | 685.87    | 0.41     |
| residual                                                       | 199038.16 | 120 | 1658.65   |          |
| Trials x Prob                                                  | 6560.21   | 3   | 2186.74   | 2.28     |
| FGRs x Trials x Prob                                           | 12037.15  | 12  | 1003.10   | 1.04     |
| residual                                                       | 115234.89 | 120 | 960.29    |          |
| Heavy intensity exercise (trials 20 and 21; N=50) <sup>a</sup> |           |     |           |          |
| Between-subjects                                               |           |     |           |          |
| FGRs                                                           | 7839.95   | 4   | 1959.99   | 0.20     |
| residual                                                       | 432088.61 | 45  | 9601.97   |          |
| Within-subjects                                                |           |     |           |          |
| Trials                                                         | 4055.36   | 1   | 4055.36   | 5.15*    |
| FGRs x Trials                                                  | 6174.65   | 4   | 1543.66   | 1.96     |
| residual                                                       | 35450.15  | 45  | 787.78    |          |
| Probabilities                                                  | 306320.66 | 2   | 153160.33 | 226.35** |
| FGRs x Prob                                                    | 5471.84   | 8   | 683.98    | 1.01     |
| residual                                                       | 60897.84  | 90  | 676.64    |          |
| Trials x Prob                                                  | 675.64    | 2   | 337.82    | 1.07     |
| FGRs x Trials x Prob                                           | 2070.40   | 8   | 258.80    | 0.82     |
| residual                                                       | 28486.30  | 90  | 316.51    |          |

<sup>a</sup> Observations based on three probability levels, the 25% probability level dropped because of missing data.

\*  $p < .05$

\*\*  $p < .01$

The tracometer has five starting positions or targets from which four directional probability levels are derived depending on the starting position (for more information see Appendix C. During one trial the frequencies of the apparition of the different directional probabilities are in order of increasing difficulty: 40 times for probability 100%, 30 times for probability 75%, 20 times for probability 50% and 10 times for probability 25%, the one most difficult to react to. It has been shown (Buck, Leonardo, and Hyde 1981) that the CRT increases as the level of difficulty defined by probability levels increases. This explains the significant difference found in the ANOVAS in Table 14 (see Probabilities) between the CRT scores for different directional probability levels for both exercise intensities. However there was no statistically significant FGRs x Probabilities interaction between trials 16 and 17 and between trials 20 and 21 which suggests that the five FGRs had similar CRT after both exercise intensities for each of the four probability levels (or three for trials 20-21) independently of their respective percentage of body fat. Furthermore there was no FGRs x Trials x Probabilities interaction and no Trials x Probabilities interaction.

#### 4.2.4 Movement time (MVT)

Movement time (MVT) is divided into NOMT and OMT since NOMT responses are usually faster than MVT responses with overshoot (Buck, Leonardo and Hyde 1981) which explains why they are

analyzed separately.

For both parameters, NOMT and OMT, the atypical scores of their respective distributions were removed. In order to differentiate NOMT from OMT an overshoot time criterion was defined. Very low values distinct from the main distribution are between six and 51 ms and are associated, according to Buck, Leonardo and Hyde (1981), to misalignments in the nearside of the target as distinct from true farside overshoot. For this reason, the error criterion overshoot time was set at 51 ms. A low magnitude criterion was established because there were no scores under 90 ms for NOMT and for OMT. However, an inclusion criterion was established for high atypical scores where the upper magnitude inclusion criterion for NOMT was set at 2800 ms and three scores were rejected. For OMT the upper magnitude inclusion criterion was set at 4000 ms and nine scores were rejected.

Data for NOMT were submitted to an FGRs (5) x Trials (2) x Target Distances (4) analysis of variance with repeated measures on Trials and Target Distances. Data for OMT scores were submitted to an FGRs (5) x Trials (2) analysis of variance with repeated measures on Trials only because of missing scores.

#### 4.2.4.1 Non-overshoot movement time (NOMT)

In Table 15, the values for trial 16 indicate that FGR 4 had the shortest NOMT at rest (740 ms) followed in order of increasingly longer NOMB by FGRs 1, 5, 2 and 3 (838 ms). A

difference of 98 ms was observed between the two extreme groups, FGR 4 and FGR 3. For trial 20, FGR 4 had again the shortest NOMT (721 ms) followed in order of increasingly longer NOMB by FGRs 5, 1, 2 and 3 (777 ms). FGRs 4 and 3 were still the two extremes FGRs. A difference of 56 ms was observed between them. The NOMT for FGRs 4, 5 and 1 are close to each other on both pre-exercise trials (16 and 20) which suggest that only a small difference in performance existed between these extreme FGRs at rest. The scores for each trial was submitted to a one-way analysis of variance on the FGRs. Results indicate that there was no significant difference among the five FGRs values for trial 16 ( $N=45$ ) ( $F(4,40)=1.03$ ,  $p > .05$ ) and for trial 20 ( $N=50$ ) ( $F(4,45)=0.78$ ,  $p > .05$ ). This suggests that before both exercise periods there was no difference in NOMT among the five FGRs regardless of their level of body fat.

The means, standard errors and the difference between the means for the NOMT performance recorded before and after the light and the heavy intensity exercises appear in Table 15 and the mean values are illustrated in Figure 6.

TABLE 15: Means (M), standard errors (SE) and difference between the means (DBM) in ms for non-overshoot movement time (NOMT) for the total group and by FGRs for trials 16 and 17 and for trials 20 and 21.

| Trial                           |    | Total group | Fat groups |       |       |       |       |
|---------------------------------|----|-------------|------------|-------|-------|-------|-------|
|                                 |    |             | FGR 1      | FGR 2 | FGR 3 | FGR 4 | FGR 5 |
| Light intensity exercise (N=45) |    |             |            |       |       |       |       |
| 16 (ms)                         | M  | 776         | 758        | 780   | 838   | 740   | 765   |
|                                 | SE | 15.0        | 38.0       | 30.0  | 35.3  | 29.3  | 34.2  |
| 17 (ms)                         | M  | 784         | 763        | 835   | 835   | 740   | 749   |
|                                 | SE | 16.1        | 39.6       | 33.4  | 37.2  | 32.7  | 34.8  |
| DBM (ms)                        |    | 8           | 5          | 55    | -3    | 0     | -16   |
| -----                           |    |             |            |       |       |       |       |
| Heavy intensity exercise (N=50) |    |             |            |       |       |       |       |
| 20 (ms)                         | M  | 748         | 738        | 775   | 777   | 721   | 727   |
|                                 | SE | 12.7        | 29.7       | 26.9  | 30.2  | 27.8  | 27.0  |
| 21 (ms)                         | M  | 805         | 819        | 858   | 819   | 768   | 759   |
|                                 | SE | 15.9        | 44.1       | 34.3  | 35.7  | 33.3  | 28.1  |
| DBM (ms)                        |    | 57          | 81         | 83    | 42    | 47    | 32    |

Note. DBM = Post-exercise NOMT - Pre-exercise NOMT where post-exercise trials correspond to trials 17 and 21 and pre-exercise trials correspond to trials 16 and 20.

Note. A negative sign attached to the DBM indicates a shorter NOMT for the post-exercise trial as compared to the pre-exercise trial while an absence of sign indicates a longer NOMT following exercise.

# NOMT MEASURED PRE- AND POST-EXERCISE

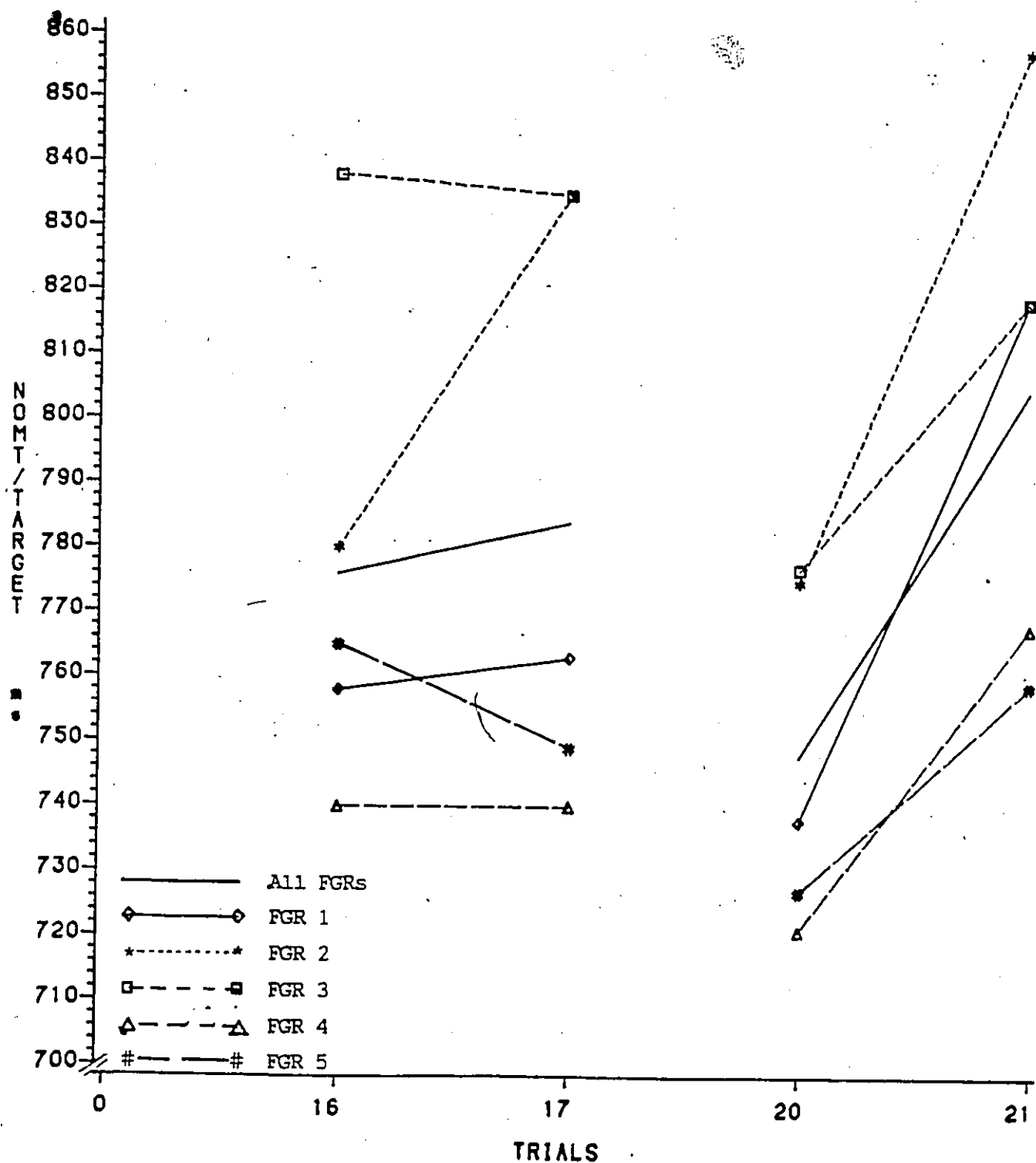


Figure 6-CHANGE IN NOMT MEASURED BEFORE AND AFTER 2 BOUTS OF EXERCISE  
IN A GROUP OF 50 SUBJECTS (30 to 39 years) CLASSIFIED  
IN INCREASING LEVELS OF BODY FAT

Following the light intensity exercise, the difference between the means of trials 17 (post-exercise) and 16 (pre-exercise) (Table 15) indicates that the NOMT for trial 17 was shorter for FGR 3 (3 ms) and FGR 5 (16 ms), and longer for FGR 1 (5 ms) and FGR 2 (55 ms). There was no change in NOMT for FGR 4. For the total group (N=45), the performance in trial 17 was eight ms longer than in trial 16. The correlation coefficient between the percentage of body fat and the difference in NOMT (trial 17 - trial 16) (N=49) was  $r = -.13$  (not significant  $p > .05$ ). The results of the ANOVA (Table 16) for trials 16 and 17 suggests that there was no significant difference among the five FGRs, no significant FGRs x Trials interaction and no significant difference in the NOMT performance between trials 16 and 17.

Following the heavy intensity exercise the difference between the means of trials 21 (post-exercise) and 20 (pre-exercise) (Table 15) indicates that the NOMT for trial 21 was longer for the five FGRs. FGR 5 had the smallest change as its NOMT was 32 ms longer on trial 21 followed in order of increasingly longer NOMT by FGR 3 (42 ms), FGR 4 (47 ms), FGR 1 (81 ms) and FGR 2 (83 ms). FGR 1 and FGR 2 had the two longest NOMT. For the total group (N=50) the performance in trial 21 was 57 msec longer than in trial 20. The correlation coefficient between the percentage of body fat and the difference in NOMT (trials 21 - trial 20) (N=50) was  $r = -.23$  (not significant  $p > .05$ ). The result of the ANOVA (Table 16) suggests that

there was no significant difference among the NOMT performance of the five FGRs and no significant FGRs x Trials interaction. However, there was a significant difference in NOMT performance between trials 20 and 21.

In summary, the difference between the means for each of the five FGRs for trials 16 and 17 and for trials 20 and 21 suggests that the NOMT of the lean (FGR 1) and the average groups (FGR 2) was longer following both exercise intensities. The NOMT of the excess body fat groups (FGRs 3, 4 and 5) was shorter following the light intensity exercise except for FGR 4. NOMT was longer for the three FGRs following the heavy intensity exercise but not as much as for FGRs 1 and 2. However, the correlation coefficients indicates that there was no significant interrelationship between changes in NOMT performance as measured by the difference between pre- and post-exercise trial values and percentage of body fat for each intensity. The results of the ANOVAS suggest that the NOMT was similarly affected throughout the range of percentage of body fat following each of the two exercise intensities.

In terms of exercise intensities, the light intensity had no significant effect on the post-exercise performance, while following the heavy intensity of the post-exercise NOMT was significantly longer.

TABLE 16: Summary of analyses of variance with repeated measures for the non-overshoot movement time (NOMT) between trials 16 and 17 and between trials 20 and 21 using all five FGRs.

| Source                                            | SS          | df  | MS         | F        |
|---------------------------------------------------|-------------|-----|------------|----------|
| Light intensity exercise (trials 16 and 17; N=45) |             |     |            |          |
| Between-subjects                                  |             |     |            |          |
| FGRs                                              | 464602.38   | 4   | 116150.59  | 1.25     |
| residual                                          | 3712663.13  | 40  | 92816.58   |          |
| Within-subjects                                   |             |     |            |          |
| Trials                                            | 5816.14     | 1   | 5816.14    | 0.66     |
| FGRs x Trials                                     | 54451.82    | 4   | 13612.96   | 1.53     |
| residual                                          | 355066.30   | 40  | 8876.66    |          |
| Target Distances                                  | 9976688.00  | 3   | 3325562.75 | 647.03** |
| FGRs x T.Dis.                                     | 80241.88    | 12  | 6686.82    | 1.30     |
| residual                                          | 616763.66   | 120 | 5139.70    |          |
| Trials x T.Dis.                                   | 26595.71    | 3   | 8865.24    | 3.57*    |
| FGRs x Trials x T.Dis.                            | 16351.62    | 12  | 1362.63    | 0.55     |
| residual                                          | 297670.91   | 120 | 2480.59    |          |
| Heavy intensity exercise (trials 20 and 21; N=50) |             |     |            |          |
| Between-subjects                                  |             |     |            |          |
| FGRs                                              | 333528.00   | 4   | 83382.00   | 1.03     |
| residual                                          | 3653716.75  | 45  | 81193.70   |          |
| Within-subjects                                   |             |     |            |          |
| Trials                                            | 321886.03   | 1   | 321886.03  | 20.08**  |
| FGRs x Trials                                     | 43426.89    | 4   | 10856.72   | 0.68     |
| residual                                          | 721274.20   | 45  | 16028.32   |          |
| Target Distances                                  | 10256492.00 | 3   | 3418830.75 | 670.92** |
| FGRs x T.Dis.                                     | 75873.05    | 12  | 6322.75    | 1.24     |
| residual                                          | 687922.77   | 135 | 5095.72    |          |
| Trials x T.Dis.                                   | 131268.77   | 3   | 43756.25   | 11.43**  |
| FGRs x Trials x T.Dis.                            | 62017.46    | 12  | 5168.12    | 1.35     |
| residual                                          | 516793.17   | 135 | 3828.10    |          |

\*  $p < .05$

\*\*  $p < .01$

The movement time from one target to another varies according to target distance, the longer the distance the longer the movement time (for more information see Appendix C). In this respect, the ANOVAS (Table 16, T. Dis.) indicate that there is a significant difference between the NOMT for the four target distances for both exercise sessions. This is explained by the fact that as the distance between targets increases it takes significantly more time to move the pointer from one target to the other. However, there is no interaction between the five FGRs and the four different target distances for both exercise intensities and no FGRs x Trials x Target distances interaction. These results suggest that the five FGRs performed similarly after both exercise intensities for each of the four target distances independently of their respective percentage of body fat. The significant Trials x Target distances interaction is explained by the fact that the NOMT per target distance became progressively longer during the post-exercise trial as the target distance increased from 41 mm to 164 mm.

#### 4.2.4.2 Movement time with overshoot (OMT)

Movement time with overshoots (OMT) occurred less often than movement time without overshoots (NOMT), 5,646 (28.3%) times compared to 14,240 (71.6%) times on a total of 19,891 movement time responses over the four trials (trials 16, 17, 20 and 21) executed by the total group. These values do not take into account the missing data. Furthermore the OMT was also longer in

duration than NOMT because of the overshoot period. In this sample of 50 subjects the mean OMT was 1,016 ms while the mean NOMT was 722 ms.

In Table 17, the values for trial 16 indicate that FGR 1 had the shortest OMT (1050 ms) followed in order of increasingly longer OMT by FGRs 4, 2, 5 and 3 (1179 ms). A difference of 129 ms was observed between the two extreme groups, FGR 1 and FGR 3. For trial 20, FGR 4 showed the shortest OMT (1053 ms) followed in order of increasingly longer OMT by FGRs 5, 1, 2 and 3 (1160 ms). A difference of 125 ms was observed between the two extremes groups FGR 4 and FGR 3. For both trials FGR 3 had the longest OMT of the five FGRs. The scores for both trials were submitted to a one-way analysis of variance on the FGRs. The results indicate that there was no significant difference among the five FGRs for trial 16 ( $N=45$ ) ( $F(4,40) = 0.63, p > .05$ ) and for trial 20 ( $N=50$ ) ( $F(4,45) = 0.82, p > .05$ ). These procedures indicate that before both exercise periods there was no significant difference in OMT among the five FGRs regardless of the percentage of body fat of each FGR.

The means, standard errors and the difference between the means for OMT performance recorded before and after the light and heavy intensity exercises appear in Table 17 and the mean values are illustrated in Figure 7.

TABLE 17: Means (M), standard errors (SE) and difference between the means (DBM) in ms for overshoot movement time (OMT) for the total group and by FGRs for trials 16 and 17 and for trials 20 and 21.

| Trial                           |    | Total group | Fat groups |       |       |       |       |
|---------------------------------|----|-------------|------------|-------|-------|-------|-------|
|                                 |    |             | FGR 1      | FGR 2 | FGR 3 | FGR 4 | FGR 5 |
| Light intensity exercise (N=45) |    |             |            |       |       |       |       |
| 16 (ms)                         | M  | 1126        | 1050       | 1143  | 1179  | 1097  | 1159  |
|                                 | SE | 22.3        | 44.4       | 45.9  | 42.5  | 51.2  | 63.2  |
| 17 (ms)                         | M  | 1137        | 1065       | 1190  | 1210  | 1094  | 1111  |
|                                 | SE | 20.7        | 51.6       | 46.1  | 44.9  | 42.3  | 45.2  |
| DBM (ms)                        |    | 11          | 15         | 47    | 31    | -3    | -48   |
| Heavy intensity exercise (N=50) |    |             |            |       |       |       |       |
| 20 (ms)                         | M  | 1097        | 1068       | 1158  | 1160  | 1035  | 1063  |
|                                 | SE | 20.7        | 47.9       | 50.9  | 50.2  | 40.9  | 38.2  |
| 21 (ms)                         | M  | 1161        | 1175       | 1223  | 1189  | 1069  | 1143  |
|                                 | SE | 24.2        | 63.6       | 46.3  | 51.1  | 59.4  | 48.8  |
| DBM (ms)                        |    | 64          | 107        | 65    | 29    | 34    | 80    |

Note. DBM = Post-exercise OMT - Pre-exercise OMT where post-exercise trials correspond to trials 17 and 21 and pre-exercise trials correspond to trials 16 and 20.

Note. A negative sign attached to the DBM indicates a shorter OMT for the post-exercise trial as compared to the pre-exercise trial while an absence of a sign indicates a longer OMT following the exercise.

# OMT MEASURED PRE- AND POST-EXERCISE

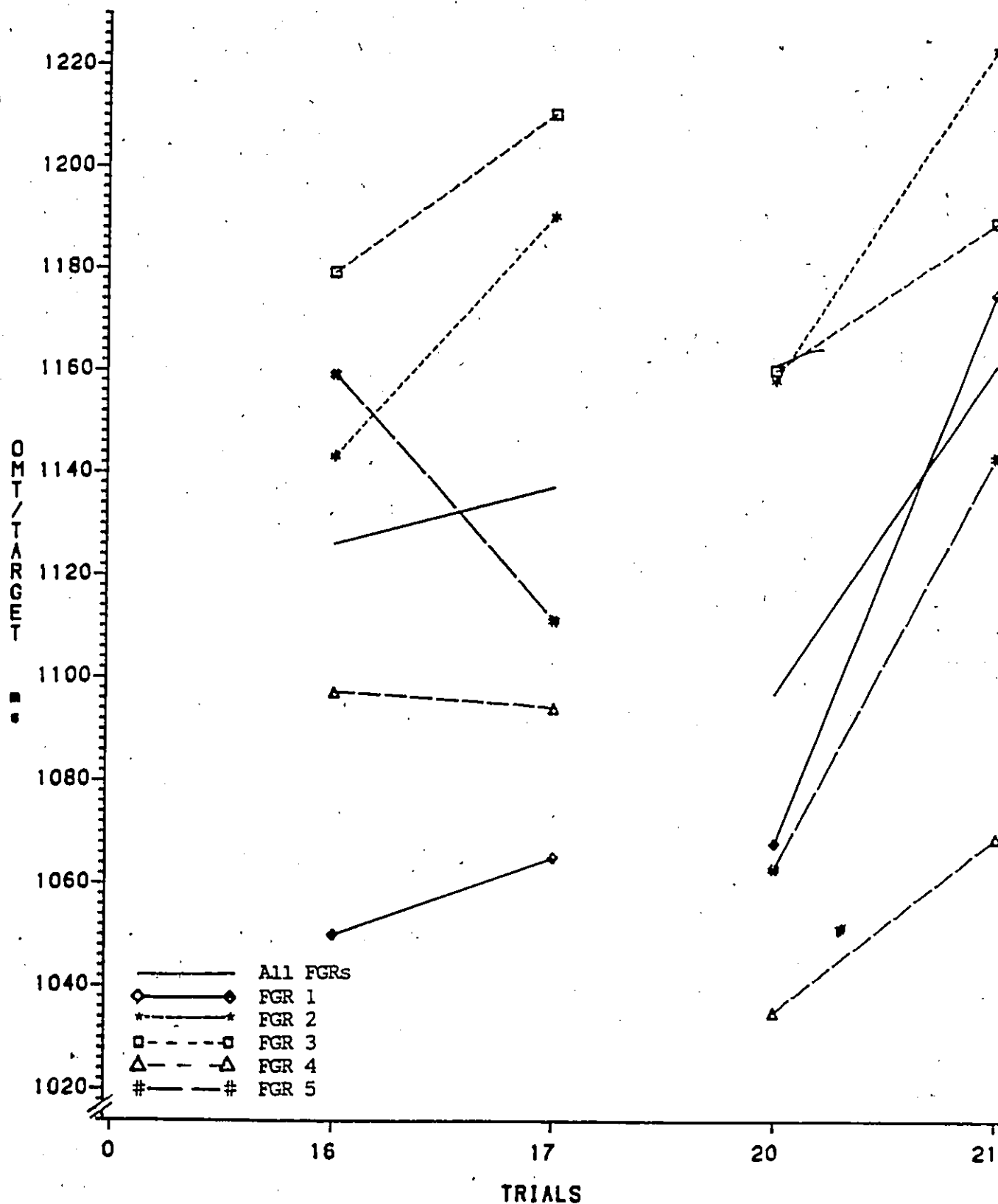


Figure 7- CHANGE IN OMT MEASURED BEFORE AND AFTER 2 BOUTS OF EXERCISE  
IN A GROUP OF 50 SUBJECTS (30 to 39 years) CLASSIFIED  
IN INCREASING LEVELS OF BODY FAT

Following the light intensity exercise, the difference between the means of trials 17 (post-exercise) and 16 (pre-exercise) (Table 17) indicates that the OMT was shorter for trial 17 by 3 and 48 ms for FGRs 4 and FGR 5. The OMT was longer for FGR 1 (15 ms), FGR 3 (31 ms) and FGR 2 (47 ms) for trial 17. For the total group (N=45), the performance in trial 17 was 11 ms longer than in trial 16. The correlation coefficient between the percentage of body fat and the difference in OMT (trial 17 - trial 16) (N=49) was  $r = -.01$  (not significant  $p > .05$ ). The scores were analyzed with a FGRs (5) x Trials (2) analysis of variance with repeated measures on Trials. The Target distance factor was not analysed separately as in the NOMT analysis instead target distances scores were averaged across the four different target distances because of missing scores. Seventeen subjects had at least one missing target distance value mostly in the fourth target distance. The missing scores could be the result of mechanical errors (damaged recording tape) or of subjects who did not overshoot during one or both of the two trials analyzed. With regard to target distance four, which only occurred 10 times per trial, the diminution in overshoots can be explained by a phenomenon called the boundary distance effect on overshooting (Buck 1976, 1978, 1979 and 1982). Under this phenomenon, targets 1 and 5 lying close to the furthest limits of movement on the tracometer display are overshoot less frequently than the others. Because of missing scores and because of the necessity of using equal cells for the ANOVAS on the NRC

computer it restricted to 35 (five FGRs of seven subjects each) the number of subjects that could be used for the analysis even if target distance four was dropped. However, by averaging the four target distances the variability in target distance four values for trials 16 and 17 diminished and the number of subjects in the population that could be analyzed increased. The results of the ANOVA for trials 16 and 17 (Table 18) suggest that there was no significant difference among the OMT performance of the five FGRs and no significant FGRs x Trials interaction. Furthermore, there was no significant difference in the OMT performance between trials 16 and 17.

Following the heavy intensity exercise the difference between the means of trials 21 (post-exercise) and trial 20 (pre-exercise) (Table 17) indicates that the OMT for trial 21 was slower for all five FGRs. FGR 3 had the smallest change (29 ms longer) for trial 21 and FGR 1 the largest change (107 ms longer). FGR 1 and 5 had the two longest OMT. For the total group (N=50) the performance in trial 21 was 64 msec longer than in trial 20. The correlation coefficient between the percentage of body fat and the difference in OMT (trial 21 - trial 20) (N=50) was  $r = -.18$  (not significant  $p > .05$ ). The scores were analyzed using an FGRs (5) x Trials (2) analysis of variance with repeated measures on Trials. Nineteen subjects had at least one missing value, mostly in target distance four. The reasons for averaging the target distances are the same as mentioned for the light intensity exercise. The results of the ANOVA (Table 18)

suggest that there was no significant difference in OMT performance among the five FGRs and no significant FGRs x Trials interaction. However, there was a significant difference in OMT performance between trials 20 and 21.

In summary, the difference between the means for each of the five FGRs for trials 16 and 17 and those for trials 20 and 21 indicates that the two excess fat groups (FGRs 4 and 5) had a shorter OMT after the light intensity exercise while the lean (FGR 1), the average (FGR 2) and the more fat than average group (FGR 3) had a longer OMT. Following the heavy intensity exercise all five FGRs experienced a slow down in performance. The correlation coefficients suggest that there was no significant interrelationship between the changes in OMT performance as measured by the difference between the pre- and post-exercise trial values and the percentage of body fat for each exercise intensity. The ANOVAS suggest that following both exercise intensities the OMT performance of the five FGRs was similar regardless of the percentage of body fat.

In terms of the exercise intensities, the light intensity had no significant effect on the post-exercise performance, while following the heavy intensity exercise the OMT was significantly longer.

**TABLE 18:** Summary of analyses of variance with repeated measures for the overshoot movement time (OMT) between trials 16 and 17 and between trials 20 and 21 using all five FGRs.

| Source                                            | SS         | df | MS        | F      |
|---------------------------------------------------|------------|----|-----------|--------|
| Light intensity exercise (trials 16 and 17; N=45) |            |    |           |        |
| Between-subjects                                  |            |    |           |        |
| FGRs                                              | 257174.78  | 4  | 64293.70  | 1.09   |
| residual                                          | 2367481.63 | 40 | 59187.04  |        |
| Within-subjects                                   |            |    |           |        |
| Trials                                            | 0.05       | 1  | 0.05      | 0.00   |
| FGRs x Trials                                     | 31419.20   | 4  | 7854.80   | 0.57   |
| residual                                          | 550023.61  | 40 | 13750.59  |        |
| Heavy intensity exercise (trials 20 and 21; N=50) |            |    |           |        |
| Between-subjects                                  |            |    |           |        |
| FGRs                                              | 246483.78  | 4  | 61620.95  | 0.93   |
| residual                                          | 2969837.13 | 45 | 65996.38  |        |
| Within-subjects                                   |            |    |           |        |
| Trials                                            | 103624.97  | 1  | 103624.97 | 9.43** |
| FGRs x Trials                                     | 30111.20   | 4  | 7527.80   | 0.68   |
| residual                                          | 494700.66  | 45 | 10993.35  |        |

\*\* p < .01

## CHAPTER V

### DISCUSSION

The hypothesis of this study was that the level of percentage of body fat would affect differentially the fine motor performance following a period of GPE. This hypothesis was tested under two exercise intensities, light and heavy. Results do not support the hypothesis for either the light intensity exercise or for the heavy intensity exercise.

The relationship between levels of percentage of body fat and fine motor performance parameters will be discussed first for the pre-exercise condition. In essence the findings for pre-exercise trials 16 and 20 indicate that there was no significant difference among the scores of the five FGRs for any of the performance parameters measured by the tracometer, i.e. TRT, CRT, NOMT and OMT nor was there any satisfactory evidence of any interrelationship between the percentage of body fat of the 50 subjects and the four performance parameters (see Appendix N).

Therefore, results suggest that at rest body fat exerted little or no influence on fine motor performance as measured by the tracometer. This observation confirms, at least for the reaction time parameter, the works of Janoff, Beck and Child (1950), Pierson (1961) and Kitagawa, Usui and Miyashita (1979). These authors compared somatotype (ectomorphy, mesomorphy and endomorphy), body build (weight and height) and percentage of body fat respectively to reaction time performance during resting.

conditions. They reported that at rest these parameters were not important determinants of reaction time performance. However, results pertaining to the present study of NOMT, OMT and TRT cannot be compared to results of other studies because to the author's knowledge, no such studies exist. Nevertheless, the lack of relationship found between body fatness and performance parameters which do not involve movement of the entire body seems to confirm previous observations (Riendeau et al. 1957, Boileau and Lohman 1977, Beunen et al. 1983) that excess body fat can only exert a negative effect on motor fitness activities where the body is moved or projected. In conclusion, results for this segment of the study suggest that the degree of body fat in itself does not affect fine motor performance as evaluated by the tracometer, when it is performed at rest, sitting. However, the amount of body fat regarded as extra weight may affect fine motor performance following a period of GPE. In this respect, the question asked in this study was to what extent does the percentage of body fat affect the performance parameters when the repercussions on physiological parameters of increasing amounts of body fat for each intensity are taken into consideration.

As predicted, the exercise intensities affected the heart rate of each FGR differently. During both the light and the heavy intensity exercises the heart rate of FGRs 3, 4 and 5 was significantly higher when compared to the heart rate of FGR 1. This lends support to the observation that the physiological cost

of an exercise at a given intensity is markedly higher for individuals with a higher percentage of body fat as compared to leaner individuals (Miller and Blyth 1955, Auchincloss, Sipple and Gilbert 1962, Turell, Austin & Alexander 1964, Hanson 1973).

This observation was further supported by the experimenter's perception that the subjects in FGRs 4 and 5 complained more frequently than the subjects in the three other FGRs during the heavy intensity exercise. The major complaints were about high ventilation frequency, pain in the calf muscles, excess sweating, problems to keep up with the treadmill load, loss of balance and heaviness in the legs. This perception was further reinforced by the fact that three subjects in FGR 5 and one in FGR 4, were forced to stop before the end of the 10 minutes of heavy intensity exercise. Of the four who were forced to stop, two did so because of high heart rate: 209 bpm after seven minutes of exercise and the other, 204 bpm after four minutes of exercise. Both subjects were in FGR 5 with a respective percentage of body fat of 29.1% and 31.7%. The remaining two subjects stopped because of breathlessness and muscular pain in the calf muscles and at the lower back level. One of the two was from FGR 5 (28% of body fat) and stopped after 7:20 minutes with a heart rate of 180 bpm and the other from FGR 4 after five minutes with a heart rate of 175 bpm. There was a significant correlation between the percentage of body fat and the RPE for the heavy intensity exercise only. However, even if the overfat subjects (FGRs 4 and 5) complained more of physical discomforts, their scores for the

perceived level of exertion (RPE) were higher but not significantly different from those of FGR 1 and FGR 2. Overall, a larger physiological cost of walking against an inclination was observed for FGRs 4 and 5 when compared to FGR 1. This cost was higher during the heavy intensity exercise.

All the differences between the means (DBM, trial 17 minus trial 16; DBM, trial 21 minus trial 20) for the four performance parameters appear in Table 19. The DBM for each FGR were classified according to changes in performance time following exercise: SHORTER, NO CHANGE or LONGER performance time and according to changes in magnitude: largest change to the smallest change. In Table 19, for both intensities, there seems to be no clear pattern of change in DBM for the present ranking of FGRs by increasing amount of body fat. For example, FGR 1 and FGR 5 are one next to the other in terms of ranking of DBM under the TRT and the OMT parameters for the heavy intensity exercise.

Analyses of variance indicate that there was no significant difference ( $p > .05$ ) between the five FGRs for any of the four performance parameters following both intensities of exercise. Furthermore, no significant interrelationship ( $p > .05$ ) was observed between percentage of body fat and fine motor parameters measured during trials 17 or 21 (see Appendix N). Likewise, no significant interrelationship was observed between percentage of body fat and difference in fine motor performance (trial 17 minus trial 16; trial 21 minus trial 20) for each performance parameter. This absence of significant differences among the

TABLE 19: Difference between the means (DBM; ms) for each of the four performance parameters by FGRs classified according to changes in performance time (SHORTER, NO CHANGE, LONGER) and changes in magnitude (LARGEST, SMALLEST) for trials 16 and 17 (light intensity exercise) and for trials 20 and 21 (heavy intensity exercise).

| PERFORMANCE<br>PARAMETER        | CHANGES IN PERFORMANCE TIME |           |                      |           |            |
|---------------------------------|-----------------------------|-----------|----------------------|-----------|------------|
|                                 | SHORTER                     |           | NO CHANGE            |           | LONGER     |
|                                 | CHANGES IN MAGNITUDE        |           | CHANGES IN MAGNITUDE |           |            |
|                                 | LARGEST                     | SMALLEST  | SMALLEST             | LARGEST   |            |
| LIGHT INTENSITY EXERCISE (N=45) |                             |           |                      |           |            |
| TRT<br>FGRs<br>(DBM)            | 4<br>(30)                   | 5<br>(16) | 3<br>(12)            | 1<br>(4)  | 2<br>(35)  |
| .CRT<br>FGR<br>(DBM)            | 2<br>(4)                    |           | 5<br>(2)             | 4<br>(1)  | 3<br>(2)   |
| .NOMT<br>FGRs<br>(DBM)          | 5<br>(16)                   |           | 3<br>(3)             | 4<br>(0)  | 1<br>(5)   |
| .OMT<br>FGRs<br>(DBM)           | 5<br>(48)                   |           | 4<br>(3)             | 1<br>(15) | 3<br>(31)  |
| HEAVY INTENSITY EXERCISE (N=50) |                             |           |                      |           |            |
| .TRT<br>FGRs<br>(DBM)           |                             |           |                      | 3<br>(29) | 4<br>(31)  |
|                                 |                             |           |                      | 2<br>(43) | 1<br>(47)  |
|                                 |                             |           |                      |           | 5<br>(60)  |
| .CRT<br>FGRs<br>(DBM)           | 3<br>(25)                   | 5<br>(6)  | 4<br>(4)             | 2<br>(4)  | 1<br>(1)   |
| .NOMT<br>FGRs<br>(DBM)          |                             |           |                      | 5<br>(32) | 3<br>(42)  |
|                                 |                             |           |                      | 4<br>(47) | 1<br>(81)  |
|                                 |                             |           |                      |           | 2<br>(83)  |
| .OMT<br>FGRs<br>(DBM)           |                             |           |                      | 3<br>(29) | 4<br>(34)  |
|                                 |                             |           |                      | 2<br>(65) | 5<br>(80)  |
|                                 |                             |           |                      |           | 1<br>(107) |

FGRs also appears in the TRT per interval for the first occurrence of the 20 possible post-exercise movements (I-1) during trials 17 and 21. One observes an average difference of 20 bpm in heart rate between FGR 5 and FGR 1 when measured during heavy intensity exercise. After the first and second minute of recovery the average differences are 26 and 25 bpm respectively. These differences do not translate into significant differences in fine motor performance values between the two extreme FGRs. The same observation applies for the difference in heart rates between FGR 4 and FGR 1, with respective average differences of 24, 32 and 29 bpm. From these observations it appears that although subjects in FGR 4 and FGR 5 did work more strenuously than those in FGR 1, mostly during the heavy intensity exercise, their fine motor performance measured over 100 targets was not significantly different ( $p > .05$ ).

A possible explanation for the lack of significant difference in post-exercise performance among the FGRs is that the differences in the level of work and physical discomfort experienced during the high intensity exercise were quickly attenuated during the recovery process. This could have occurred because the pursuit tracking task was performed in a sitting position where the excess fat subjects (FGRs 4 and 5) had their weight supported. This may have offered them more stability and allowed them to allocate more attention to the task itself, possibly compensating for the effects of exercise.

Another possible explanation may be found in individual

differences in the capacity to compensate for changes induced by exercise. Different individuals may be more or less resistant to the effects of exercise. This resistance could be due to individual skills or to the large number of practice trials preceding the exercise period. They could have rendered some subjects less sensitive to post-exercise disruption, that is better able to compensate for the effects of exercise. For trial 21, in addition to numerous practice trials, subjects had prior experience of the impact of exercise on their fine motor performance and could possibly have anticipated the effects of exercise more readily and compensated for them after the heavy intensity exercise.

With respect to the effects of prior exercise on the fine motor performance parameters of the total group, results suggest that following the heavy intensity exercise, TRT was significantly longer than that of the pre-exercise. However, TRT was not significantly different following the light intensity exercise except during the first interval where TRT was slower ( $p < .01$ ) as compared to pre-exercise. TRT was also significantly slower ( $p < .01$ ) during the first three intervals (I-1, I-2 and I-3) following the heavy intensity exercise during which it gradually returned to pre-exercise values. The duration and the amplitude of the slow down in TRT performance were more important following the heavy intensity exercise than following the light one. The shorter recovery period after the light intensity exercise as compared to the heavy one could suggest

some kind of perceptual-motor recovery pattern where the recovery time for motor performance is partially linked to the intensity of the exercise. However, for both exercise intensities, there was no inter-relationship between the improvement in TRT during the first minute of recovery (difference between I1-I3) and the heart rate during recovery for the same period of time. This suggests that the TRT performance does not improve as a function of rest as does the heart rate during recovery. In fact, the correlation coefficients indicate that there is no relationship between the heart rate during exercise or during recovery and the TRT parameter. A number of studies (Hammerton and Tickner 1968, Meyers, Zimmerli, Farr and Baschnagel 1969) have found no interrelationship between heart rate measured during the exercise period and/or heart rate measured during the post-exercise period and motor performance.

The initial adverse effect of both exercise intensities on fine motor performance as measured by the TRT indicates that a leg-induced GPE can affect a perceptual-motor task even after a light intensity exercise. However, being transferred from a moving treadmill to a sitting position may have contributed to a certain extent to the slight changes in TRT seen in the first interval after the light intensity exercise. Nevertheless, these observations contradict those of a number of authors (Hammerton and Tickner 1968, Welch 1969, and Dickinson, Medhurst and Whittingham 1979), who have shown that heavy leg work does not impair perceptual-motor performance when performed immediately

after the exercise. One study (Hammerton and Tickner 1968) did find a decrement in performance when the complexity of the task was increased through the use of a second order of acceleration control thumb joystick. The step-input, self-paced pursuit tracking task can be considered a complex task. It requires attention, the ability to make decisions and high movement inhibition in order to hit the targets. In this respect, Gutin (1973) suggested that tasks high in movement inhibitions should be performed at a low level of exercise-induced activation. In the present context, it is possible that the task may have been more susceptible to disruption induced by high intensity exercise. This may explain the significant changes in CRT, NOMT and OMT observed after the heavy intensity exercise.

Nonetheless, the longer TRT can only be explained in terms of changes in CRT and/or MVT since it is a product of both these parameters.

With regard to the CRT parameter, which represents the cognitive and nervous processes involved before the initiation of the movement, the present findings indicate that following the heavy intensity exercise CRT was significantly shorter as compared to pre-exercise values. However, there was no difference following the light intensity exercise. Previous studies on the relationship between strenuous exertion and reaction time indicate that prior exercise had no effects on reaction time performance (Phillips 1963, Meyer et al. 1969, Bender and McGlynn 1976). These studies used simple reaction

time tasks while in the present study the pursuit tracking task somewhat resembles a 4-choice reaction time task with the distinction that the starting position is never the same. Therefore it can be considered as a variable 4-choice RT task. The difference in task complexity, the level of intensity of the GPE performed by sedentary subjects as well as its duration could possibly explain why the present results differ from those in the literature.

The MVT as measured by NOMT and OMT is the parameter that shows the most significant change after the heavy intensity exercise. It is associated with the execution of movement following the decision time measured by CRT. The movements were significantly longer for all five FGRs following the heavy intensity exercise while there was no significant difference following the light intensity one. This observation contradicts Phillips' (1963) results which showed that following a heavy warm-up using a stepping task, MVT was shorter when measured by a standardized large arm movement. Levitt and Gutin (1971) also found that as the heart rate increased from one work load to another, MVT as measured by a five-choice reaction time task was improved. However, MVT was assessed during the exercise period contrary to Phillips and the present study where MVT was measured after the exercise period. To the author's knowledge there are no other studies in the literature which involve physical exertion and MVT. The longer MVT observed following the high intensity exercise could be the result of a change in strategy

with some individuals deciding to move more cautiously toward the targets after the exercise in order to improve accuracy, therefore increasing their MVT (NOMT). Another possible explanation could be the adverse effect of prior exercise on hand steadiness (Gutin, Fogle, Meyer and Jaeger 1974) and its possible repercussions on target overshooting. This unsteadiness could also lengthen the overshoot time by increasing the amount of time necessary to realize a proper alignment with the target, therefore increasing OMT.

The present findings indicate that subjects possessing a range of percentage of body fat from lean to overfat have similar fine motor values at rest. Furthermore, although the overfat subjects worked more strenuously during the high intensity GPE, they performed as well as the lean subjects on the pursuit tracking task during the first post-exercise trial. The heavy intensity GPE did however affect all five FGRs' fine motor performance by increasing the TRT. The longer TRT was partially explained by a shorter CRT and a longer MVT (NOMT, OMT). The changes measured in the post-exercise fine motor performance did not correlate with recovery heart rates.

## CHAPTER VI

## SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary:

The purpose of this study was to assess the effects of different levels of body fat on the fine motor performance of sedentary men following a light and a heavy intensity walk on a treadmill. The NRC tracometer, a subject-paced, step-input pursuit tracking task, was utilized to measure fine motor performance with respect to four performance parameters: total response time, correct reaction time, non-overshoot movement time and overshoot movement time.

The hypothesis tested was: the percentage of body fat affects differentially fine motor performance following a period of physical exertion. The hypothesis was further broken down into the following two sub-hypotheses: 1. the percentage of body fat affects differentially fine motor performance following a period of light physical exertion; 2. the percentage of body fat affects differentially fine motor performance following a period of heavy physical exertion.

Fifty healthy volunteers ranging from 30 to 39 years of age had their cardiorespiratory fitness and their percentage of body fat assessed. They were sedentary subjects with an aerobic capacity classified as average according to the 1981 CFS. They received 16 practice trials on the tracometer over a two day period before undergoing the two bouts of physical exertion on the second day. On this second day after the eight initial

practice trials, they performed a 10 minute walk on a treadmill at a light intensity immediately followed by four more trials on the tracometer. After a 15 minute rest period, they were back on the treadmill, this time for a 10 minute walk at a heavy intensity also followed by four more trials. For each of the two bouts of physical exertion, only the pre-exercise trial and the first post-exercise trial were considered for the present analysis.

#### Conclusions:

Within the limitations of this study, the following conclusions can be drawn:

1. At rest, all five FGRs performed similarly which suggests that the percentage of body fat in itself had no effect on the performance parameters as measured by TRT, CRT, NOMT and OMT.
2. Following both the light and the heavy intensity exercise, the five FGRs performed similarly, which suggests that the amount of body fat carried during these two general physical exertion periods did not significantly affect the performance parameters as measured by TRT, CRT, NOMT and OMT.
3. A general physical exertion carried out at a high level of intensity can significantly affect over a short period of time the post-exercise performance of a fine motor task.
4. There is no interrelationship between the post-exercise heart rate and the performance parameters as measured by TRT,

CRT, NOMT and OMT.

Recommendations:

The present study confirms, as seen in the review of literature, that the relationship between exercise and motor performance is complex. In this context, the overfat subjects, despite experiencing a higher level of exertion than the lean subjects, performed as well on the tracometer following exercise; this may be due to the fact that subjects performed the fine motor task while sitting on a chair. Since previous studies have indicated that excess body fat exerts a negative effect on activities where the body fat is carried, it is suggested that the issue be further explored by asking subjects covering a larger range of body fat to stand up while performing on the tracometer during the pre-exercise and the post-exercise trials.

In order to gain more understanding of the relationship between exercise-induced physiological states and motor performance, it is also suggested that the concentration levels of certain substances such as lactate and ammoniac be monitored during and following the exercise period since their levels may affect the central nervous system. Furthermore, researches should be carried on the effects of exercise on cognitive processes. A study by Glencross, Brenton and Snigg (1982) does suggest that changes in RT performance during exercise are more closely related to changes in attentional strategies than to changes in heart rate levels or changes in EEG alpha activity.

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## APPENDIX A

NORMS AND PERCENTILE SCORES BY AGE GROUPS FOR  
ESTIMATED PERCENTAGE OF BODY FAT (%) IN MALES

Norms and percentile scores by age groups for estimated  
percentage of body fat (%) in males (CFS 1984)

| Classification Percentiles |    | Age Groups (yrs) |       |       |
|----------------------------|----|------------------|-------|-------|
|                            |    | 20-29            | 30-39 | 40-49 |
| Overfat                    | 95 | 25               | 27    | 32    |
|                            | 90 | 23               | 26    | 30    |
|                            | 85 | 22               | 25    | 29    |
| More Fat Than<br>Average   | 80 | 20               | 24    | 28    |
|                            | 75 | 19               | 24    | 27    |
|                            | 70 | 19               | 23    | 27    |
|                            | 65 | 18               | 22    | 26    |
| Average                    | 60 | 17               | 22    | 26    |
|                            | 55 | 16               | 21    | 25    |
|                            | 50 | 16               | 21    | 24    |
|                            | 45 | 15               | 20    | 24    |
| Less Fat Than<br>Average   | 40 | 14               | 20    | 23    |
|                            | 35 | 13               | 19    | 22    |
|                            | 30 | 13               | 18    | 22    |
|                            | 25 | 12               | 18    | 21    |
| Lean                       | 20 | 11               | 17    | 20    |
|                            | 15 | 11               | 16    | 20    |
|                            | 10 | 10               | 15    | 18    |
|                            | 5  | 9                | 13    | 14    |
|                            | 1  | 7                | 12    | 11    |

APPENDIX B  
ADVERTISEMENT

JUNE TO OCTOBER, 1985

UNIVERSITY OF OTTAWA - DEPARTMENT OF KINANTHROPOLOGY

**RESEARCH PROJECT**  
**ON**  
**PHYSICAL ACTIVITY AND FINE MOTOR PERFORMANCE**

REQUIRED: Male subjects aged 20 to 39.

Individuals who participate regularly in vigorous physical activity are not eligible.

TIME REQUIREMENT: Two 1 1/2-hour sessions which include a free fitness appraisal.

NATURE OF THE EXPERIMENT: Performance of a tracking test prior to and following 2 short periods of mild exercise.

LOCATION: Montpetit Hall, 35 McDougal Lane, third floor, room 318.

Participants will receive a detailed analysis of their fitness results and will be provided with an exercise prescription.

For further information, please contact the  
Department of Kinanthropology, University of Ottawa:

Josée Barsalou

or

Jean-Luc Leblanc (Project coordinator):

564-5946 ext. 8 (days)

MJ-KIN 1985

APPENDIX C  
THE TRACOMETER



The National Research Council (NRC) tracometer is a subject-paced step-input pursuit tracking task initially conceived by C.B. Gibbs (1965, 1966) and further developed in the Control Systems Laboratory of the NRC in Ottawa under the name NRC Stressalyser. This last name was derived from its first application as a device capable of detecting and recording subtle differences in psychomotor performance as well as decision-making by the operator during stress inducing conditions.

The apparatus itself is divided into 2 units, one being the pursuit tracking unit and the other the control unit. The pursuit tracking unit (Figure 8) consists of a steering wheel which controls a pursuit pointer moving across a 5 target display where each target is the end of an illuminated 2.4 mm diameter optic fibre. Each target is separated from the other by a 41 mm interval along an arc of  $52^\circ$ . The control unit (Figure 9) features a cassette recorder to store information, a total response time counter in seconds, a target counter and a display where one of 10 different sequences of movement patterns can be selected before each trial to minimize familiarization with any one sequence.

For each trial, tracking movement begins at the middle position where the subject, gripping the steering wheel with both hands, must hold the pointer aligned with this initial position for 200 ms following which he must chase the targets. As the

FIGURE 8

## The Pursuit Tracking Unit with Probability Scale

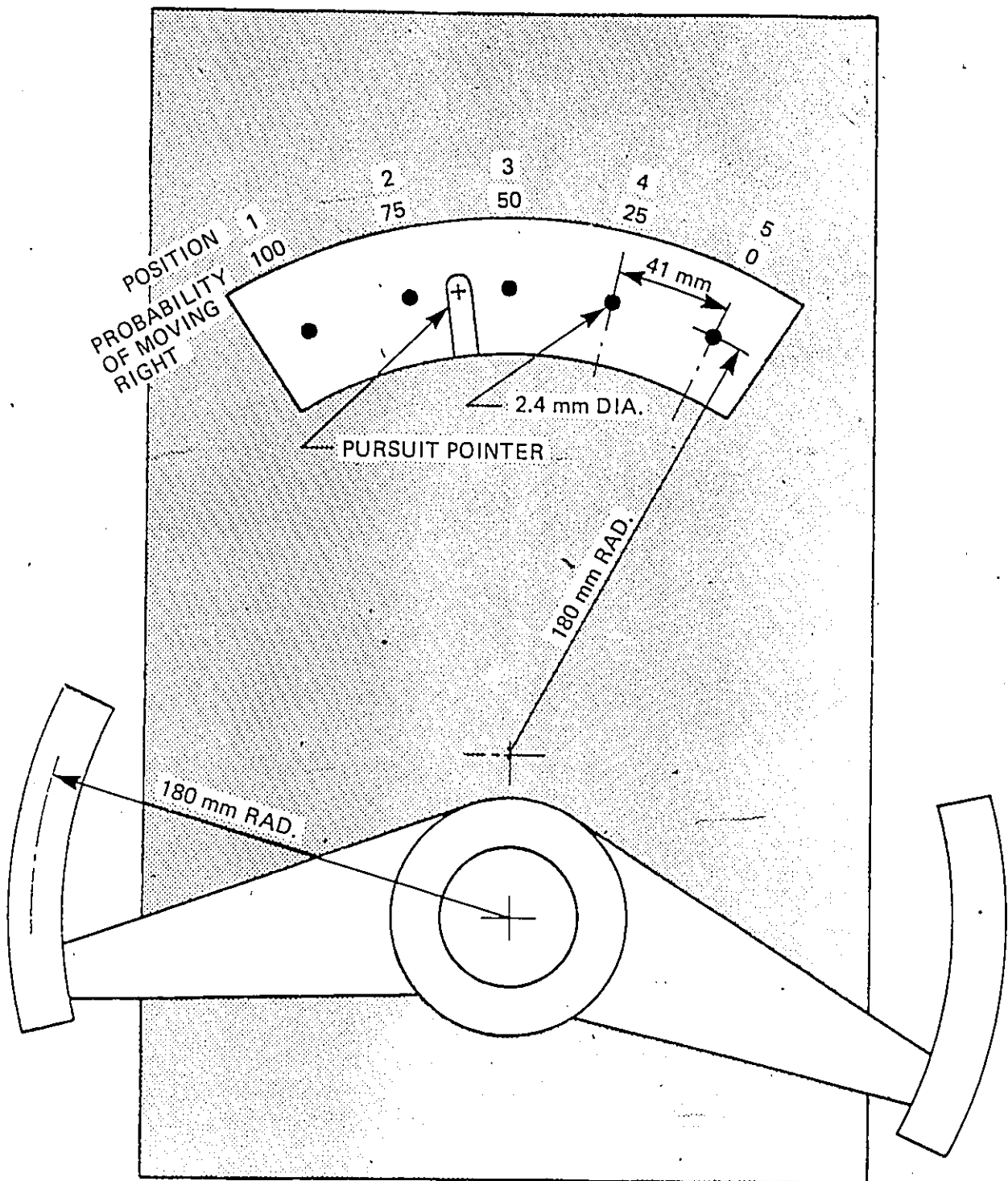
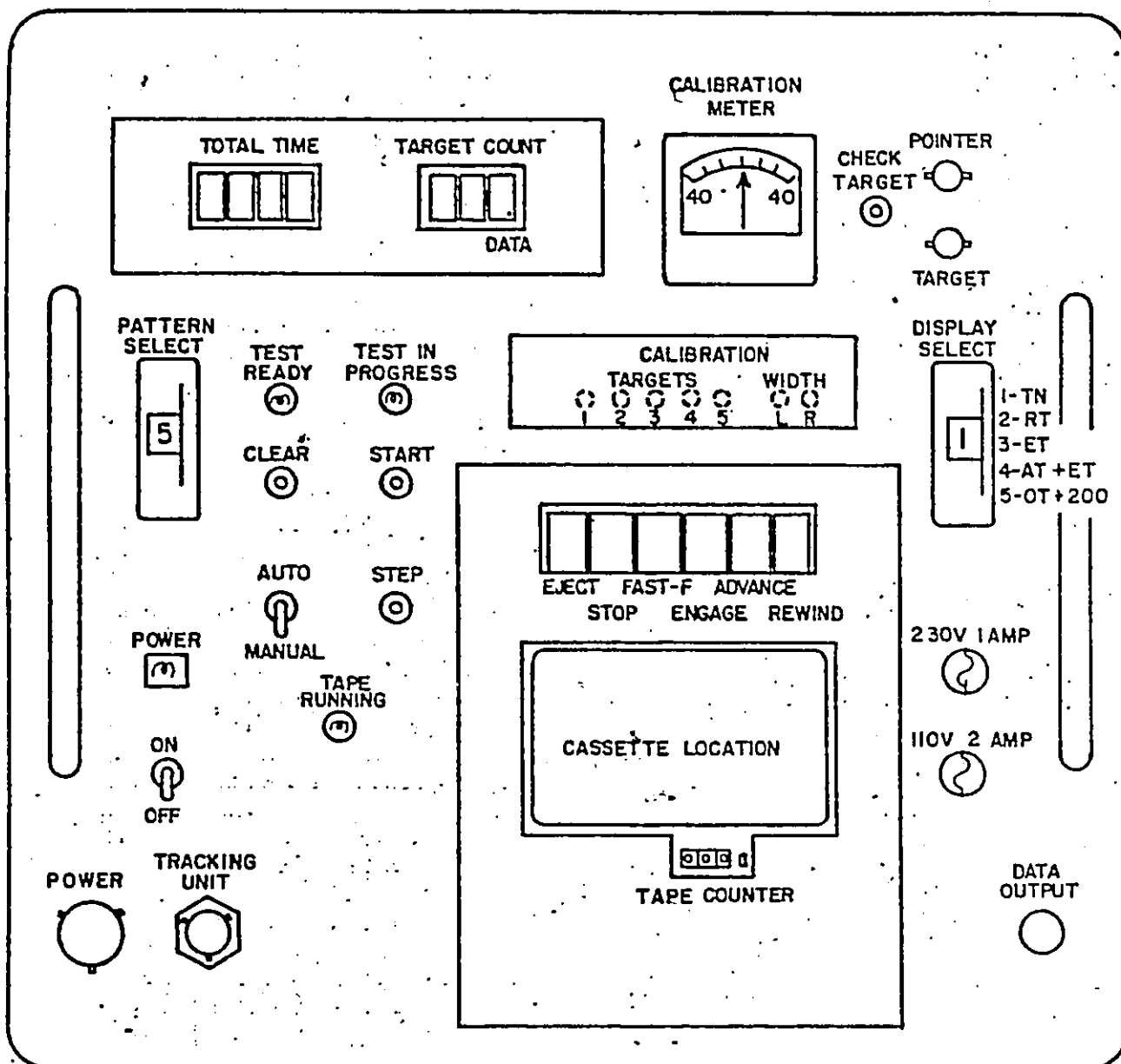


FIGURE 9

201.

# The Control Unit

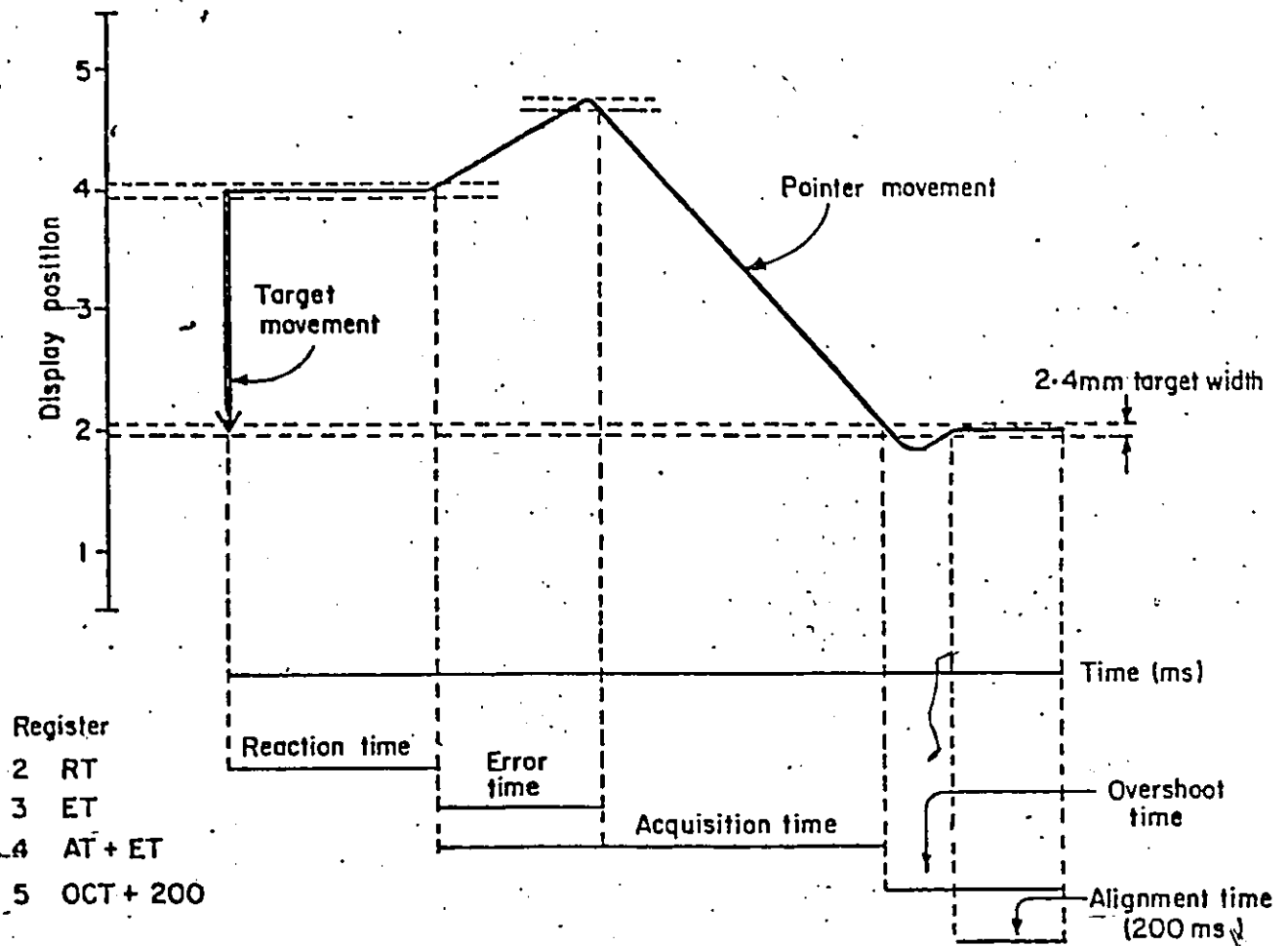


7

target is illuminated, the subject must move the pointer and accurately align it with the target for an uninterrupted 200 ms. Following this, the lamp extinguishes and the next target is illuminated initiating another pursuit. This procedure continues in random fashion for 100 targets during which time each of the 20 possible movements between pairs of positions occurs 5 times.

For each pursuit movement the 4 following factors are recorded (Figure 10): 1) reaction time (RT) described as the time spent between target illumination and the initiation of the pursuit; 2) movement time (MVT) or the time taken between the initiation of the pursuit toward the target and the initiation of the 200 ms uninterrupted alignment; 3) error time (ET), the time spent moving away from the target when a movement is initially in the wrong direction; 4) overshoot time (OT), defined as the time between the first alignment of the pointer with the target which is interrupted before 200 ms and the beginning of a successful 200 ms alignment period. Each trial generates 400 measurements which are stored on a cassette. A computer program is used to retrieve the information and to further subdivide it into the following parameters. The first is correct reaction time (CRT), defined as the RT associated with a correct response that is, precise movement from one target to another with an alignment of 200 ms. Reaction time involving a movement where the pointer initially went in the wrong direction before changing its orientation is classified as RT for error response. As noted

Schematic Trajectory of Two Pursuit Movements



by Buck (1981) this generally involves a faster RT than for correct responses. Furthermore, before moving from one target to the next, the subject always has a choice between four movements defined, in the case of the CRT variable, as levels of directional probabilities. These probabilities levels are 1:00, 0.75, 0.50 and 0.25. When a subject rests on target 1 (see Figure 1), the probability level is 100% that the next target will be to the right on the tracking unit dial. However, when the subject is resting on target 2, the probability level of his moving to the left is 25% and 75% to the right. Target 4 represents the reverse directional probabilities, 25% chance of moving left and 75% to the right. On target 3, there is a 50% chance of moving either to the right or to the left. The level of difficulty of the task varies across these 4 levels of directional probability. The second parameter is non-overshoot movement time (NOMT), the MVT for responses made without an overshoot. It was noted by Buck (1981) that these are usually faster than MVT where overshoots are made. On the tracometer, there are five target lights and during a trial, 100 target movements are executed using one, two, three or four units of interval between target positions. The smallest interval or unit between two targets is 41 mm (see Figure 8) and occurs 40 times per trial; the second interval or unit is 82 mm ( $2 \times 41$ ) or two target intervals and it occurs 30 times per trial; the third is 123 mm or three target intervals and occurs 20 times per trial, while the fourth interval unit, 164 mm or four target intervals

occurs 10 times per trial. Because MVT is affected by the distance to the target, NOMT and OMT are given for four levels of target distance. The third parameter, overshoot movement time (OMT), is the MVT taken to correct the overshoot. It makes the overall MVT slower. The fourth parameter, error rate (ER) is the frequency of initial movements of the pointer away from the target position. Because it varies with directional probability the measurements are broken down into 4 probability levels as for CRT. The final parameter, overshoot rate (OR) is defined as the number of overshoot movements and is a function of boundary distance. Buck (1978) explained that movement rate within a task varies according to the distance of the target from the display boundary in the direction of movements; because of this we have an OR for 4 levels of boundary distance.

The above mentioned points indicate that the tracometer monitors the 5 parameters at 4 levels, each for the appropriate within-task variable (directional probability, target distance or boundary distance). In addition, it also gives the total response time (TRT) which is the period that includes RT and MVT but not the 200 msec alignment time for each pursuit movement. The TRT can be computed for a trial, comprised of 100 alignments, or subdivided into intervals where the 100 alignments of the trial are organized into intervals where the 100 alignments of the trial are organized into 5 intervals of 20 movements. Each interval representing one of the occurrence of the 20 possible movements among the 5 positions on the tracking unit dial. In

conclusion, the tracometer can provide researchers with 21 parameters relevant to the analysis of a skilled performance. However, in this study only the TRT, CRT, NOMT and OMT with their respective within-task variables will be analyzed.

### Research

#### Literature on the tracometer

The tracometer, previously known in the literature as the NRC stressalyser, is a pursuit tracking task combined with a choice RT. This device which can follow 100 start-stop movements per trial with continuous monitoring, which can depict a complex task necessitating motor controls and decision-making, is well suited for research trying to quantify the effects of stressors on the fine motor skill performance of human operators. Its first appellation comes from its early application as a standardized task sensitive to human psychomotor performance under a variety of stressful conditions. Following is a brief description of some of the research dealing with the use of this apparatus where operators are subject to a variety of stressful conditions.

Hypoglycemia was investigated by Fraser, Buck and McKendry (1974) for its possible hazardous effects on drivers' performance. A group of 16 male and female subjects, all normal and healthy, were asked to go through a practice session where they had to complete at least 10 trials, after each of which they were given their TRT. These practice sessions were designed to

allow the subjects to become familiar with the apparatus and to determine their baseline level of performance. During the test sessions 3 more trials were given. Following the trials, subjects were given intravenous injections of insulin in order to induce hypoglycemia following which blood samples were taken at specific intervals to estimate plasma glucose concentration. During this time 1 trial on the tracometer was undertaken every 5 minutes in the first 60 minutes and then every 10 minutes until 90 minutes had elapsed since the onset of the test. Using TRT, they observed in 14 subjects changes in tracometer performance when plasma glucose was reduced to 32 mg/dl. At this point, 7 of the subjects were classified as having signs and symptoms of hypoglycemia and they had a decrease in speed of performance mostly due to an increase in MVT and to a lesser extent, to increased RT. Error rates and OR, both accuracy parameters, did not significantly increase during hypoglycemia. In conclusion, researchers, looking at healthy subjects during mild to moderate insulin induced hypoglycemia, observed lower psychomotor response times and incoordination during the execution of the tracking movement.

The effects of sleep deprivation on human behavior have been the object of numerous studies. Buck (1975) chose to look at sleep deprivation in relation to motor performance using 2 experimental conditions. In the first, 12 male subjects underwent 2 days and one intervening night of sleep deprivation and in the second, 8 other subjects had 3 days and 2 intervening

nights of sleeplessness. A few days before testing all subjects completed 12 initial trials on the tracometer with feedback as to TRT per trial. During the following 2 weeks the 2 groups were further broken down into 2 alternating categories. The first, remaining awake at night and staying in the laboratory for the duration of the experiment, was the experimental group; the other, sleeping at home and spending the remaining time in the laboratory, was the control group. Both had to complete 3 trial runs on the tracometer every 4 hours for a total of 5 daily sessions without knowledge of results. Results indicated that RT and MVT, also defined as response speed, increased by 5% in the experimental group compared to the control group following one night without sleep. A 16% increase in RT and a 23% increase in MVT were observed following 2 nights of sleep deprivation. There was no evidence that ER and OR, 2 accuracy parameters, were affected as a result of sleep loss suggesting that although response speed was slower, accuracy was unaffected.

The effects of psychoactive drugs on the central nervous system (CNS) are of interest to government health agencies and drug manufacturers (Paterson 1982). In order to assess CNS reactions in relation to plasma level of drugs, numerous test instruments have been used. In light of this fact, the tracometer was one of the devices used by Orr, Dussault, Chappel, Goldberg and Reggiani (1976) in a research concerned with the relation between drug induced CNS effects and plasma level of diazepam in humans. It was used because of its capacity to

detect subtle variations in psychomotor skill, possibly associated with the ingestion of various doses of diazepam or a placebo. Fifteen male subjects between 18 and 55 years of age were trained on the device before 2 series of experiments. For the purpose of the experiment, subjects had to ingest doses of 10, 20 or 30 mg of diazepam or a placebo following which they were tested on the tracometer at 30 to 60 minute intervals during 8 consecutive hours. Orr et al. (1976) observed that 10 mg of diazepam initially produced no change in CRT and actually resulted in an improvement following several hours compared to the placebo condition. This dosage also produced an increase in the non overshoot acquisition time (NAT), the time needed to bring the pointer to the next target without overshoot, and in TRT for the first 3 hours after which there was a marked improvement. The 20 mg dose produced improvements in CRT and TRT as well as an increase in NAT for the first 3 hours; the 30 mg dose produced long lasting impairment in CRT, NAT and TRT. Based on subjects' performance, the authors concluded that depending on the dosage of diazepam and changes in plasma level, subjects were slower to react to stimuli and moved more slowly toward a new target without increasing their error rate. They suggest that motor function is impaired by diazepam while decision making is unaffected, at least for the doses studied. Furthermore, they observed that at low dosages it seems that diazepam has an initial stimulating effect. They also indicated that all test parameters used in conjunction with the tracometer had a high

degree of sensitivity due to its capacity to detect changes at minimal concentrating of diazepam.

The relation between time of day and level of performance was examined by Buck (1977) as he attempted to determine if performance of a tracometer task is affected by circadian rhythms. Forty volunteers, 20 women and 20 men from 18 to 70 years of age were divided into 4 groups of 5 subjects each; each group was assigned one of 4 cycles beginning at either 6:00, 7:00, 8:00 or 9:00 a.m. and ending 16 hours later, covering most waking hours. They were all subjected to the same training regime involving 16 successive trials on the apparatus with knowledge of results before testing began. During the testing period, which lasted 48 hours from 14:00 hours Tuesday until 17:00 hours Thursday, subjects were to test themselves at home or at work every 4 hours and were to sleep during their normal hours. Results showed that performance, as measured by TRT, CRT, NOMT and OR, were generally affected by the time of day. Performance speed increased rapidly at the beginning of the waking day while accuracy deteriorated during this same period. As the day wore on, speed performance deteriorated significantly in terms of TRT and MVT while accuracy measured by the number of errors and overshoots, improved. Since speed and accuracy measures were in inverse phase, Buck saw evidence of a speed versus accuracy trade-off in circadian rhythms.

The 4 above mentioned articles underline the sensitivity of this apparatus in measuring how different stressors affect

skilled motor performance as well as its capacity to produce reliable and accurate quantitative data and its adaptability to different research methodologies. Other research projects have been conducted with the help of the apparatus in areas such as circadian rhythms and arctic workers (Buck 1980), sleep patterns and psychomotor performance of aircrews flying transmeridional routes (Buck 1976), driver aptitude-testing (Engel, Paskaruk and Green 1978) and motor skill acquisition in Down Syndrome children (Kerr and Blais 1984).

#### Utilization

Buck, Leonardo and Hyde (1981) claimed a high degree of test/re-test reliability for the tracometer based on a research conducted with 150 subjects, designed to measure their pursuit tracking ability. For the novice in terms of practical utilization, the greatest improvement in performance based on the mean TRT parameter, occurred in the first 4 out of a total of 16 trials. After 16 trials, the pursuit tracking skill is learned and tracometer parameter values remain stable from one trial to the next.

APPENDIX D  
CONSENT FORM (DAY I)

# **FITNESS CONSENT FORM**

I, ☐ AUTHORIZE/ ☐ DO NOT AUTHORIZE THE University of Ottawa to administer and conduct an exercise fitness test designed to determine my physical work capacity. I understand that I will perform tests of grip strength, sit-ups, push-ups, and trunk flexion.

I understand that I will step up on double 20.3 cm. steps at speed identified for my age group. During the performance of the test my heart rate will be monitored and my blood pressure will be measured prior to and upon completion of the test.

I will first be given a three minute warm-up exercise at a rate equivalent to 65 to 70% of the average aerobic power anticipated in a person in a 10 year older age group than mine. If a predetermined heart rate is not exceeded, I will then exercise for a further 3 minutes at 65 to 70% of the average aerobic power for a sedentary person of my own age. If again my predetermined heart rate is not exceeded I will exercise a further three minutes at an exercise rate equivalent to 65 to 70% of the average aerobic power for an individual ten years younger than I. The test will be discontinued when I reach a predetermined heart rate if I become distressed in any way or develop any abnormal response or whichever of the above occurs first. Every effort will be made to conduct the test in such a way as to minimize discomfort and risk. However, I understand that just as with other types of exercise and fitness tests there are potential risks. These include episodes of transient lightheadedness, fainting, chest discomfort.

In agreeing to such an examination, I waive any legal recourse against the members of the staff of the department of Kinesiology from any and all claims resulting from personal injuries sustained or death resulting from these tests. This waiver shall be binding upon my heirs and my personal representatives.

APPENDIX E  
LIFESTYLE QUESTIONNAIRE I

## UNIVERSITY OF OTTAWA - DEPARTMENT OF KINANTHROPOLOGY

RESEARCH PROJECTONPHYSICAL ACTIVITY AND FINE MOTOR PERFORMANCE

## LIFESTYLE QUESTIONNAIRE I

## I. Medical information:

A. When did you last receive a medical examination?

(Month) (Year)

B. Where you advise of any potential medical problem?

☐ Yes☐ No

If yes, could you specify: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

C. Are you presently under medication?

☐ Yes☐ No

If yes, could you specify: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

## II. In relation to physical activity, did you exercise, in the past 2 month,

A. ☐ A little if any☐ Occasionally☐ RegularlyB. List the type, number of sessions per week, duration and intensity  
where duration refers to minutes per exercise session.Intensity: Light= slight change above normal state  
Moderate= perspiration and breathing above normal  
Heavy= heavy perspiration and heavy breathing

ACTIVITY

AMT. WEEKLY

DURATION

INTENSITY

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

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\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

C. Commentary: \_\_\_\_\_

APPENDIX F  
PHYSICAL ACTIVITY SCREENING QUESTIONNAIRE (PAR-Q)

## Department of Kinanthropology

University of Ottawa

## Clinical Fitness Research Appraisal Programme

Family Name \_\_\_\_\_ Age \_\_\_\_\_  
 Given Name \_\_\_\_\_ Date of test \_\_\_\_\_  
 Y/ m/ d

Physical Activity Readiness Questionnaire (PAR-Q)

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

- |                                                                                                                                                                      | YES                      | NO                       |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|
| 1. Has your doctor ever said you have heart trouble?                                                                                                                 | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Do you frequently suffer from pains in your heart or chest?                                                                                                       | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Do you often feel faint or have spells of serious dizziness?                                                                                                      | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Has a doctor ever said your blood pressure was too high?                                                                                                          | <input type="checkbox"/> | <input type="checkbox"/> |
| 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? | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Is there a good physical reason not mentioned here why you should not follow an activity programme even if you wanted to?                                         | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Are you over age 69 and not accustomed to vigorous exercise?                                                                                                      | <input type="checkbox"/> | <input type="checkbox"/> |

\_\_\_\_\_  
 signature

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APPENDIX G  
PERSONAL DATA SHEET (DAY 1)

DEPARTMENT OF KINANTHROPOLOGY  
UNIVERSITY OF OTTAWA  
CLINICAL FITNESS RESEARCH APPRAISAL PROGRAM

E.K.G. ☐  
BLOOD ☐  
CHFT ☐  
GLAZER ☐  
QUEST. ☐  
CONSENT  
FORM ☐

PERSONAL DATA

FAMILY NAME: \_\_\_\_\_ LAB NO: \_\_\_\_\_  
GIVEN NAME: \_\_\_\_\_ DATE OF TEST: \_\_\_\_/\_\_\_\_/\_\_\_\_  
AGE: \_\_\_\_\_ YR. \_\_\_\_ M. \_\_\_\_ D. \_\_\_\_

RESTING MEASUREMENTS

H.R. \_\_\_\_\_ (60 sec) S.B.P. \_\_\_\_\_ D.B.P. \_\_\_\_\_

ANTHROPOMETRIC DATA

HEIGHT STANDING (M) \_\_\_\_\_ WEIGHT (kg) \_\_\_\_\_

GIRTHS (cm)

|                | 1     | 2     | MEAN  |
|----------------|-------|-------|-------|
| Chest: _____   | _____ | _____ | _____ |
| Abdomen: _____ | _____ | _____ | _____ |
| Gluteal: _____ | _____ | _____ | _____ |
| Thigh: _____   | _____ | _____ | _____ |

SKINFOLDS (mm)

|                   | 1     | 2     | MEAN  |
|-------------------|-------|-------|-------|
| Triceps: _____    | _____ | _____ | _____ |
| Biceps: _____     | _____ | _____ | _____ |
| Sub-Scap: _____   | _____ | _____ | _____ |
| Suprailiac: _____ | _____ | _____ | _____ |

STRENGTH - FLEXIBILITY - MUSCULAR MEASUREMENTS

| Grip Strength (kg) |       | Upper Body Strength (kg) |       | Trunk Flexion (cm) |
|--------------------|-------|--------------------------|-------|--------------------|
| Right              | Left  | Push                     | Pull  |                    |
| 1) _____           | _____ | _____                    | _____ | _____              |
| 2) _____           | _____ | _____                    | _____ | _____              |
| Max. _____         | _____ | _____                    | _____ | _____              |

Sit-ups (N/60 sec.): \_\_\_\_\_

Push-Ups (N): \_\_\_\_\_

BLOOD BIOCHEMICAL ANALYSIS:

|                              |                 |
|------------------------------|-----------------|
| Cholesterol (mg/dl): _____   | CHOL/HDL: _____ |
| Triglycerides (mg/dl): _____ | LDL/HDL: _____  |
| HDL (mg/dl): _____           | HDL/LDL: _____  |
| LDL (mg/dl): _____           |                 |

PERSONALITY PROFILE:

|         |              |                   |
|---------|--------------|-------------------|
| GLAZER  | TOTAL: _____ | TYPE: _____       |
| EYSENCK | E: _____     | N: _____ L: _____ |

CANADIAN HOME FITNESS TEST

Pre-ex. Measurement: H.R. \_\_\_\_\_ (b/60sec.) S.B.P. \_\_\_\_\_ D.B.P. \_\_\_\_\_

Post-ex. Heart rate: (0:05 - 0:15)

STAGE: \_\_\_\_\_ (b/10 sec.)

STAGE: \_\_\_\_\_ (b/10 sec.)

STAGE: \_\_\_\_\_ (b/10 sec.)

Post-ex. Blood pressure: (0:30 - 1:00)

S.B.P. \_\_\_\_\_

D.B.P. \_\_\_\_\_

Post-ex. Blood pressure (2:30 - 3:00)

S.B.P. \_\_\_\_\_ D.B.P. \_\_\_\_\_

Heart rate (3:00 - 3:15)

H.R.: \_\_\_\_\_ (b/60 sec.)

Examiner \_\_\_\_\_

APPENDIX H  
TRACOMETER TEST RECORD SHEET

# STRESSALYSER TEST RECORD

CASSETTE

No. SIDE

Use a new Record Sheet for each side of the Cassette.

EXPERIMENT  
CONTROL UNIT

| TEST INFORMATION |      |      |             | DECODING INFORMATION |         |            |            |          |          |          |             |                              |          |
|------------------|------|------|-------------|----------------------|---------|------------|------------|----------|----------|----------|-------------|------------------------------|----------|
| RUN              | TEST | DATE | TIME of DAY | PRO-GRAM             | SUBJECT | TOTAL TIME | TAPE COUNT | DEC; No. | DATA SUM | EDI; No. | CORRECTIONS | FACTOR LEVELS<br>1:2:3:4:5:6 | LAB; No. |

Make an entry each time START is pressed, whether or not the run is completed

|   |  |  |  |  |  |  |  |  |  |  |  |  |  |
|---|--|--|--|--|--|--|--|--|--|--|--|--|--|
| 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 4 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 5 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 6 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 7 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 8 |  |  |  |  |  |  |  |  |  |  |  |  |  |

Check amount of unused tape before continuing

|    |  |  |  |  |  |  |  |  |  |  |  |  |  |
|----|--|--|--|--|--|--|--|--|--|--|--|--|--|
| 9  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 10 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 11 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 12 |  |  |  |  |  |  |  |  |  |  |  |  |  |

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|              |         |        |          |
|--------------|---------|--------|----------|
| EXPERIMENTER | DECODER | EDITOR | LABELLER |
|--------------|---------|--------|----------|

REMARKS

APPENDIX I  
GUIDELINES

UNIVERSITY OF OTTAWA - DEPARTMENT OF KINANTHROPOLOGY

**RESEARCH PROJECT**

ON

**PHYSICAL ACTIVITY AND FINE MOTOR PERFORMANCE**

Your evaluation is scheduled for:

DATE: \_\_\_\_\_

TIME: \_\_\_\_\_

ROOM: \_\_\_\_\_

ADDRESS: \_\_\_\_\_  
\_\_\_\_\_

If you cannot keep your appointment, please call 231-5946 ext. 8  
and ask for:

Josee Barsalou or Jean-Luc Leblanc

or leave a message with the Dept. secretary.

The following are some guideline in order to achieve  
standardization of measurments:

1. Please avoid exercise and other energetic bodily activities for 6 hours prior to the test.
2. Do not ingest a heavy meal before beginning the test; eat a light meal, if necessary, at least 2 hours before evaluation.
3. Do not smoke or drink coffee and tea for two hours prior to the test and refrain from alcoholic beverages for 6 hours.
4. Bring a pair of shorts, running shoes and a towel.

Thank you for your cooperation.

APPENDIX J  
CONSENT FORM (DAY II)

UNIVERSITY OF OTTAWA - DEPARTMENT OF KINANTHROPOLOGYRESEARCH PROJECTONPHYSICAL ACTIVITY AND FINE MOTOR PERFORMANCE

## Consent form

I, \_\_\_\_\_, hereby volunteer to take part in a research experiment designed to investigate the effect of a low and a moderate intensity work load on my tracking skills.

I understand that I will walk on a portable motor treadmill for two 10 minute sessions of exercise separated by a 15 minute rest period. I will first of all be given 8 trials of the tracking task on the trackometer followed by a 10 minutes walk on a motor treadmill at a speed of 3.0 mph and at a grade of 7.5% in order to establish a heart rate in the range of 130 bpm. Immediately after the end of the 10 minutes walk I will be transferred from the treadmill back to the tracking apparatus where I will complete 4 more trials. During the following 15 minutes period I will rest, remaining in the same room. After this rest period I will step back onto the treadmill for a walk at a speed of 3.5 mph and at a grade of 12% in order to establish a heart rate in the range of 160 bpm. Immediately following the end of the 10 minutes walk I will once again be transferred from the treadmill back to the tracking apparatus for 4 more trials. My heart rate will be monitored at rest, during the exercises and during the tracking task periods by a portable electrocardiogram. Blood pressure will be measured and recorded at rest and during exercise at periodic intervals. The test will be discontinued if I become distressed in any way or develop any abnormal response or whichever of the above occurs first. Every effort will be made to conduct the test in such a way as to minimize discomfort and risks. However, I understand that in agreeing to participate in this experiment, I waive any legal recourse against the examiners for any and all claims resulting from personal injuries sustained or death resulting from this experiment. This waiver shall be binding upon my heirs, my executors, my administrators and my personal representatives.

Date: \_\_\_\_\_

Subject: \_\_\_\_\_

Witness: \_\_\_\_\_

APPENDIX K  
LIFESTYLE QUESTIONNAIRE II

## UNIVERSITY OF OTTAWA - DEPARTMENT OF KINANTHROPOLOGY

RESEARCH PROJECTONPHYSICAL ACTIVITY AND FINE MOTOR PERFORMANCE

## LIFESTYLE QUESTIONNAIRE II

I. Have you done any vigorous physical activity today?

☐ Yes

☐ No

If yes, could you specify: \_\_\_\_\_  
\_\_\_\_\_

## II. Smoking

A. Please circle the MOST appropriate response

☐ Smoker

☐ Ex-smoker(stopped)

☐ Non-smoker

B. If smoker then: ☐ Cigarettes ☐ Pipe ☐ Cigars ☐ Other

C. Amount smoked up to now today: \_\_\_\_\_

D. Amount smoked per day: \_\_\_\_\_

E. Number of years as: An ex-smoker: \_\_\_\_\_ A smoker: \_\_\_\_\_

## III. Coffe intake

A. Do you drink coffe?

☐ Yes

☐ No

B. Number of cups today? \_\_\_\_\_

C. Average number of cups per day? \_\_\_\_\_

## IV. Tea intake

A. Do you drink tea?

☐ Yes

☐ No

B. Number of cups today? \_\_\_\_\_

C. Average number of cups per day? \_\_\_\_\_

## V. Alcohol consumption

A. Do you

☐ Presently drink

☐ Occasionally drink

☐ Ex-drinker

☐ Never drank

B. Did you consume alcohol today?

☐ Yes

☐ No

APPENDIX L  
PERSONAL DATA SHEET (DAY II)

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## UNIVERSITY OF OTTAWA - DEPARTMENT OF KINANTHROPOLOGY

## RESEARCH PROJECT

ON

## PHYSICAL ACTIVITY AND FINE MOTOR PERFORMANCE

## DATA SHEET

Name: \_\_\_\_\_ Lab No.: \_\_\_\_\_  
 Time: \_\_\_\_\_ Date: \_\_\_\_\_  
 Room temperture: \_\_\_\_\_ °C Age: \_\_\_\_\_

1. Resting measurements (pre-test):

HR: \_\_\_\_\_ (bpm) SBP: \_\_\_\_\_ DBP: \_\_\_\_\_

2. Trackometer trials (N=8):

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

3. Treadmill measurements (3 mph, 7.5%):

3.A (4:50min)HR: \_\_\_\_\_ (bpm) SBP: \_\_\_\_\_ DBP: \_\_\_\_\_

(9:40min)HR: \_\_\_\_\_ (bpm) SBP: \_\_\_\_\_ DBP: \_\_\_\_\_

3.B Perceived exertion rating: \_\_\_\_\_

Observations: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## 3.C Post-treadmill measurements:

Beginning of the first mov. HR: \_\_\_\_\_ (bpm)

After 1 minute HR: \_\_\_\_\_ (bpm)

After 2 minutes HR: \_\_\_\_\_ (bpm)

After 3 minutes HR: \_\_\_\_\_ (bpm)

After 4 minutes HR: \_\_\_\_\_ (bpm)

After 5 minutes HR: \_\_\_\_\_ (bpm)

---

---

4. Resting measurements(After 14 min. of rest):

HR: \_\_\_\_\_ (bpm) SBP: \_\_\_\_\_ DBP: \_\_\_\_\_

---

---

5. Treadmill measurements (3.5 mph, 12%):

5.A (4:50min)HR: \_\_\_\_\_ (bpm) SBP: \_\_\_\_\_ DBP: \_\_\_\_\_  
(9:40min)HR: \_\_\_\_\_ (bpm) SBP: \_\_\_\_\_ DBP: \_\_\_\_\_

5.B ~ Perceived exertion rating: \_\_\_\_\_

Observations: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

5.C Post-treadmill measurements:

|                             |                 |
|-----------------------------|-----------------|
| Beginning of the first mov. | HR: _____ (bpm) |
| After 1 minute              | HR: _____ (bpm) |
| After 2 minutes             | HR: _____ (bpm) |
| After 3 minutes             | HR: _____ (bpm) |
| After 4 minutes             | HR: _____ (bpm) |
| After 5 minutes             | HR: _____ (bpm) |

2

APPENDIX M

BORG'S RATE OF PERCEIVED EXERTION SCALE

THE BORG SCALE FOR RATING 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 |                  |

## APPENDIX N

CORRELATION COEFFICIENTS BETWEEN THE PERCENTAGE OF BODY FAT  
AND PERFORMANCE PARAMETERS AS MEASURED BY THE TRACOMETER

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Pearson product moment correlation coefficients between percentage of body fat and performance parameters as measured by the tracometer during pre-exercise trials (16 and 20) and post-exercise trials (17 and 21) (N=50).

| TRIAL           |            | PERFORMANCE PARAMETERS (ms) |       |        |        |
|-----------------|------------|-----------------------------|-------|--------|--------|
|                 |            | TRT                         | CRT   | MVT    |        |
|                 |            |                             |       | NOMT   | OMT    |
| 16              | % body fat | 0.069                       | 0.064 | 0.040  | 0.185  |
| 20              | % body fat | -0.060                      | 0.107 | -0.012 | 0.019  |
| 17 <sup>a</sup> | % body fat | -0.040                      | 0.047 | -0.044 | 0.067  |
| 21              | % body fat | -0.055                      | 0.076 | -0.173 | -0.110 |

a For trial 17, N=49

\*  $p < .05$