An Ergonomic Evaluation of Occupational Stress in Professional Football

by

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In any discussion of physical fitness, reference is properly made to athletes as they exemplify the best or fittest individuals, amongst whom are the world record-holders for varying feats of physical performance. But it has become obvious that there is not one class of individuals who can be labelled 'athletes', and about whose characteristics valid generalisation can be made.

(Edholm, 1969).

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Summary

This thesis describes an investigation of occupational stress in professional football. This necessitated assessment of the strain imposed on players in training, competition and habitual contexts and of their capacity to meet strain levels encountered. Capacity was evaluated from the results of a multi-item test battery which included physical, physiological and psychological fitness parameters.

Subjects comprised the complete professional playing staff of an English First Division soccer team. Fitness tests were administered at critical points during the season. Fitness profiles were significantly altered by a six week pre-season training programme, improvements being largely confined to the circulatory system. Leg power was below maximum potential at the start of the year's competitive programme. In general, fitness was maintained throughout the competitive season. Subjects showed increased drive and reduced apprehensiveness at the end of the League programme. It was possible to discriminate between First Team and Reserves on the basis of fitness data, discriminability being improved after principal component analysis of test items. Multivariate analysis of the test battery allowed extraction and identification of factors of fitness which endured through the season. The factor accounting for the greatest proportion of total variance at each test was identified as relating to body size.

Emotional tachycardia was the criterion of pre-match psychological stress. Mean heart rate prior to match play was 87 beats/min in players, who showed higher rates than substitutes. Psychological stress was greater at home than at away games, and was greater at F.A. Cup than at League games. Results showed evidence of a habituation to competition stress. No significant correlations were found between

the pre-match anxiety reaction and invidividual or team performance.

A methodology incorporating motion analysis for the quantification of work rate during competition was devised and validated. Match play typically involved about 900 separate movement activities. Differences were found in distance covered per game between positional roles, the work load being greatest in mid-fielders and least among outfield players in centre-backs. A significant positive correlation was obtained between distance covered per game and predicted maximum oxygen uptake. Distance covered per game was found to correlate negatively with muscular power. Results permitted identification of critical attributes for particular positional roles. A decrement in performance over the second period of play was observed.

Heart rate during training was employed as the indicant of physiological strain. Mean heart rate monitored in training for a complete week in 23 subjects was 132 beats/min. Mean duration of daily training was 75 min. Work was greatest in intensity and duration on Wednesday. A classification of the components of a training session was devised. Games were found to accurately simulate the demands of competition and were given greatest temporal emphasis. In no other routine was the intensity of competition stress presented. Mean heart rate during games was 157 beats/min in outfield players and 125 beats/min in goalkeepers. Energy expenditure during this routine was estimated to be 16·4 kcal/min. Only in two other routines, drills and running, did work intensity exceed the threshold evoking adaptive physiological responses. Performance tests administered in training were unreliable when endurance was a test factor. The training was critically appraised as preparation for competition from an examination of results.

A retrospective analysis of injury records for one season was made.

injuries incurred in competition were the major source of absence from work. Frequency of injury was 1 per 11•7 player exposures in the First Team and 1 per 16 player exposures among all categories of representative teams. Results highlighted the vulnerability of the lower limb in soccer, the knee being the major site of severe injury. No physical attribute was identified as a predictor of injury proneness. A significant correlation was found between joint injuries and apprehensiveness.

Daily energy transformations were slightly higher than normal values but calorific requirements were not exceptional. The majority of the day, amounting to 19•5 hours, was spent in inactivity. Energy expenditure during the 18•5 working hours per week was estimated to be 6•9 kcal/min. The occupation was described as moderate work.

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SECTION ONE

INTRODUCTION

1. INTRODUCTION

1.1. The Concept of Stress

Stress is a polymorphous concept. The meaning assigned to the term "stress" has in the past depended on the viewpoint of the researcher, the situation in which observations were made or the variables measured. Earlier behavioural scientists considered the affecting situation as stress, while at other times definitions were based on changes in performance characteristics. More recent investigators have inferred that stress is an intervening variable located between the situational input and the movement output (Cratty, 1973).

The concept of stress as an internalised preparation to meet an immediate or future threat, temporarily inducing biological imbalance, was presented by Selye (1956) in his general stress theory. This involves identification of a General Adaptation Syndrome (GAS) relating to the non-specific adaptation of the organism to general impingement or to disruptive events. GAS is evidenced in increased adrenal, pituitary and thymus gland activity and is temporally divisible into the alarm stage, the stage of resistance or adaptation stage and the exhaustion stage. According to Selye, stressors might include exercise, injury, infection, environmental conditions or frustration.

During the alarm stage the organism responds first by a depletion of resistance followed by a surge of vigorous overcompensation during which the body adjusts to the particular stress. If the stress continues to draw on adaptation energy the extension effectuates a stage of exhaustion during which the functional efficiency of the organism is impaired and eventually breakdown ensues. Though Selye's theory is largely an abstraction as the physiological constituents of adaptation energy were unexplained, Carlile (1956) noted its correspondence with his own empiric observations on the reactions of swimmers to their training regimes. The search for the optimal training stimulus can be described as treading the thin line between training and straining. This represents the margin between useful maximal load and harmful overload. Training for competitive sport involves a spiralling upward cycle of load-fatigue-recovery.

In a more recent application of Selye's theory to exercise physiology, Cureton (1969) expanded the three into five stages:-

1. Alarm (marked sympathetic excitement).
2. Resistance (adjustment to the stress).
3. Trained haemodynamics (holding the trained state without harm).
4. Overtraining (temporary exhaustion).
5. Possibility of death (seldom seen).

In this definition, overtraining is seen as a harmful acute stage to be avoided in the sportsman, if possible. The sportsman will achieve his optimal performance in Stage 3.

Ogilvie and Tutko (1966) listed attitudinal correlates of the GAS to describe the positive side of the part played by wholesome anxiety (sic). Ideally the physiological and psychological factors converge to interact harmoniously to enhance physical efficiency.

Antithetical to the generalised response of Selye is the suggestion of Lacey (1950) that there is variability between individuals in the quality of their responses to stress. An individual's somatic reactions have a distinct pattern which is consistent between different stresses. Graveling and Brooke (1974) cited evidence which suggests intra-individual variations in response to different stresses.

Singleton et al (1971) expressed disillusion with the imprecision of the concept of stress as found in the literature. They suggested some clarification is obtained by adopting the engineering convention of using stress in the sense of a deforming force or stressor and strain for the resultant deformation or the reaction of the stressee. Stress sources may be work or the environment. Strain can be measured using physiological or psychological techniques. Physiological methods might involve monitoring of chemical, electrical or physical parameters, while psychological methods require measurement of performance, activity or subjective states. Work and environmental variables can be quantified and the results juxtaposed on the strain measurements. The internal environment of the organism monitors changes in the external environment to maintain constancy. This phenomenon was first identified by Bernard (1865) who emphasised the constancy of the internal milieu as a prerequisite for what he termed free and independent existence. Cannon (1939) stressed the constancy of stability and coined the term homeostasis to designate the co-ordinated physiological processes which maintain most of the steady states in the organism. The term was meant to describe a condition which may vary but which is relatively constant. The concept provided an insight into the process of continuous physiological adaptation to progressively increasing levels of stress.

Continuous adaptation is implied in the principle of overload. The theory, at first applied to the musculo-skeletal system, stated that only when a muscle is required to function with an intensity greater than normal does the muscle hypertrophy. The principle is applied to the organism as a whole in the law of use and disuse which indicates that structure is modified by function. Use through movement, exercise or activity, is a factor determining well-being while disuse through inactivity brings about deterioration of function. Steinhaus (1963) indicated that overload is a mechanism through which the heart, lungs, muscles and other bodily systems develop for maximal efficiency. The principle is applied in physical training to reduce the risk of injury occurring during competition. Corbin (1971) outlined three factors to be recognized concerning optimal benefits of overload: (a) the specificity of overload, (b) that overload should be progressive, (c) bouts of exercise overload should be accompanied by regular rest periods so that recovery occurs from the stress induced by the exercise per se.

Structural adaptations develop slowly and include the increase in heart and muscle mass and the expansion of intracellular elements. A second type of adaptation involves a regulatory response where the functional connections within the nervous system are established. The time course is quite rapid and the new patterns of regulation may be fully developed within a few weeks (Shephard, 1972). Ekblom (1969) outlined three phases in which adaptation occurs. In the first phase there is an increase in maximum oxygen uptake which he associated with a re-distribution of blood flow and an increased muscle mass. The duration of this phase is six months or more. During the second phase of training, relatively small changes occur in static dimensions which include heart volume, blood volume, red blood cell volume. During the third phase, following many years of training, the athlete is able to work closer to his maximum oxygen uptake for prolonged periods of time.

1.2. The Ergonomics perspective

A satisfactory perspective from which to study the problems of stress is provided by ergonomics. This embodies an interdisciplinary approach to the study of the human operator in his interaction with his work and working environment. It embraces the human sciences, utilises physiological, psychological and anthropometric research while devising unique evaluative techniques to solve problems. It focuses on problems and fundamental principles of human performance.

An *a priori* assumption in many studies of human performance is that the human has limited capacity (Welford, 1973). Capacity refers to current ability and is manifested in a ceiling in function. This sets limits to both quantitative and qualitative aspects of performance. The dimensions of work are its intensity, its frequency and its duration. Factors which place upper limits to these dimensions and to the quality of work can be bio-chemical, anatomical, psychological or physiological. The physiological factor might be one of a number of physiological systems, the critical work-level being determined by the least efficient link in the chain of variables contributing to performance. The provision of techniques for the quantification of limits to performance within populations and within individuals is a mandate of ergonomics.

An observation which follows is that capacity can be altered by appropriate training procedures in accordance with the principle of overload. Adoption of training regimes embraces a philosophy of fitting the man for the job. This is illustrated by Murray (1963) who demonstrated that a six-week programme of progressive resistance training enabled gun-crews to keep a new mechanical loader, which they had hitherto been unable to operate, supplied with heavy shells. There is a minimum training stimulus threshold below which overload does not take place and no improvement in capacity is effected.

The degree of improvement in capacity with an optimal training stimulus is itself limited. Potential represents the additional improvement in capacity that will be effected by training. It will vary with the subject, his initial state of fitness and the biological system that is being trained. Munrow (1963) suggested 50% approximates the order of improvement possible with regard to muscle strength. Åstrand (1967) regarded an increase in maximum aerobic work power of 20% as a good result of training. Gollnick et al (1973) demonstrated adaptation of muscle to endurance training is greater than the adaptation of the oxygen transport system and can exceed 100%. Because the effects of training are limited to this order of magnitude and individual differences are greater, genetic factors are important for a good performance potential.

A training regime may produce general benefits,as when an improved oxygen transport system facilitates the performance of endurance work, or its benefits may be specific. Karvonen (1959) concluded that to some extent changes effected by training in parameters of the cardio-vascular system were independent of each other. Morehouse (1960) demonstrated that training a muscle may strengthen it for one task but not another. Specificity studies typified by Henry and Berg (1950) lead to the conclusion that psychological factors as well as physiological limits determine performance.

A further characteristic of a training effect is its reversibility. This is a corollary of the law of use and disuse. Any improvement in functional efficiency will regress if training is discontinued. The rate of regression may be a function of the training procedure initially employed.

The proportion of the individual's working capacity deployed in the working situation depends on the relative severity of that work. In some competitive sports the performer is forced to work at or close to his maximum. In complex multi-dimensional work-situations, a taxonomy of requisite abilities is not immediately palpable. The job can be broken down into its constituent tasks. A conceptual framework for applying task analysis based on hierarchical breakdown to sports situations has been proposed by Stammers (1974). A field invasive sport like soccer can be seen as comprising a job which circumscribes a number of tasks. The allocation of tasks or sets of tasks to individuals within the team is based on a judgement of team management. It may be that individuals exchange tasks in the dynamics of the competitive situation. The profile of tasks is tailored to the profile of abilities of the individual. The philosophy is one of fitting tasks to the man by tactical considerations. Preparation for competitive team sport consists of synchronously fitting each man for his job and fitting the job to the man by appropriate procedures of training, selection and strategy decisions. The sum total of team members' jobs is circumscribed by the overall job of the team which in the context of competitive sport is essentially fixed. A comprehensive study of football should embrace an analysis of the interface between the performer, his work in its multi-variate forms and the total working environment.

Work imposes a load on the performer and may be manifested as strain in physical, physiological and psychological terms. Where demands are rigid and excessive, the more suitable performers are those capable of meeting the demands. In these instances selection could be based on evaluative techniques which test fitness. The work of Hagerman and Howie (1971) with New Zealand's international rowing crew is paradigmatic of the use of physiological variables in selection. An example of the application of scientific principles to the training and selection of South African rowers was offered by Strydom et al (1967).

1.3. The concept and the measurement of fitness

According to Darling's (1947) definition, "fitness consists in the ability of the organism to maintain the various internal equilibria as closely as possible to the resting state during strenuous exertion and to restore promptly after exercise any equilibrium which has been disturbed". Cummings (1967) defined fitness as the capacity to do physical work and to recover quickly and completely from doing this work. Durnin (1967) took fitness to mean a state where the body - particularly the muscular, cardiovascular and respiratory systems - reacts to hard physical work in a manner near to the ideal and where minimal stress is caused. Taylor et al (1963) considered maximum oxygen uptake ($\dot{V}O_{2\,max}$) was the best single index of general fitness, though no one test of fitness existed. A more reasonable approach is to view fitness as multi-factorial in nature and fitness criteria should relate to the context in which the performance takes place. An index of fitness can only have established meaning in terms of the task to be accomplished.

According to Clarke (1967), early pioneers of fitness testing were trained in medicine and turned their attention to constructing anthropometric tests to evaluate exercise programmes. Sargent (1921) shifted emphasis to assessment of muscular strength and to performance measurement. Measurement of the efficiency of the circulatory system developed as it began to be considered the common denominator of physical fitness. Initially these tests were at rest or during mild exercise and there was an obvious need for new measurements which would be indices of available reserves. Exercise tests evolved which may be described as submaximal or maximal depending on the response induced in the subject.

The Schneider test (1920) was the earliest of the more comprehensive cardiovascular tests. This six-item test comprised resting pulse rate and systolic pressure, the increment in both variables with standing, pulse rate after exercise and its rate of return to normal standing after exercise. A step-test for clinical medical assessment was used by Master and Oppenheimer (1929). The test is still considered standard by many cardiologists for the detection of coronary insufficiency. The Harvard Step Test was constructed for college men, used during the second world war for the selection of combat officers and later became widely used for the testing of athletes (Brouha, 1943). A fitness index is computed based on the effects of a controlled work-load on the post-exercise pulse rate and on its rate of recovery. Meyers (1969) found high reliability for this test and Chrastek et al (1965) emphasised its value in the testing of sportsmen. Åstrand and Rhyming (1954) equated aerobic capacity with physical fitness and developed a nomogram for the calculation of the aerobic capacity from the pulse response to a fixed submaximal work load. The aerobic capacity depends on the maximum oxygen uptake ($\dot{V}O_{2\,max}$) and is generally taken as synonymous with it. Later, Åstrand (1967) used the pulse rate per minute at the end of a fixed continuous submaximal work-load as an index of fitness.

1930 saw the establishment of a sports psychology laboratory in which the temperament as well as the motor abilities of athletes was studied (Griffiths, 1930). This pointed the way towards a more holistic evaluation of the sports performer and the defenestration of Cartesian dualism from the concept of fitness.

Variations in protocol for fitness testing and disagreement on basic ideas have prompted (a) the use of multi-variate procedures and (b) the attempt to standardise tests. Multi-variate procedures were employed by Fleischman (1961) who used factor analysis to identify components of psychomotor and motor abilities. Factor analysis of various cardiovascular-respiratory tests was performed by Cureton (1947) and Larson (1947). Various factor analyses carried out in the area were studied by Cureton (1966). Falls et al (1965) used factor analysis and multiple regression techniques to develop physical fitness test batteries and an operational definition of physical fitness in terms of the variables used to assess it.

Weiner and Louire (1969), arising from the human adaptability project of the International Biological Programme, have recommended procedures for measurement in human biological studies. They advised measurements should only be undertaken by trained personnel. Assessment protocols were outlined for anthropometry,work capacity and pulmonary function, morphological measurements in work capacity and pulmonary studies, assessment of habitual physical activity, performance tests and medical and metabolic studies. Shephard et al (1968) have carried out experiments with a view to setting standards for submaximal exercise testing which were sought by both the World Health Organisation and the International Biological Programme.

Asmussen (1969) defined physical fitness as "a degree of conformity to accepted standards of a given criteria". As criteria to be considered from a physiological point of view he listed mobility, muscle strength, anaerobic power, aerobic power and endurance, and neuromuscular co-ordination. Multi-variate analyses to study the relationships between motor performance and personality have been employed by Kane (1972). Uni-variate methods have been used for the same purpose by Tillmann (1965). That there are pre-requisites in personality factors for top-class performance in sport has been underlined by Ogilvie (1968). This suggests that personality assessment ought to be included in a battery of measurements of fitness for top-class sport. The suggested battery would involve an extensive evaluation of capacity using anthropometric, physiological and psychological techniques.

1.4. Occupational stress in professional footballers

In the initial formulation of Selye's theory, exercise constituted a specific stressor. That the atmosphere of top-class competition imposes intense psychological stress on all contestants, both in anticipation of and during competition, has been stated by Shephard (1968). The outcome is expressed as strain in the circulatory system, which he equated with an anxiety reaction. Von Euler (1964) emphasised individual differences in reaction to a specific disturbing mental stressor. Professional footballers participate at least once a week before large audiences, a context which can reasonably be presumed to constitute an intense psychological stressor. It is not known if professional footballers habituate to this or if there are long-term psychological adjustments to the overall demands of their occupation.

The amateur and professional sportsman differ in a fundamental respect. The commitment of the amateur performer to his sport is of a voluntary nature as is his submission to a training regime advised by his coach. The professional chooses a specific sport as his occupation. His competitions are imposed, usually fixed well in advance. His hours of training and training regime are determined by his management staff. His occupation is located in sport, a context which to the amateur and to other members of society constitutes non-work.

The concept of professional life-space presented by Parker (1971) includes all time taken up by professional considerations as hours of work. 'Life-space' means the total of activities or ways of spending time that people have. Parker proposed a time scheme for the analysis of life-space into work-time and non-work time; work-time may be subdivided into work and work obligations. A study of occupational stress in soccer requires consideration of factors operating within working hours. In addition to time spent training, professional life-space covers time spent travelling as a group to training environs or to competition venues. Work obligations might include time spent in voluntary individual training.

Analogous to professional football is the acting profession. Both entertain large audiences during their major performances. Both involve long periods in training and rehearsals in preparation for the public performances. Training and rehearsals for each occupation constitutes work. It is pertinent that footballers refer to their everyday routine as "going to work".

It is conceivable that aspects of life-style and habitual activity might have repercussions within professional life-space. There are unwritten rules in the case of high-performers in amateur sport which restrict dimensions of habitual activity. These codes are inscribed into the regulations of professional football clubs. It is not unreasonable to suppose that habitual activity could effect fitness and ultimately be reflected in performance and is relevant in a consideration of stressors in professional football.

The circumstances where stressful situations can confront the footballer can be divided into pre- and post-competition, competition, training and habitual activity. A taxonomy of occupational stressors is proposed:-

1. Competition - (a) psychological (pre-match anxiety): circulatory strain elicited by the anxiety reaction.

(b) physiological: work output and circulatory strain.
(c) physical: injuries and critical incidents.

2. Training - (a) physiological: circulatory strain.
(b) physical : injuries

3. Habitual activity - (a) physiological: daily energy metabolism.

4. Long-term - (a) psychological: personality factors.
(b) physical condition: seasonal fluctuations in fitness profiles.
(c) physical: chronic injuries.

1.5. PREVIOUS RESEARCH IN SOCCER

1.5.1. Assessment of footballers

Age, height and weight of eighteen professional footballers at Tottenham Hotspur F.C. were reported by Davies (1973). Mean age was 26·4 (S.D. = 3·3) years, mean height 178·5 (S.D. = 5·3) cm, mean weight 77·5 (S.D. = 5·7) kg. Data on height, weight, percentage body fat, $\dot{V}O_{2\,max}$ and $\dot{V}_{E\,max}$ for nine professional footballers at Aberdeen F.C. were reported by Williams et al (1973). The soccer players were significantly smaller (mean height 174·6; S.D. = 2·9 cm) and had significantly higher $\dot{V}O_{2\,max}$ values (mean 57·77; S.D. = 6·5 ml/kg/min) than University rugby players. The mean weight of the Aberdeen players was 69·4 (S.D. = 6·3) kg.

Caru et al (1970) examined ninety-five non-professional footballers aged 14-18 to compare their values of maximal anaerobic and maximal aerobic ($\dot{V}O_{2\,max}$) muscular power with the corresponding average values of the population. The average value of $\dot{V}O_{2\,max}$ at each stage was not significantly different from that of sedentary subjects of similar age ($p > \cdot05$). The mean values for anaerobic muscular power were about 12% higher in the athletic group, the differences being significant at all ages. When players were subdivided into six groups according to their tasks - goalkeeper, back, half, wing, forward and centre-forward - the highest values of $\dot{V}O_{2\,max}$ were observed in the wings, the lowest among goalkeepers. Only the difference between the goalkeeper group and the other five groups was statistically significant. There were no significant differences in anaerobic power between any of the six groups. The authors did not indicate the competitive standard of their subjects' weekly match. Their conclusions that the performance of the football players does not necessarily require an appreciably high aerobic power should not be adopted as applicable to professional football in view of this and the age of their subjects.

Da Silva (1973) put intelligence highest on the list of psychological aptitudes for excellence in soccer. His protracted list of personality requirements were backed by theoretical considerations rather than research. Ogilvie and Tutko (1966) claimed to have identified personality dimensions which are essential to competitive success. The successful top-class competitor is highly-driven, dominant, emotionally stable, conscientious, conservative and realistic. Cratty (1973a) concluded that athletes are generally high in intelligence, are likely to be extraverted and possess stable traits evidencing emotional control and tough-mindedness. Cooper (1969), in a review of the current state of knowledge, cited evidence supporting in general the notion that athletic ability goes with a greater motivation to achieve, greater social adjustment and ascendancy, and higher emotional stability. The point was underlined that the psychology of team membership may be different in important ways from the influence of physical activity on individuals. Kane (1968) emphasised that although one can point to personality differences in those who make up successful soccer-teams, the variation is not great and a "soccer-type" can be described. This type is a "stable, extraverted, tough-minded radical of good general ability and ruthless efficiency".

Cooper and Payne (1972) studied personality orientations and performance in seventeen English League First Division teams. The more successful teams were found to have significantly more players who were high in self-orientation and low on both interaction and task-orientations. The criterion of success was the number of League points obtained at the end of a season. The investigation contained a risk of *post hoc propter ob hoc* reasoning, while the fact that the inventory was administered towards the end of the competitive season when League positions were relatively well consolidated does not suggest a useful predictive tool.

Yaffe (1973) administered an adapted sociometric scale to a top team (Ferencvarcs) in the Hungarian First Division and to a bottom team (M.T.K.). Positive relationships existed among many of the successful team while in the unsuccessful team there were a number of solitary players. It was found that players friendly with each other passed the ball to each other significantly more than to those with whom they were not friendly, and when a player was under pressure in a match he tended to pass only to the players he liked. His conclusion was that friendship is the most important factor in passing the ball. It is the present author's subjective impression that in critical situations the alternatives open to a player are more constrained than Yaffe's results suggest, and that the configuration of adjacent players both opponents and colleagues as well as entrained strategies are the determining factors. In addition the implied causal relationship of sociometric states and team success could be an effect of successful performance compatible with a general expectation.

1.5.2. Assessment of the game demands

The oxygen consumed during work is the physiological indicant of the severity of that work. Direct measurement of oxygen uptake ($\dot{V}O_2$)

during a soccer game is impractical, as wearing a respirometer is likely to interfere with the performance to be monitored. In a population of English League professional footballers, collection of expired gas for analysis of O_2 and CO_2 is felt to be socially unacceptable in both the field and laboratory situation.

Durnin and Passmore (1967) quoted a range of 5-12 kcal/min for the energy requirements of soccer. Their subjects were University students kicking a ball about on a pitch. The authors concluded that few players expend 600 kcal in a soccer game and many much less. Covell et al (1965) reported a range of 5•2-10•6 kcal/min, their subjects also were undergraduate students. Muckle (1973) gave an estimate of 800-1200 kcal per match but no indication of how this estimate was arrived at.

Seliger (1968) gave a value of 0•18 kcal/kg/min as the energy demand of playing a soccer game. The weights of his subjects were not given but this works out at 12•6 kcal/min for a 70 kg individual. Mean heart rate during the game was 160 (S.D. = 14•4) beats/min while maximum heart rate was 166 (S.D.= 13•6) beats/min. The circulatory load was equivalent in kayak-paddling (mean heart rate 166 beats/min) but was found to be greater in some other sports examined by Seliger - basketball (mean heart rate 172 beats/min) and ski-running (mean heart rate 180 beats/min). Elsewhere, Seliger(1968a) quoted mean values for soccer of about 165 (sic) beats/min when clearly referring to the same data and supplied further details. His subjects (n = 163, mean age 21•5 years) were examined in a model game lasting ten minutes. No indication was given of their level of skill.

According to Yomaoka (1965) the excess cost of 90 minutes soccer playing over resting metabolism is 588 kcal. Energy expenditure for the game amounts to 696 kcal if 1•2 kcal/min is included for basal metabolism

(Durnin and Passmore, 1967). Relative metabolic requirements (energy demand relative to resting metabolic rate) reported were 1 ∿ 2 for the goalkeeper and 7 ∿ 9 for other players. These low values are likely to have resulted from an underestimate in Yomaoka's calculations which were based on the duration and speed of movements during the game though no reference was made to how these movement parameters were monitored; besides, studies of Japanese subjects may have dubious application for European footballers.

Total distance covered during a game can be used as an index of work-load in view of the linear relationships between work output and energy expenditure. Wade (1962) reported a range of 1750 to 6000 yards for distance covered during ninety minutes competition. The total distance covered at speed was attributed a range of 250 to 2000 yards, and walking or jogging pace a range 1500 to 4000 yards. No indication was given of how these figures were arrived at. At the upper extreme, Vinnai (1973) cited Russian reports of footballers covering up to 17 km during a match. No reference was made to methodology.

Knowles and Brooke (1974) gave a mean value of 5343 yards for Manchester City F.C. outfield players, range 4070 to 7030, over 1 competitive game. Mean value over four games was 5286 yards. Data were obtained by a group of observers employing subjective estimates of distances. The authors claimed a reliability coefficient for their techniques of 0·61 but made no attempt to establish objectivity. Measurements were obtained in units of five yards, a procedure likely to introduce insensitivity into the method.

Zelenka et al (1967) referred to Seliger's observations that a centre-forward runs 11·5 km, expends 13·1 kcal/min amounting to an average of 1183 kcal during a match and metabolism is increased to 1370% of basal metabolic rate. In a review of other studies in training and in matches in Czechoslovakia they stated that footballers run more than 6 km in a match mostly in 5-10 m runs. It was not disclosed how distance was estimated or how energy values were derived. The authors concluded that footballers are under heavy physical strain.

The disparity in data on work-load during competition is highlighted by the observations of Saltin (personal communication, 1973, August 16th). Nine soccer players were studied by taking a movie of each player for a three minute period. Three matches were filmed. Movements of the players were pencilled in on playback on a white paper screen and distances determined from this. It is not clear if parallax errors were accounted for. Mean distance covered was 10·9 km, 37% at walking pace and 20% at maximal speed. Glycogen content (thigh muscle) was found to be depleted in four players at the end of the game.

1.5.3. Training

Fardy (1969) investigated the effects of a ten-week soccer training programme and five weeks detraining on selected cardiac and metabolic measures in eleven members of the University of Illinois soccer team. The training programme resulted in significant improvement of cardiorespiratory endurance, $\dot{V}O_{2\,max}$ increasing by 15·5%. The five week detraining period resulted in significant deterioration of fitness gains. No anthropometric data were given but the trained $\dot{V}O_{2\,max}$ values (mean = 3·35 ℓ/min) do not suggest these were supra-normal individuals.

No physiological investigation of the intensity or duration of training has been made in English professional soccer clubs. Wade's adumbration of the conventional patterned build-up towards week-end competition suggests pronounced day-to-day variations (Wade, 1962, op cit).

1.5.4. Physical stress

Medical aspects of professional association football have been described by Phillips (1970) in a retrospective classification of injuries sustained at Middlesbrough F.C. over the five-year period 1963-68. Muscle and tendon injuries accounted for 43·1% of all injuries while muscle, tendon and joint injuries represented over 75% of the total number of cases seen. The figures underline the vulnerability of the ankle-joint. No suggestions with regard to prognoses were made. The author did suggest the need for "a continual assessment of the training programme, in order to avoid the development of mental and physical fatigue".

Bass (1967) published an analysis of the clinical records at Arsenal F.C. over the six-year period 1960-1966. His paper affords some standardisation for the presentation of injury statistics. The commonest lesion occurring in soft-tissue was muscle damage. Soft-tissue injuries may be extrinsic, i.e. caused by factors outside the players immediate control OR intrinsic, i.e. caused by tear during muscle contraction. Injuries to joints accounted for 35% of the total trauma sustained. Ankle injuries were 50% more common than knee injuries. Frey (1969), in a study of Swiss Olympic Games teams over a number of years, found joint injuries predominant in soccer which had a high frequency of ankle and knee injuries.

In an extensive study, Adams (1973) investigated the incidence of osteoarthrosis in the knee joint of sportsmen. All fifty-one professional footballers at Leeds F.C. and fifteen ex-professionals were examined by clinical and radiological methods. Osteoarthrosis was considered to be probably present in four of the ex-professionals and in none of the active footballers. A postal survey of 1490 professional footballers gave an incidence of 3·2%, suggesting that osteoarthrosis is unlikely to be common among professional footballers. This contradicts the conclusion of Solonen (1966) on studying sixty amateur Finnish footballers, that osteoarthrosis seems to be a characteristic phenomenon of intensive football. His diagnostic criteria were considered by Adams to be of doubtful value.

Adams provided a hypothetical list of some of the variables contributing to injuries in contact sports - "physical fitness, muscular development, timing, balance, skill, assessment of the playing situation, determination, courage, reaction time, playing surface, weather. These are a combination of physical and psychological, internal and external factors". The value of any of these factors as predictors of injuries does not seem to have been investigated.

1.5.5. Habitual activity and daily energy expenditure

No study has been made of the daily energy expenditure of British professional footballers. Durnin and Passmore (1967 op cit) gave a figure of 3200 kcal per day based on a report of the Food and Agricultural Organisation of the United Nations for a reference man, aged 25, weight 65 kg. Kvanta (1972), introducing a symposium where the majority of the research considered was carried out on Italian footballers, gave a figure of 4000-5000 kcal for top athletes engaged in hard training programmes. Daily energy transformations of Finnish athletes were here reported to have increased from 3000-3500 kcal/day in 1968 to 5000-6000 kcal/day with an increase in training distance covered from 70-80 km/week to 250-350 km/week. Kvanta stated that professional athletes have a greater energy demand than amateurs though no factual basis for claiming this was presented. Grafe (1971) reported computed daily energy expenditures of 5350 kcal/74 kg for soccer during the preparatory training period. The standard of performance was not stated and it is not clear if the habitual activity outside of training was investigated. Edwards et al (1935) reported figures of 5600 kcal/day for American university football players and Widdowson et al (1954) cited Schenk's (1936) figures of 7300 kcal/day for Olympic athletes. Muckle and Shepherdson (1975) stated that a footballer may need double the normal daily energy requirement of an average worker but the basis for their statement is obscure.

1.6. Overview

It is apparent that there has not been a multi-factorial assessment of the fitness of professional footballers. A model for the testing of international standard sportsmen from an interdisciplinary perspective has been proposed by Thomas (1970). The proposal was later amplified and the test-items grouped into sub-divisions - circulation, ventilation, anthropometry, strength and personality (Thomas, 1970a). Thomas (1969) subdivided critical circulation needs into cruising efficiency and stress tolerance. The model incorporates provision for items to test for capability requirements specific to the sport investigated and has been employed to evaluate the fitness of international competitors, e.g. the Davis Cup tennis team (Thomas, 1970a op cit), and cyclists (Thomas, 1970 op cit). The test battery embraces all the dimensions of fitness described in Section 1.3.

Fitness for work can only have ascribed meaning when the demands of the work in their variegated forms are established. It is evident there has not been an extensive interdisciplinary analysis of occupational stress among professional footballers. This thesis represents an attempt to initiate the bridging of the gap.

SECTION TWO

BACKGROUND

2. BACKGROUND

During Summer 1972, a fitness consultancy was established between Everton F.C. and Liverpool Polytechnic. The major objective was to test the fitness of the club's professional players and to monitor fitness profiles throughout a full season. The professional playing staff excluding apprentices was the full complement of thirty-one, a limit imposed by regulations of the Football Association.

A test battery designed by Thomas (1970 op cit) was administered in the laboratory by a team of eight Polytechnic staff trained in the test procedures. First and Second Team squads attended on consecutive days. Tests were administered at critical stages during the season to permit comparison of fitness profiles. These points were:

(i) before pre-season training.

(ii) at the end of pre-season training.

(iii) mid-season.

(iv) at end of season.

The data generated by these series of tests were made available to the author by the Director of Physical Education at Liverpool Polytechnic. In addition, performance data obtained by the club's coaching staff during normal training were analysed.

Tests administered covered a range of anthropometric, ventilatory, cardiovascular, personality and performance variables. The laboratory was equipped for functional testing with sphygmomanometer, anthropometer, stadiometer, dynamometer, cable tensiometer, skinfold caliper, vitalograph, electrocardiogram, treadmill, bicycle ergometer, step-up bench, chronoscope. Performance tests and maximal shuttle-run test were carried out in an adjacent gymnasium.

Access to players during their working hours was permitted by club management throughout the 1972-73 season. Specific priveleges allowed were:

(i) inclusion with the club party during both pre-season training and a competitive tour in Sweden. Access to players during sleep was permitted at their training accommodation.

(ii) attendance at all club training sessions. Permission was granted to monitor physiological variables during training using socially acceptable monitoring instruments (SAMIs) and non-invasive techniques.

(iii) inclusion with the team party at home and away matches.

(iv) pre-match access to players until they left the dressing room for the playing pitch.

(v) provision of stand accommodation at a pre-selected location for home and away games.

(vi) access to players for administration of structured questionnaires and collection of personal diary records.

(vii) access to records of absences, illnesses, injuries and treatment kept by the club's physiotherapist.

The First Team competes in the Football League Championship, F.A. Cup and Football League Cup. The Championship involves 42 matches in a 37 week period. The F.A. Cup starts for First Division teams in January, the League Cup starts in September and all matches except the final are played in mid-week. In the 1972-73 season, Everton were eliminated in the fourth round of the F.A. Cup and the first round of the League Cup, in the following season they were eliminated at the same stage of the F.A. Cup and the second round of the League Cup. Four friendly and testimonial games, three in Sweden and one in Scotland, were played before the start of the League Championship, two testimonial games were played during the season and one at the end of the season. At the end of the season the club played exhibition games in Spain in 1973 and in Singapore in 1974. The working year was 45 weeks. An additional competition, the Texaco Cup, was contested in 1973-74 from which Everton was eliminated in the first round. Excluding friendly, exhibition, tournament and testimonial games, the First Team competed in 45 competitive games in 1972-73 and 49 the following season. Two of the staff played for an English representative side, a third represented Scotland during a Summer tour of Europe and a fourth was included in the Welsh international squad for a training week-end during the 1972-73 season.

Demands on professional playing staff were examined in detail during the 1972-73 season. Players returned from vacation on July 10th to undergo a six-week period of pre-season training. The club's Medical Officer carried out a medical examination on the first day. On the following two days before the training programme commenced, subjects reported in two squads at the laboratory to enable reference fitness profiles to be established. After three weeks a pool of twenty players was selected by management and taken to a training camp in Sweden for a ten-day period.

Training typically takes place at the club's training grounds which are located about three miles from the main headquarters. The grounds accommodate two full sized playing pitches, and a large indoor playing area. Training is sometimes conducted on sand at a nearby beach. To facilitate training the staff is divided into two squads with a degree of flexibility from week to week between squads. The "Reserves" team competes in a regional league - the Central League - which involves forty-two competitive games invariably played before small audiences. It is expected that all reserves aspire to playing in the First Team.

The third eleven or 'A' team is mostly comprised of apprentices and competes in the Lancashire League. Full-time professionals do not normally play in this side.

Usually more than twenty players are called on each season to represent their club in the English League First Division. Twenty-six players represented Everton in this competition in 1972-73, twenty-three in 1973-74. It is frequently suggested that there is an association between overall performance and the number of players representing the First Team in a season. Success might be a product of improved team cohesion with few personnel changes. Increased incidence of injuries reduces the personnel from which First Team selection is made. If predictors of injuries could be identified, preventive measures could be recommended. These reasons suggest an analysis of injury statistics is warranted.

Saturday competition invariably alternates between home and away fixtures. For away fixtures the party ordinarily travels on Friday by coach or train to stay overnight near the opponents' ground. On Saturday morning the players breakfast in bed, a half-hour tactical discussion precedes lunch at noon and the party arrives at the ground one hour before kick-off. Players leave the dressing-room for the pitch five to eight minutes before kick-off. The game ends at 16.45 hrs and the homeward journey has commenced by 17.30 hrs. For home games, selected players and reserves report at the dressing-room at 14.00 hrs. Sunday is free for all but the injured players who are required to report to the training grounds for treatment.

The daily routine varies as a function of competitive demands. Staff report at the training grounds at 10.00 hrs - altered to 9.30 hrs at the start of the 1973-74 season. Training commences thirty minutes later. Lunch is provided, except on Friday when training is of short duration. Usually afternoons are free except for younger professionals who are sometimes required for extra training in mid-week. Sometimes staff are given the day off by management. Occasionally training takes place indoors or on the beach because of environmental conditions or for the specific purpose of introducing variety into the training programme.

Professional working hours amount on average to 2•75 per day Monday to Thursday, and two hours on Friday. On Saturday a home game involves three hours at the ground, while an away game involves an extra 3•5 hours on Friday and 4 hours on Saturday in travelling. An arbitrary figure of 15 minutes is added to allow for the average extra consumption of time in treatment of injury on Sunday. This amounts to 18•5 hours work per week. Knowledge of the energy expended in this time would permit comparison to be made with other occupations. The severity of work could then be graded according to the categorisation of Christensen (1953) whose classification of work loads in terms of physiological reactions is presented in Table I.

Table I. Christensen's (1953) classification of work loads in terms of physiological reactions

Work load	Oxygen consumption (ℓ/min)	Energy expenditure (kcal/min)	Heart rate during work (beats/min)
Light	0•5 - 1•0	2•5 - 5•0	60 - 100
Moderate	1•0 - 1•5	5•0 - 7•5	100 - 125
Heavy	1•5 - 2•0	7•5 - 10•0	125 - 150
Very Heavy	2•0 - 2•5	10•0 - 12•5	150 - 175
Unduly Heavy	> 2•5	> 12•5	> 175

SECTION THREE

OBJECTIVES AND HYPOTHESES

3. OBJECTIVES AND HYPOTHESES

3.1. Objectives of the study

The general objective of this study is to analyse the physical, physiological and psychological demands imposed on a population of professional footballers and to assess the capacity of players to meet these demands. This circumscribes a number of more specific objectives in view of the diversity of demands in this occupation.

The specific objectives are:

1. fitness: to monitor fitness profiles of subjects throughout the playing season. This data should permit:
   - (a) comparison with data for other top-class sportsmen.
   - (b) comparison between squads at each test.
   - (c) comparison between tests to assess the effects of the intermediate training, particularly the pre-season training regime and the long-term seasonal effects.
   - (d) investigation of the independent components of fitness in the population studied.
2. competition:
   - (a) to determine the absolute and relative levels of psychological stress preceding competition. This includes the study of individual differences and comparison with reported levels for other sports.
   - (b) to study the relationship between pre-match psychological stress and performance variables.
   - (c) to devise a methodology for evaluating work-rate during competition using motion analysis.
   - (d) to investigate differences in work-rate and behavioural characteristics according to positional roles.

3. training: to determine the level of physiological strain and assess it critically as preparation for competition.

4. occupational stress: to evaluate occupational stress from training and competition data according to the classification of Christensen (1953 op cit).

5. physical stress:

   (a) to identify critical incidents from behavioural classification during competition.

   (b) to analyse injury records over a complete season. This should permit their classification and allow comparison to be made with the data of Bass (1967 op cit) and Adams (1973 op cit), as well as the investigation of relationships with fitness variables.

6. habitual activity: to determine the level of daily energy expenditure and the postural nature of habitual activity.

3.2. Hypotheses

3.2.1. Occupational success for a professional footballer depends on recognition as a regular First Team member. First and Reserve Team squads undergo similar training regimes and participate equally frequently in competition. It is supposed that all professional playing staff aspire to playing in the First Team and that those with the requisite skill, physiological and psychological make-up succeed. It is hypothesised that there are significant differences in fitness profiles which discriminate between "First" and "Reserve" team members.

3.2.2. Saltin et al (1969) found an 8-10 week training regime two or three times a week effected significant improvement in circulatory and pulmonary variables of sedentary subjects. Fardy (1969 op cit) found similar changes in soccer players over a ten-week period of conditioning, though the frequency of training was not mentioned. There have been many investigations of the effect of a training regime (e.g. Sharkey and Holleman, 1967; Fox et al, 1973; Brynteson and Sinning, 1973). Sloan and Keen (1959) reported significant improvement in circulatory variables in oarsmen and rugby players with 2-4 months training and Shephard (1968a) observed significant improvement in fitness variables in sedentary subjects after six weeks. It is not customary for professional footballers to continue active training during their seven-week vacation. It is expected that disuse effects occur in this period. It is hypothesised that a six-week pre-season training regime significantly alters fitness profiles in the population studied.

3.2.3. Welford (1968), in a review of the relevent literature, concluded that stressing agents which increase arousal - a concept that can in broad terms be equated with Shephard's (1968) 'anxiety reaction' - could be expected in mild degrees to improve performance and in more severe degrees impair it. The result is an inverted U shaped relationship between level of arousal and performance which is illustrated in Fig. I. Though individual differences must be expected within a team in the degree of the anxiety reaction, the mean level may be considered as an index of group arousal. Because the stressing context is experienced weekly it is not expected that the degree of reaction is severe. It is hypothesised that there is a positive correlation between mean arousal level and team performance.

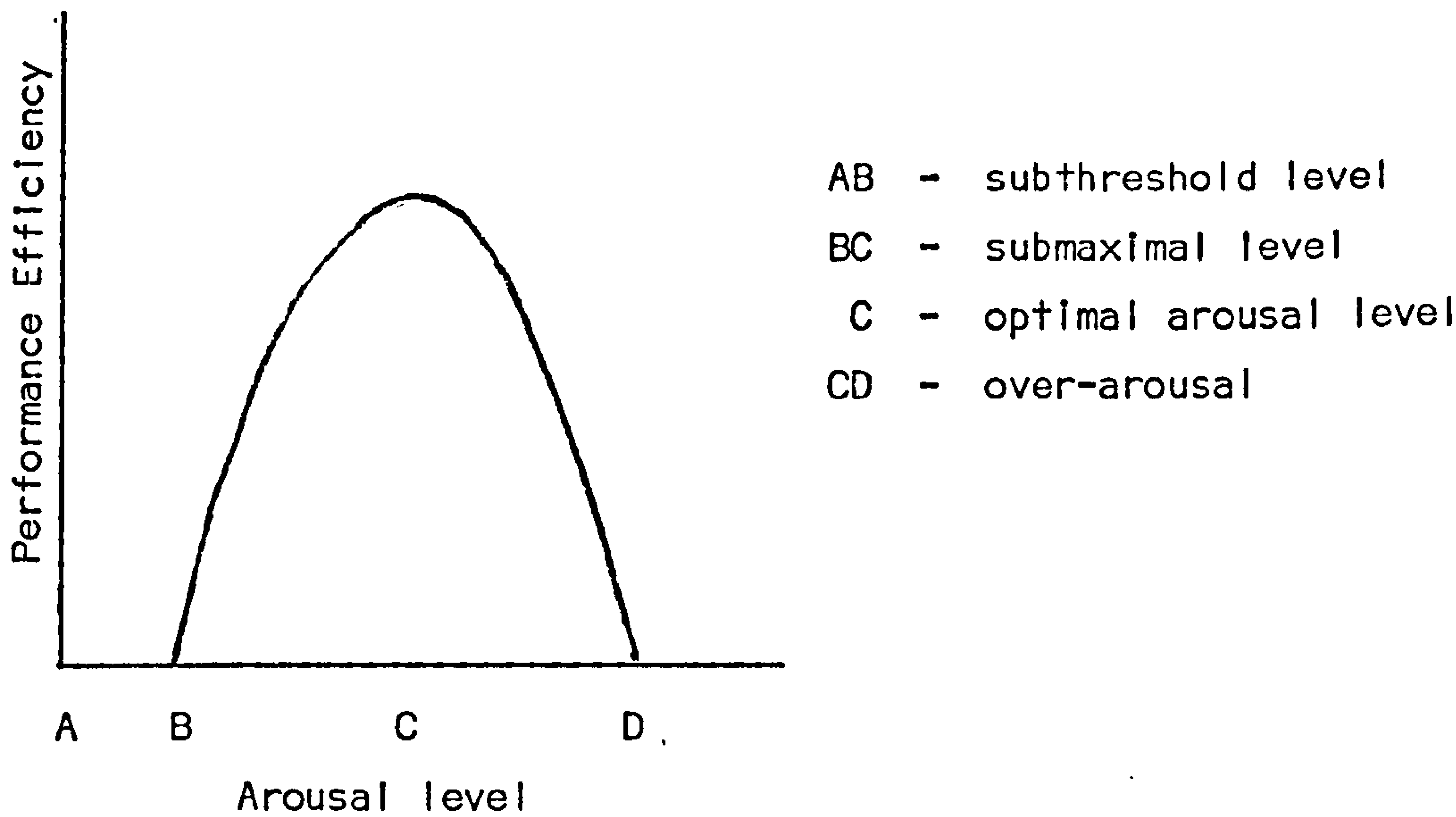

Figure 1. The relationship between level of arousal and performance efficiency

3.2.4. The demands imposed by competition on the goalkeeper are obviously different in essence from the demands of playing outfield. It seems his involvement is in short busts of activity requiring vigilance and concentration when play is in his vicinity, interspersed with pauses while his goal is not threatened. Outfield players are mostly considered as a homogeneous group, each equally contributing in work-rate during the game.

According to current styles of outfield team configurations, players may be classified into the following positional roles - centre-back (2), full-back (2), mid-fielder (3) and striker (3). This formation is commonly known as four-three-three. The centre-backs are essentially defenders, the full-backs are defenders who assist in attacking manoeuvres, mid-fielders act as linkmen between defence and attack, the attackers are known as 'strikers' because of their goal-scoring role. It is hypothesised that there are differences between each group in the work-rate demanded by the game and that the greatest demand is imposed on mid-fielders because of their linking role.

3.2.5. In soccer the lower extremity is more vulnerable to injury than the upper body as it is usually fixed to the ground, burdened by the rest of the body weight and subjected to shear and rotational stresses from extrinsic forces. Increased mobility and strength might be expected to provide greater protection against injury. Goven and Koppenhaver (1965) asserted the existence of accident proneness and hypothesised that specific personality patterns tend to be found in accident-prone individuals. They found no relation between neuroticism and injuries in sixty American football players. Brown (1971) found no relationship between injuries in high school American footballers and personality traits. The inventory used does not measure anxiety factors. Davis (1948) presented the observation of clumsiness and increased liability to accidents in acutely anxious patients who are preoccupied with their worries. He suggested the accident-prone are unresponsive to the stimuli comprising the work situation. Hayes (1974) discussed the apparent relationship between the incidence and severity of sports injuries and aggression from a sociological perspective. It is a frequently articulated belief that the more anxious and apprehensive players tend to get injured in soccer. In the present study the hypothesis of a relationship between personality factors pertaining to an anxiety dimension and injuries is proposed.

3.2.6. The time consumed by professional life-space of footballers is much less than many other occupations. A considerable proportion of this time is taken up by dressing, eating and travelling. In non-professional life-space, footballers are not encouraged to participate in vigorous physical activity because of a risk of injury. It is hypothesised that the level of habitual activity and daily energy expenditure of subjects is of the same order as the normal population and approximates the values quoted for the "reference man" (Durnin and Passmore, 1967).

3.3. Summary of hypotheses

1. It is possible to discriminate between First and Second squads by means of fitness profiles.
2. Fitness profiles are significantly altered by a six-week pre-season training regime.
3. There is a positive relation between pre-match arousal and team performance.
4. There are specific work-rate requirements imposed by the game according to position, the greatest demand being on mid-fielders.
5. There is a relation between injuries and personality aspects, the more anxious and apprehensive tending to get injured.
6. Daily energy transformations of footballers do not differ from ordinary levels.

SECTION FOUR

METHODS

4. METHODS

4.1. Subjects

4.1.1. Procedures

A battery of fitness tests was applied to subjects at four points during the season:

(a) pre-season (T1) — n = 31.

(b) end of pre-season training (T2) — n = 31.

(c) mid-season (T3) — n = 30.

(d) end of season (T4) — n = 28.

T3 included one subject not involved in the previous tests. T4 included two subjects not tested previously and one subject not present at T3 due to injury. Ss were allocated to Squad 1 or Squad 2 by management. Squad 1 represented the pool from which the current First Team was selected. Squads attended the laboratory for testing separately on consecutive days. Measurements accorded with standardised procedures (Weiner and Louire, 1969 op cit; Clarke, 1967 op cit). The serial order of tests was unchanged between individuals and between tests. The experimenters consisted of eight qualified physical educationists who were trained in the measurement procedures employed.

S's weight and height were determined in his socks and shorts using an Avery Type 3306 ABV weighing scales and a stadiometer mounted on the scales (Plate 1). Height was measured to the nearest cm with the Frankfort plane horizontal and a counterweight board brought down on S's head. A ponderal index (PI) was computed using the formula:

$$PI = \frac{\text{Height}}{\sqrt[3]{\text{Weight}}} \qquad \text{(Parnell, 1958)}$$

Body Surface Area (BSA) was determined using the nomogram of Sendroy and Collison (1960).

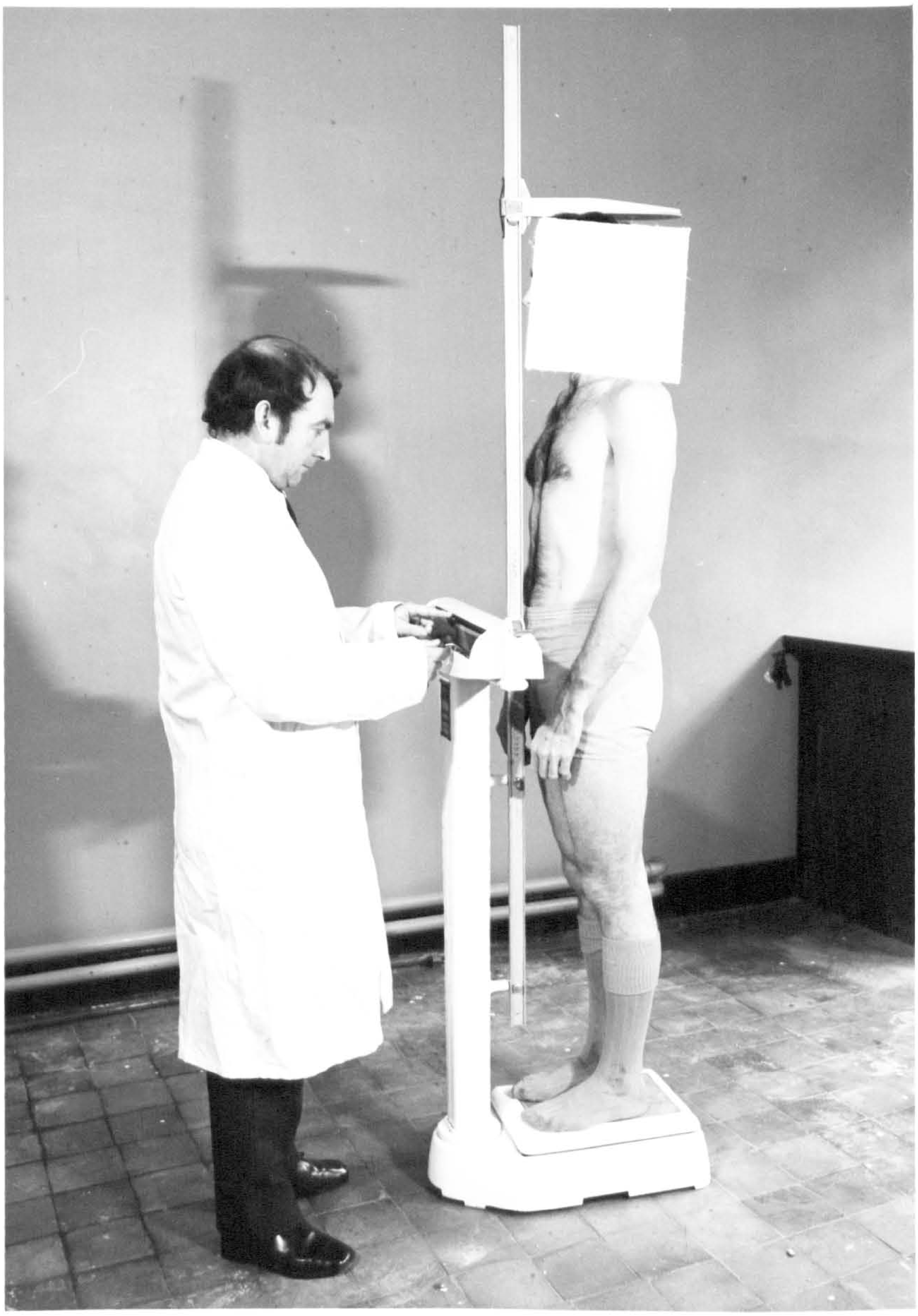

Plate I. The apparatus used for measuring height and weight.

Limb circumference and length were measured on the left side of the body using a steel tape and recorded to the nearest cm. Upper arm girth was taken horizontally at the point of maximum circumference with the arm flexed and tensed. Calf circumference was measured horizontally at the point of maximum circumference with S seated and the knee at an angle of about ninety degrees. Thigh circumference was taken with S standing freely, feet slightly apart, with the tape round the thigh horizontally, its top edge under the gluteal fold. Pelvic circumference was measured horizontally at the superior margin of the iliac crest. Chest circumference was measured at the marked union of the third and fourth sternebrae at right angles to the longitudinal axis of the body both at the end of a maximal inspiration and at the end of a normal expiration. The difference between these measures was expressed as a proportion of the latter value to form an additional variable ('chest difference'). Upper arm length was taken as the distance from the external superior border of the head of the humerus to the inferior border of the olecranon process. Thigh length was taken to be the horizontal distance between the rearmost point of the left buttock to the front of the patella, with S sitting erect, feet resting on the floor and knees bent at about right angles. Limb lengths were measured only in T1 and T3, except for the two subjects who were first tested at T4.

Ankle mobility was measured with a flexometer in accordance with the design of Nowak (1972). The difference in degrees between the deflection at full plantar-flexion and full dorsi-flexion of a pointer moved by S's foot and incorporated in a goniometer was taken as the index of mobility of the ankle joint. The maximum of three readings was recorded. Measurements were not obtained at T2.

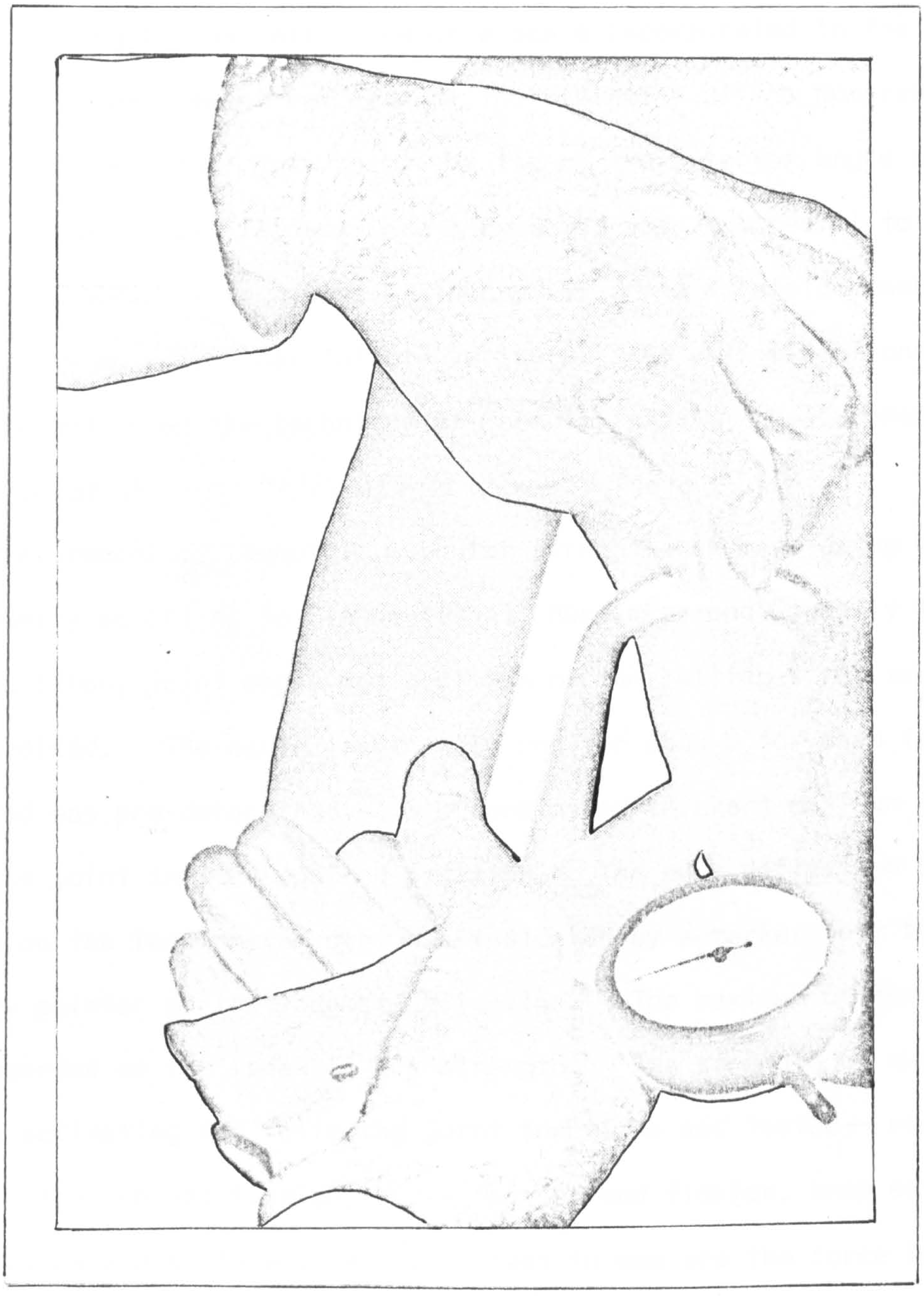

Plate 2. Measurement of sub-scapular skinfold thickness using Harpenden caliper.

Fatfold measurements were taken at three sites — triceps, sub-scapula, and supra-iliac — with a Harpenden skinfold caliper which exerts a constant pressure at varying openings of the caliper jaws. The width of the opening is read off in mm on a scale incorporated in the apparatus. The triceps measurement was made at the mid-point of the humerus, the sub-scapular was made just below the tip of the inferior angle of the scapula, the supra-iliac was made 1 cm above and 2 cm medial to the anterior superior iliac spine. The sum of three skinfold measurements was used as an additional fatfold variable. An estimate of endomorphy was obtained using the technique of Parnell (1958). Measurement of sub-scapular skinfold thickness is shown in Plate 2.

Measurement of isometric muscular strength was made using cable tensiometry according to Clarke (1954), Hunsicker and Donnelly (1955). Body position, joint angle and position of the pulling strap were standardised. The cable length required for each S for each function measured was pre-determined. S's were asked to exert maximum effort with the joint in the required position. The peak deflection of a needle on the tensiometer dial was indicated by a marker left by the primary pointer at its largest deflection. The maximum of three trials was recorded as the index of S's strength. The strength of muscle groups activating the following joint functions was tested — neck flexion, trunk extension and flexion, hip extension and flexion, knee extension and flexion and ankle extension. A test to measure the force exerted in a two-handed overhead pull was applied. Grip strength of each hand was measured using grip dynamometry (Clarke, 1967 op cit). Measurement of neck flexion and grip strength are illustrated in Plate 3 and Plates 4 and 5.

Vertical jump and standing broad jump performances recorded to the nearest cm were used as criteria of muscular power. The best performance of three trials was recorded after one warm-up (Clarke, 1967 op cit).

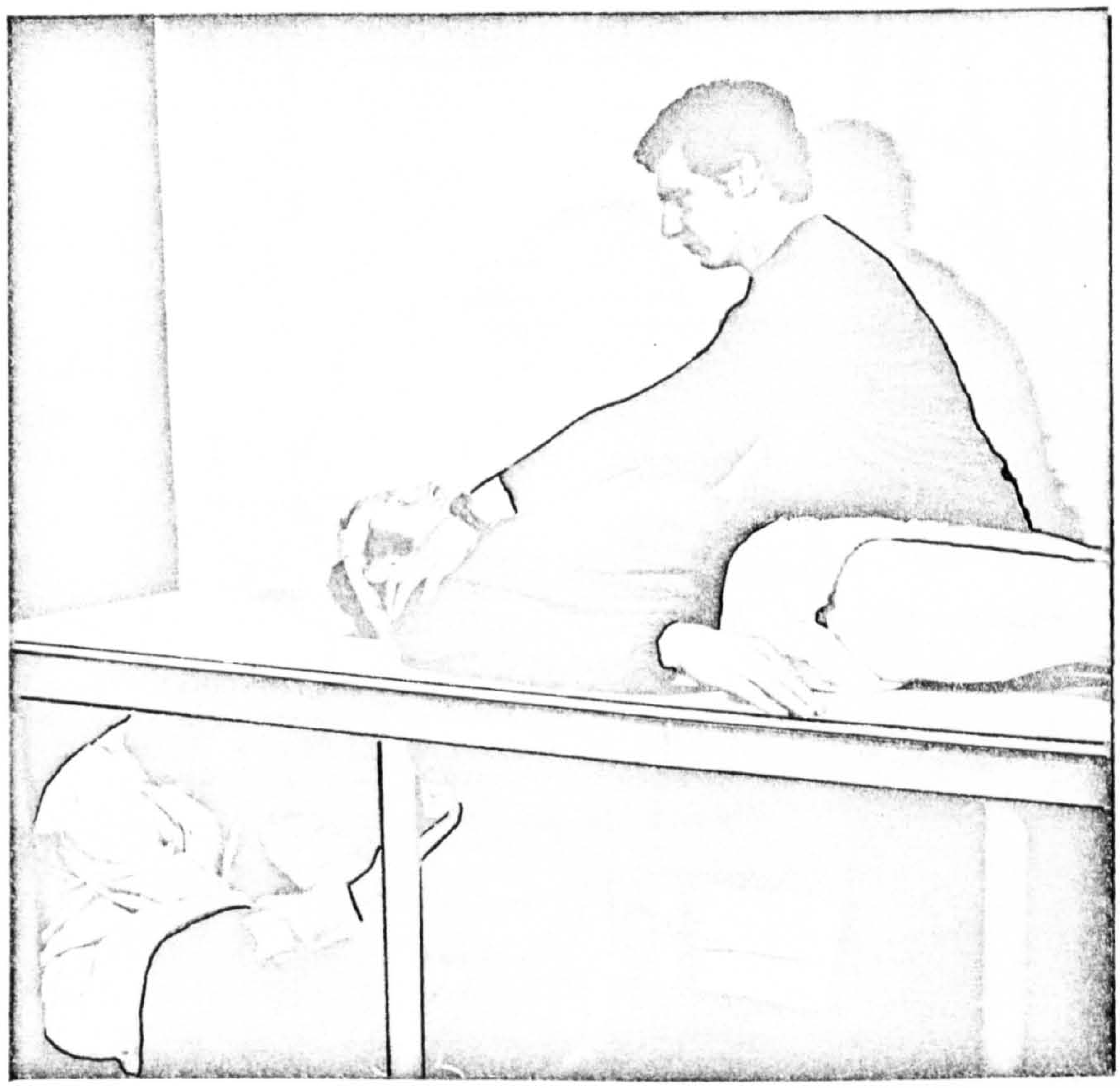

Plate 3. Measurement of neck flexion strength using cable tensiometry.

Plate 4. Grip strength measurement using grip dynamometry.

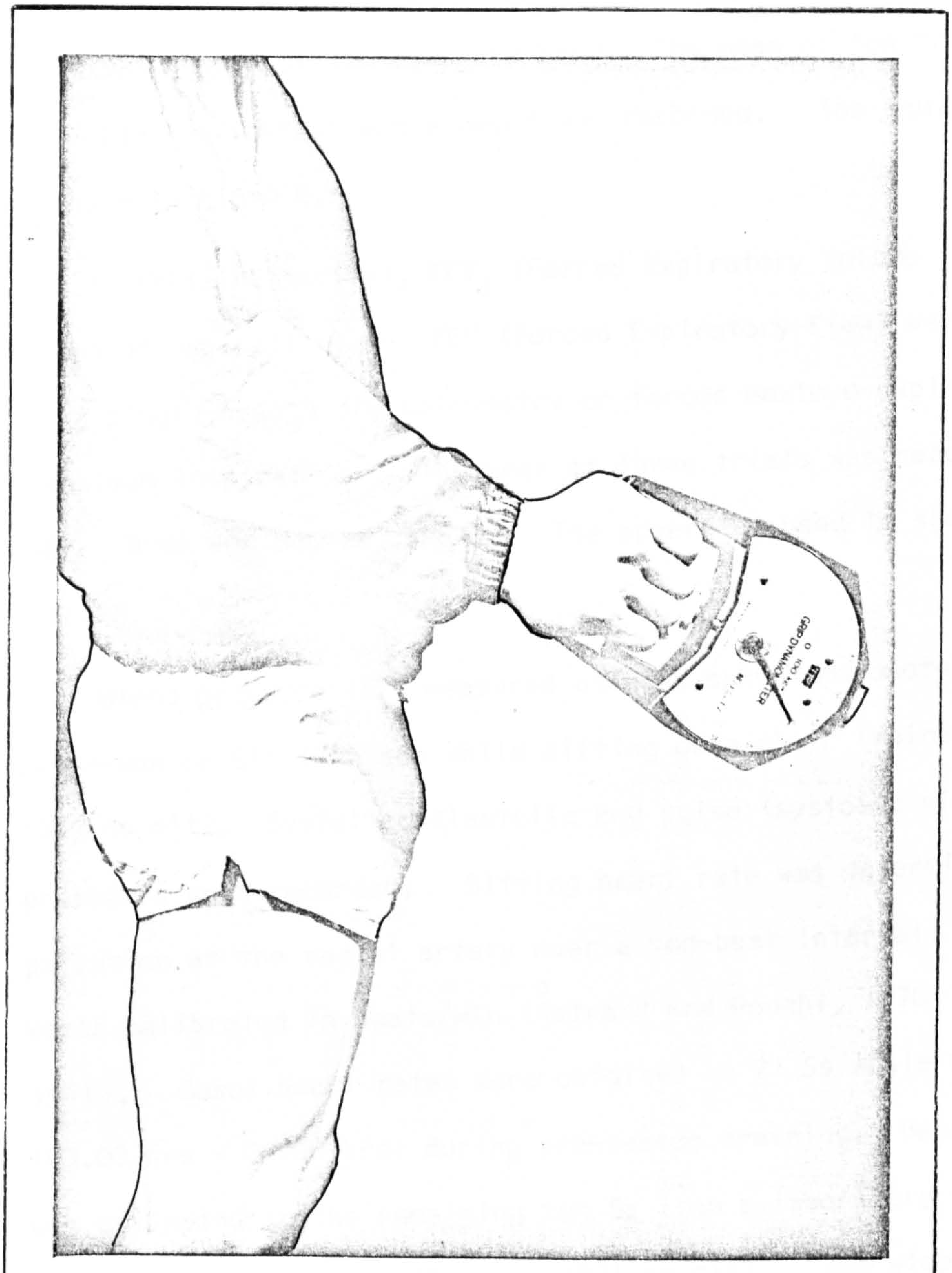

Plate 5. Grip strength measurement using grip dynamometry.

Simple reaction time was measured using a Heuer chronoscope (Teichner and Krebs, 1972). S was instructed to respond to the presentation of a visual stimulus by depressing a push button with the index finger of his dominant hand. The mean of ten trials after excluding the fastest and slowest was recorded. The equipment used is shown in Plate 6.

VC (Vital Capacity), FEV_1 (Forced Expiratory Volume in the first second of expiration) and FEF (Forced Expiratory Flow) were determined using single-breath dry spirometry on forced maximum expiration after a maximum inspiration. The peak of three trials was recorded (Cotes, 1965; Drew and Hughes, 1969). The apparatus used is shown in Plates 7 and 8.

Blood pressure (BP) measured using a sphygmomanometer (Plate 9) was taken on S's left arm while sitting on a chair (Weiner and Louire, 1969 op cit). Systolic, diastolic and pulse (systolic minus diastolic) pressures were recorded. Sitting heart rate was determined by palpation at the radial artery over a ten-beat interval, using a stop-watch calibrated in beats/min (Åstrand and Rodahl, 1970; Thomas, 1971). Basal heart rates were obtained on 21 Ss while sleeping (03.00 hrs - 04.00 hrs) during pre-season training. Basal heart rate was estimated in the remaining ten Ss from a laboratory resting heart obtained while sitting (Thomas, 1971 op cit). The stop-watch is shown in Plate 10.

The Harvard Step Test was administered according to Brouha (1943). S stepped up and down thirty times a minute for five minutes on a bench twenty inches high (cf Plate 11). The pulse rate while sitting was counted by palpation at the radial artery from 1-1·5 min, 2-2·5 min and 3-3·5 min after exercise ceased. The Harvard Index (HI) was computed from the formula:

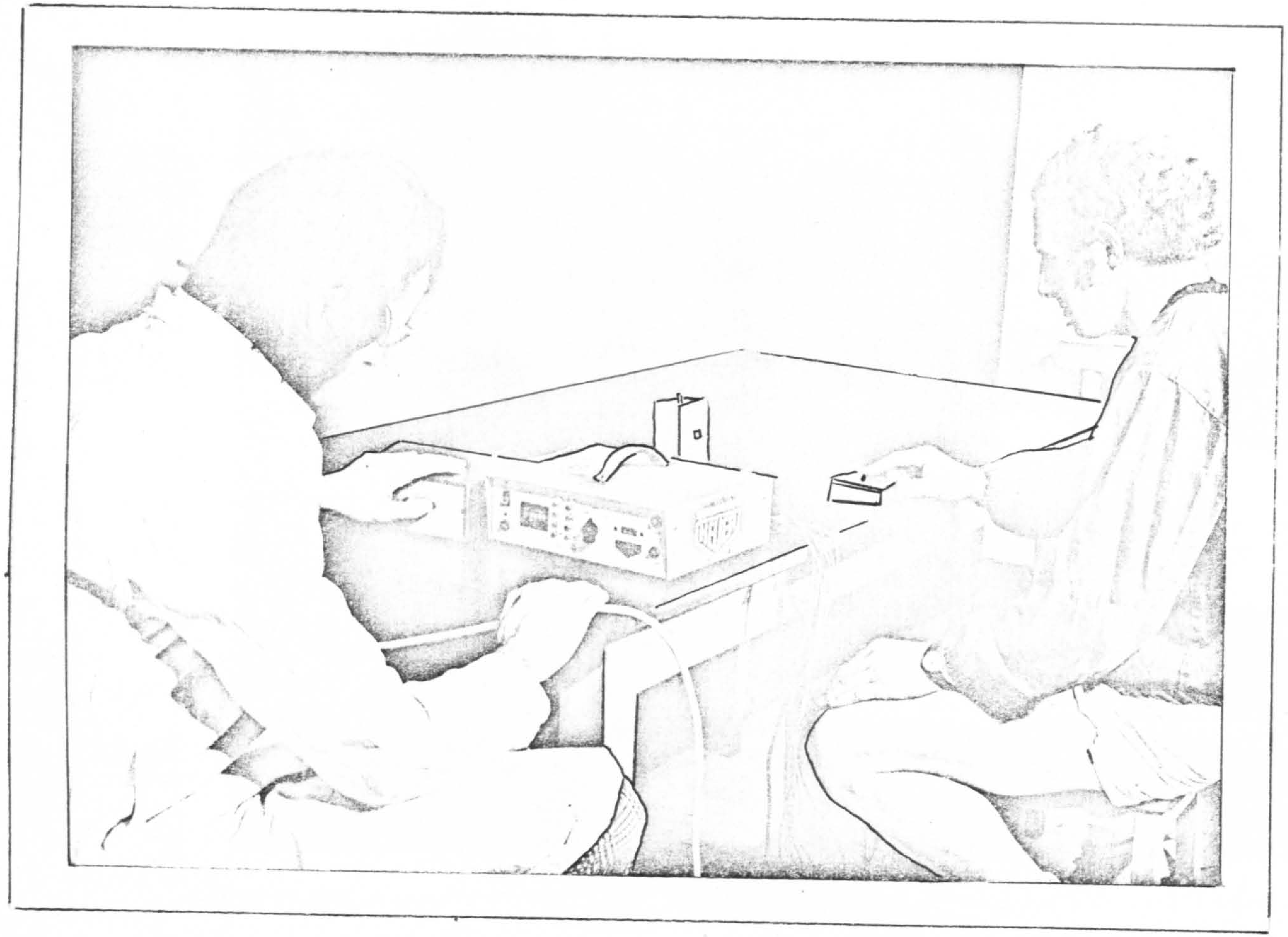

Plate 6. Simple reaction time (RT) measured using a Heuer chronoscope.

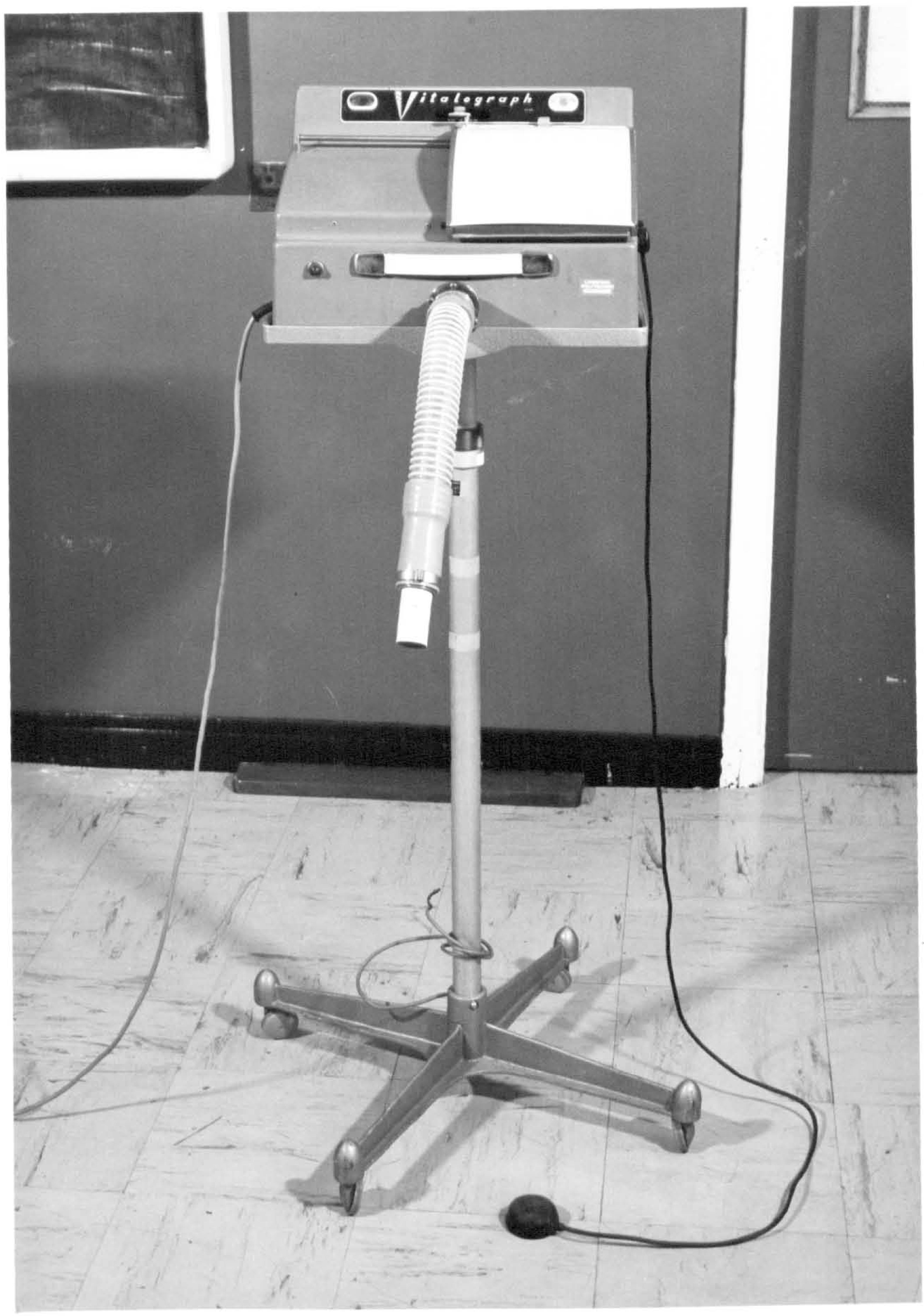

Plate 7. The Vitalograph used to measure lung function.

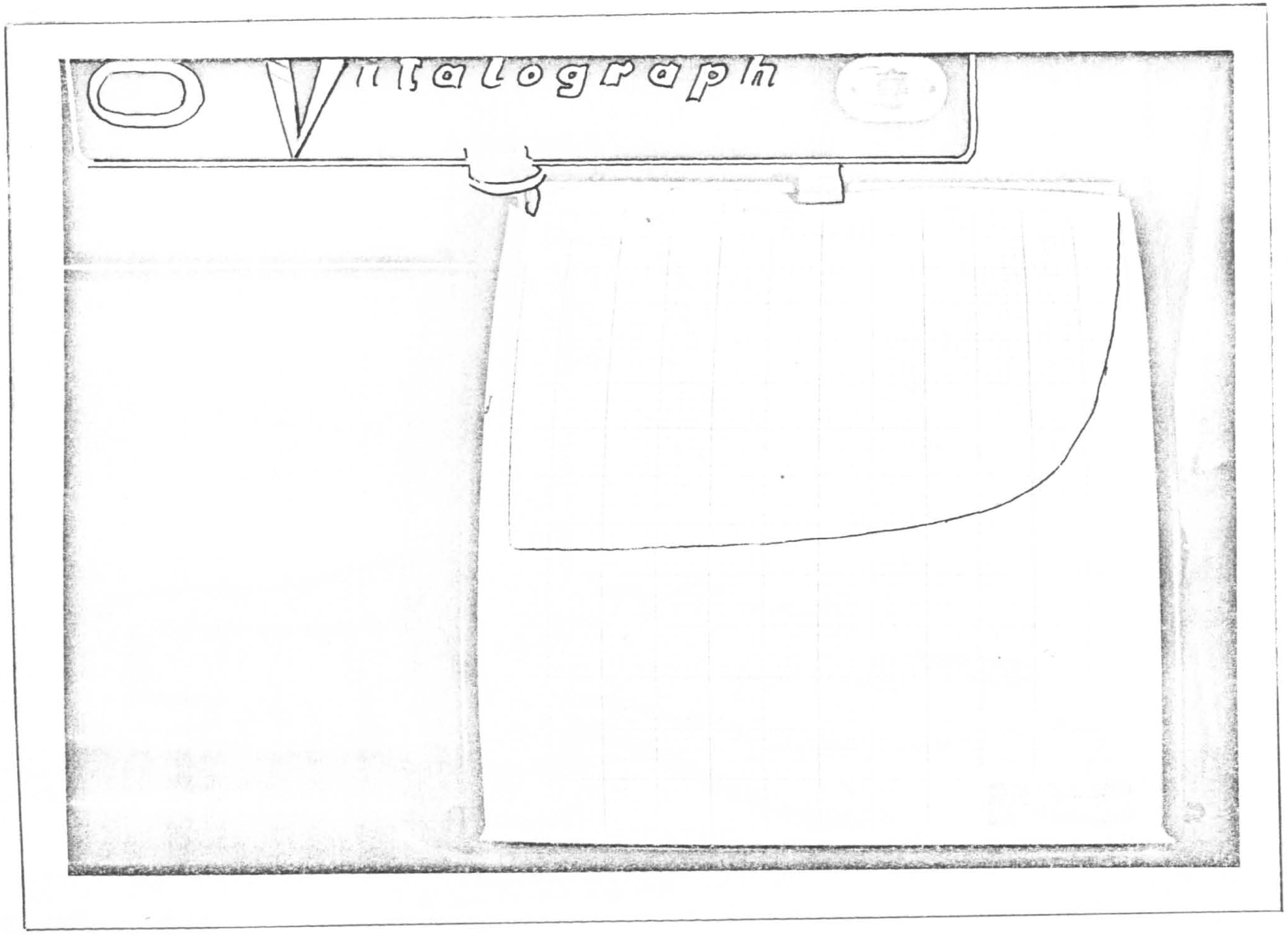

Plate 8. The chart recording of lung function.

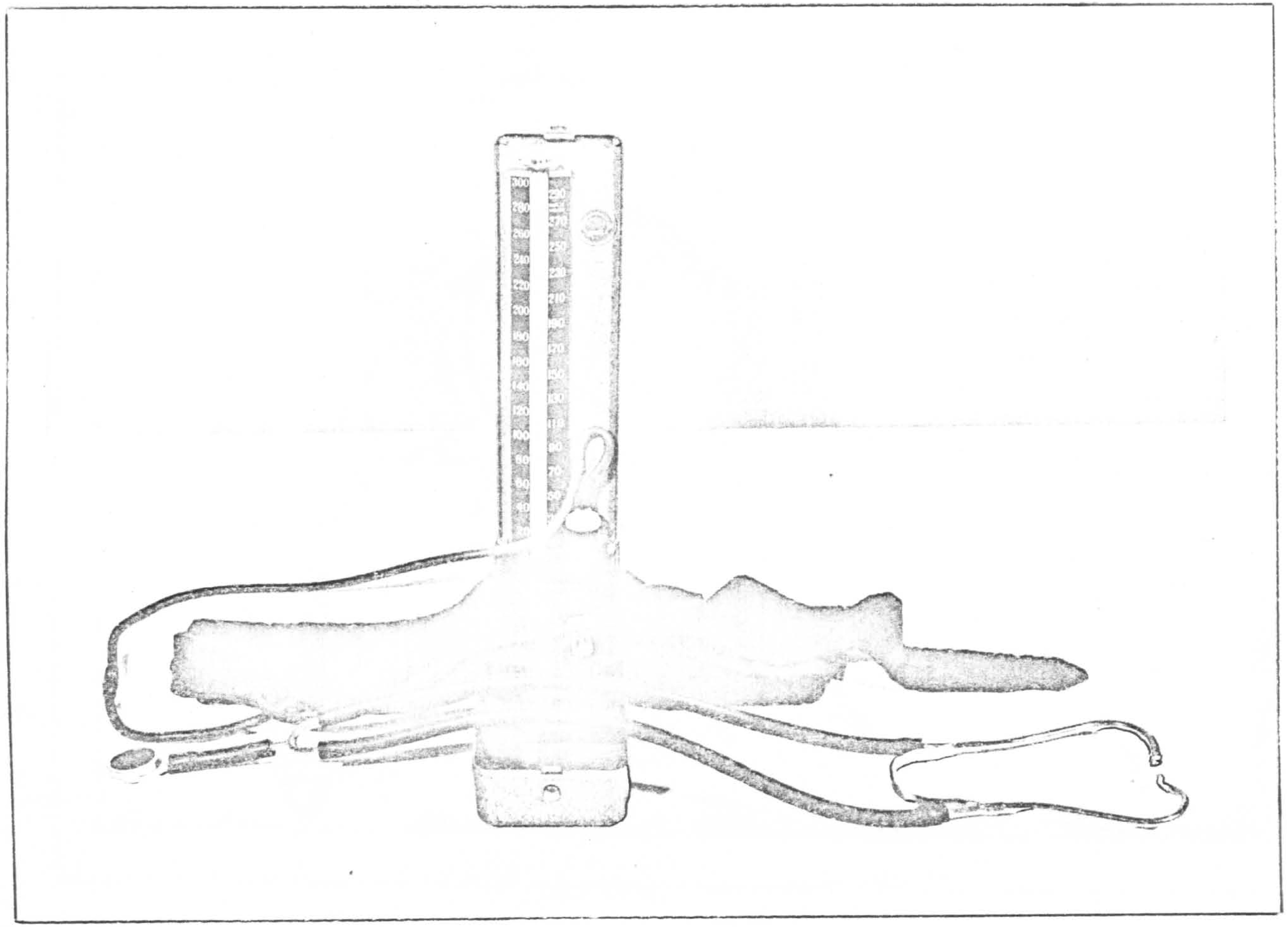

Plate 9. Sphygmomanometer used to measure blood pressure.

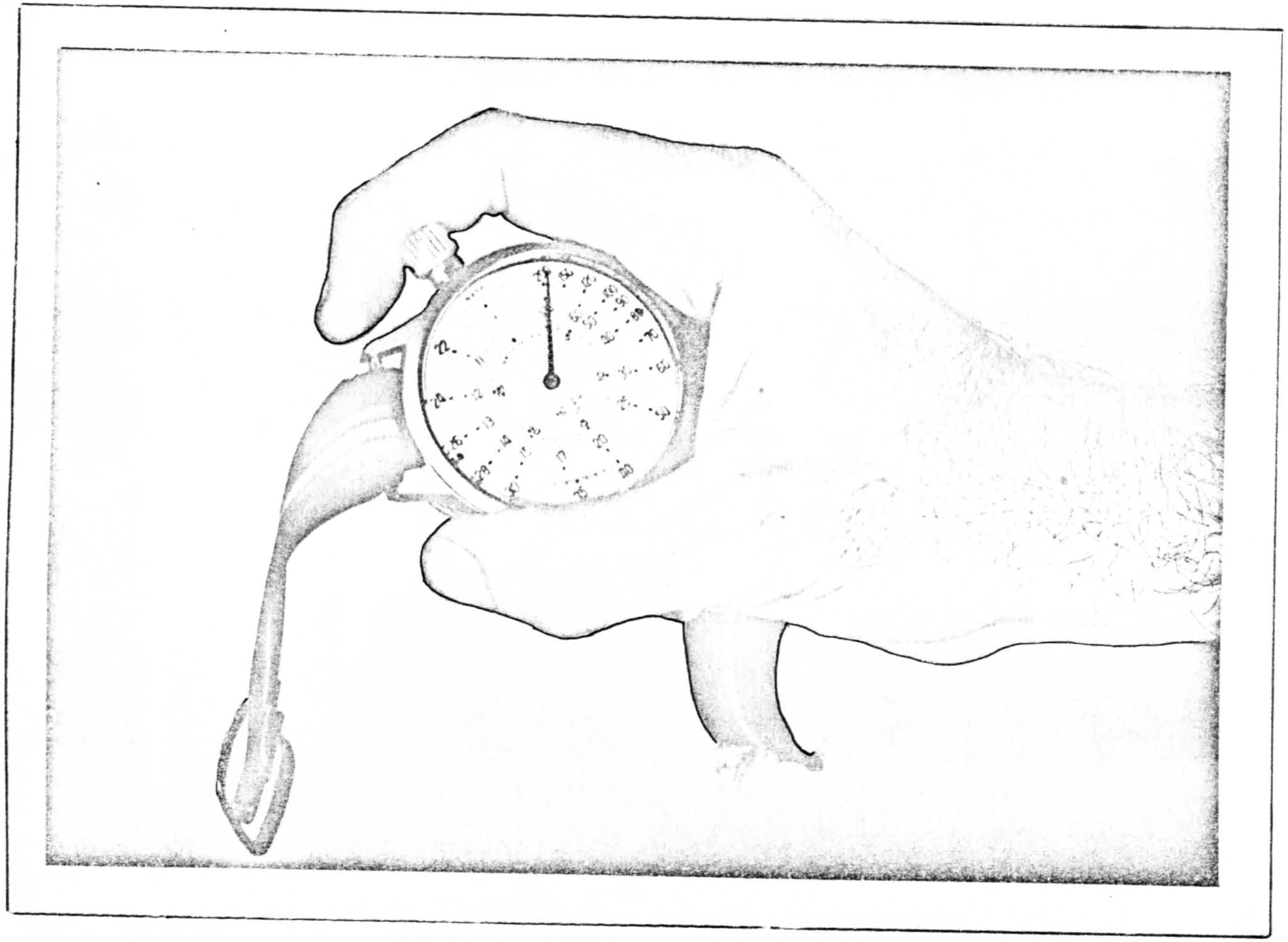

Plate 10. Heuer stop-watch calibrated in beats/min used to obtain heart rate measurements.

Plate II. Administration of the Harvard Step Test.

$$HI = \frac{30,000}{2 \times \text{sum of Recovery Pulse Counts}}$$

A treadmill test was administered according to Åstrand (1953). S ran on a motor-driven treadmill at 10 km/h and an angle of 1° for 5 minutes. Heart rate was obtained by palpation at the carotid artery at the cessation of exercise and the exercise heart rate predicted according to Thomas (1971 op cit). The apparatus used is shown in Plate 12.

Maximum heart rate (fH_{max}) was obtained during a shuttle run to exhaustion (Thomas, 1973) (Plate 13). The exercise heart rate was predicted from the post-exercise rate according to the formula of Thomas (1971 op cit). A cardiac assessment factor was computed from the formula:

$$CAF = \frac{fH_{max}}{fH_{min}} \times 10$$

Self-reported waking heart rates were found unreliable. The laboratory sitting heart rates were reduced by 18% in the calculation of CAF (Thomas, 1971 op cit) for T1, T3 and T4. Basal values obtained as described earlier in this section were used in T2.

Personality was assessed using the Cattell 16 P.F inventory (Cattell, 1963). Standard scores were established according to the norms of Cattell and Eber (1962).

4.1.2. Analysis of Data

Means, ranges and standard deviations were obtained for the group as a whole and separately for First and Second Team squads. Management's separation of players into their squads was adopted in the analysis of T1 and T2. For T3 and T4, players who had established or consolidated their positions as First Team performers since the previous test were adjudged to be in Group I (i.e. First Team).

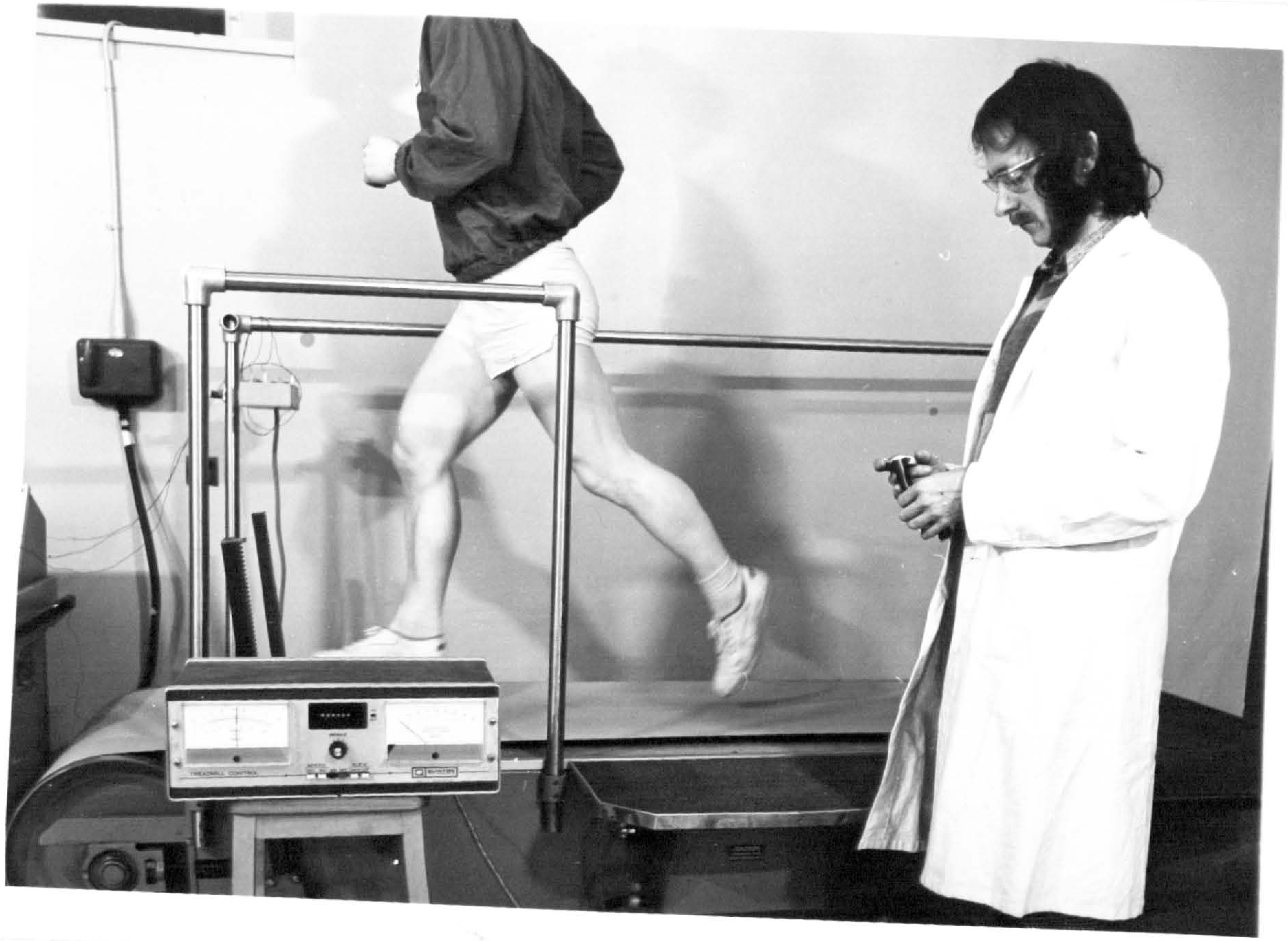

Plate 12. S running at a fixed work-load on motor-driven treadmill.

Plate 13. Measurement of heart rate during shuttle run.

Differences between tests and between groups were investigated using analysis of variance. The model employed was of the form:

$$A(I) + B(J) + C(K) + BC(JK) + E(IJK)$$

where A represents the between subjects' variance,
B represents the variance between groups,
C represents the variance between tests,
BC is the interaction term,
and E is an error term.

In some instances the mean values between tests were compared using the 't' test.

For each test battery data a principal components analysis was employed using all the variables in the test battery. The programme used was the ICL 1902 Mark II Statistical Package. This analysis maximises the variance between individuals and where independent components of fitness are isolated allows grading of individuals according to their scores on each component extracted. Identification and interpretation of components were attempted from the combination of test items contributing high eigenvector values to the sums of squares for each component.

According to Gorsuch (1974), factor analysis "allows one to analyse numerous variables at a time, to unravel relationships among variables correlated in highly complex ways, to report gradated relationships to factors, and to stress parsimonious solutions". Factor analytic techniques were employed to investigate independent factors of physical fitness. In view of Cattell's (1962) claim that no rigid orthogonal solutions can yield such good match across experiments as oblique solutions, two analyses were performed using the SPSS programme: i) Factor analyses with orthogonal rotation, ii) Factor analyses with oblique rotation (Nie et al, 1970). The personality variables were excluded from the original test battery. Non-pure variables, i.e. combinations of two or more other variables were excluded to avoid ill-conditioning the correlation matrix (Ismail et al, 1965). Further reductions based on an inspection of the correlation matrix using all the original variables were made. This was necessary because the dimensions of the matrix exceeded the current core storage facilities for this programme with the computer used at Manchester Regional Computing Centre. The maximum number of variables that could be employed was established by trial and error for each test. Four tests were analysed in view of Cureton's comment that factors are affected by relative state of fitness (Cureton, 1966 op cit).

A series of discriminant function analyses was employed to investigate the discriminability between groups for each test as well as multivariate discriminability between T1 and T2. This method has been employed by Kroll and Carlson (1967) to differentiate between levels of karate proficiency on the basis of personality profiles. This analysis maximises the variance between groups in order to best discriminate between them. As the analysis is invalid when the number of variables exceeds the number of subjects, the test battery was split for separate analyses into four parts comprising: i) anthropometry and blood pressure, ii) strength and muscular power, iii) cardiac and iv) personality variables. In addition, scores on the first eight components in T1 and on the first six components in the remaining tests were analysed for their ability to discriminate between groups.

The discriminant function analysis tests the significance of group separation on the basis of a set of variables which are considered as a whole. The analysis first tests the hypothesis that the group covariance matrices are equal irrespective of group mean vectors using: (a) Box's Criterion M (Jones, 1964), (b) F Ratio. The hypothesis that the group mean vectors are equal is then tested under the assumption that the group covariance matrices are equal. Univariate F Ratio for each variable is obtained and transformed to a scaled eigenvector. This represents the discriminant co-efficient for each variable and reflects the real relative importance involved in discriminating between the groups. Two tests are available to test the significance of the roots through calculation of Wilk's lambda: (a) Rao's F Test — this tests the significance of group separation, (b) Bartlett's chi-squared — this tests the individual contributions of the discriminant functions with no roots removed. Each S is allocated to one of the groups in the Hits and Misses Table and his membership probability for each group calculated.

4.2. Competition

4.2.1. Pre-Match Stress

A number of physiological parameters have been used as dependent variables in studies of increased activation and arousal induced by stress. In the context of the soccer dressing-room, these concepts of arousal and activation can be considered as synonymous with the anxiety reaction. Welford (1968 op cit) reviewed the use of muscle tone and autonomic activity over the past forty years in studies of intensity in the field of emotion. Lacey (1950) used systolic and diastolic blood pressures and palmar conductance as measures of autonomic arousal. Heart rate and skin conductance were used by Campos and Johnson (1966). Von Euler (1964 op cit) concluded mental stress situations could be quantitatively evaluated from analyses of urinary excretion of catecholamines. Åstrand ét al (1973) used epinephrine and norepinephrine levels as indicants of work stress in coastal fishing. This avenue of investigation was inapplicable in the current context as the collection of blood and urine samples was not feasible in the dressing-room pre-match situation.

Behavioural indicants of the anxiety reaction employed in research include perceptual-motor steadiness as measured by the degree of hand tremor (Hammes and Wiggins, 1962; Vaught and Newman, 1966). Caille et al (1972) used behaviour observation, a technique not suited to the pre-match dressing-room environment. A pilot investigation did not suggest that the use of subjective excitement scales as described by Gabler (1972) would be efficacious as the semantic differential technique was adjudged to lack sensitivity for current purposes. Paper and pencil tests were disregarded as it was felt this technique might intrude into the mental preparation of subjects for the impending game. The technique employed required to be unobtrusive and administratively convenient.

The phenomenon of emotional tachycardia has been described by many authors including Åstrand (1967), Hickam et al (1948), Faulkner (1964) and more recently Carruthers (1974). Ruffell Smith (1967) emphasised that as heart-rate varies with both physiological and psychological phenomena, it can only be used as a measure of stress (sic) when one or other of them is known to be absent. Results of Bateman et al (1970) suggest sensitivity is increased if measurement is delayed as late as possible before the event inducing the tachycardia.

In pilot investigations it was established that heart-rate data could be unobtrusively obtained on all players over a five-minute period prior to leaving the dressing-room for the playing pitch. It was further established that heart-rate was stable over this period.

.2.1.1. Procedures

Heart-rates were obtained on 12 players prior to 41 League games, 3 Cup matches and 4 friendly or testimonial games. Measurement was performed by palpation at the radial artery over a ten-beat interval using a Heuer stop-watch calibrated in beats/min (Åstrand and Rodahl, 1970 op cit). Measurements commenced with the goalkeeper thirteen minutes before kick-off time. Ss were seated some time (minimum four minutes) before heart-rate was determined. This was already conventional dressing-room procedure as sitting to lace football boots is performed late in the dressing routine.

Two separate indices of arousal were employed: i) the absolute heart-rate value, ii) the increment over basal heart rate (obtained by palpation during sleep between 03.00 hrs - 04.00 hrs). Mean values of the eleven players excluding the substitute were employed as the criteria of team arousal. An arbitrary ten-point scale was devised to score team performance. This scale is illustrated in Table 2.

Table 2. Scale for grading gross team performance

Result	Venue	Margin	Points
Win	Away	> 1 goal	10
Win	Home	> 1 goal	9
Win	Away	1 goal	8
Win	Home	1 goal	7
Draw	Away	draw	6
Draw	Home	draw	5
Lose	Away	1 goal	4
Lose	Home	1 goal	3
Lose	Away	> 1 goal	2
Lose	Home	> 1 goal	1

4.2.1.2. Analysis of data

Means and standard deviations were obtained for absolute heart-rate values and for increments over basal values:

(a) for each game.

(b) for each player in his League appearances.

(c) for all home League games and for all away League games.

(d) for all League games.

(e) for F.A. Cup games.

(f) for each player making his first team appearance of the season or returning to the side after an interval of more than one intervening game.

Spearman rho (Siegel, 1956) was used to investigate the correlations between the mean level of each S and:

i) his overall performance during a game.

ii) drive and anxiety dimensions of personality.

Team mean values were compared when playing at home and away to twenty different teams using a sign test (Walsh, 1946). The difference between F.A. Cup matches and League games was analysed using Students 't' test.

The correlation between individual mean levels and work-rate during competition was investigated using Spearman rho. This method was used to investigate correlation between team mean values and spectator attendances.

4.2.2. Match play and competition work-rate

The measurement of physiological parameters is impracticable during competitive professional football. The energy expended in performance is directly related to the mechanical work output, a measure of which in a field invasive game is the total distance covered. Pollock (1968) suggested how a time-motion analysis can be used to quantify a training prescription but his technique has no utility as an evaluative tool for current purposes. The cine-film technique used by Saltin (personal communication, 1973, August 16th) is too expensive to employ for collecting the amount of data required to investigate positional differences, apart from the technical problems of obtaining measurements of distance from the film. A methodology for assessing the extent and intensity of movement, incorporating motion and activity analysis, was designed for application during competition.

4.2.2.1. Procedures

Each discrete activity during competitive play was recorded from observation, any change in the nature and level of behaviour constituting a new activity. Movement was divided into walking, backing and running. Running was sub-divided according to intensity into jogging, cruising (running with manifest purpose and effort) and sprinting. Where distance was covered in possession of the ball, this was recorded. Jumps off the ground for the purposes of heading or kicking the ball and of avoiding tackles were recorded. Frequency and duration of time on the ground, standing still during play or during an injury pause were recorded by counting at a 1-second rate when the duration of the stop was short (< 3 s) or with the assistance of a stop-watch when the duration was long, the watch being activated on the count of three.

To assist the estimation of distance a number of cues on the playing pitch and its boundaries were used. A map of the home pitch was drawn up and a grid superimposed on this. The lime markings on the playing pitch provided the framework for this purpose. Longitudinal divisions were derived by extending the penalty area side-lines to meet at mid-field. Transverse divisions were obtained by designedly painting markings on the boundary walls at intervals of ten metres starting at each end line for each half of the pitch. Gradations in colour of grass on the pitch due to the mode of grass-mowing provided additional transverse and longitudinal cues. Distances were pre-determined using a steel tape. The map was mentally rehearsed and kept available for checking purposes at competitive matches. The map used is illustrated in Figure 2.

At away games the dimensions of the playing pitch were obtained from ground staff and checked using a steel tape on one half of the pitch. Convenient visual cues incorporated in the advertisement hoardings along the far side-line were used as a basis for interpolating between pitch markings.

Observations were made from a seat in the Directors' Box overlooking the half-way line in 1-metre units. The activity of one individual was monitored for the duration of a complete game. A coded commentary of his activity was recorded using a casette tape-recorder.

A total of fifty-one competitive games was observed. Everton players were studied at both home and away games on forty-two occasions, along with one game against the 'Reserves' at the experimental home ground. Seven opposition players were observed each on one occasion. In addition, observations were made during two full international matches played at Goodison Park, the experimental home ground.

4.2.2.2. Validation

The validity of the methodology for estimating work output required the establishment of its reliability and its objectivity. Clarke (1967 op cit) defined reliability as "the degree of consistency with which a

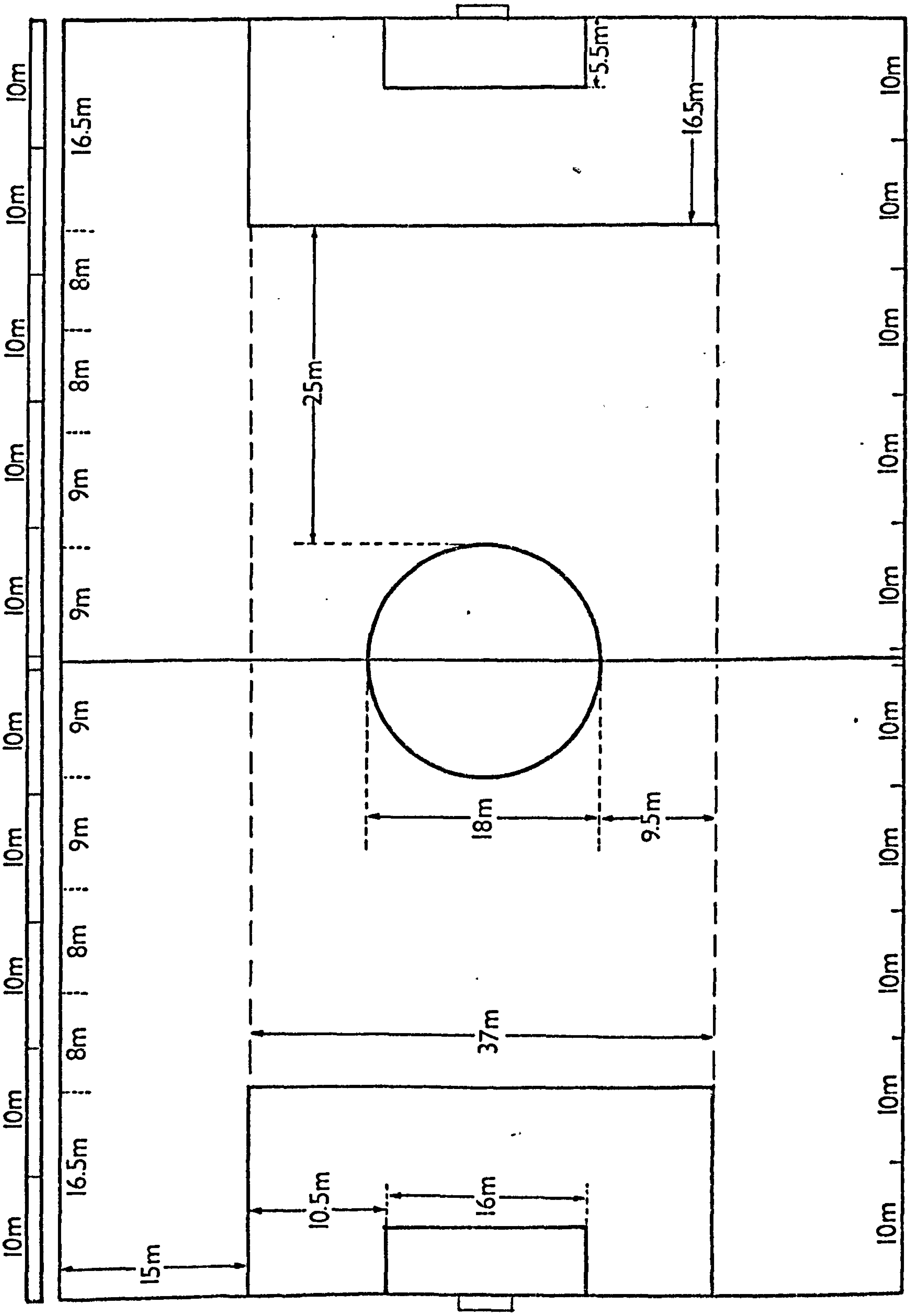

Figure 2. Map of experimental home ground.

measuring device may be applied". Because the activity here monitored could not be reproduced with the consequent availability of repeated measures, the conventional statistical procedures of test-retest or split-half correlations implied in the definition were not appropriate. Feldt and McKee (1958) wrote about a skill test:

> "There is no single index which may be rightfully called the reliability of the test. There are in fact as many reliabilities as there are ways in which one may rationally partition the variance of obtained scores into true and error components".

The analysis of variance procedure and the models used by Hoyt (1941), Henry (1959) and Baumgartner (1969) were not fitted to the current design, which required the establishment of a criterion and the comparison, activity by activity, between the estimated figure and the criterion figure. A criterion which employed mechanical instruments and was error-free in the extraction of data could be regarded as producing a true score as connoted by Feldt and McKee (1958 op cit). A true score of movement parameters could be achieved by concurrently filming competition and applying the subjective methodology. The coefficient of correlation between the estimates and synchronous measurements obtained from the film record is a *de facto* coefficient for the reliability of the experimental method.

Objectivity as a concept has different meanings. According to Clarke (1967 op cit), objectivity in testing is achieved when no disagreement occurs among competent persons in scoring any given subject while using the same test. In the current context, inter-personal comparisons were adjudged invalid as it was felt the degree of training in the methodology and the pre-requisite commitment to the research were not easily replicable.

Frequently in physical performance testing, objectivity only is computed - the assumption being that if objectivity is established, reliability is automatically assured. A measurement instrument can have a high degree of reliability without an appreciable degree of objectivity. In this instance the concept of reliability is contained within the concept of objectivity as the method could conceivably contain a consistent underestimate or overestimate. The concept of objectivity in the current context means that the subjective estimates concord with the actual distances covered, concomitantly obtained using mechanical tools of measurement and the same units. The establishment of reliability alone and a consistent measurement error would vindicate the experimental technique if a correction factor could be applied to it. The validity of the method is then a logical sequel.

In conjunction with the experimental method a video-tape recording was made by an assistant, the camera following the same S throughout one complete match. Data was extracted during playback on a modified 'TV' screen. The systems used are shown in Plate 14 and Plate 15. Activity was analysed according to the taxonomy of the experimental method. For each discrete activity the number of strides was counted and converted to distance using the mean length of stride of S at each type of movement. Högberg (1952) found that there was for every runner and every speed an optimum of stride length and frequency. The most economical stride length always lay in the region of the freely chosen one with well-trained subjects. Bøje (1944) showed that the frequency of steps was only slightly increased with increasing speed in running but the length of the steps was greatly increased. More recently, Knuttgen (1961) found that increases in running speed are largely effected by increases in stride length rather than stride rate. In view of this, separate mean stride lengths were established for the three levels of running intensity employed.

Plate 14. Portable battery-operated video recording unit and camera.

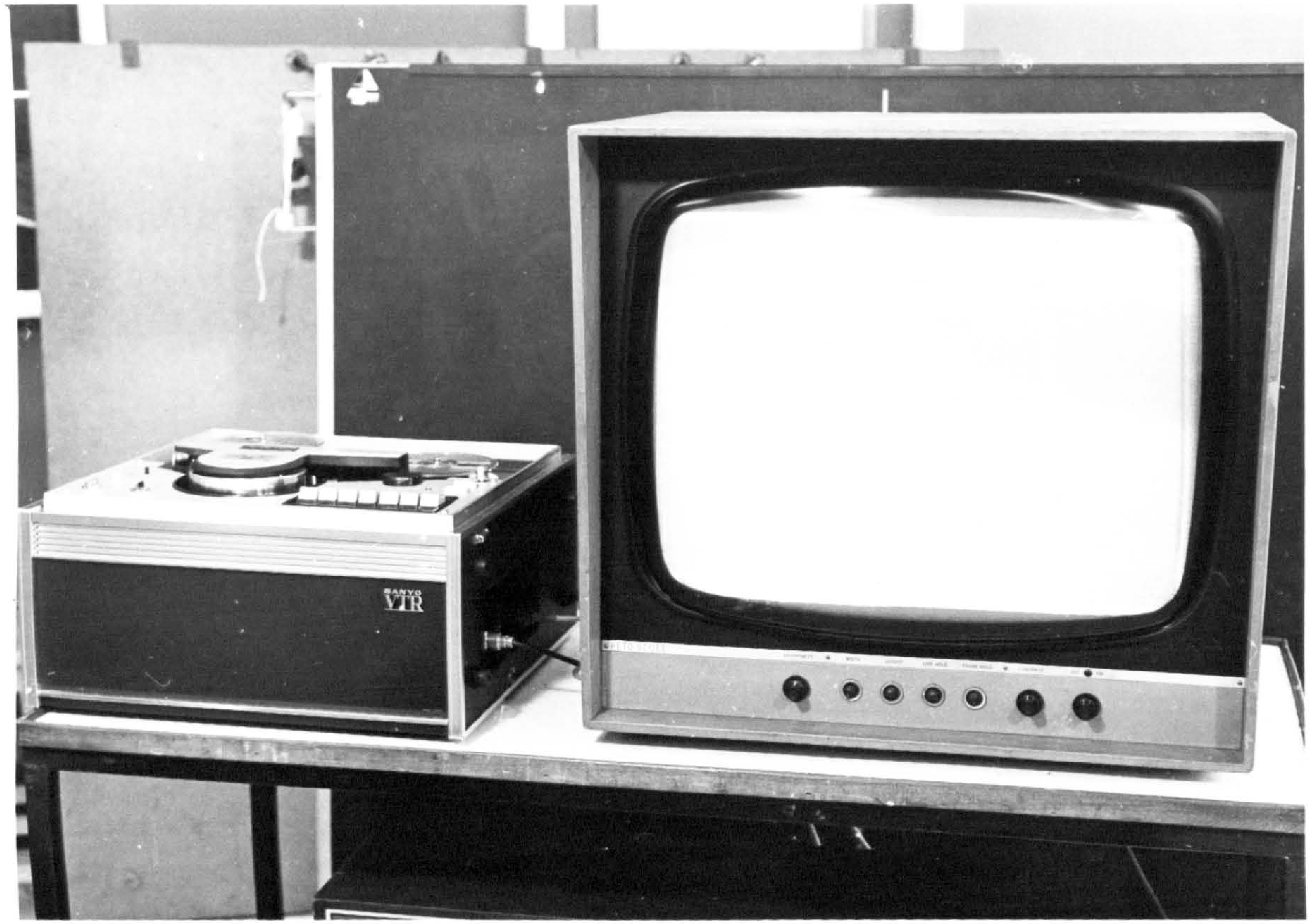

Plate 15. Slow-motion video recording unit and TV screen used in data extraction from video tape.

Mean stride lengths were determined during training by instructing S to cover a distance between two marked points at each type of activity and at a level corresponding to the experimental classification. For each type of activity, mean stride length between the points - which were fifteen metres apart - was determined. After the conversion of strides during competition to distances for this S, the measurements taken from the tape-recording were comparable, activity by activity, with the data obtained by the experimental methodology.

The reliability of the experimental methodology was investigated using cross-product correlation analysis. Objectivity was established using regression analysis. If the method were perfectly reliable and perfectly objective it should have a correlation coefficient of one, the regression equation should have an intercept of zero and a slope of one. Perfect objectivity would also imply a constant stride length for a given level of activity irrespective of the distance of a discrete movement activity.

Reliability coefficients (r) obtained were highly significant for all types of activity. The values for r were: backing 0•92, walking 0•97, jogging 0•96, cruising 0•92, sprinting 0•97. No omissions in recorded activities were found, indicating no attentive lapses on the part of E during the observation period. Disagreement in classification of activity was infrequent, occurring on thirteen instances during the match. Misclassifications were excluded from the data in the correlational analyses, but were included in the regression analysis.

Mean stride lengths were found to be 0•60 m for backing, 0•64 m for walking, 0•9 m for jogging, 1•13 m for cruising, 1•24 m for sprinting. These values consistently concorded with results taken off the video-tape record during typical movements ∿ 9 m when the distance between two marked points allowed accurate determination.

When distances were estimated from stride frequency for each movement activity the results correlated highly with the measurements using the devised methodology (r = •97). The regression equation to predict distance as computed using the stride counts (y) from the experimentally derived values (x) was: $y = -\cdot539 + 1\cdot065\,x$. Over a typical match involving 900 discrete movements and a total of 9000 m, this amounts to an error of less than one per cent which is well within acceptable limits for this type of investigation.

4.2.2.3. Analysis of Data

Mean and standard deviation of the total distance covered in a game were obtained for all Everton outfield players observed. Means and standard deviations of the frequency and distance of each type of activity were determined.

Ss were subdivided according to four positional roles (centre-backs, full-backs, mid-fielders and strikers) and the significance of differences between positions analysed using the 't' test.

Figures for home and away games when the same S played in similar positional roles were compared using a sign test to investigate the difference between home and away conditions. Where the difference in duration of first and second half was less than one minute, results were analysed using the sign test to investigate a 'fatigue' effect represented by a significant decrement in performance (total distance covered) in the second half of the match.

4.3. Assessment of training load

4.3.1. Methodology

Oxygen consumption is taken as a valid index of the severity of work (Brouha, 1960; Durnin and Passmore, 1967, op cit). The resultant proportionate load on the circulatory system is an indicant of its severity in an individual. The relative load is of greater importance to the individual than the energy demand (Åstrand, I. 1967). Ascertaining the relative load necessitates the expression of the $\dot{V}O_2$ demands of work as a percentage of the individual's $\dot{V}O_{2\,max}$ which is equivalent to his maximum aerobic power. $\dot{V}O_{2\,max}$ may be measured directly during maximal work or predicted from submaximal measurements of one or more exercise intensities by using the known linear relationships between heart rate (fH) and $\dot{V}O_2$ and extrapolating to an assumed maximum heart rate, which with European male subjects aged 20-30 is 195 beats/min (Åstrand and Rhyming, 1954).

The heart rate may be measured during work in the field situation and applied to the individual's fH-$\dot{V}O_2$ curve determined in the laboratory to estimate the energy demands of work. Åstrand (1971) emphasised that $\dot{V}O_2$ can be estimated in the laboratory during controlled work on a bicycle ergometer, step-test or treadmill running as the mechanical efficiency of these activities is relatively constant. These principles have been applied to estimate the energy cost of basketball by McArdle et al (1971), of a number of selected sports by Skubic and Hodgins (1967), by Åstrand I. (1967 op cit) in the building industry and Åstrand I. (1971 op cit) in housekeeping activities. This method circumvents the inherent shortcoming of indirect calorimetry in that it is impossible for a footballer to play while carrying a Douglas bag or K-M respirometer.

Bradfield (1971) recommended that energy expenditures for a period of time be obtained by using the mean heart rate for the corresponding period and referring to the individual's regression line for the energy expenditure corresponding to the heart rate. Caloric values may be obtained by assuming the $\dot{V}O_2$ and energy expenditure relationship of Weir (1941):-

$$E = 4{\cdot}92 \times \dot{V}O_2$$

where E represents energy in kcal/min and
$\dot{V}O_2$ is consumption of oxygen in ℓ/min.

To avoid the dangers of extrapolation, Bradfield suggested submaximal work at three levels - one in the area 120-130 beats/min, a second in the area 140-150 beats/min, and a third at a rate exceeding 160 beats/min. Sjostrand (1947) employed two submaximal work-loads and extended the two points obtained for the heart-rate/work-load relationship through the 170 heart rate line to determine physical working capacity (PWC_{170}). Margaria et al (1965) employed two submaximal work levels of bench step-ups to predict $\dot{V}O_{2\,max}$. de Vries and Klafs (1965) reported that the use of two work-loads to determine a slope line in the Sjostrand test offered no advantage over the shorter Åstrand-Rhyming (1954 op cit) procedure in which the maximal O_2 uptake is predicted from one submaximal work-load.

Booyens and Hervey (1960) concluded the pulse rate method is valid during moderate exercise for measuring the energy metabolism. They did not investigate high work intensities. The type of activity and posture can have an important influence. Andrews (1969) investigated the influence of bodily site of work on the fH-$\dot{V}O_2$ relationship and found a significant subject × site of work interaction. In addition, Bradfield's conclusion (that heart rate is a better predictor of oxygen consumption with subjects that are moving than with subjects that are sitting or standing) advises the use of treadmill running as the laboratory work-mode with the population studied here, as this should adequately represent the gross muscular involvement in playing soccer.

The relationship between fH and $\dot{V}O_2$ may not be linear throughout the range from minimum to maximum values. Booyens and Harvey (1960 op cit) reported that at rest there was too much variation in both fH and $\dot{V}O_2$ with changes in posture for fH to be useful in measuring metabolic rate, but that during muscular activity a consistent relationship obtained. Henderson and Prince (1914) had shown that in any one individual there was one relation between fH and $\dot{V}O_2$ which held good during rest and very light activity, and that there was an abrupt transition to a second relation when exercise was undertaken which was more constant and linear, and which in turn broke down at high levels of exertion.

Cardiac output ($\dot{Q}$) is one of the important measures of the contributions of the heart to the metabolism during physical work. Stroke volume (SV) of the heart is involved as well as its rate of contraction and this is represented in the equation: $\dot{Q}$ = SV x fH. Brooke (1969) cited Brouha and Radford's (1960) conclusion that after a low level of exercise, demanding about 1ℓ/min O_2 uptake, SV in the human remains practically unchanged and increases in fH depict the cardiac adjustments to physical work. Berggren and Christensen (1950) found that pulse rates could be used advantageously as an index of the metabolic rate. In the ranges of 1 to 4ℓ.O_2 min, an increase of 30 cc in oxygen uptake corresponded to one heart beat/min. Malhotra (1963) related oxygen consumption to heart rates and had to construct two linear regression lines for each S — pre and post heart rates of 95 beats/min — indicating a functional difference at this level of work. Åstrand et al (1964) demonstrated that at heart rates of approximately 110 beats/min or at oxygen uptakes of approximately 40% of maximum, almost maximal stroke volumes were reached and no tendency to a decrease in stroke volume was noticed when maximal work was performed. Jones and Foster (1964) demonstrated that over an exercise range up to a level demanding heart rates of 171 beats/min, there is a high correlation between heart rate and duration of left ventricular ejection (r = 0•86) with only a minor increase in correlation with the addition of stroke volume to the heart rate measure.

Results of Hamley and Thomas (1967) with racing cyclists suggest linearty between fH and $\dot{V}O_2$ holds to exhaustion at heart rates of ∿ 200 beats/min. Brooke et al (1968) investigated the relationship of heart rate to a continuously increasing work load in eleven racing cyclists. The responses of three Ss were linear to exhaustion at 195 beats/min. In the other Ss, linear regression equations adequately fitted the curves up to heart rates in the range 160 to 180 beats/min. The second part of these Ss' responses were fitted by exponential equations to the form $Y = ax^n$. Åstrand et al (1960) found a constant O_2 uptake per pulse beat from the second minute onward in a study of one S working to a maximum tolerable time of nine minutes. They concluded:

> "this might indicate a constant stroke volume and a constant aerterio-venous O_2 difference and if it does, the increase in $\dot{V}O_2$ between the second and ninth minute can be explained entirely by a simultaneous increase in heart rate from 160 to 180 beats/min".

The heart rate can be affected by the emotional state of the subject, causing deviations from the expected response. Åstrand et al (1960) noted the general observation that during work the psychic influence on heart rate is more or less abolished. Hickam et al (1948) concluded that when persons with the anxiety reaction undertake muscular exercise the normal relationship between $\dot{Q}$ and $\dot{V}O_2$ is re-established. Åstrand (1967 op cit) reported that one world-class downhill skier did have an elevation in heart rate 20 beats/min in excess of the O_2 transport requirements during his run. The emotional tachycardia is not incompatible with expectations in this type of sport. It is unlikely that an emotional component is involved in the daily training heart rate data of footballers though an emotional tachycardia may be expected to intermittently obtain during competition.

Another source of variability in fH during work is heat stress as $\dot{Q}$ subserves the function of preserving thermoequilibrium. Christensen (1953) reported increases in fH disproportionate to $\dot{V}O_2$ changes. The heat stress effects are additive at all levels of work intensity except at the highest (Le Blanc, 1957). Brooke (1969 op cit) concluded that except for severe heat stress, the variability in fH is within the limits of normal error estimation. Thermoregulatory problems do not arise during training sessions of footballers. Severe ambient wet-cold conditions are avoided by use of the indoor facilities when necessary. Outdoors during the football season, dissipation of body heat would not seem to be a major requirement.

Hansen and Maggio (1960) have reported that static effort resulted in pulse increases that overestimated the actual metabolism. There is little or no distinct static component in playing soccer or in training procedures employed.

The cyclical nature of work during competitive games might affect the validity of using heart rate to predict oxygen consumption. Hill (1923) coined the term 'oxygen debt' to describe the amount of oxygen utilised above resting level during the recovery period. The lag in oxygen uptake at the beginning of exercise — called "oxygen deficit" by Christensen et al (1950) — has been said to be due to the oxygen need in the tissues as a result of the production of oxidisable substrate (Henry, 1951; Schneider, 1968). Wasserman et al (1967) found oxygen debt to be equal to oxygen deficit at submaximal work loads. Whipp et al (1970) found oxygen debt to be twice as large as oxygen deficit at short work loads of 2-3 min, but that they were equal if the duration of submaximal exercise was 4 min or more. Morton (1974) proposed that the total oxygen debt may be subdivided into three related but distinct components. The first component includes that amount of oxygen necessary to repay those oxygen sources utilised during exercise in addition to the oxygen uptake during exercise to provide for aerobic energy production. The second component includes that amount of oxygen necessary to repay the oxygen equivalent of anaerobic sources utilised during exercise. The third component of the oxygen debt consists of the amount of oxygen needed during recovery to re-establish a normal resting metabolic rate. The investigations of Margaria (1964) and Knuttgen (1970) accentuate the complexity from a theoretical perspective of the oxygen debt-oxygen deficit relationship. For practical purposes the findings of Christensen et al (1960), that the deficit in oxygen transport during 20 min of actual work performed intermittently was taken up during the 120 rest pauses of 5 s each, provide a firm experimental basis for the use of continuously monitored heart rate during sports performance as employed, for example, by McArdle et al (1971) to predict oxygen consumption. Seliger (1968 op cit), who has investigated intensity of work during performance in a number of sports employing this approach, stated that where exercises lasted for a period longer than five minutes the work was performed in steady state.

The available evidence suggests that heart rate data can validly be employed in field studies for estimating the energy demands of work ranging from light to near maximal intensities. Especially encouraging is the work of Andrews (1971 op cit), who found that the subject-to-subject variation relating fH and $\dot{V}O_2$ can be reduced to statistical non-significance if the wide variation from subject-to-subject in resting heart rate is taken into account. The variation at rest was attributed to differences in physical condition (sic).

Regression equations for each individual for the fH-$\dot{V}O_2$ relationship could not be obtained without inconvenience to the subjects. One point on the fH-$\dot{V}O_2$ curve was obtainable for each S from the results of the treadmill test conducted in the laboratory. Two nomograms are available to calculate the oxygen cost (ml/kg/min) of treadmill running from the treadmill speed and incline (Shephard, 1969; Margaria et al, 1963). Results of Åstrand (1953) imply supra-normal mechanical efficiency in treadmill running for top-class Swedish footballers aged 20-30 and support the use of the Margaria nomogram based on athletic subjects. Using this procedure the oxygen cost of the treadmill test was estimated to be 36·25 ml/kg/min. $\dot{V}O_{2\,max}$ was obtained using the Åstrand-Rhyming nomogram to give a second point. The slope of the regression line was described by connecting these two points and the energy demands of work obtained by interpolating to the working heart rate. In effect the slope of the regression line for each S was determined by the Åstrand-Rhyming nomogram. In the light of the findings of Malhotra et al (1962), in a study of different activities which included hockey, cycling and physical training, the absolute energy values so derived should be corrected for S's body weight.

A number of authors have suggested that, apart from its use as a predictor of energy demands, the heart rate can be used on its own as an index of strain. The simplicity of the method favours its use. Rozenblat and Solonin (1966) advocated its suitability as an index of the intensity of physical exertion in contemporary athletic training and in industry, stating that it is at once an expression of the total load imposed on the body. Booyens and Hervey (1960 op cit) concluded that where pulse rate is being determined by factors other than metabolism, it is a better indicator of the physiological strain the situation imposes than measurement of metabolic rate alone. Maxfield and Brouha (1963) validated its use as a measure of cardiac strain while Maxfield (1964) demonstrated the usefulness of heart rate information to measure cardiac performance in young women during physical training. Åstrand (1960) concluded that heart rate gives a good measurement of the work-load level during continuous work. Åstrand I. (1967) recognised that most jobs are intermittent and that an objective measurement of the degree of strain can be attained in such cases by recording the heart rate continuously for an extended time. Hanson and Tabakin (1964) monitored heart rate using radio-telemetry in competitive skiing for this purpose. Kozar and Hunsicker (1963) used group mean heart rate data to compare the severity of physical exercise in badminton, handball, paddleball, tennis, volleyball and bowling. The gross heart rate values can be used in the present study as an indicant of training load and as an indicant of strain during full-scale simulated competitive games, in addition to their use as a predictor of energy demands.

Basal and maximum heart rate values were available from the laboratory tests. Used in conjunction with these values, training heart rates could be expressed as a proportion of the increment in heart rate possible in any individual. This principle was employed in the laboratory tests used by Harrison and Reeves (1968) and Lester et al (1969). The fundamental assumption is that the basic challenge to the coronary circulation is related to the percentage of the maximal possible heart rate that is achieved during exercise. The assumption may be criticised in view of the fH-$\dot{V}O_2$ relationship in the range from rest to maximum exertion already reviewed, but the procedure has irrefutable utility value in the quantification of circulatory strain.

A major difficulty of analysing the demands of training is the categorisation of the various activities which commonly form a training session. Sessions vary enormously in terms of content and the serial ordering of routines from day to day. Preliminary observation suggested that eight sub-divisions could be made based on the manifest objectives of the routines:

1. Warming up.
2. Calisthenics and mobility work.
3. Running.
4. Circuit and Weight-training.
5. Skills Practice (individual and small-group skills training).
6. Drills (shadow, pressure, team-drills).
7. Games (indoor, outdoor, 11, 6 or 5-a-side competition).
8. Recovery (total of all intermediate rest-periods).

It was considered necessary to investigate each routine individually as well as the overall training session.

It was possible to assess the accuracy of the simulated intensity of competition in the training environment in one subject. One training game (First Team vs. Reserves) was held at the experimental home ground where the technique for assessment of distance covered could be applied. The duration of the game was 74 min and the results were extrapolated to the full competitive period. Results were compared with the values for distance covered by the same subject in League competition later in the week. The training pitch generally used for simulated games exactly replicated the dimensions of the experimental home ground. It was felt estimates of distance could not validly be made at the training ground as the array of environmental cues normally employed to assist the perception of distance was absent.

4.3.2. Materials

Heart rate during training was recorded continuously in 23 Ss using radio telemetry (NEC Type 101), each S being monitored throughout one week's training programme. S was prepared before training with the system which consisted of two lead electrodes on his chest connected by leads to a transmitter strapped on S's shorts. A rubber belt and cushions on both sides were worn as a precautionary measure for contingencies of falling or physical contact. A whip antenna carried dangling on S's side facilitated transmission. The telemetry system used is shown in Plate 16.

Electrodes were placed just below the left nipple, one to the left and one to the right and ∿ 9 cm apart. The skin was first cleaned with alcohol and a thin film of electrode jelly put on the centre of the electrodes. The electrodes were fixed to the skin by adhesive tape and a specially adapted elastic belt 2•5 cm wide placed over the electrodes and round the chest secured them against displacement during exercise. The electrode positions are shown in Plate 17 and accessories worn are shown in field conditions in Plate 18.

The ECG signal was transmitted to a receiver at the end of the pitch and the R spike of the wave-form converted to an audio signal. Heart rate was obtained either directly from the audio-signal by concurrent manual recording, or sampled from a tape-recording of this signal, using a Heuer stop-watch calibrated in beats/min (Astrand and Rodahl, 1970 op cit; Thomas, 1971 op cit). The manual concurrent sampling and recording method at an undetermined sampling frequency was compared with sampling from a tape-record at a pre-determined 10/min rate during a 6-a-side indoor football game of 25 minutes

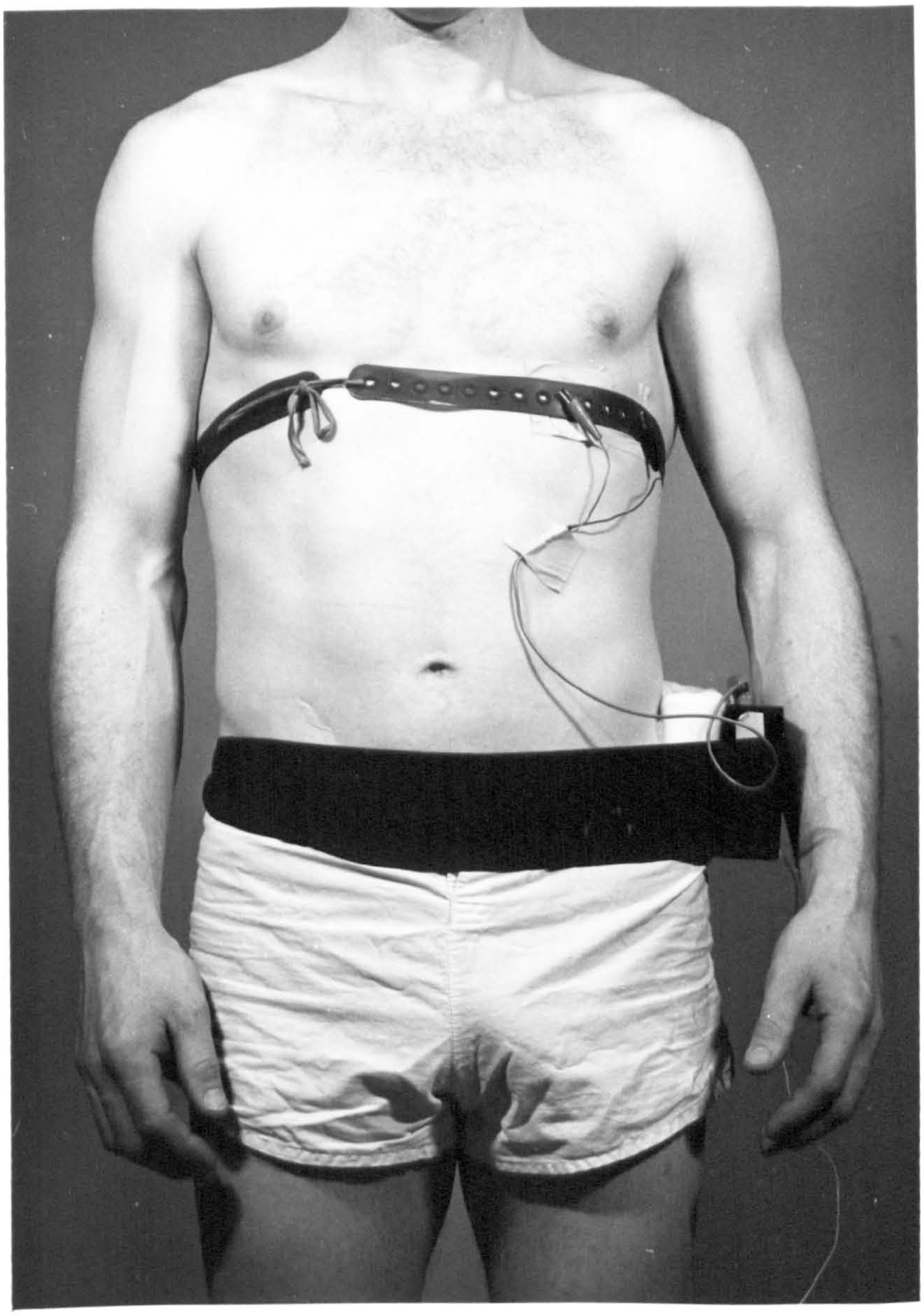

Plate 16. Shows the equipment worn by S for obtaining heart rates in training.

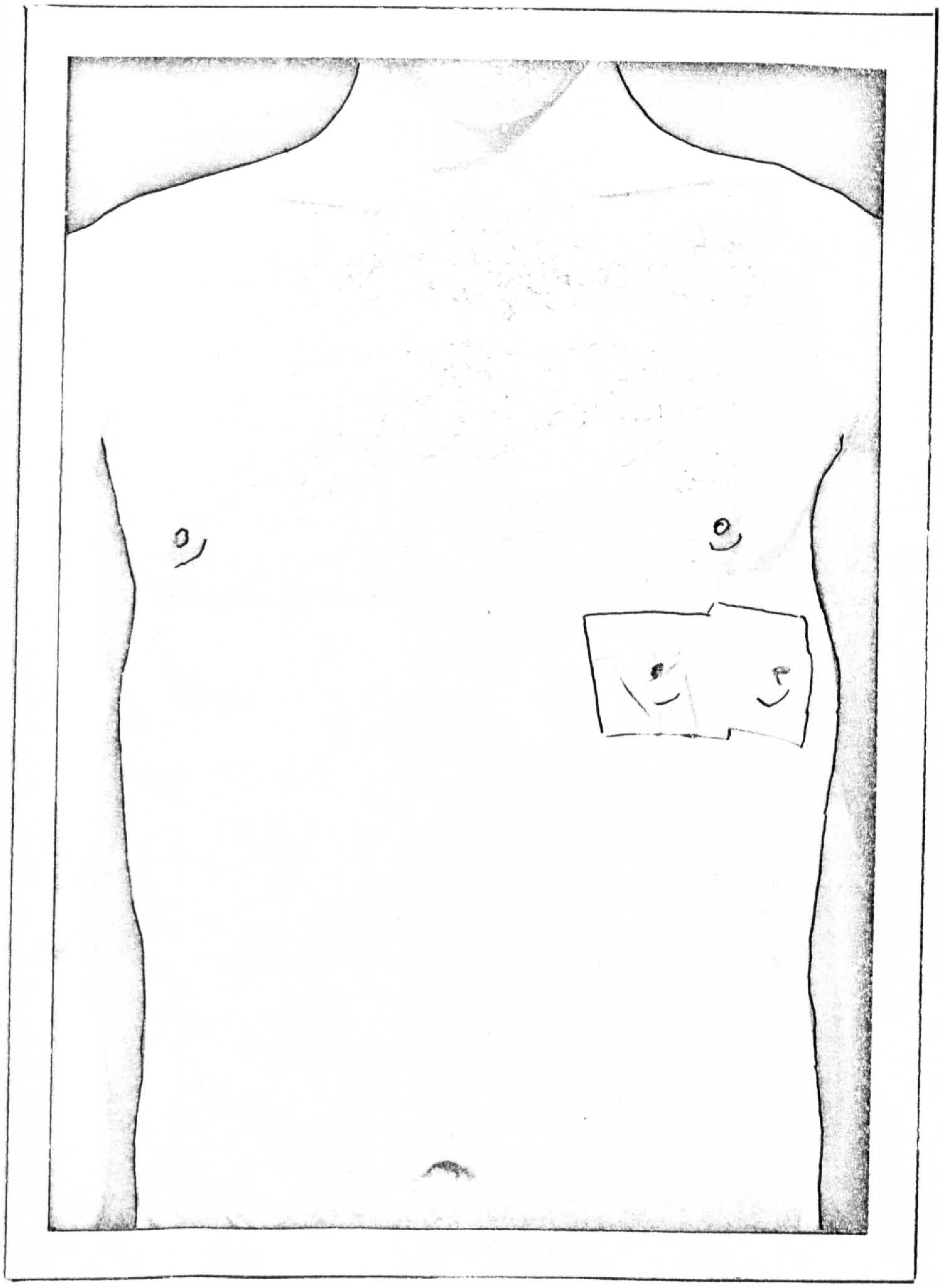

Plate 17. Placement of electrodes for continuous monitoring of heart rate.

Plate 18. Shows S in field conditions wearing SAMIs.

duration. The mean sampling frequency effected by the manual method was six observations per minute. Both methods gave identical values to the nearest beat/min over this period with a standard error of difference between the methods of less than one beat/min.

During training sessions players invariably used the whole area of the extensive training grounds, S sometimes going beyond the range of the system's transmission capability. During running routines the signal was sometimes interrupted by obstacles or buildings intervening between S and the receiver. The equipment required changes of location during training sessions to stay within telemetry range of S. For these reasons both concurrent manual recording and tape-recording methods of obtaining heart rates were employed. Sampling was attempted at least once every ten seconds.

Over the 23 weeks of investigation only 2 mid-week League matches were played, one on Tuesday and one on Wednesday. Matches took place in the evening and training was performed in the morning on both occasions.

4.3.3. Processing of data

A computer programme was written to incorporate the following statistical descriptions:-

(i) Mean and S.D. for each S (n = 23) for each routine (8) for each day.

(ii) Mean and S.D. for each S for each routine for day of week (5).

(iii) Mean and S.D. for each S for each day of week.

(iv) Mean and S.D. for each routine for each day of week.

(v) Mean and S.D. for each routine (across all Ss and days).

(vi) Mean and S.D. for each day of the week.

(vii) Mean and S.D. for duration of each routine for each day of the week.

(viii) Mean and S.D. for duration of each routine.

(ix) Mean and S.D. for duration of training for each day of the week.

(x) Mean and S.D. for duration of training.

To obtain the mean heart rate level for each day the mean heart rate level for each routine was multiplied by its duration before obtaining composite values to be divided by the total duration. The resultant mean value indicated the mean level throughout the training period, the method of calculation precluding any bias due to possible variations in sampling frequency between routines. This method of delineating energy costs by integrating heart rates over timed periods has been employed by Hunt and Marcus (1967).

4.3.4. Training performance tests

Reliability of performance tests was investigated from the results of timed runs over one lap and four laps of a running track. The lap was approximately 160 m. Runs were performed on consecutive days and repeated one week later. Tests were administered by the club's coaching staff. Reliability coefficients were computed using the Pearson product method.

4.4. Physical stress

4.4.1. Procedures

Medical and physiotherapy treatment records kept by the club over the 1972-73 season were extracted. The records included a diagnosis of the injuries incurred, details of treatment and the dates treatment commenced and terminated. This enabled a profile to be built up on each player with regard to the type and frequency of injury and the number of days treatment received throughout the season. A treatment was not considered to be an injury unless it necessitated being excused from full training for more than one day. This permitted a comparison to be made with published data regarding the injury risks per player exposure. The precise time during competition of the injury's occurrence was not recorded as the temporal aetiology can seldom be exactly pinpointed. Injuries were classified into soft-tissue, joint and miscellaneous.

Preliminary observations showed the application of the critical incidents technique according to Flanagan (1954) was impracticable in that it could not adequately be incorporated into the coded commentary of the activity of one S. Data on gross behavioural variables of the activity of one individual throughout a game were obtainable from the motion-analysis employed to evaluate work-rate.

4.4.2. Analyais of data

The number of injuries incurred was used to calculate the incidence of injury per player exposure. Correlations between the injury variables (frequency of injury and total days treated) were separately investigated using Spearman rho with the following variables:-

(i) Anthropometry — leg strength variables, grip strength, ankle mobility (obtained at T2);

(ii) Personality — Factors C, E and O as determined in T2 using the Cattell 16 PF;

(iii) Pre-match arousal level;

(iv) Work-rate during competition.

4.5. Habitual activity and daily energy expenditure

Diary methods, where activities are recorded using a simple code, can be used as a method of assessment of habitual physical activity. Weiner and Louire (1969 op cit) suggested that fifteen code letters can adequately cover the habitual activities of any particular individual. The method involves keeping a minute by minute diary of the time spent in all activities. Conventional values for different kinds of activities are obtainable from tables provided by Passmore and Durnin (1955) and Durnin and Passmore (1967). This method was employed by Grieve (1967) in establishing daily activities and estimating energy expenditure in housewives.

Mahadeva et al (1953) found $\dot{V}O_2$ during treadmill walking or stepping at a constant step frequency to be a linear function of body weight. This is also true for cycling and stepping at a constant rate of external work (Cotes, 1965; Wyndham et al, 1966). Durnin (1959) concluded that gross body weight is the most suitable known reference standard for dealing with measurements of energy expenditure. It seems necessary to make a correction for S's body weight in the application of the conventional values.

4.5.1. Procedures

Fifteen Ss (mean weight 73 kg) completed specially designed daily diaries for one week. Each diary page contained 120 squares covering two hours of minute-by-minute recording. An example of a completed diary page is presented in Figure 3. The precise times when an activity commenced and ended were marked. Diaries were collected each morning for the previous day's record of activities and any ambiguities were clarified at interview. During the week S completed the diary his heart rate was monitored during training using radio-telemetry as described in Section 4.3.2. Records were checked by observation during working hours. An estimate of S's work-rate during competition was made using the methodology described earlier in this Section (4.2.2.1). Energy demands of training and competition were calculated using the methods outlined in Section 4.3. Training games were assumed to accurately simulate the intensity of competition, since distance covered (m/min) in training 11-a-side competition and League competition corresponded in the one subject initially studied.

The duration of time per day at each activity was tabulated and converted to energy values as outlined in Table 3. A correction factor for S's body weight was applied.

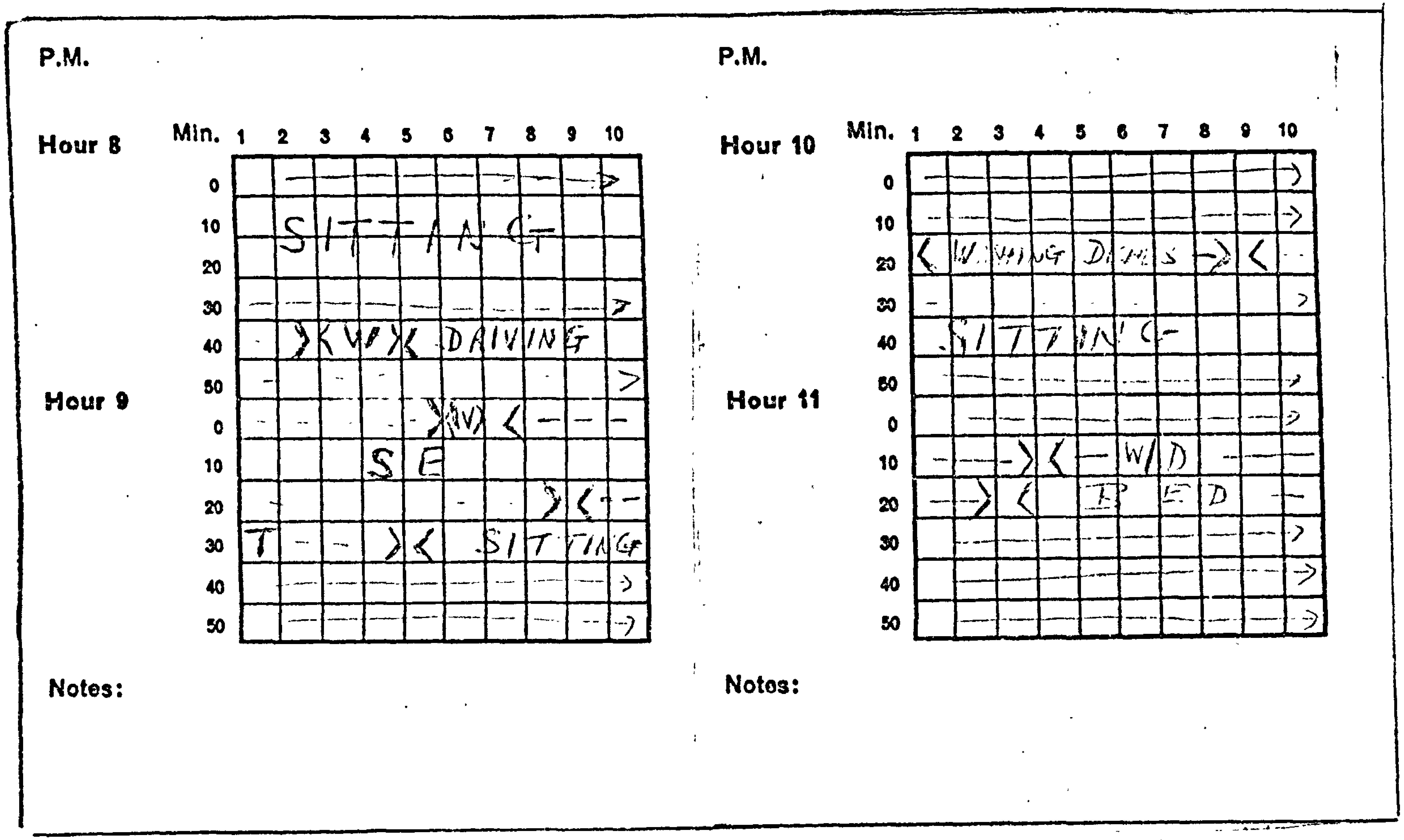

Figure 3. Completed diary cards used to record habitual activity.

Table 3

Estimated energy costs of recorded activities.

Activity	Energy Cost (kcal/min)	Reference Body Wt. (kg)	Source
In Bed	1·1	65	Robertson and Reid (1952)
Lying at Ease	1·5	70	Passmore and Durnin (1955)
Sitting at Ease	1·6	66	Passmore and Durnin (1955)
Standing	1·7	69	Passmore and Durnin (1955)
Sitting Writing/Eating	1·9	64	Passmore and Durnin (1955)
Sitting Playing Cards	2·0	78	Passmore and Durnin (1955)
Washing/Toilet/Dressing	2·6	68	Passmore and Durnin (1955)
Driving Car	2·8	64	Passmore and Durnin (1955)
Cooking/Washing Dishes	3·1	65	Durnin and Passmore (1967)
Out Shopping	3·3	77	*Durnin and Passmore (1967)
Playing with Child	3·5	64	Passmore and Durnin (1955)
Walking Slowly (2·5 mph)	4·0	77	Durnin and Passmore (1967)
Making Bed/Tidying Room	4·4	65	Durnin and Passmore (1967)
Cleaning Car/Cleaning Windows	4·4	65	Durnin and Passmore (1967)
Table-tennis	4·4	65	Durnin and Passmore (1967)
Gardening	4·8	66	Passmore and Durnin (1955)
Golf	5·0	65	Gordon (1958)
Dancing	5·2	65	Durnin and Passmore (1967)
Stair-climbing	7·0	65	Durnin and Passmore (1967)
Weight-training	8·6	80	Reilly (1971)

* No direct measurement was available. Activity was taken as equivalent to walking at 2 mph. This level seemed justifiable on consideration of Grieve's (1967) values for female subjects.

No attempt was made to collect diary information relating to sexual activity as this was considered an unwarranted invasion of personal privacy. This convention was established by Passmore et al (1952) in their study of miners. More recently, Shephard (1967) adopted a similar attitude in his study of Canadian city dwellers. From the findings of Masters and Johnson (1966), the metabolic effort ignored by the exclusion is likely to be negligible in the context of daily energy expenditure rates.

4.5.2. Processing of data

Means and standard deviations for the times spent lying in bed and sitting were obtained for each day of the week as well as for overall daily values. The time spent in sedentary and recumbent postures was expressed as a proportion of a 24 hour day. Means and standard deviations of estimated daily energy expenditures as well as the rates for each day of the week were obtained. Additionally, an estimate was made of the mean energy expenditure per day during the time consumed by 'professional life space'.

SECTION FIVE

RESULTS

5. RESULTS

5.1. Fitness assessment

5.1.1. Descriptive statistics

The same 31 Ss attended T1 and T2. Ss (n = 30) at T3 included one individual not previously tested; Ss (n = 28) at T4 included two individuals not previously tested and one individual who was not present at T3 because of injury but who had attended the first two tests. The First Team (Group 1; n = 15) was the same for T1 and T2, had three changes in personnel at T3 (n = 15) and a further five changes between T3 and T4 (n = 14).

Anthropometric details of Ss are presented in Appendix I. Age at T1 ranged from 17•5 to 29•9 years with a mean value of 22•5 (S.D. = 3•2) years. Height ranged from 165 to 186•5 cm with mean value 176 (S.D. = 6) cm. Ss weighed between 59•3 and 95•7, with mean 73•2 (S.D. = 8•2) kg. Body Surface Area ranged from 1•65 to 2•19, with mean 1•87 (S.D. = 0•13) m^2. These parameters showed little fluctuation throughout the season. Endomorphy ranged from 1•0 to 4•5. The difference between T1 (mean 2•8; S.D. = 0•8) and T3 (mean 2•6; S.D. = 0•7) was not significant ($p > •05$). There were no differences in skinfold thicknesses between tests for any combination of test comparisons ($p > •05$).

Vital Capacity (VC) ranged from 4•8 to 7•7 ℓ (B.T.P.S.) with a mean value of 5•8 (S.D. = 1•0) ℓ. Mean predicted from height and age using the nomogram of Garbe and McDonnell (1964) was 5•15 (S.D. = 0•34) ℓ. This difference is highly significant ($p < •001$). This parameter remained relatively constant throughout the season, mean at T4 being 6•0 (S.D. = 0•9) ℓ. FEV_1 ranged from 3•8 to 7•05 (mean 4•95; S.D. = 0•9) ℓ. The mean predicted from height and age was

4•3 (S.D. = 0•25) ℓ, a result significantly different from the obtained mean ($p < •001$). This parameter was relatively stable throughout the season; the mean at T4 was 5•05 (S.D. = 0•8) ℓ.

Mean mobility at the ankle joint was 61•6 (S.D. = 8•5)^{o} at T1 with a range from 46 to 81^{o}. Mean at T3 was 54•6 (S.D. = 7•6)^{o} with a range from 33 to 68^{o}, and at T4 was 54•1 (S.D. = 6•5)^{o} with a range from 36 to 68^{o}. The differences between means for T1 and each of the later tests were significant ($p < •05$).

Reaction time ranged from 139 to 232, with mean 177 (S.D. = 19) ms at T1, and 123 to 188, with mean 149 (S.D. = 14) ms at T2. This difference is significant ($p < •05$). Results similar to T2 were found for the remaining tests.

Mean resting systolic pressure was close to the normal value of 120 mm Hg (Åstrand and Rodahl, 1970 op cit) except for the elevated values at T1 (mean 133; S.D. = 13 mm Hg). Two Ss had systolic pressures of 150 mm Hg or above at T1. The highest value at T1 (170 mm Hg) and T2 (140 mm Hg) was found in the same S. Mean diastolic pressures were lower than the normal 80 mm Hg quoted by Åstrand and Rodahl (1970 op cit) at all tests. Pulse pressure ranged from 31 to 82, with mean 60 (S.D. = 13) mm Hg at T1 and from 28 to 71, with mean 52 (S.D. = 14) mm Hg at T2. Results of blood pressure variables were similar to the figures of T2 at the remaining tests. Blood pressure data are included in Appendix 1.

Results of the muscular strength and power tests are presented in Appendix 2. Grip strength remained stable throughout the season with no significant difference between successive tests or any combination of test comparisons using Students 't' test ($p > •10$). A high cross-product correlation was obtained between T1 and T2 measurements of right-hand grip strength (r = •80). Ankle extension strength was excluded from the test battery after a ceiling effect with the existing equipment was found in the first two tests. Trunk extension was discarded from the list of functions tested after T2 due to difficulties in test administration. Measurements of flexion and extension strength were obtained on both legs after T1. Mean values in all cable tension measurements showed a significant decline between T1 and T4 ($p < •01$).

Vertical jump scores at T1 ranged from 44 to 69, with mean 58•0 (S.D. = 6•15) cm. Standing broad jump (SBJ) at the same test ranged from 187 to 255, with mean 219 (S.D. = 16•5) cm. The decrease in vertical jump of 2•4 cm at T2 was non-significant ($p > •05$). Performance on the succeeding tests were similar to results at T2. SBJ showed a non-significant decrease at T2 ($•05 < p < •10$) and a subsequent significant increase at T3 using a 't' test ($p < •05$). SBJ performance at T1, T3 and T4 were similar. Test-retest correlation coefficients were 0•79 (T1-T2) and 0•59 (T2-T3), both results being significant ($p < •01$).

Results of the cardiac variables are presented in Appendix 3. Mean value for "Sitting Heart Rate" for T1 and T3 was close to the figure generally quoted for normal subjects of ∿ 65 beats/min. Mean was 54 (S.D. = 9•6) beats/min at T2 and 59 (S.D. = 8•3) beats/min at T4. These values were close to the 59 beats/min reported by Bălănescu et al (1968) for Roumanian footballers. Basal pulse rates (n = 20) obtained during sleep ranged from 37 to 49, with mean 45 (S.D. = 6•3) beats/min. Maximum heart rate at T1 ranged from 179 to 223, with mean 198 (S.D. = 7•8) beats/min. Results of the remaining tests were of a similar order of magnitude. Cardiac Assessment Factor (CAF) ranged at T1 from 32•1 to 49•4, with mean 40•6 (S.D. = 3•3). Similar results were found in the other three tests.

Scores on the Harvard Step Test improved from T1 (mean 78•8; S.D. =

7•1) to T2 (mean 99•5; S.D. = 12 3), performance improving in all Ss. This improvement is highly significant using Students 't' test ($p < \cdot001$). No subsequent change over the rest of the season occurred ($p > \cdot05$). A highly significant reduction of 26 beats/min was found on the treadmill test between T1 and T2 ($p < \cdot001$), improvement occurring in all Ss. This corresponds exactly to the reduction in fH on a fixed submaximal load found by Ekblom et al (1968) after 16 weeks training. The difference between T2 (mean 132; S.D. = 14•4 beats/min) and T4 (mean 139; S.D. = 13•4 beats/min) does not represent a significant deterioration over the active season ($p > \cdot05$). The results of T3 (mean 137; S.D. = 15•2 beats/min) were not significantly different from the results at T2 and T4.

A description of high and low scores on each of the 16 personality factors is presented in Appendix 4. Results of the personality assessments are presented in Appendix 4A. At T1 the mean score diverged significantly from the mean of the population calculated as 5•5 for each trait for Factor A ($p < \cdot01$), Factor C ($p < \cdot01$), Factor G ($p < \cdot01$), Factor O ($p < \cdot001$), Factor Q2 ($p < \cdot01$) and Factor Q4 ($p < \cdot01$). The group could be described as extraverted, neurotic, unconscientious, highly apprehensive, self-sufficient, and highly driven. At T2 the mean score diverged significantly from the population mean for the following traits: B - intelligent ($p < \cdot05$); C ($p < \cdot01$); F - cheerful ($p < \cdot05$); G ($p < \cdot01$); L - suspicious ($p < \cdot05$); O ($p < \cdot001$); Q2 ($p < \cdot05$); Q4 ($p < \cdot05$). Mean score at T3 differed significantly from the population mean for traits C ($p < \cdot01$); E - submissive ($p < \cdot05$); G ($p < \cdot001$); H - withdrawn ($p < \cdot01$); I - realistic ($p < \cdot05$); O ($p < \cdot001$), and Q2 ($p < \cdot05$). At T4 mean score differed significantly from the population mean for A ($p < \cdot01$); C ($p < \cdot01$); E - dominant ($p < \cdot01$); G ($p < \cdot001$); I ($p < \cdot001$); L ($p < \cdot05$); M - Bohemian ($p < \cdot001$), and Q3 - lax ($p < \cdot05$). At this test Factor Q2 (mean 6•35; S.D. = 2•34) did not differ significantly from the population mean ($\cdot05 < p < \cdot10$).

5.1.2. Analysis of Variance

Because of the changes in personnel and in group membership between T2, T3 and T4, three separate series of ANOVAs were performed. A 16 × 2 × 2 model was used for T1/T2, a 15 × 2 × 2 model for T2/T3 and a 13 × 2 × 2 model for T3/T4. Results of these analyses are presented in Appendices 5, 6 and 7 respectively for each variable analysed. In some cases anthropometric variables were not studied where changes with training were improbable.

5.1.2.1. ANOVA T1/T2

The between-subjects variance accounted for a significant amount of the total variance in Body Surface Area, limb circumference (hip, thigh and calf girth), lung function (VC, FEV_1 and FEF), skinfold thickness (triceps, sub-scapular, supra-iliac and summated fatfolds), strength (grip and trunk flexion) and SBJ. Trunk flexion strength showed a significant groups/tests interaction ($p < \cdot 05$). There was a significant between-tests difference in neck flexion ($p < \cdot 01$), representing a decrease in performance. SBJ performances showed a between-groups difference, the superior scores being found in the First Team.

Blood pressure parameters showed significant reductions between tests (systolic, $p < \cdot 01$; diastolic, $p < \cdot 05$; pulse pressure, $p < \cdot 05$). Significantly higher values were found in the First Team for both systolic ($p < \cdot 05$) and diastolic ($p < \cdot 01$) pressures. The interaction term for pulse pressure was significant ($p < \cdot 05$).

Sitting heart rate showed a significant reduction between tests ($p < \cdot 01$) and the interaction term was significant ($p < \cdot 05$). For both maximum heart rate and CAF the variance between subjects accounted for a significant amount of the total variance. Improved circulatory efficiency between tests was found on the treadmill test ($p < \cdot 01$) and the Harvard Step Test ($p < \cdot 05$). In both tests the variance between subjects accounted for a significant amount of the total variance.

The variance between subjects accounted for a significant amount of the total variance in 9 of the 16 personality factors. There was a significant difference between groups in traits E ($p < \cdot 01$), Q1 ($p < \cdot 01$) and Q2 ($p < \cdot 05$), the First Team being more submissive, more conservative and less group-dependent.

5.1.2.2. ANOVA T2/T3

The variance between subjects accounted for a significant amount of the total variance in limb circumference (calf girth), lung function (VC, FEV_1), skinfold thickness (triceps, sub-scapular, supra-iliac and summated fatfolds) and strength (grip and neck flexion). There was a significant difference between tests in neck flexion and trunk flexion ($p < \cdot 01$) representing a decrement in strength. Analysis of variance was not pursued on the remaining strength variables when significant reductions were found between tests in strength of overhead pull, hip flexion and extension (right and left), knee flexion and extension (right and left) using the 't' test ($p < \cdot 01$). A difference between groups was found in triceps fat, the Reserves having the higher skinfold thickness ($p < \cdot 05$). The inter-correlations between strength variables for T2 and T3 are presented in Appendices 9 and 10 respectively.

The variance between subjects accounted for a significant amount of the total variance in SBJ performance. Performance improved significantly between tests ($p < \cdot 01$) and the interaction between groups and tests was significant ($p < \cdot05$).

Variance between subjects accounted for a significant proportion of the total variance for pulse pressure, sitting heart rate, maximum heart rate, Harvard Index and CAF. Sitting heart rates showed a significant increase between tests ($p < \cdot01$) and a high correlation between tests ($r = \cdot73$; $p < \cdot01$). Significant between-groups results were demonstrated, the First Team having the lower sitting heart rates, the lower maximum heart rates, the higher CAF scores, and the superior performances on both the treadmill and step test.

The variance between subjects accounted for a significant amount of the total variance for personality factors E, G and Q2 ($p < \cdot05$). A significant difference between groups was found for Factor L ($p < \cdot05$), the First Team being more withdrawn.

5.1.2.3. ANOVA T3/T4

The variance between subjects accounted for a significant amount of the total variance for limb circumference (calf girth), lung function (VC, FEV_1, FEF), skinfold thickness (sub-scapular, supra-iliac and summated fatfolds), grip strength and SBJ performance. The difference btween tests was significant for strength of neck flexion ($p < \cdot05$), trunk flexion ($p < \cdot01$), right hip flexion ($p < \cdot01$) and right knee extension ($p < \cdot01$), representing a reduction in strength between tests. The remaining strength variables were analysed for differences between test means using Students 't' test. A significant reduction was found for strength of overhead pull ($p < \cdot01$), left hip flexion ($p < \cdot05$), left hip extension ($p < \cdot05$), and left knee extension ($p < \cdot01$). The difference betweentest means was non-significant for right hip extension, right and left knee flexion ($p > \cdot05$). The correlation coefficients between tests for these strength variables were significant in all cases (·64 > r > ·42) except for left hip extension (r = ·15). The intercorrelations between strength variables at T4 are shown in Appendix II.

A significant difference between groups was found for ankle mobility ($p < \cdot 01$), SBJ performance ($p < \cdot 05$) and vertical jump ($p < \cdot 01$). The First Team had the lesser ankle mobility, and the superior performance in both SBJ and vertical jump.

The variance between subjects accounted for a significant amount of the total variance for sitting heart rate, maximum heart rate, CAF and treadmill test performance ($p < \cdot 01$). The variance between subjects was significant for personality factors F, Q1, Q2, Q3 and Q4. Factor H showed a significant difference between groups, the First Team being more withdrawn ($p < \cdot 05$). Significant differences between tests were demonstrated for Factor E and Factor O, representing increased dominance and reduced apprehensiveness at the end of the season ($p < \cdot 01$).

5.1.3. Multi-variate Analyses

5.1.3.1. Principal Component Analysis

Utilising the Pearson Product Moment Formula of Correlation, a matrix of intercorrelations among the test items was obtained. The data were then subjected to factor analysis using the principal axes form of preliminary solution (Harman, 1960). The ICL (Statistical Analysis Mark 2, 1900 Series) programme employed calculates its eigenvalues and eigenvectors using the QR algorithm as described by Bowdler et al (1968). Separate analyses were performed on each of the four test batteries. Components were extracted in accordance with Kaiser (1958). Identification of components was attempted from the test-item eigenvectors on the principles recommended by Child (1970).

5.1.3.1.1. Principal Component Analysis (T1)

A matrix of intercorrelations among the 65 variables investigated at T1 was obtained and the data subjected to principal component analysis. Twelve components were extracted which accounted for 82 percent of the total variance. The first eight components accounted for 70 percent of the total variance, the relative contribution of Component No.1 being 23 percent. The components were interpreted and tentatively named:

No.1	Size
No.2	Ponderosity
No.3	Resting Cardiac Efficiency
No.4	Endurance
No.5	Anxiety
No.6	Muscular Power
No.7	Sociability
No.8	Self-Sufficiency combined with Introversion
No.9	Surgency
No.10	Stress Tolerance
No.11	Aerobic Power
No.12	Ankle Mobility

Components 3, 4 and 10 were identified as circulatory factors. Psychological variables underlay four of the components — 5, 7, 8 and 9. Component 5 had high negative contributions from skinfold thickness, systolic pressure and Factor C, high positive contributions from Factors O and Q4. Component 7 proved difficult to interpret in view of the high contribution of SBJ performance along with personality factors A, F and N. Component 9 proved difficult to interpret in view of the contributions from blood pressure variables along with ambivalent strength loadings. Components 7 and 9 were named with a low level of confidence.

The table of component eigenvalues is presented in Appendix 13. The matrix of eigenvector loadings is presented in Appendix 14. Ss scores on components No.1 and No.2 and on components No.3 and No.4 are presented in Figures 4 and 5 to illustrate clustering according to playing positions. The most homogeneous group appeared to be centre-backs followed by goalkeepers and mid-fielders. Five individuals who failed to gain a series of First Team representations during the season or in the two subsequent seasons clustered together. Further analysis of the clusters was not pursued due to a number of players (7) changing positional roles according to tactical requirements.

5.1.3.1.2. Principal Component Analysis (T2)

A matrix of intercorrelations among the variables investigated at T2 was obtained and the data subjected to principal component analysis. Twelve components were extracted which accounted for 80 percent of the total variance. The first eight components accounted for 67 percent of the total variance, the relative contribution of the first component being 23 percent. The components were interpreted and tentatively named:

No.1 Size
No.2 Ponderosity
No.3 Resting Cardiac Efficiency
No.4 Endurance
No.5 Strength
No.6 Quadriceps Strength

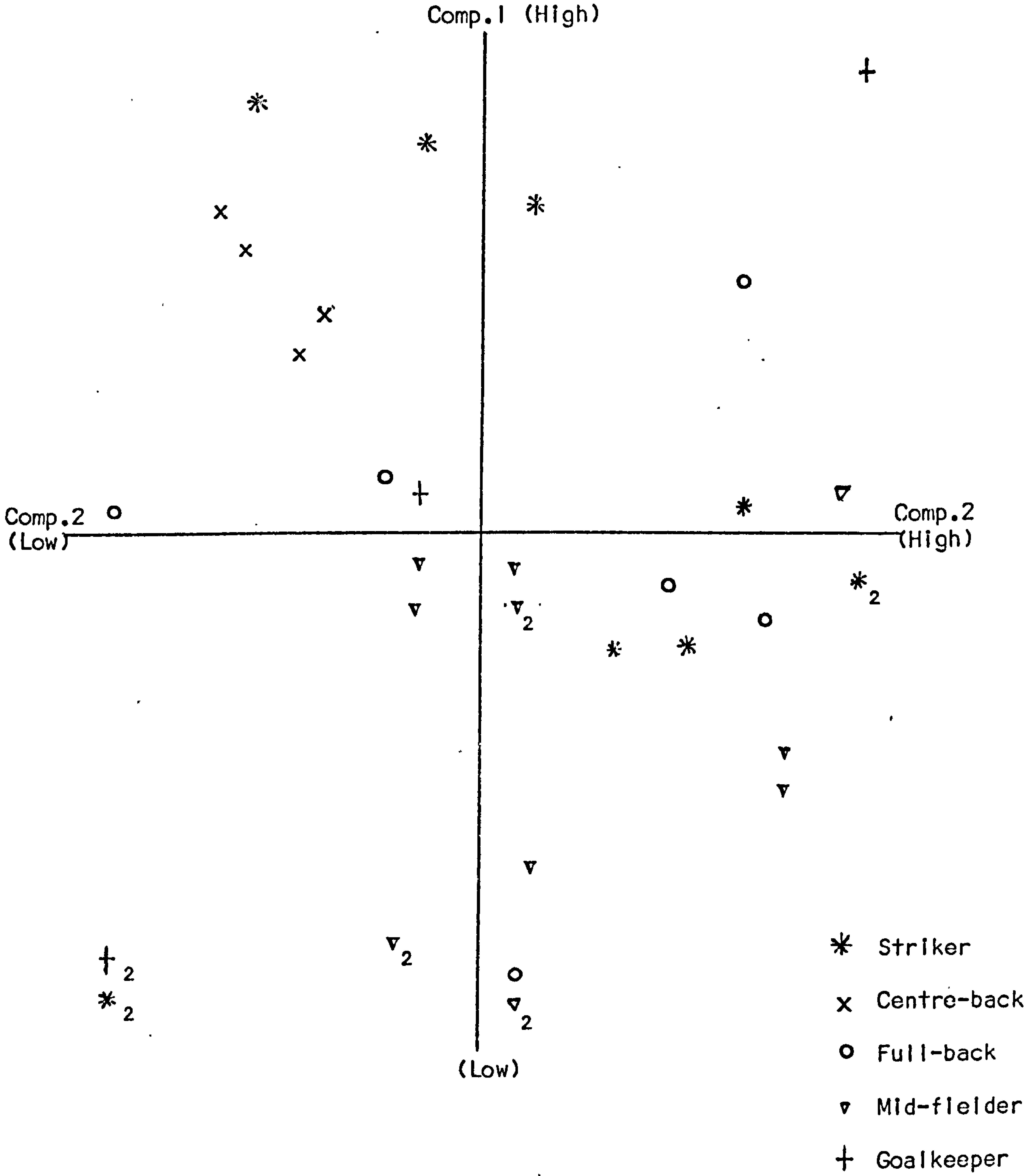

Figure 4. Clustering according to playing position on Components 1 and 2 (T1). Positions are those Ss most frequently played in. Subscript (2) designates Ss who did not play regularly for the First Team at any time during the course of the study.

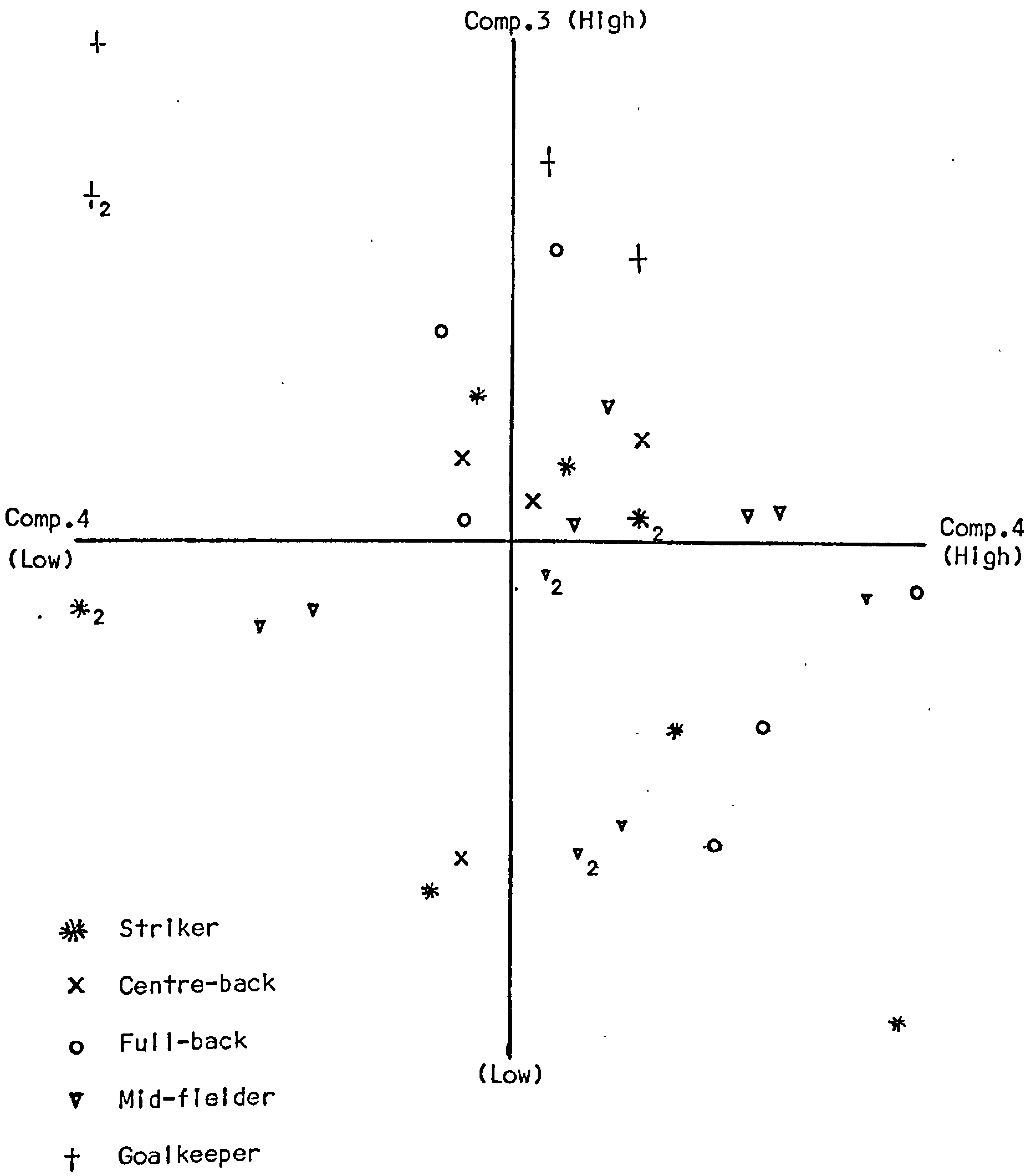

Figure 5. Clustering according to playing positions on Components 3 and 4 (TI). Positions are those Ss most frequently played in. Subscript (2) designates Ss who did not play regularly for the First Team at any time during the course of the study.

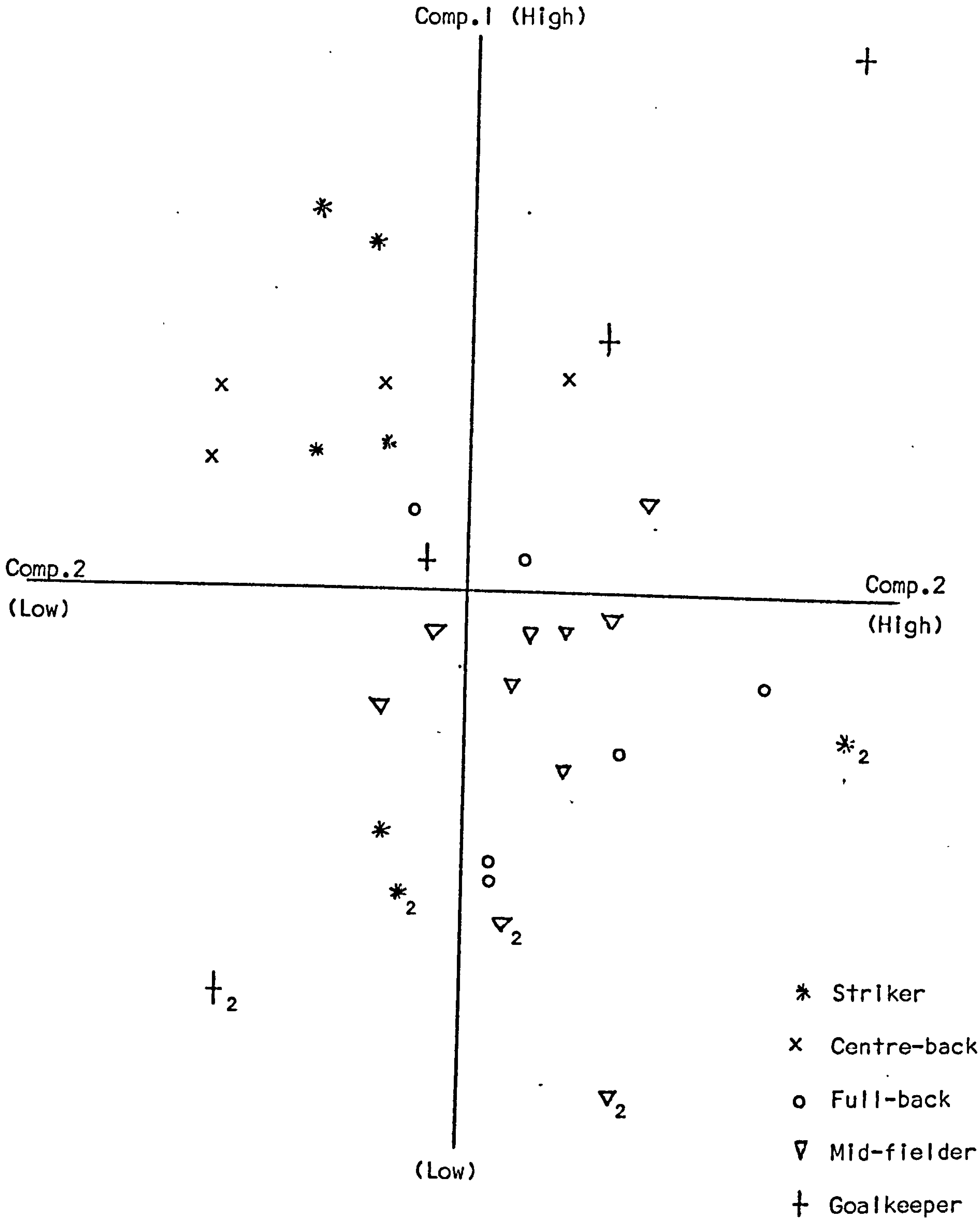

Figure 6. Clustering according to playing position on Components 1 and 2 (T2). Positions are those Ss most frequently played in. Subscript (2) designates Ss who did not gain regular First Team selection at any time during the course of the study.

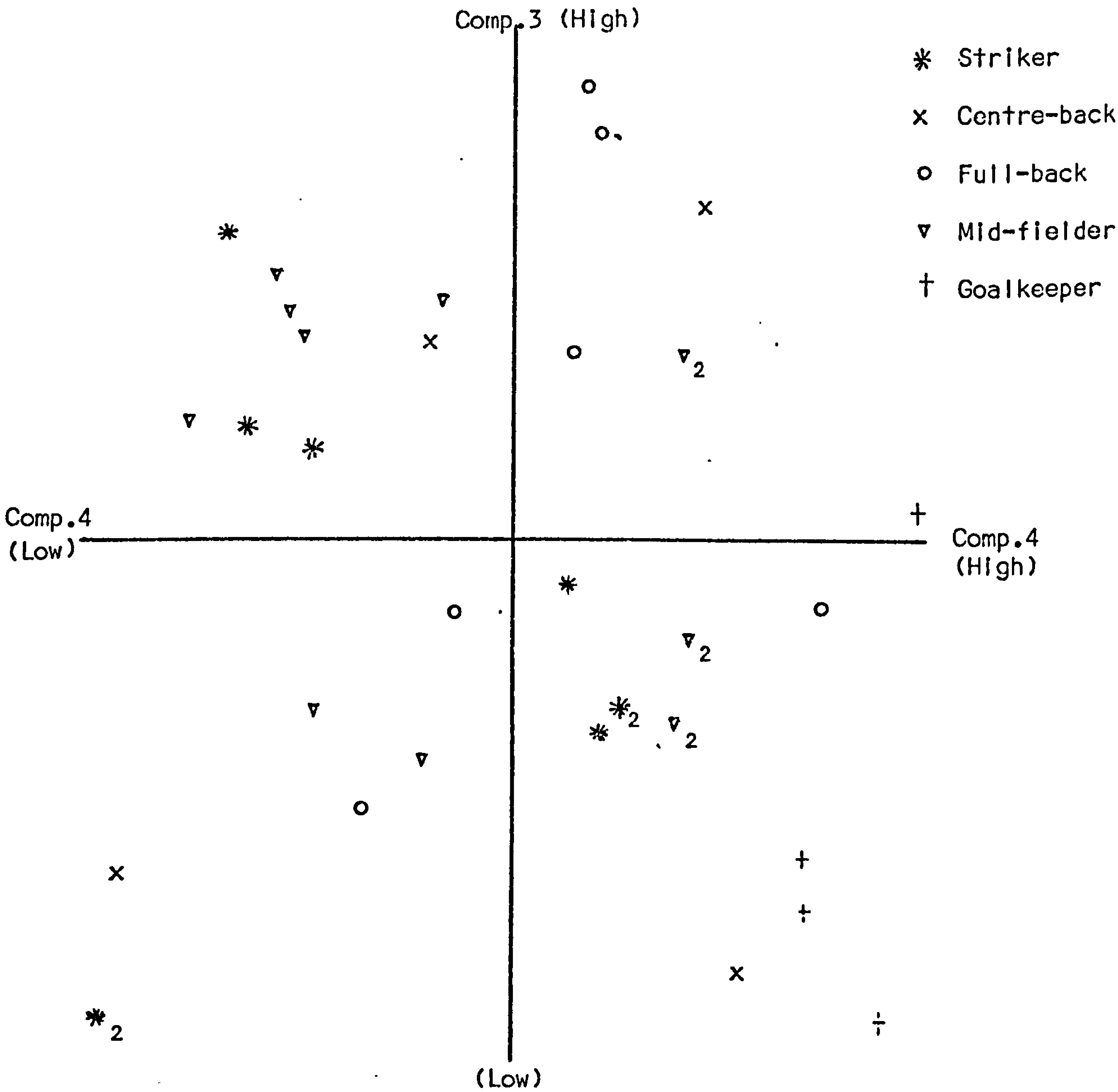

Figure 7. Clustering according to playing position on Components 3 and 4 (T2). Positions are those Ss most frequently played in during the 1972-73 season. Subscript (2) designates Ss who did not gain regular First Team selection at any time during the course of this study.

No.7 Responsibility
No.8 Conservatism
No.9 Stress Tolerance
No.10 Power
No.11 Lung Power
No.12 Social Alertness

Two psychological components were among the twelve extracted. Component 7 had high positive eigenvectors on personality factors C and G and a high negative eigenvector loading on M. This component was difficult to identify in view of the high negative loading on pulse pressure. Component 8 had a high positive loading on L and high negative loadings on Q1 and systolic pressure. Component 9 had high positive loadings on maximum heart rate, the step and treadmill tests and high negative loading on Factor H. Component 10 included a high positive loading on Factor B. Component 12 had a high positive loading on Personality Factors H, N and Q3.

The table of component eigenvalues is presented in Appendix 15. The matrix of eigenvector loadings is presented in Appendix 16. Ss scores on components 1 and 2 and on components 3 and 4 are presented in Figures 6 and 7 to illustrate clustering according to current playing positions. The most homogeneous group according to these components appeared to be the centre-backs followed by goalkeepers and midfielders. The greatest heterogeneity was found in strikers, though the strikers with similar tactical roles clustered together.

5.1.3.1.3. Principal Component Analysis (T3)

A matrix of intercorrelations among the 62 variables investigated at T3 was obtained and the data subjected to principal component analysis. Twelve components were extracted which accounted for 82 percent of the total variance. The first eight components accounted for 69 percent of the total variance, the relative contribution of component No.1 to the total variance being 20 percent. The first two components accounted for 33 percent of the total variance and were interpreted and tentatively named 'size' and 'cardiac efficiency'. This second component included high negative loadings on skinfold measurements. Identification of further components was not pursued due to equivocal test-item contribution.

5.1.3.1.4. Principal Component Analysis (T4)

A matrix of intercorrelations among the 66 variables was obtained for T3 and the data subjected to principal component analysis. Twelve components were extracted which accounted for 83 percent of the total variance. The first eight components accounted for 68 percent of the total variance, the relative contribution of component No.1 being 22 percent. The first four components,which accounted for 47 percent of the total variance, were interpreted and tentatively named 'size', 'ponderosity', 'physical maturity' and 'resting cardiac efficiency'. Further identification was not pursued as eigenvectors suggested ambivalent test-item contributions.

5.1.3.2. Factor Analysis

The incomplete results in T3 and T4 and the inconsistencies between tests using principal component analysis suggested further factor analysis using rotational procedures. Composite variables were discarded in accordance with the recommendations of Falls et al (1965). Each test data were analysed using S.P.S.S. (Nie et al, 1970). This necessitated the reduction of the matrix until the core storage available to the computer programme employed was not exceeded. Personality variables were excluded and further reductions made from an inspection of the correlation matrix using all test items. CAF was retained for analysis in T2 and T3 when found that it did not ill-condition the correlation matrix. The number of variables of physical fitness analysed for each test battery was 35 (T1), 35 (T2), 33 (T3) and 35 (T4).

Oblique rotation of the principal axes was carried through using Kaiser's (1958) normalisation on each of the four test matrices. The data for T2 and T3 were subjected to orthogonal rotation using Kaiser's Varimax criterion to allow comparison of results of the rotational procedures. The practice of comparing results of different rotational procedures has been employed by previous investigators, Cureton and Sterling (1966), for example.

5.1.3.2.1. Factor Analysis (T1)

Ten factors were extracted which accounted for 86 percent of the total variance. The oblique factor structure matrix after rotation, along with the percentage contribution of each factor, is presented in Appendix 17. The factors were identified from the factor loadings and tentatively named.

Factor 1 ('size') loaded highly on a wide range of anthropometric variables and was interpreted as relating to body size.

Factor 2 had high positive loadings on endomorphy, summated skinfolds, and high negative loadings on VC and FEV_1. The interpretation proposed was the existence of a substratum supporting inertia. This factor was described as 'ponderosity'.

Factor 3 had high positive loadings on sitting heart rate, the treadmill test and negative loadings on the Harvard Index. This factor was named 'endurance'.

Factor 4 loaded highly on a combination of leg length, circumference and strength measurements and was described as 'leg strength'.

Factor 5 loaded highly on vertical jump and SBJ performances and was described as 'muscular power'.

Factor 6 had a high negative loading on ankle mobility. This factor was difficult to identify as it loaded positively on basal pulse rate. It was named 'ankle mobility' with a low level of confidence.

Factor 7 loaded highly on FEF and was described as 'lung power'.

Factor 8 loaded highly on pelvic circumference and was described as 'pelvic girth'.

Factor 9 had a high positive loading on reaction time and high negative loadings on a range of anthropometric and strength variables. This factor was difficult to identify. The table of factor pattern correlations showed a low but non-significant negative correlation with Factor I (r = - •39) and no correlation with Factor 2. The interpretation proposed was that this factor was a general aspect of muscular efficiency and was described as 'roborization'.

Factor 10 had high loadings on systolic and diastolic pressures and was named 'blood pressure'.

5.1.3.2.2. Factor Analysis (T2)

Eight factors were extracted for the two rotational procedures, which accounted for 81 percent of the total variance in each case. The first four factors closely concorded for the different methods and were tentatively named. Results are presented in Appendix 19 and Appendix 20.

Factor 1 loaded highly on a number of anthropometric and strength variables and was described as 'size'. It represented a similar statistical construct to the first factor extracted in TI.

Factor 2 loaded highly on the same variables as contributed to the second factor extracted in TI. This factor was named 'ponderosity'.

Factor 3 had high negative loadings on sitting heart rate and basal pulse rate and high positive loadings on CAF. The oblique factor pattern matrix demonstrated a negative loading on reaction time which was not found with Varimax rotation. Maximum heart rate did not contribute to the factor, which was described as 'resting cardiac efficiency'.

Factor 4 had high loadings on systolic and diastolic pressures and was named 'blood pressure'.

Factor 5, extracted using the oblique rotational procedure, corresponded to Factor 8 employing the Varimax method. It had high positive loadings on sitting heart rate, the treadmill test and high negative loading on the Harvard Index. The factor was named 'endurance'.

Factor 6, extracted using the oblique method, had negative loadings on strength of hip extension and knee flexion and positive loading on SBJ performance. These contributions are not necessarily incompatible. The factor pattern matrix was in general agreement with the pattern matrix for the seventh factor extracted using the Varimax rotational procedure when the signs of the loadings were inverted. It loaded highly on hip extension and knee flexion strength and was described as 'hamstring strength'.

Factor 7, extracted using the oblique method, had high loadings on age and strength of neck flexion, overhead pull and knee extension. These functions are employed in the soccer skills of heading, throwing-in and kicking the ball. The factor was described as 'soccer-specific strength'. It corresponded to the sixth factor, extracted using the alternative rotational method.

Factor 8, extracted using the oblique method, loaded highly on strength of trunk extension and hip flexion. This corresponded to the fifth factor extracted using the orthogonal method of rotation and was described as 'trunk strength'.

The factor pattern matrix of intercorrelations showed low but non-significant correlations between Factor 1 and Factor 7 (r = •38) and between Factor 1 and Factor 8 (r = •34). Factors 7 and 8 were not significantly correlated (r = •29).

5.1.3.2.3. Factor Analysis (T3)

Eight factors were extracted which accounted for 79 percent of the total variance for both rotational methods. The first four factors represented identical constructs for the two procedures. Factors 5, 6 and 7, extracted using the oblique method of rotation, corresponded to Factors 7, 5 and 6 respectively using the Varimax method of orthogonal rotation. Factor 8 was identified from the oblique factor structure matrix. Results are presented in Appendix 20 and Appendix 21.

Factor 1 loaded highly on a number of anthropometric and strength items and was identified as relating to body size. The factor was named 'size'.

Factor 2 had a high positive loading on sitting heart rate, the treadmill test and maximum heart rate. A high negative loading was found on knee extension strength and sitting heart rate. The factor was construed to represent the same construct as Factor 3 (T1, T2) and was described as 'endurance'.

Factor 3 loaded highly on lung function variables and was named 'lung function'.

Factor 4 had a high negative loading on basal pulse rate and a high positive loading on CAF. This factor was described as 'stress tolerance'.

Factor 5, extracted using the oblique method of rotation, loaded highly on a number of strength items. The factor was interpreted to represent a general aspect of muscular strength and was named 'strength'.

Factor 6 had high loadings on systolic and diastolic pressures. The negative loadings on flexion strength of knee and hip were difficult to explain. These loadings were not found with the high loading on systolic pressure for Factor 5 extracted by orthogonal rotation.

Factor 7 loaded highly on the vertical jump and on SBJ and was described as 'muscular power'. It was identified as a similar construct to Factor 5 (T1).

Factor 8 loaded highly on age, weight, limb circumferences and a number of strength variables. The factor was identified as representing a general aspect of strength which was related to body size. The factor pattern correlation showed a non-significant correlation ($p > .05$) with Factor 1 ($r = .29$) and Factor 5 ($r = .19$). The factor was described as 'roborization'.

5.1.3.2.4. Factor Analysis (T4)

Ten factors were extracted by oblique rotation which accounted for 84 percent of the total variance. Results are presented in Appendix 22.

Factor 1 loaded highly on a wide range of anthropometric and strength variables and was described as 'size'.

Factor 2 loaded highly on summated fatfolds, endomorphy and thigh circumference and was described as 'ponderosity'.

Factor 3 loaded highly on vertical jump and on SBJ and was described as 'muscular power'.

Factor 4 had a high positive loading on the treadmill test and a high negative loading on the Harvard Index. The factor was described as 'endurance'.

Factor 5 loaded highly on sitting heartrate and was described as 'resting cardiac efficiency'.

Factor 6 was found difficult to identify. It included a high negative loading on strength of overhead pull and additionally had negative loadings on diastolic blood pressure, chest circumference (deflated and inflated). The factor was tentatively named 'upper body strength'.

Factor 7 loaded highly on systolic and diastolic pressure. The loading on ankle mobility was difficult to interpret. The factor was described as 'blood pressure'.

Factor 8 had a high, positive loading on simple reaction time and additionally loaded negatively on 'age'. The conjunction of these two test-items in one factor would not be expected in a normal population. Their compatibility with the current subjects is acceptable in that the older players are generally those who have successfully survived the earlier trial years of their profession and might be presumed to have had a congenital advantage in reaction time. Aging per se is unlikely to have much effect on simple reaction time in the relatively narrow age range of Ss. This factor was described as 'reaction time'.

Factor 9 had high loading on trunk extension and described as 'trunk strength'.

Factor 10 had high loadings on height, circumference of arm and thigh, strength of knee flexion and grip. The factor had a non-significant factor pattern correlation ($r = \cdot 33$; $p > \cdot 05$) with Factor 1. It was interpreted as representing a general aspect of strength and was described as 'strength'.

Over the season as a whole a number of constructs representing similar factors of physical fitness were replicated. These were size, ponderosity, resting cardiac efficiency, endurance, strength, roborization, muscular power, lung function, blood pressure. The first factor identified and tentatively named 'size' made the greatest single contribution (∿ 30%) to explain the total variance on each test occasion.

5.1.3.3. Discriminant Function Analysis

5.1.3.3.1. Anthropometry and Blood Pressure

The homogeneity of group means for 17 anthropometric and blood pressure variables is presented in Appendix 23. The F Ratio is significant on only one item — ankle mobility ($p < \cdot 01$). The F Ratio using Box's criterion was 4·16 ($p < \cdot 01$). Both Rao's F Test and Bartlett's chi-squared test used as significance tests on eigenvalues gave non-significant results ($p > \cdot 10$). The Hits and Misses table showed five misclassifications, three in Group 1 and two in Group 2. All three players in Group 1 were subsequently injured and were displaced on the First Team, while one of the misclassifications in Group 2 subsequently gained regular First Team recognition.

5.1.3.3.2. Strength and Muscular Power

The tables showing homogeneity of group means for strength and muscular power variables for the four series of tests are presented in Appendices 24, 25, 26 and 27. 13 items were analysed in T1, 18 in T2, 15 in T3 and 15 in T4.

T1 - Strength and Muscular Power

No one item had a significant univariate F Ratio ($p > \cdot 10$). Rao's F Ratio (1·5) and Bartlett's chi-squared (17·2) were non-significant results ($p > \cdot 10$). The Hits and Misses table showed three misclassifications in each group. Two of the players in Group 1 did not represent the First Team until mid-season, while two of the three individuals in Group 2 established themselves in the First Team before mid-season.

T2 - Strength and Muscular Power

Univariate F Ratios for strength of overhead pull, right and left knee extension, were highly significant ($p < \cdot 001$). The superior values were in each case recorded in the First Team (Group 1). Rao's F Ratio (5·00) demonstrated significant group separation ($p < \cdot 01$). Bartlett's chi-squared (41·33) was a significant result ($p < \cdot 01$). The Hits and Misses table predicted no misclassifications.

T3 - Strength and Muscular Power

Univariate F Ratio showed a significant result for strength of right knee extension ($p < \cdot 001$). The superior measures on this variable were found in the First Team. Rao's F Test and Bartlett's chi-squared test found non-significant results ($p > \cdot 05$). One misclassification was forecast in Group I and two misclassifications in Group 2. The misclassification in Group I lost his First Team place soon after the test-battery was administered, while one of the misclassifications in Group 2 was an experienced player who had been displaced from the First Team at the beginning of the current season.

T4 - Strength and Muscular Power

Univariate F Ratios were significant for strength of trunk flexion ($p < \cdot 05$) and left knee extension ($p < \cdot 01$) and for vertical jump performance ($p < \cdot 005$). The superior values for trunk flexion and vertical jump were recorded in the First Team who had inferior scores for left knee extension strength. Rao's F Ratio (3·76; $p < \cdot 05$) and Bartlett's chi-squared (32·9; $p < \cdot 01$) showed significant group separation. One misclassification was forecast in each group. The misplacement in Group I had replaced the misplacement in Group 2 on the First Team early in the second half of the League programme due to the latter individual incurring an injury. The displaced individual did not regain his place on the First Team during the season.

5.1.3.3.3. Cardiac Variables

Five cardiac variables were employed to investigate discriminability between groups for each of the four tests. The items were sitting heart rate, treadmill test, Harvard Index, maximum heart rate and CAF. The tables showing the homogeneity of group means for each test are shown in Appendices 28 to 31.

T1 - Cardiac Variables

No significant univariate F Ratio was found ($p > \cdot 05$). Rao's F Ratio (2·74; $p < \cdot 05$) and Bartlett's chi-squared (11·57; $p < \cdot 05$) were results demonstrating significant group separation. Four misclassifications in Group 1 and three misclassifications in Group 2 were forecast. Three of the four Group 1 misclassifications were not selected for the early League programme. One of the Group 2 misplacements gained regular First Team selection during the season.

T2 - Cardiac Variables

No one variable demonstrated a significant univariate F Ratio ($p > \cdot 05$). Rao's F Test and Bartlett's chi-squared test gave non significant results ($p > \cdot 05$). The Hits and Misses Table forecast four misclassifications in Group 1 and five misclassifications in Group 2. One of the misplacements in Group 1 was the goalkeeper, while three of the five misplacements in Group 2 were later to become established First Team players.

T3 - Cardiac Variables

The univariate F Ratio was significant for sitting heart rate ($p < \cdot 05$), treadmill test ($p < \cdot 01$), Harvard Index ($p < \cdot 001$) and maximum heart rate ($p < \cdot 05$). Superior fitness values were found in Group 1 for sitting heart rates, the treadmill test and the Harvard Index but this group had the lower maximum heart rates. Both Rao's F Ratio and Bartlett's chi-squared were significant results ($p < \cdot 05$). Of four misclassifications in Group 1, one was the goalkeeper, two were centre-backs and the fourth played only five games before being excluded from the First Team in mid-season. This individual was also misclassified at this test according to analyses of the strength and muscular power data. Of the misplacements in Group 2, one was later to become established as a regular First Team player.

T4 - Cardiac Variables

Univariate F Ratios were not significant for any one item ($p > \cdot 05$). Rao's F Test and Bartlett's chi-squared test gave non-significant results ($p > \cdot 10$). The Hits and Misses Table showed eight misclassifications in Group 1 and three in Group 2. In the light of the non-significance of group separation along with marginal membership probabilities in the majority of the misclassifications, a study of the forecasts was not pursued.

5.1.3.3.4. Personality

Sixteen personality factors (16PF) were employed to investigate discriminability between groups at each of the four seasonal tests. Tables showing the homogeneity of group means are presented in Appendices 32 to 35.

T1 - Personality Factors

A significant univariate F Ratio was found for Q1 ($p < 01$). Group 1 were the more radical. Group separation was non-significant according to the statistical test of Rao ($p > \cdot 05$). Bartlett's chi-squared was significant ($p < \cdot 05$). One misclassification was predicted in Group 2. The misplacement was a current youth international player who gained regular First Team recognition during the season.

T2 - Personality Factors

No one of the personality factors showed a significant univariate F Ratio ($p > \cdot 05$). Rao's F Test and Bartlett's chi-squared test gave non-significant results ($p > \cdot 05$). Two misclassifications were predicted in both groups. The misplacements in Group 1 were both ex-international players and were among the three oldest on the staff. Neither played regularly for the First Team during the 1972-73 season or in the Football League competition in subsequent seasons. One of the misplacements in Group 2 had consistently poor results on measurements of strength and did not represent the First Team during the season; the other gained selection in mid-season but lost his place after four Football League matches.

T3 - Personality Factors

None of the personality factors showed a significant univariate F Ratio ($p > .05$). Rao's F Test and Bartlett's chi-squared test gave non-significant results ($p > .05$). Three misclassifications were forecast in Group 1 and one in Group 2. The misplacements in Group 1 had all lost their place on the selected League team shortly before the administration of the inventory. The misclassification in Group 2 had consistently poor performances on the strength and muscular power measures and did not compete during the season in the Football League competition.

T4 - Personality Factors

No one of the personality factors showed significant univariate results ($p > .05$). Rao's F Test and Bartlett's chi-squared test produced non-significant results ($p > .05$). One misclassification was found in Group 1. The misplaced individual had not played in the First Team until his selection for four League matches towards the end of the season. This individual was an experienced player and had been forecast as misplaced in Group 1 at T2 on the basis of his personality.

5.1.3.3.5. Discriminant Function Analysis of Principal Components

To telescope the discriminability between squads, Ss' scores on the principal components extracted from each test battery were employed in four separate discriminant function analyses. Eight components were employed in the analysis of T1 data. The first six components were employed in the analyses of subsequent test results. Tables showing the homogeneity of group means are presented in Appendices 35-39.

T1 - the discriminant function of principal components

Significant univariate F Ratios were found on Component 3 (resting cardiac efficiency) and Component 8 (self-sufficiency/introversion). Superior resting cardiac efficiency and greater self-sufficiency/introversion was found in Group 1. Rao's F Test and Bartlett's chi-squared test showed highly significant results ($p < \cdot 01$). One misclassification was forecast in Group 1 — this individual did not establish himself as a regular First Team player during the season. Two misplacements were predicted in Group 2, both of whom were later to hold regular First Team places.

T2 - the discriminant function of principal components

Significant univariate F Ratios were found on Component 1 (size) and Component 3 (resting cardiac efficiency). Group 1 had the superior values on 'size' and on 'resting cardiac efficiency'. Significant group separation was demonstrated in the results of Rao's F Test and Bartlett's chi-squared test ($p < \cdot 01$). The analysis forecast three misclassifications in Group 1 — one was the goalkeeper, the other two retained their First Team place throughout the season. Two misclassifications were forecast in Group 2 — one established himself as a regular First Team player during the season, the other did not retain a First Team place after playing four League matches in mid-season.

T3 - the discriminant function of principal components

A significant univariate F Ratio was found on Component 2 (endurance) at T3 ($p < \cdot 01$). The superior values were found in Group I. Rao's F Test and Bartlett's chi-squared test showed non-significant group separation ($p > \cdot 05$). Four misclassifications were forecast in Group I, the same individuals misclassified in discriminant function analysis of the five cardiac variables at this test. In addition to the two misplacements in Group 2 according to discriminant function analysis of the five cardiac variables, one S who had been in Group I at T1 and T2 was predicted as misplaced in Group 2 at this test (T3).

T4 - the discriminant function of principal components

A significant univariate F Ratio was found on Component 5. This component had not been named. It had high positive loadings on personality factors L and O and negative loading on RT. The higher values on this component were found in Group I. The component indicates increased withdrawal, increased timidity and worry and faster reaction time. Significant group separation was found using Rao's F Test ($p < \cdot 05$).

5.1.3.3.6. Discriminant Function Analysis of pre-season training

Twenty-three variables were selected from the battery of physical fitness test items to investigate discriminability between start and terminal pre-season training. Selection of items was made on inspection of the intercorrelation matrix of the original variables. The table showing the homogeneity of group means gives the list of variables used in the analysis (see Appendix 40). The observation matrix was 62 × 23; Group I consisted of 31 Ss at T1, Group 2 consisted of the same Ss at T2.

The univariate F Ratios were significant ($p < \cdot 05$) for blood pressure (systolic and diastolic), cardiac variables (sitting heart rate, treadmill test, Harvard Index and CAF), and strength variables (neck flexion, overhead pull, hip extension, knee flexion and extension). F Ratios were non-significant ($p > \cdot 05$) for strength variables (trunk flexion and extension, knee and ankle extension, left and right grip strength), muscular power (vertical jump and SBJ), summated fatfolds, chest circumference (deflated) and maximum heart rate.

Rao's F Test and Bartlett's chi-squared test both showed highly significant results ($p < \cdot 0001$). The Hits and Misses table showed a forecast of two subjects at T2 to represent T1 fitness profiles. Both individuals were goalkeepers.

5.2. Competition

5.2.1. Pre-match anxiety reaction

The mean of the pre-match pulse rate values was taken as indicating the level of team arousal for each competitive game. The level of team arousal throughout the season is presented in Figure 8. Arousal levels for home and away League games are presented in Figure 9. Home and away values were compared in playing twenty opposing teams. Results were first studied as pairs of scores. Values for home games were higher on sixteen of the twenty repeated-measures, a difference significant using a sign test ($p < \cdot 01$). Secondly the games were considered as

Figure 8. Mean pre-match heart rates throughout 1972-73 football season. Matches are serially numbered in the order they were played.

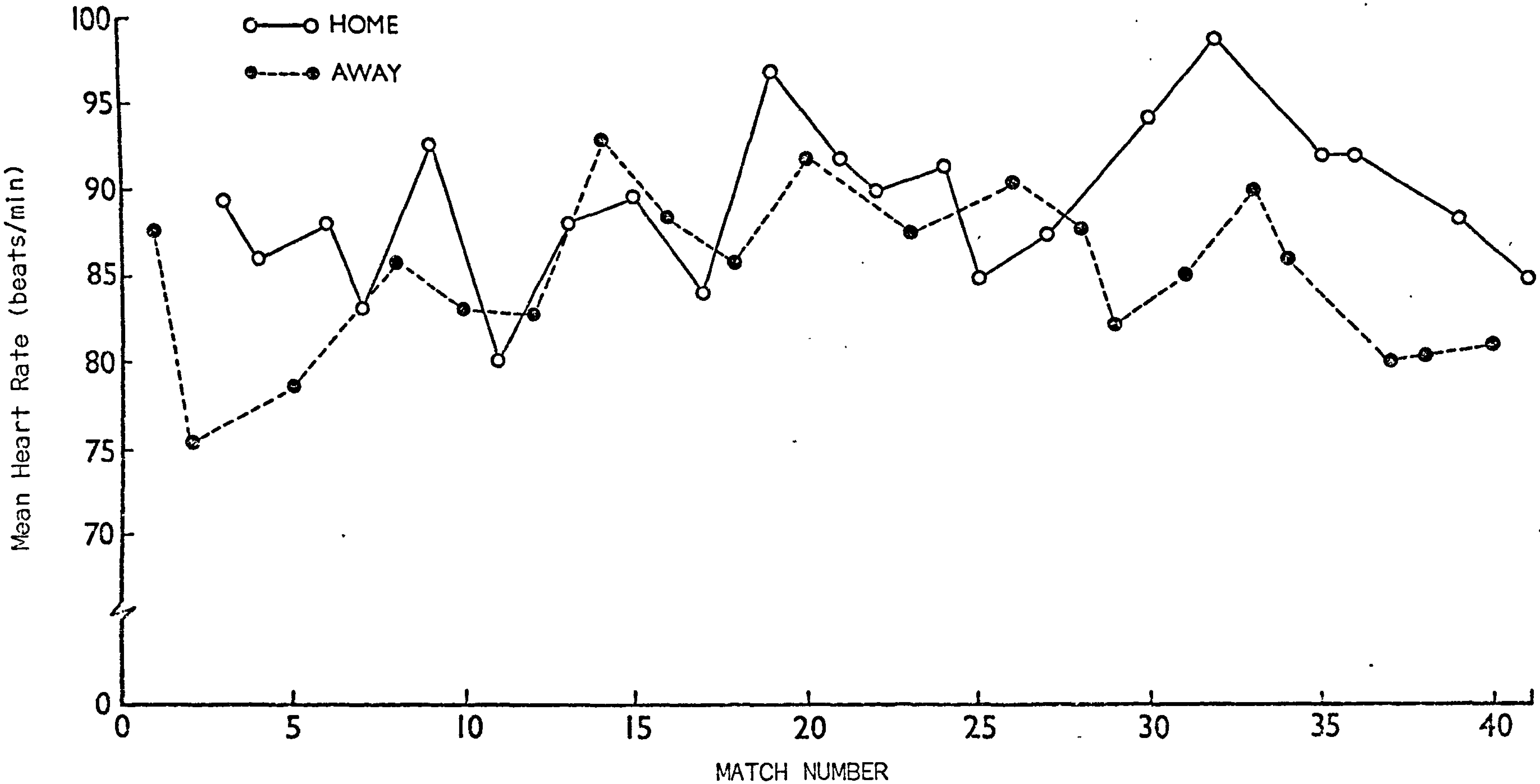

Figure 9. Mean pre-match heart rate - home (o) and away (●) for 41 League matches. Matches are serially numbered in the order in which they were played.

independent measures and the difference between home and away compared using the Mann-Whitney test for large samples. The difference was found to be significant ($p < \cdot 05$).

Mean pre-match absolute heart-rate values and standard deviation over the 47 games ranged from 99•7 (S.D. = 18•4) beats/min for the first game of the season to 80•2 (S.D. = 15•1) beats/min for an away game towards the end of the season. Mean of all observations on players (n = 517) was 87•4 (S.D. = 15) beats/min. The mean for observations preceding League games (n = 448) was 87•4 (S.D. = 14•8) beats/min and preceding F.A. Cup games (n = 22) was 93 (S.D. = 8•4) beats/min. The difference was significant using a 't' test ($p < \cdot 01$).

Team arousal levels did not correlate with team performance as measured by match results using the scale outlined in Table 2. Levels seemed to lag previous results in that a series of poor results effected an increase in team arousal which was in turn reversed by a good result. (This phenomenon could not be statistically evaluated in one team only). Arousal increased for matches affecting the club's League status where players were offered financial incentives to win. Levels of arousal did not correlate with spectator attendances over 44 Cup and League games ($p > \cdot 05$).

There were wide variations among individuals ranging from 48 to 128 beats/min. The highest values were consistently found in the goal-keeper, whose mean level over 41 games was 111 (S.D. = 7) beats/min. Once the season commenced, individuals making their first competitive appearance of the season or returning to the First Team after injury had values higher than their individual season mean on 22 out of 28 instances. This bias is significantly greater than the sampling error of a proportion ($p < \cdot 05$).

Results were consistent for individuals between games. Values for consecutive games were compared every six games as a check on reliability using the cross-product method of correlation. Coefficients obtained were in all cases significant ($p < \cdot 05$) and ranged from 0•90 to 0•58.

Prior to one game, measurements were obtained 50 minutes before kick-off and compared to the measurements obtained at the usual experimental period. The heart rate increased in all twelve Ss, the mean increasing significantly from 63•3 (S.D. = 12•8) to 80•1 (S.D. = 13•6) beats/min ($p < \cdot 001$). The correlation coefficient between the two sets of values ($r = 0 \cdot 50$) did not reach statistical significance ($p < \cdot 05$). This suggests individual differences in the slope of the emotional tachycardia.

Pre-match heart rates for the substitute ranged from 39 to 105 beats/min, mean 70•4 (S.D. = 14•5)beats/min ($n = 48$). The mean level for home matches was 67•6 (S.D. = 13•4) beats/min and for away matches 73•5 (S.D. = 15•3) beats/min. This difference between means was not significant ($p > \cdot 05$). The difference between substitutes and players was highly significant ($p < \cdot 01$).

For each S, mean values were obtained for pre-match heart rates over 4 games preceding T2 and 6 games preceding T3. For each of the tests the mean was expressed as:-

i) an absolute heart rate,

ii) the increment over Sitting Heart Rate determined in the laboratory,

iii) a proportion of the treadmill test terminal heart rate.

No significant correlations were obtained between derived indices and Factors C (emotional stability), and Q4 (ergic tension) using the cross-product method ($p > \cdot 05$). A significant negative correlation was obtained between the pre-match increment over Sitting Heart Rate and Factor O ($r = -\cdot 47$; $p < \cdot 05$) at T2. The absolute heart rate values were also found to correlate negatively with Factor O scores at this test ($r = -\cdot 42$; $p < \cdot 05$). None of these correlations was evident at T3.

5.2.2. Match play and competition work-rate

The results of distances covered at each activity level for Ss observed (n = 40) are presented in Appendix 41. The values for the goalkeeper and for 7 opposing players are not included. Appendix 42 presents the results according to positional role of centre-back (n = 7), full-back (n = 8), mid-fielder (n = 11), striker (n = 14).

The mean overall distance covered during competition according to positional role is illustrated in bar diagram form in Figure 10. The results for the goalkeeper (n = 1) are represented here.

The overall distance covered by outfield players during competition ranged from 7069 to 10921 m with a mean of 8680 m and a standard deviation of 1011 m. Of this, 36•8% was covered jogging, 24•8% walking, 20•5% cruising, 11•2% sprinting and 6•7% backing. The proportion of the overall distance covered in possession of the ball ranged from 4•0 to 0•26% with a mean of 1•73% and a standard deviation of 0•87%.

The competition mean work profile involved 853 separate movement activities comprising 239 jogs, 114 cruises, 62 sprints, 308 walks and 120 backing movements. Frequency of jumps per individual per game was 15•5 (range 0 to 38), shots at goal 1•4 (range 0 to 6) and instances on the ground 5•3 (range 0 to 14). Frequency of movement pauses per game was 43•3 (range 11 to 120) while mean cumulative time standing still per game was 143 s (range 19 to 455 s). This amounts to over 900 discrete activities during a game.

The overall distance covered per game was 7759 (S.D. = 521) m for centre-backs, 8245 (S.D. = 816) m for full-backs, 9805 (S.D. = 787) m for mid-fielders and 8397 (S.D. = 710) m for strikers. Centre-backs covered significantly less distance than strikers ($p < •05$) and mid-fielders ($p < •01$). Mid-fielders covered significantly more distance than strikers and full-backs ($p < •01$). The difference between full-backs and centre-backs was not significant ($p > •05$).

Full-backs exhibited the greatest variance in overall distance covered, range 7,324 to 10,023 m. The lowest value was recorded in a game when S was not directly confronted by an attacking opponent because of the opposing team's unorthodox formation. The greatest value was observed in another S, who had in the previous season and in subsequent seasons played in mid-field.

Of the total distance covered by centre-backs, 37•5% was jogging, 22•8% was walking, 20•6% cruising, 10•7% sprinting and 8•4% backing. Though the proportion of total distance covered backing was greater than in the other positional groups, the distance covered moving backwards did not differ between groups. The frequency of jumps was 20•4 (S.D. = 6•4) in this group, which was similar to the jumping frequency in strikers of 19•6 (S.D. = 9•8). Both groups were significantly greater than full-backs (mean 11•1; S.D. = 4•5) and mid-fielders (mean 10•3; S.D. = 4•5) ($p < •01$). Frequency of discrete walks was less in centre-backs than in full-backs or mid-fielders ($p < •05$).

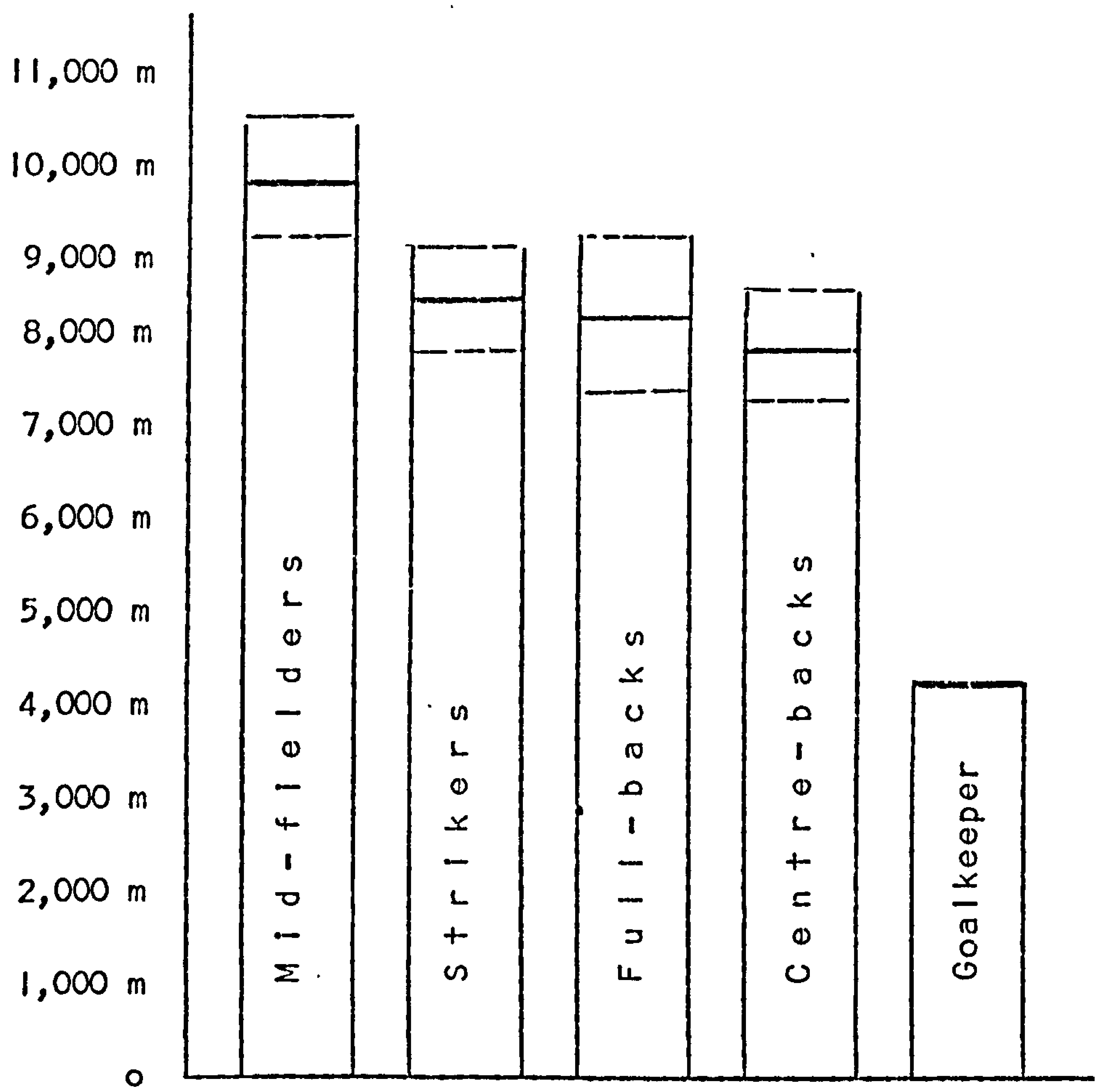

Figure 10. Work-rate (mean ± standard deviation) per game according to positional roles.

As the distance per discrete walk did not differ between groups ($p > \cdot05$), the indication is that the pace of walking was slower in the centre-backs.

Full-backs sprinted less frequently than mid-fielders or strikers ($p < \cdot05$) but not less frequently than centre-backs. Overall distance covered sprinting was less for both full-backs and centre-backs than the strikers and mid-fielders ($p < \cdot05$). The proportionate distance covered in possession of the ball was greatest in strikers (mean 1•99; S.D. = 1•05)% and least in centre-backs (mean 1•32; S.D. = 0•70)%, but this difference was not significant ($p > \cdot05$). When the overall distances covered in possession of the ball were compared there were no significant differences according to positional roles ($p > \cdot05$).

Opposition players observed comprised 1 centre-back, 1 full-back, 4 mid-fielders and 3 strikers. The centre-back covered 7569 m or 2•4% less than the mean of the experimental centre-backs. The full-back covered 8318 m, a distance approximating the mean value for the experimental full-backs to within less than 1%. The mid-fielders covered 9656 (S.D. = 673) m, the strikers 8759 (S.D. = 774) m, values close to the means of the corresponding experimental groups.

The goalkeeper covered 3972 m during competition, 10•3% of this in possession of the ball. Jogging comprised 27•4% of the distance covered, walking 33•7%, cruising 12•5%, sprinting 0•8% and moving backwards 25•6%. Sprints were infrequent, amounting to 7 and ranging in distance from 1 to 12 m. Distance moved backwards was 1020 m, a distance exceeded in outfield players on only one occasion. Time spent stationary amounted to 776 s, comprised of 252 separate pauses. There were 957 discrete movement activities. Frequency of jumping to play the ball was 13, the ball was received from his defence on 24 occasions. A total of 17 shots at goal by the opposition were off target. The ball was kicked out by S on 59 occasions and thrown out 8 times. The pattern of movement and activity indicates greater direct involvement by the goalkeeper in play than by any outfield player.

The methodology was additionally applied in observation of one S (a centre-back) in simulated competition at Goodison Park against the 'Reserves' during the week prior to the opening League match of the season. The duration was 17·5 min short of the usual competitive period. Results were extrapolated to the full period. The overall distance covered was 7805 m, which is of the same order of magnitude as results for the other centre-backs observed. The same S was found to cover 7633 m in a League match. This is taken as evidence supporting the accuracy of simulated competition in 11-a-side training matches.

The difference in work-rate at home and away competitive venues was analysed by matching each S's performance under both conditions and comparing the difference using the sign test. The difference was non-significant ($p > \cdot05$).

Decrements in performance during the period of competition were investigated by comparing total distance run (combined jogging, cruising and sprinting) in each half for each individual using the sign test. 32 out of 44 had higher values in the first half, this difference being significant ($p < \cdot01$). All 7 centre-backs and 12 out of 14 strikers had higher figures for the first half, this difference between halves being significant ($p < \cdot01$). The results for mid-fielders and full-backs did not reach statistical significance ($p > \cdot05$).

5.3. Training

5.3.1. Assessment of training load

The mean duration of training for each day of the week was: Monday 69•17 min, range 43 to 103 min; Tuesday 76•72 min, range 27 to 114 min; Wednesday 101•68 min, range 31 to 157 min; Thursday 82•00 min, range 41 to 103 min; Friday 45•4 min, range 26 to 55 min. The mean duration of a training session was 75•00 min. The durations, together with the intensity of training routines, are summarised in Table 4.

In the analysis of the separate components of a training session, routines not conducted were not included in the calculations. For this reason the mean durations of the separate training routines together exceed the overall mean duration of a training session which might not in any one day have included all eight routines. The longest routine was 'games', mean 24•65 (S.D. = 6•94) min, 'drills' lasted 19•75 (S.D. = 3•92) min, while 'skills practice' took 15•41 (S.D. = 0•92) min. Running took 10•53 (S.D. = 1•93) min, while 10•31 (S.D. = 1•93) min were taken up by circuit training. Warm-up took 8•32 (S.D. 1•00) min and calisthenics were performed for 6•60 (S.D. = 0•18) min. The time consumed by recovery intervals within a training session was 7•41 (S.D. = 1•42) min.

If the total time over the 23 weeks of training is apportioned among the constituent 8 routines, the proportion of total time allocated to each reflects the temporal emphasis put on it. The greatest emphasis was on 'games', which consumed 24•9% of total time allowed, followed by 'skills practice' (17•3%) and 'drills' (14•8%). 'Running' occupied 12•3%, warm-up 10•5%, calisthenics 8•2% and circuit-training 3•7%. 'Recovery intervals' took 8•3% of total training time. The mean proportion of training time allotted to each routine is illustrated in Figure 11.

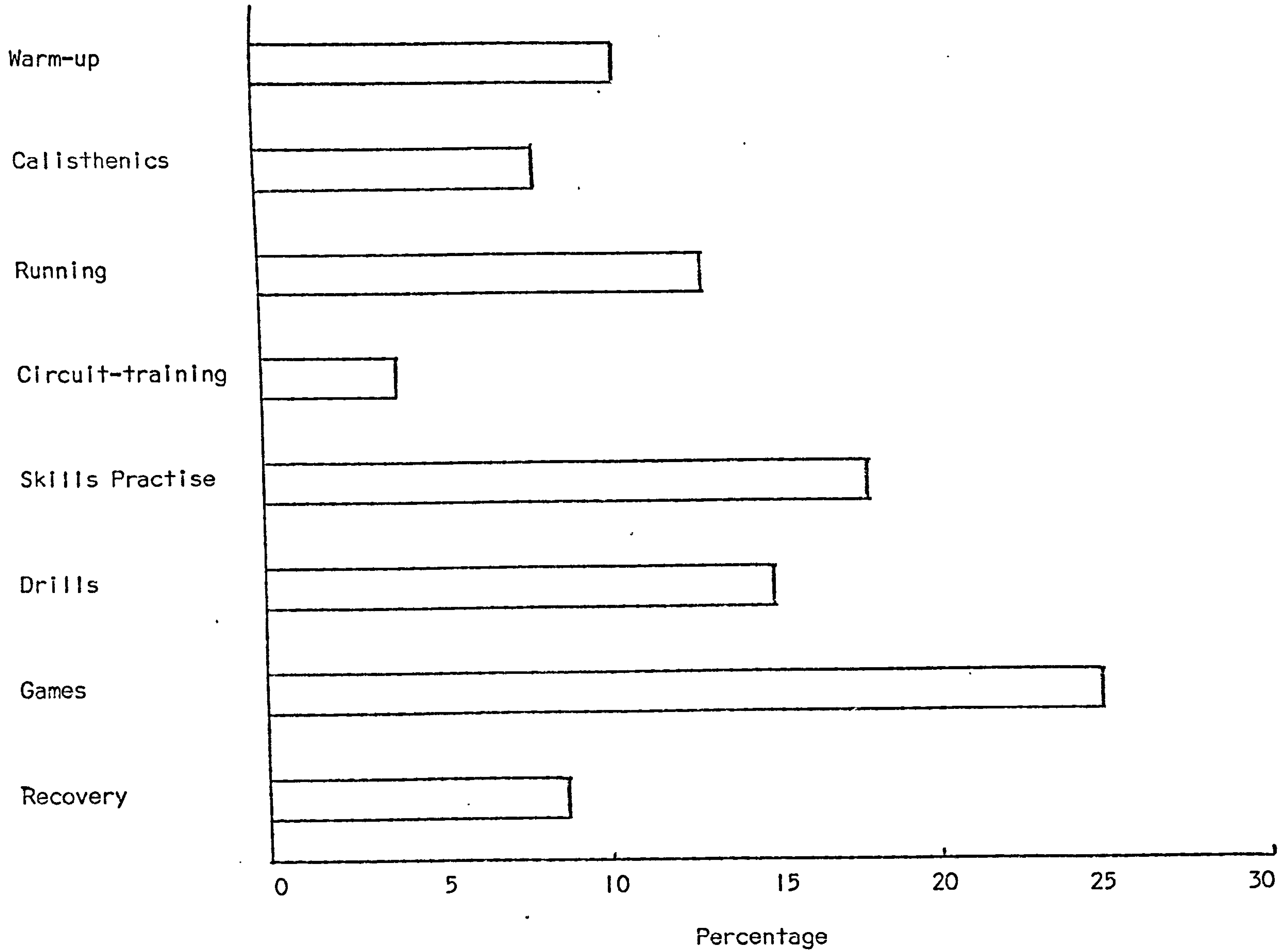

Figure 11. Proportion of overall training time allotted to each training routine.

Mean heart rate results for each training routine, as well as the mean duration of each routine, are presented in Table 4 along with the standard deviations. The most strenuous training routine was 'games'. Mean heart rate was 155•6 (S.D. = 8) beats/min. When the outfield players only were included in the analysis, the mean heart rate was 157 (S.D. = 7) beats/min. Mean heart rate of the two goalkeepers during 'games' was 123 and 126 beats/min. According to Harrison and Reeves' (1968) criteria, this routine constituted a 68% coronary challenge to the outfield players (mean basal pulse rate 45 beats/min, mean maximum heart rate 196 beats/min) and a 51% coronary challenge to goalkeepers.

Mean heart rate during running was 144•2 (S.D. = 4) beats/min. The most intensive running was performed on Tuesdays, requiring a mean heart rate of 150 beats/min for 11•38 min. Running and 'games' were infrequently carried out on Fridays. 'Drills' produced a mean heart rate of 137 (S.D. = 3•5) beats/min. The most intensive 'drills' sessions were performed on Tuesday (mean fH = 141•8 beats/min) and Wednesday (mean fH = 141•5 beats/min), the mean durations being 16•09 and 25•33 min respectively. Heart rate during the skills practice (mean 127•5; S.D. = 4•9) beats/min and the circuit training (mean 124•7; S.D. = 3•5) beats/min were of the same order of magnitude.

The lowest work-intensities were recorded in the two routines initiating the training sessions. Mean heart rate during warm-up was 119•8 (S.D. = 2•2) beats/min and during calisthenics, 111•9 (S.D. = 2•7) beats/min. Calisthenics, according to Harrison and Reeves' criteria, presented a 44% coronary challenge. Mean heart rate during the accumulated rest periods was 101•8 (S.D. = 2•9) beats/min.

Mean heart rates from Monday to Friday were 133•7, 129•3, 139•2, 130·5 and 123·0 beats/min. The results show a peak in intensity on Wednesday and a tapering-off over the rest of the week in anticipation of competition on Saturday. The mean heart rate in training across individuals, across routines, across days, was 132·3 beats/min. According to Harrison and Reeves' criteria, this represents a 58% coronary challenge.

$\dot{V}O_{2\ max}$ was estimated for the 23 subjects using the Åstrand/Rhyming nomogram. Using the Margaria nomogram, the oxygen cost of the treadmill running test item as employed in the test battery was 36·25 ml/kg/min. For each S the terminal treadmill heart rate used to predict $\dot{V}O_{2\ max}$ was the mean of the two tests temporally adjacent to the week his training was monitored. The treadmill heart rates showed correlation coefficients of 0·80 between T2 and T3 and 0·97 between T3 and T4. The difference between means was non-significant in both cases ($p > \cdot 10$). The regression line for each S, formed by connecting the treadmill fH result to the predicted maximum fH, enabled their correspondent energy expenditure values to be ascribed to the training heart rates. The calculations were performed separately for each S.

The mean weight of Ss was 73·0 (S.D. = 7·0) kg, range 62·0 to 88·0 kg. The mean heart rate on the treadmill was 136 (S.D. = 7·6) beats/min. These mean values represent an oxygen cost of 2·63 ℓ/min. Predicted $\dot{V}O_{2\ max}$ was 4·82 ℓ/min or 66 (S.D. = 13) ml/kg/min. The absolute values ranged from 3·00 to 6·25 ℓ/min. Six subjects had values exceeding 5·5 ℓ/min, three of whom were over 6·0 ℓ/min. The relative values ranged from 44 to 85 ml/kg/min.Four Ss had predicted values of 80 ml/kg/min or greater, while two others had values of 75 and 76 ml/kg/min. Only two Ss, one a goalkeeper, showed a capacity below 50 ml/kg/min.

From the slope of the fH-$\dot{V}O_2$ relationship obtained using the

Åstrand/Rhyming nomogram it was calculated that the energy expenditure during 'games' was 16·4 kcal/min. The calculated rate of energy expenditure for outfield players was 17·4 (S.D. = 0·9) kcal/min and for the two goalkeepers 4·5 and 5·25 kcal/min. The outfielders were probably working at close to 75%, while the goalkeepers were working below 50% of their aerobic capacity. The heart rate results during running routines correspond to an energy expenditure of 14 kcal/min. This represents an approximate loading of 60% of the aerobic capacity. The estimated energy demands of the 'drills' routine was 12·8 kcal/min which represents a loading of about 55% of the aerobic capacity. The computed energy expenditure during the 'skills' and circuit training routines were 10·8 kcal/min and 10·3 kcal/min respectively. Energy expenditure was computed to be 9·3 kcal/min during warm-up and 7·5 kcal/min during calisthenics. The estimated energy demands over a complete training session was 12·4 kcal/min. This probably represents a loading between 50% and 55% of aerobic capacity. The estimates of energy expended during each routine are included in Table 4.

Table 4. Intensity and duration of training routines.

	Heart Rate (beats/min) — mean ± S.D.	Duration (min) — mean ± S.D.	Estimated Energy Expenditure (kcal/min)
Warm Up	119·8 ± 2·2	8·32 ± 1·00	9·3
Calisthenics	111·9 ± 2·7	6·60 ± 0·18	7·5
Running	144·2 ± 4·0	10·53 ± 1·93	14·0
Circuit Training	124·7 ± 3·5	10·31 ± 1·93	10·3
Skills Practice	127·5 ± 4·9	15·41 ± 0·92	10·8
Drills	137·0 ± 3·5	19·75 ± 3·92	12·8
Games	157·0 ± 7·0	24·65 ± 6·94	16·4
Recovery	101·8 ± 2·9	7·41 ± 1·42	5·4

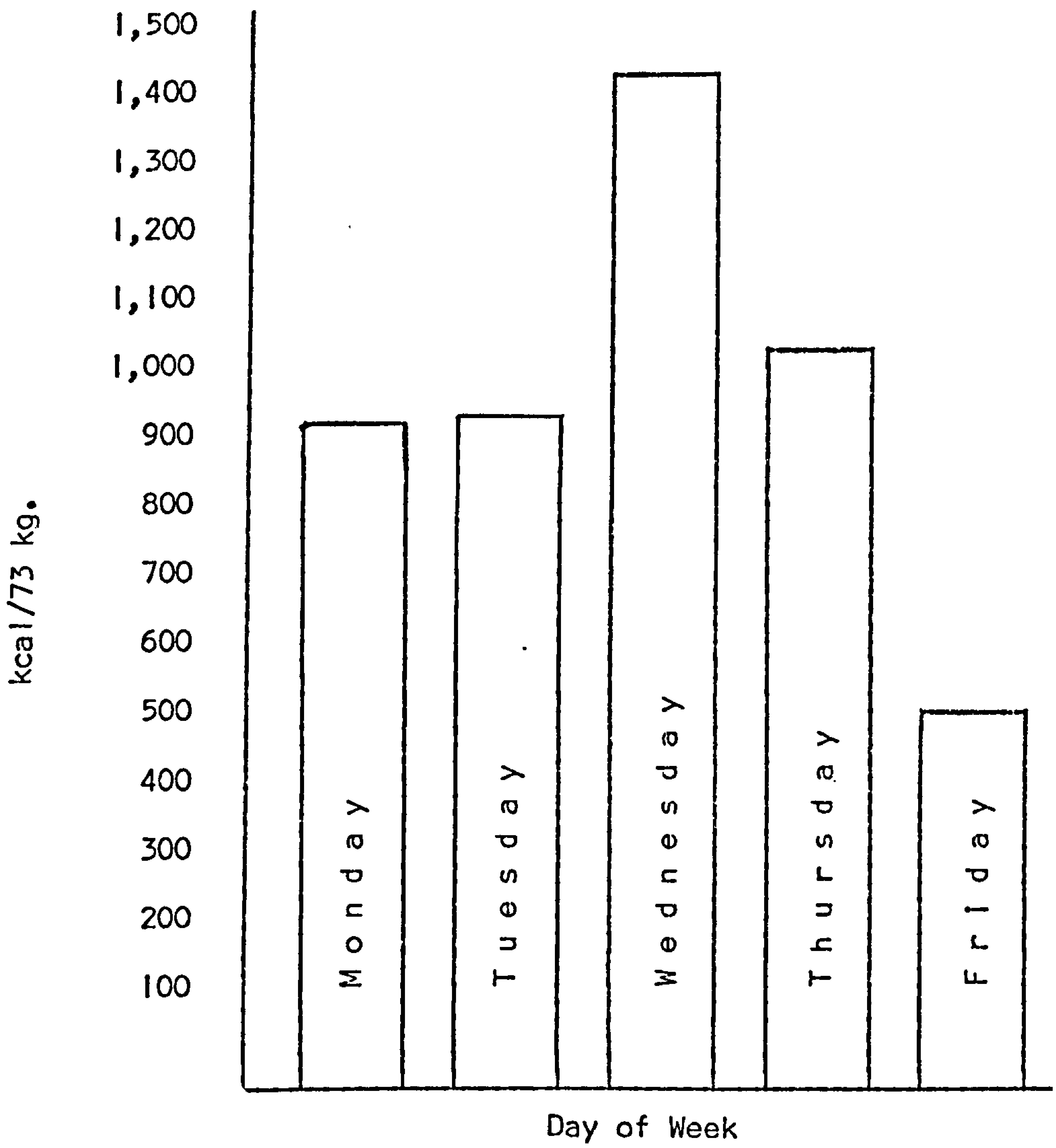

Figure 12. Distribution of daily energy expended in training according to the day of the week.

The calculated gross energy expended in a training session had a mean value of 942 kcal. The distribution of a weekly training energy cost of 4784 kcal according to individual days is shown in Figure 12. The figures show a build-up to a peak of 1409 kcal on Wednesday and a reduction over the remainder of the week in preparation for Saturday competition. The values from Monday to Friday respectively were 911, 917, 1409, 1066 and 481 kcal.

5.3.2. Training performance tests

Running performance data were obtained from time trials administered by training staff on a sand running track (n = 27). Ss were timed over four and over one laps on consecutive days and retested one week later. Mean time for one lap improved from 18•5 (S.D. = 0•4) s to 18•0 (S.D. = 0•6) s ($p < \cdot01$), only one subject showing an inferior time on retest, three showing identical times and the remainder showing improvement. Time for the four-lap run improved from 107 (S.D. = 6•2) s to 90 (S.D. = 0•6) s, performance improving in all Ss. The one-lap and four-lap times were significantly correlated at both initial testing ($r = 0{\cdot}42$; $p < \cdot05$) and retest ($r = 0{\cdot}51$; $p < \cdot01$). Test-retest reliability coefficient for the one-lap run was 0•54 ($p < \cdot01$) and for the four-lap run 0•33 ($p > \cdot05$). The four-lap times were not significantly correlated with terminal treadmill heart rate or to scores on the Harvard Step Test which were obtained two weeks later in the laboratory.

5.4. Physical Stress

There were 103 separate absences from full training for two days or more in the 35 Ss tested at least once in the laboratory. A total of 71 injuries were incurred during competition, 20 were incurred in training, I during extra-occupational activity and 11 absences due to influenza.

Of the competition injuries, 45 were incurred by Ss playing for the First Team, 19 by Ss playing for the 'Reserves' and 7 by Ss while representing the 'A' or the Youths' Team. One full game was considered to expose 11 players to injury. In the 'A' and Youths' matches, only Ss tested in the laboratory were studied so that games at this level invariably involved 3 or 4 player exposures. The results of injuries per player exposure for each category of representative team are presented in Table 5.

Table 5. Injuries and player exposure risks for three categories of representative competition.

	Number of Games	Player Exposures	Injuries	Injury per player Exposure
First Team	48	528	45	1/11·7
Reserves	45	495	19	1/26·1
A and Youths' Team	44	116	7	1/16·6
Aggregate	-	1139	71	1/16·0

The highest incidence was found in First Team competition, with one injury for every 11·7 player exposures. The incidence in the 'A' or Youths' Team matches was one injury for 16·6 player exposures. The lowest incidence, one injury every 26·1 player exposures was observed in the 'Reserves'. An aggregate rate of an injury every 16 player exposures was found for the club's professional playing staff.

An injury was adjudged to be severe if it necessitated three weeks or more off full training. Table 6 shows the frequency and nature of severe injuries along with mean disability time. The most frequent

Table 6. Severe injuries incurred during the 1972/73 season.

	Frequency	Mean disability time (days)
Adductor Strain	1	21
Ankle Strain	1	21
Calf Muscle	1	23
Slipped Disc	1	182
Hamstring	1	35
Knee Joint	3	56
Metatarsal Fracture	1	- *

* This injury was incurred at the end of the competitive season. The individual was able to resume full training at the end of the vacation.

site of severe injury was the knee, with a frequency of 3 and a mean disability time of 56 days. Altogether there were 7 knee-joint injuries during the season, with a mean disability time of 27 days. This is close to the frequency of injuries to the knee-joint per season reported by Bass (1967 op cit) and Phillips (1970 op cit) of 6 and 10 respectively but less than the figure of 13 reported by Adams (1973 op cit).

The extant data studied permitted the subdivision of injuries into soft-tissue (muscle and tendon) and joint injuries. Joint injuries were not described in detail other than a record of the joint affected. Injuries to the foot and ankle were as frequent as knee-joint injuries but were less severe. This is apparent in the figures presented in Table 7. Three cases of fractures occurred during the season. There was a fracture of the lower ascending ramus (disability time 14 days), a fractured nose (disability time 8 days), and a fracture of the fifth metatarsal incurred during the last week of the competitive season.

Table 7. Site of joint injuries and their severity,

Site	Frequency	Mean disability time (days)
Hip	1	4
Knee	7	27
Foot	7	5
Ankle	8	7
Arm and Shoulder	2	8
Back	3	68
Head	3	11

For 27 Ss who were employed by the club throughout the season, the number of days of physiotherapy treatment for injuries as well as the frequency and severity of soft-tissue and joint-injuries were obtained. The frequency of separate injuries was not significantly correlated with the total number of days on which physiotherapy was received ($p > \cdot05$). Altogether there were 1301 visits for physiotherapy during the season. Fitness variables at T2 were considered most appropriate for the study of injury predictors. No significant correlations were found for height, ankle mobility, right knee flexion and extension strength, trunk flexion strength, grip strength, vertical jump and SBJ, with the injury variables ($p > \cdot05$). Personality factors C and E did not significantly correlate with injury variables ($p > \cdot05$). A significant correlation was found between Factor O (apprehensiveness) and:-

a) number of days treated by physiotherapy for joint injuries ($r = \cdot44$; $p < \cdot05$);

b) days off training with joint injuries ($r = \cdot46$; $p < \cdot05$).

These relationships were not demonstrated in the case of soft-tissue injuries ($p > \cdot05$).

5.5. Habitual activity and daily energy expenditure

The estimated energy expenditures for each day of the week are presented in Figure 13. The highest values were on Wednesdays, mean 4096 kcal, range 2882 to 5277 kcal. Mean energy demands on Saturday were estimated to be 3890 kcal, ranging from 3203 to 4886 kcal. The lowest values were found on Sunday, mean 2591 kcal, range 2147 to 3247 kcal. The lowest values for a training day were found on Friday, mean 3026 kcal, range 2483 to 4132 kcal. The remaining week-day values were: Monday, mean 3378 kcal, range 2832 to 4067 kcal; Tuesday, mean 3734 kcal, range 2992 to 4267 kcal; Thursday, mean 3415 kcal, range 2686 to 4033 kcal.

Over one week the mean daily energy expenditure was 3447 kcal. Values ranged from 3026 to 4134 kcal, these extreme values being recorded in the lightest and heaviest subject respectively.

On average just under 8 hours were spent in training and competition over one week. This amounts to 4·7% of each day. If Saturday and Sunday are excluded, the time spent training amounts to 4·4% of the day. Four Ss did extra voluntary training. One S ran for 15 min each day Monday-Thursday after group training concluded. Three Ss performed weight-training on their own volition at a private gymnasium once a week. One of these subjects also played 18 holes of golf once a week while another played table-tennis for one hour. Altogether there were three Ss who played 18 holes of golf once a week and one who played pitch-and-putt.

The mean time spent lying in bed was 10 h 27 min. This accounts for 43·5% of the day. On Saturday, mean time spent lying in bed was 11 h 1 min, the time exceeding 12 h in two Ss. Time spent lying down was 10 h each day except Wednesday, when the mean time was 9 h 43 min.

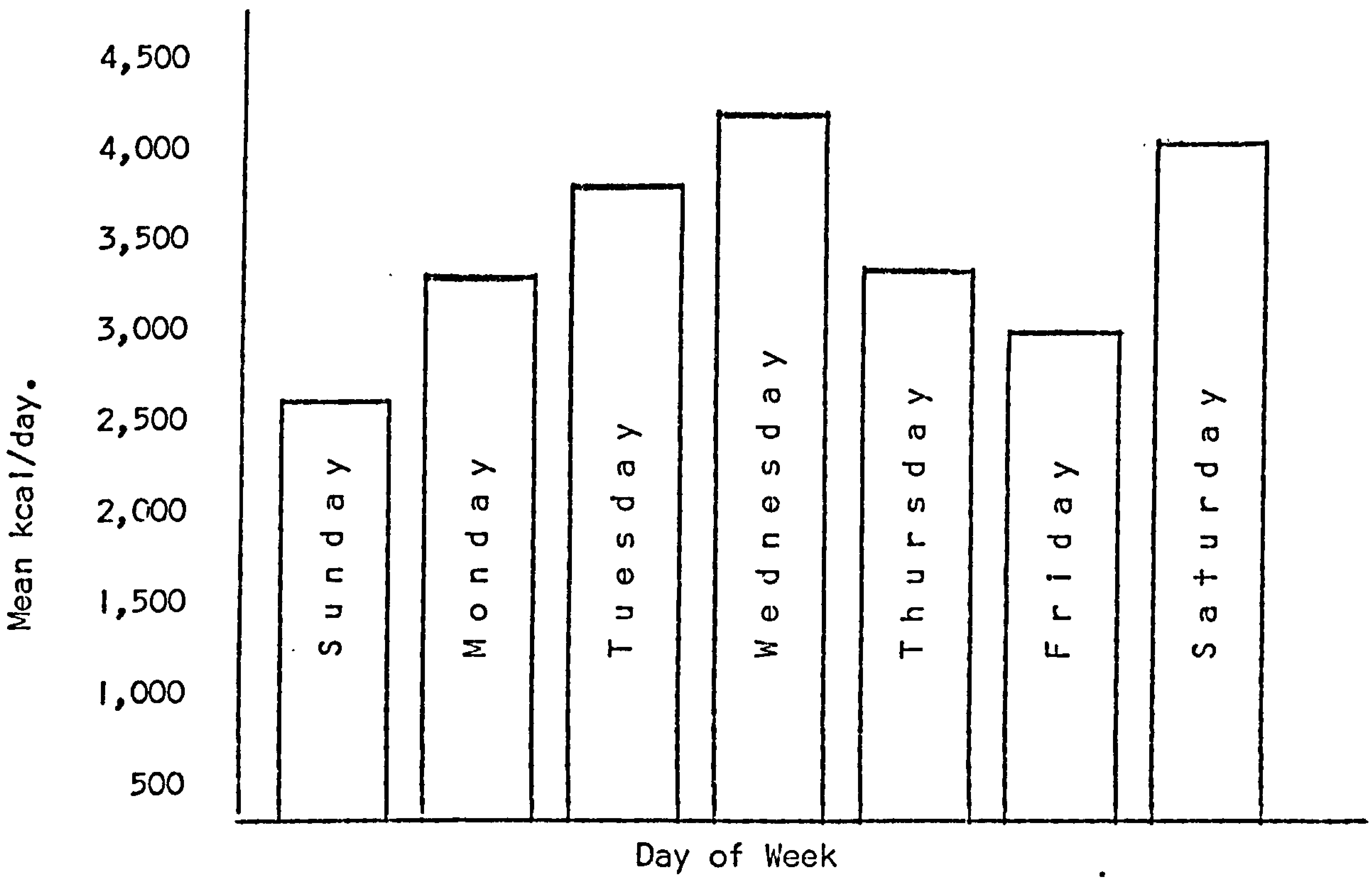

Figure 13. Mean daily energy expenditure levels for each day of the week.

The mean time spent sitting per day was 7 h 48 min or 32•5% of the day. This does not include time spent sitting driving, which averaged 1 hr 14 min per day.

Mean time spent in changing, washing and toilet necessities amounted to 51 min per day. The time spent walking and out shopping averaged 49 min per day. The mean time spent in light recreative sport and voluntary training was 17 min a day and various forms of light domestic work took 4 min per day. The distribution is shown in Figure 14.

The energy expenditure during occupational commitment (18•5 h/week) was estimated to be 7703 kcal per week. This works out at a mean value of 1284 kcal for each of the six working days. This figure is only marginally augmented by consideration of professional life-space in view of the infrequency of voluntary training.

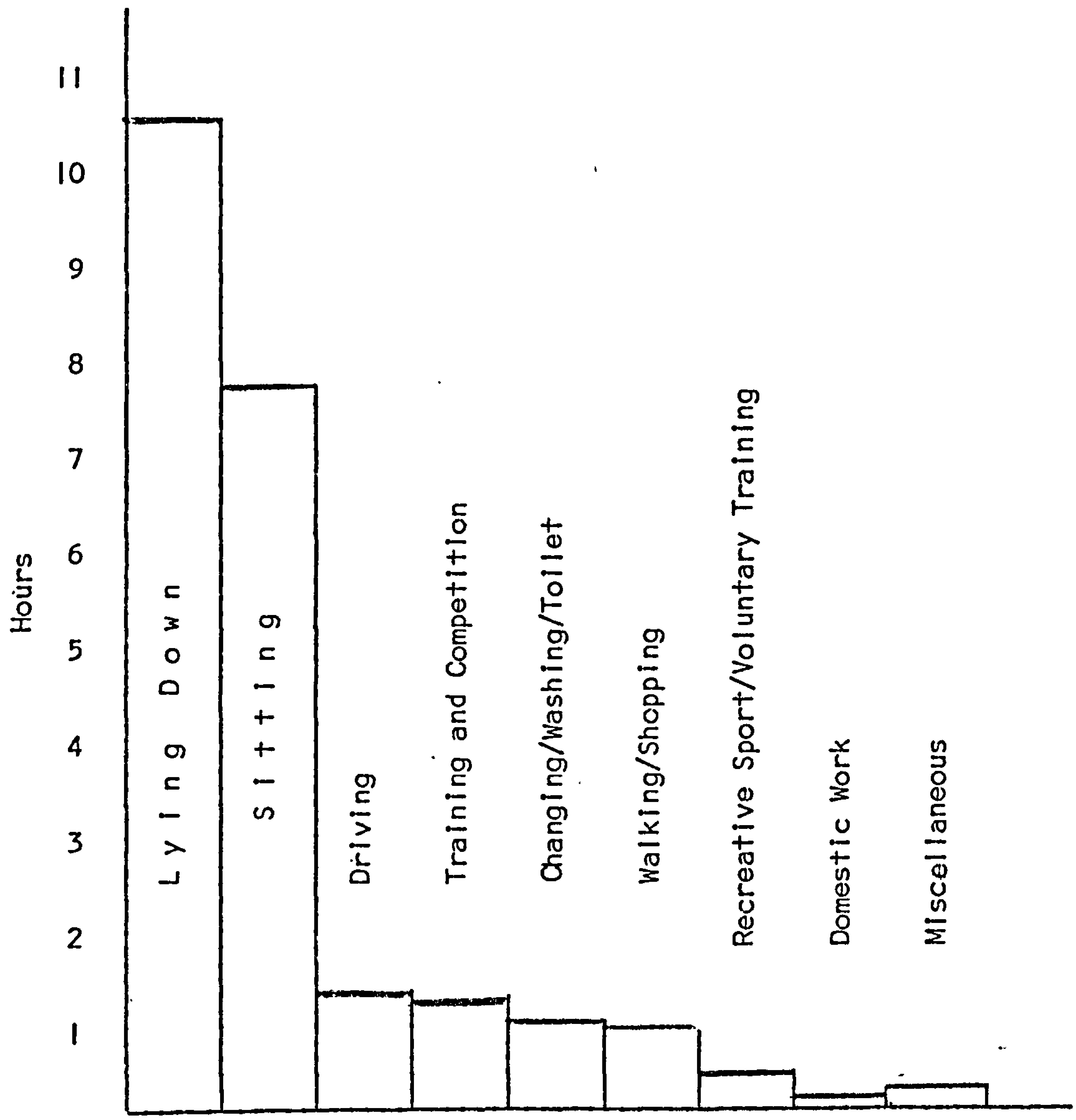

Figure 14. Mean aggregate times for daily activities.

SECTION SIX

DISCUSSION

6. DISCUSSION

6.1. Fitness

The Everton footballers were significantly younger (mean difference = 4•0 years) than the Tottenham Hotsput players studied by Davies (1973 op cit). Davies did not include the younger professionals who had not established themselves as First Team performers. Ss mean height lay between the heights reported for Aberdeen and Tottenham Hotspur footballers. Ss were heavier (mean difference = 3•8 kg) than the Aberdeen players studied by Williams et al (1973 op cit) but lighter (mean difference = 4•6 kg) than the Tottenham Hotspur players. It is possible that English League First Division footballers are taller and heavier than their Scottish counterparts but information on more teams is needed before this can be concluded.

Measurements may be compared with those of Olympic athletes (Tanner, 1964) where procedures were similar. Ss closely resembled the 400 m Hurdlers in weight and thigh circumference but were smaller, had higher skinfold thicknesses and rated higher on endomorphy. Thigh and calf circumference, endomorphy and skinfold thicknesses were close to the values obtained on Triple-jumpers, who were lighter and taller. The Everton footballers were unlike any of the other track and field athletes studied by Tanner. Controlled explosive effort is required in the triple-jump and to some extent in the 400 m Hurdles, a requirement also in many competitive footballing contexts. The footballers were heavier and smaller than the Olympic athletes they most closely resembled in physique.

The range of mobility found at the ankle joint agrees with the normal values for adult male subjects reported by Nowak (1972 op cit).

The deterioration in this function during the season was unexpected, as were the superior values for the 'Reserves' team at T3. It is possible that this function was affected at T3 and T4 by strenuous Football League competition two days before testing in each instance, the Reserves being tested one day later. The results at T1 were significantly less than observed for male subjects aged 14-18 years ($p < \cdot 05$) by Thomas, Reilly and Middleton (unpublished observations). It seems footballers may not be superior to the normal population in mobility at the ankle joint and that this function deteriorates with age.

Lung function parameters were superior to the normal standards for subjects' sex, age and height. VC was slightly higher than the values found by Åstrand (1952) for well-trained males aged twenty-five. The values of 8·1 ℓ reported by Åstrand and Rodahl (1970 op cit) for an Olympic cross-country skiing champion is 400 ml higher than the largest value found in this investigation. Several authors have found that VC is higher in athletic than non-athletic subjects of similar body size (Cureton, 1947 op cit; Kroll, 1954; Stuart and Collings, 1959). No changes were found in VC or FEV_1 throughout the season. Changes in FEV_1 with a programme of physical conditioning have not generally been investigated. Shaver (1974) concluded that a season of training and competition of varsity wrestling can change pulmonary volumes by inducing a significant increase in vital capacity, inspiratory capacity, inspiratory reserve volume and maximum breathing capacity. Bachman and Horvath (1969) found a significant increase (313 ml) in VC in swimmers undergoing four months of typical physical conditioning. No changes in VC were found in wrestlers over the same period. The results of Adams (1968) indicated a period of several months of daily training, even in an activity demanding maximal or near-maximal ventilation was insufficient to effect changes in the VC of college track and field athletes. This is in line with findings in the present investigations. Whether the footballers studied had developed a larger than normal VC and FEV_1 after several years of training and competition or whether the supra-normality could be more satisfactorily explained by a hereditary factor must remain unanswered. The correlation reported by Thomas (1970b) in a study of 12 international canoeists between FEF and CAF was found at T4 only. FEF was found to correlate negatively ($p < \cdot05$) at T2 and T4 with basal heart rate, one of the items contributing to the calculation of CAF.

The reaction times were faster than the normal values generally quoted for visual reaction time of $\sim$ 200 ms (Knapp, 1961). The short reaction times are in accord with Knapp's comparison of sportsmen and university students. The difference between T1 and T2 is interpreted as representing a learning effect. It is likely that Ss advantage in reaction time over normal individuals was genetically derived.

Grip strength was similar to values reported for amateur SCUBA divers by Thomas and Reilly (1974) and for tennis players by Thomas (1970a op cit). No significant changes occurred throughout the season. Deterioration in grip strength had been identified by Rogers (1934) as signifying a decrement in physical condition. The stability of grip strength measures suggested the absence of a cumulative fatigue factor over the football season.

Cable tensiometry results showed there were no differences in strength of function between limbs at all tests where both limbs were measured. This is an important safety consideration as a strength imbalance between the limbs would increase the likelihood of injury (Klein and Allman, 1969). The deterioration in static strength throughout the season may not have been reflected in impaired performance of dynamic work. Factors modifying the expression of human strength have been described by Ikai and Steinhaus (1961). Their findings appear to support the thesis that in every voluntarily executed all-out maximal effort, psychological factors determine the limits of performance. The results determined by cable tensiometry at T3 and T4 probably represent increased unwillingness on the part of Ss to voluntarily exert maximum isometric force.

The constancy of musculo-skeletal function demonstrated by non-significant changes in vertical jump performances throughout the season was not corroborated in SBJ results. The significant correlations between tests cannot be taken as reliability coefficients for the test, due to the interval between testing when training or disuse effects might have occurred. The variance was similar for all combinations of test comparisons. A second possibility was the existence of an inhibitory factor in SBJ at T2 which did not apply to the vertical jump. Another tenable explanation may lie in the training methods employed. During pre-season training, emphasis was placed on methods that could be expected to improve oxygen transport whereas no specific methods to train muscular strength or power were employed. Faulkner (1968) described two types of muscle fibers with differences in functional characteristics and three types of training stimuli operating at the cellular level. White muscle fibers are designed for rapid powerful contractions, have limited blood supply and very few mitochondria. The smaller red fibers develop less force per motor unit and are suited to slow frequent contractions of an enduring nature due to the rich blood supply and the high concentration of mitochondria. There is a wide range in the number of fibers in both red and white motor units.

Gollnick et al (1972) found that the red or slow-twitch fibers predominated in the muscles of endurance athletes and that the oxidative capacity of both types of fibers was improved with a 5 month training programme. Barnard and co-workers (1971) reported that physical training resulted in an increase in the percentage of red fibers at the expense of white fibers in guinea pig muscle. The question of convertibility of fiber types has still to be adequately probed by experimentation. The types of training stimuli described by Faulkner are:

1. A strength training stimulus which results in the thickening and an increase in the number of myofibrils, particularly in white fibers.
2. A speed training stimulus which is difficult to differentiate from a strength training stimulus on the basis of available data but which requires the movement of light loads at high velocity.
3. An endurance training stimulus which results in increases in muscle mitochondria, in energy liberating enzymes in the sarcoplasm and in electron transport capacity.

Gordon (1967) summarised animal investigations of intracellular changes following short bouts of exercise and prolonged training. Contractile constituents were found to increase with forceful types of exercise while rises in sarcoplasmic protein accompanied prolonged repetitive effort. Gordon et al (1967) found increased sarcoplasmic protein in rats performing prolonged work daily for eight weeks which was accompanied by a fall in contractile protein. Opposite effects were found in subjects exercising forecefully fifty times daily - concentration of contractile protein rose and sarcoplasmic protein fell. Prolonged activity requires local endurance and the muscle adapts by augmenting energy-producing constituents. Intense effort requires strength and adaptation moves towards contractile elements.

The interaction of strength, speed and endurance training stimuli requires elucidation by further research employing controlled experimentation and histochemical analysis. An explanation of changes in muscular power in reductionist terms was outside the scope of the present investigations. The difference between T2 and T3 in SBJ suggests that muscular power was below maximum potential at the start of the competitive season and advised that strength and speed training routines should not be neglected in the pre-season training programmes.

The highest values in the vertical jump were found in two centre-backs and in two strikers who function tactically during competition as "target-men" because of their ability to win the ball in the air. The performance of one of the centre-backs was marginally higher, and the performance of a second centre-back and a striker were similar to performances of seven-foot high jumpers reported by Kaufmann and Roessler (1974). The remaining centre-backs all had high performances in the jump tests, as had the goalkeepers, while performances were relatively poor in mid-fielders. It seems exceptional leg power is required in centre-backs, goalkeepers and in specific striker roles.

The slightly elevated systolic blood pressures at T1 requires some explanation. The subjects with no previous experience of the test protocol may have felt apprehensive at their first visit to the laboratory. It is possible that this apprehensiveness was further evidenced in the sitting heart rate values at T1. Alternatively the reduction in blood pressures and sitting heart rates with pre-season training may represent a genuine training effect. This was the conclusion of Shaver (1974 a) in a similar experimental context, who attributed reductions in systolic and diastolic pressures and in resting heart rates over twenty-five weeks of varsity wrestling to a training effect. A reduction in resting heart rate with a two-months hard training regime was found by Frick et al (1963), and by Sloan and Keen (1959 op cit) with a 2-4 months training programme. A decrease in self-reported resting heart rates with a four-week training regime was found by Karvonen et al (1959). A genuine training effect in resting heart rate and blood pressure in the present study is probable.

Blood pressure and sitting heart rates closely corresponded for T2 and T4. The elevated sitting heart rates at T3 require explanation It is unlikely that this increase represented a mid-season deterioration in resting physical condition. The elevation could not be due to environmental conditions as room temperatures were similar at both tests. The increased rates were unlikely to have been caused by anxiety induced by the poor Football League performances that coincided with the test as the increases predominated in the 'Reserves' team. The raised sitting heart rates may have reflected alterations in behavioural patterns of subjects before entering the laboratory, a factor directly outside of the experimenter's control.

Predicted $\dot{V}O_{2\,max}$ in mid-season was 8 ml higher than the 58 ml/kg/min reported for the Aberdeen footballers and considerably higher than the 43 ml/kg/min reported by Di Prampero et al (1970) for Olympic Games soccer players. The mean was similar to values found in international footballers, but lower than in international cyclists, canoeists, long-distance runners and rowers studied by Hollman (1972). The highest value (85 ml/kg/min) found in a mid-fielder is similar to the highest reported by Saltin and Åstrand (1967) for a cross-country skiing world champion and exceeds the 82 ml/kg/min of an Olympic steeplechase winner. The greatest absolute value of 6·25 ℓ/min is greater than the highest recorded by Saltin and Åstrand in a Swedish orienteering champion but less than the 6·75 ℓ/min found by Wilmore and Haskell (1972) in a professional American footballer.

The standard error for the method for the prediction of maximal oxygen uptake from submaximal exercise using the Åstrand/Rhyming nomogram is about ten percent in relatively well-trained individuals of the same age. Åstrand and Rodahl (1970 op cit) stated that untrained persons are often underestimated; extremely well-trained athletes are often overestimated. Glassford et al (1965) and Teräslinna et al (1966) found good agreement between measured and predicted $\dot{V}O_{2\,max}$ using the nomogram of Åstrand/Rhyming. Rowell et al (1964) found $\dot{V}O_{2\,max}$ to be underestimated when the nomogram was used. Nine of the current subjects were estimated to have capacities of 70 ml/kg/min or greater which implies exceptional efficiency in oxygen transport. In view of the problems inherent in prediction it would seem important that $\dot{V}O_{2\,max}$ be actually measured in the population investigated here.

According to norms for the Harvard Step Test established on 8,000 American college students, performance on this test was "high-average" on initial testing and "excellent" in subsequent tests (Clarke, 1967 op cit). The improvement in HI with pre-season training was greater than the improvement reported by Sloan and Keen (1959 op cit) in a rowing team over 2-4 months. Ishiko (1967) reported HIs for competitors at the Tokyo Olympic Games. Mean fitness index of the soccer players was 119·5, the highest indices (160·2) being found in marathon runners. The intra-season levels of the Everton players were well below the 122 reported by Chrastek et al (1965 op cit) for top-class basketball players. The highest value of 127 was considerably less than the 172•4 and 174•2 reported by Cureton (1956) for two world-record holders in track-racing.

The treadmill tests indicated that significant improvement in circulatory efficiency was effected by the pre-season training regime and this improvement was retained but not enhanced through the competitive season. The stability of circulatory efficiency over a prolonged period of competitive sport has been found by Coleman et al (1974) on studying aerobic responses of college basketball players during a season. The results of the initial test indicate that disuse effects had eventuated over the off-season. It appears that professional footballers gain considerably in circulatory fitness during the pre-season training programme. The gains are maintained throughout the season and lost in the off-season. The pre-season programme's emphasis on training of the circulatory system would be assisted if players were encouraged to do voluntary training or participate regularly in recreative activity, providing a training stimulus to the oxygen transport system,during the off-season. Additionally this would facilitate the incorporation of strength and speed training in the pre-season training regime.

Significant effects of the pre-season training programme were confined to improvements in the circulatory system, especially as measured in the heart rate response to a fixed work-load of treadmill running and bench-stepping. The reductions in sitting heart rate, blood pressure (systolic, diastolic and pulse pressure) could be partly attributable to elevated rates on initial testing. The reductions in RT were probably a practice effect. No significant changes were found in ahthropometric variables (weight, skinfold thicknesses, limb circumferences, lung function). Leg power and grip strength were unchanged. Decrements in strength determined using cable tensiometry probably reflected decreased motivation to exert maximum effort on the tests of isometric strength. No changes of personality structure were found during this period.

Personality assessment found that subjects were in certain respects different from the expected profile of top-class team sportsmen. Changes in personality factors during the season suggest that to some extent the personality of footballers may be changed by the process of interaction with their occupational environment. Some of the accepted pre-requisites for success obtained throughout the season, notably extraversion and intelligence. Drive, a recognised characteristic of superior performers, was reduced at the end of the season. Personality profiles at T1 differed from the successful soccer-type of Kane (1968 op cit) in that Ss lacked emotional control, conscientiousness, confidence, and were too self-sufficient. Group 2 were in fact more dominant and group dependent at the beginning of the season. By mid-season Ss lacked dominance and adventurousness, traits that are generally linked with success in team sports. This coincided with poor First Team results. At this stage the First Team were more suspicious than the Reserves, a condition that should be expected to precipitate specific coaching difficulties. At the end of the season Ss showed increased dominance and reduced apprehensiveness, changes in the direction of the profile expected of successful teams. During the season in which the personality inventory was administered, Everton won only thirteen League games, were in the bottom half of the League table for most of the season and were eliminated from the knock-out Cup competitions at an early stage. It is a matter of surmise as to whether personality structures would have been differently affected, if at all, by successful team performance. A profitable approach would seem to be to regularly monitor morale and transient affective states throughout the season - using for instance the techniques of Lewis et al

(1964) or McNair and Lorr (1964) or devising appropriate techniques - with a view to studying their relationships with match results.

Univariate analyses of differences between squads found the First Team were more radical at initial testing, more suspicious during the first half and more withdrawn during the latter half of the competitive season. When the total personality domain was employed to investigate group separability, no significant differences were demonstrated. If the groups had shown a consistent monotonic increase or decrease on any factor by level of group membership, this might have suggested the existence of some pattern. The fluidity of potential and actual movement between groups may make the identification of consistent patterns improbable. In effect, discriminability on a personality domain is obstructed by the sample size of the groups studied as well as the inconstancy of group membership.

Univariate analyses of the physical fitness test-items found the First Team had higher blood pressures and greater leg power at the beginning of the season, and had greater strength, lower resting heart rates and more efficient circulatory responses to work by mid-season. Over the latter half of the season the First Team had the greater leg power and the more efficient circulatory responses to exercise. The multiple discriminant analyses found groups were separable on the basis of cardiac measures at T1 and T3 and of muscular strength and power at T2 and T4. The pre-season training regime is likely to have caused the equivalence of cardiac measures at T2. It seems fitness of the circulatory system at the beginning of the season is important. This is borne out by the non-selection of three of the misclassifications in Group 1 at T1 for the early League programme and reinforced by the fact of three of the misclassifications in Group 2 at T2 going on to establish regular First Team selection.

Discriminability between squads was highlighted when the data was first subjected to principal components analysis,and group separation based on principal component scores. Group separation based on multiple discriminant analysis of component scores was demonstrated at TI and T2. Univariate discriminability was found on at least one individual component at all four tests. The profitability of this statistical procedure for evaluative and predictive purposes is apparent from inspection of the Hits and Misses table. In the majority of cases, individuals forecast as misclassified in Group 2 were later to win regular First Team selection. In general, misclassification in Group I moved group membership in the reverse direction in accordance with the statistical prediction. Apart from its possible use as an aid to selection the analysis facilitates pinpointing individuals'incompatibilities with their group fitness profiles. This would permit identification of specific weaknesses and appropriate remedial training could be devised to repair them.

Results of the factor analyses point to the consistency of certain factors of physical fitness throughout the season. The preliminary solution indicated that psychological as well as physical and physiological components of fitness exist. The greatest single component was a physical attribute described as size. The cluster analyses illustrated that though some homogeneity according to position does occur the phenomenon is not general. An inspection of team selections over the three years of this study showed that eight out of thirty-five subjects played competitively in at least two of the four outfield positions in this period. This versatility was largely confined to the younger players. The establishment of clear-cut positional distinctions on the basis of fitness components would require a larger sample than was here available, the sample being confined to individuals well established in defined roles. An interpretation of the present results is that some mobility between conventionally defined positional roles is a requirement of current top-class competitive football. This permits a wider range of tactical manoeuvres to be deployed during competition, since a few individuals are capable to meeting team configuration needs as contingencies of strategy arise. It may be that clustering would become clearer if competitive behavioural characteristics were related separately, or in conjunction with positional groupings, to the fitness components.

The centre-backs have probably the most clearly defined positional role. The homogeneity of this group is apparent in the cluster analysis as an indication of the potential of this statistical technique for the purposes of early selection of individuals for this role. A further indication of its value is the close proximity on component scores of individuals who in the context of this study would be described as being unsuccessful in their occupation.

6.2. Competition

6.2.1. Pre-match anxiety reaction

The pre-match heart rates were low compared with values reported by other investigators. Carruthers (1974 op cit) reported rates of 150 beats/min in a television reporter during a live performance and rates found in public speakers were of a similar order of magnitude. Åstrand (1967 op cit) found an anticipatory heart rate of 150 beats/min in a world class downhill skier which increased to 200 beats/min immediately prior to starting his run, and a similar rate of 200 beats/min for a girl attending a Beatles' stage performance. Taggart and Gibbons (1967) found heart rates exceeding 200 beats/min in racing car drivers awaiting the starter's flag while Skubic and Hilgendorf (1964) reported a rate of 138 beats/min or 66 beats/min higher than the resting rate in female track runners 30 s before beginning their runs. In comparison the mean of 87 beats/min in the current study is low. The observation on a substitute of a rate of 39 beats/min suggests exceptional emotional quiescence. The difference of 17 beats/min between substitutes and selected players is an indicant of the degree of extra psychological burden on competitors. The finding of an accelerated rate in individuals returning to the First Team after a period of displacement, or on making their initial appearance of the season, is evidence supporting the existence of habituation to competition stress. According to Jones (1973) this phenomenon can be interpreted as a reduction in sensory stimulation and a higher level of stress tolerance accruing from regular subjection to match play. When habituation results in decreased arousal below the optimal level, as might occur if match-play were too frequent, performance will be adversely affected.

The pre-match data were not related to individual performance as measured by work-rate during the game or to team performance as measured by the match result. It may be that individual difference in the anxiety reaction and the complexity of interrelationships between individual and team performances mediate against the discovery of optimal levels of arousal for both individual team members and the team. It is also probable that gross measures like work-rate and the match result are insufficient on their own as indicants of performance level because of the innate chance element in the result of field invasive games. A study of sensitive indicants of skilled performance in competitive soccer was beyond the scope of the present investigation.

6.2.2. Match play and competition work rate

The results of the motion analysis of competition delineate the frequent alterations in movement intensities and the infrequency of rest pauses. The mean distance per discrete movement was 10 m. Three walks were taken on average every minute, which give an indication of the rapidity of work-load alterations imposed on the individual. Stationary rest pauses with a mean deviation of 3·2 s were taken by outfield players once every two minutes. The furthest distance covered was found in a mid-field player with the highest predicted $\dot{V}O_{2\,max}$, who rested for a total of 11 s during the game. The greatest overall distance covered was found in mid-fielders, all of whom had high aerobic capacities. The significant correlation between distance covered and predicted $\dot{V}O_{2\,max}$ emphasises the importance of endurance as a fitness requirement. If the premise that demands are imposed by the game is valid, the results outline the relative importance of circulatory fitness according to positional roles.

In outfield players the lowest distances covered were found in centre-backs. The frequency of jumping in this position was once every 4·5 min, which suggests that jump endurance is not a specific requirement. The winning of the ball in the air by the centre-back seems to be a critical defensive need. The ability of the centre-back to win aerial possession can also be exploited in finite offensive manoeuvres. The high scores of this group in vertical jump and SBJ performance might indicate that to some extent a process of self-selection for this position occurs, muscular power as well as physical attributes being pre-requisites. Additionally the negative correlations obtained between the jumps (vertical jump and

SBJ) and distance covered in a match suggests centre-backs and the goalkeeper have high muscular power endowments, mid-fielders having the lower muscular power. Mid-fielders are in fact infrequently involved in jumping for possession of the ball and great muscular power is not required for their task.

Full-backs and strikers are intermediate between the mid-fielders and centre-backs in terms of work-rate. The variability in total distance covered in a match shown by full-backs probably reflects the greater flexibility in this group in movement activity during competition. Results indicate that between games the full-back may oscillate between a defensive function similar to the work-rate profile of the centre-back, and an offensive function linking with strikers and a corresponding work-rate profile close to that of the mid-fielders. Though the frequency of sprinting in full-backs was less than in strikers or mid-fielders the variability in this group suggests that speed-endurance might be required to meet strategic contingencies of rapid reversals of function and that speed-endurance training should not be neglected. The mean frequency of sprinting for outfield players of once every 90 s indicates speed-endurance training is advisable for all outfield players.

The critical demands on the goalkeeper may be to a degree disguised in the results. The high proportion of distance covered in possession of the ball is due to a number of factors. When he has the ball the goalkeeper does not run the same high risk of being dispossessed as outfield players and can hold it longer. He usually takes the ball to the edge of his area before releasing it. He may carry the ball across his area to retain it longer for tactical purposes. Reception of the ball from his own defence amplifies his work-rate with only marginal increase in skill requirements. It seems also that when there is no direct threat to his goal he does not stand still. This involuntary movement may represent an attempt to maintain arousal and assist performance. Whiting and Sanderson (1972) have demonstrated that in tasks requiring dynamic visual acuity,performance is facilitated by a fore-period of light exercise. There is ample evidence that capacity for action is reduced by periods of inactivity (Broadbent, 1958). In the case of the goalkeeper the excess distance covered is only indirectly imposed by the game. In addition to the skills specific to his position the goalkeeper needs great muscular power for successful jumping and for short sprints. This concords with the high scores in vertical jump and SBJ found in the four goalkeepers tested in the laboratory. It seems jump endurance, speed endurance and aerobic power are not critical for this position.

The work-decrement found in the second half may represent the existence of a "fatigue" effect as defined by Bartlett (1953) as due to "..... those determinable changes in the expression of an activity which can be traced to the continued exercise of that activity .....". It is also possible that the usual reduction of uncertainty of the result as the match progresses effects a change in work-rate. Saltin (1973) reported a similar reduction in the distance covered between the first and second periods for 9 footballers. The players with the lowest glycogen content in their thigh muscle at the start of the game covered 25% less distance than the other players. An even more marked difference was observed for running speed. The players with low glycogen content covered half the total distance walking and 15% at maximal speed, compared with 27% walking and 24% sprinting for the high glycogen players. Saltin concluded that initial muscle glycogen appears to be important in playing soccer.

Saltin and Hermansen (1967) made recommendations for augmenting local muscular stores of glycogen before competition. Their method involves manipulation of both diet and exercise for a seven day period prior to competition. This method has been generally adopted by distance runners but is not directly applicable to professional football because of the hierarchy of objectives in the weekly training programme and the frequent occurrence of mid-week competition. Thomas (1971a) demonstrated that ingestion of a glucose syrup solution prior to endurance work is accompanied by greater efficiency during exercise and recovery, manifested by lower heart rates for similar work-loads. Blood glucose levels during and after extended submaximal exercise were raised. The response curves suggested that ingestion should be effectuated both prior to competition and during the intermission.

A fatigue effect in the second period of match play has been demonstrated. Further investigation would throw additional light on the temporal distribution of competitive performance in both its quantitative and qualitative aspects, within as well as between periods.

In general, 98% of the total distance covered was without possession of the ball. It seems that the vast majority of movement is concerned with movement off the ball either in attempting to dispossess the opposition or in assuming positions of optimal strategic benefit when team-mates have possession. The maximum contribution in work-rate must to an extent be determined by the aerobic power. It follows that high aerobic power is desirable in outfielders especially in the positions where movement activity is flexible, in mid-field and full-back.

6.3.3. Training

An indication of the physiological strain on professional footballers in their training is provided by the mean heart-rate of

132 beats/min over the average 75 min training period. This merited classification as 'heavy' work according to Christensen (1953 op cit). Of the seven active training routines, warm-up, calisthenics and circuit-training were 'moderate', skills-practice, 'drills' and running were 'heavy', while only 'games' could be described as 'very heavy'. The estimated energy expended in daily training of 942 kcal falls well short of the 2000 kcal/day offered by Müller (1953) and Christensen (1962) as acceptable guidelines for heavy work over an eight-hour shift. Employing Müller's criteria for establishing the length of rest pauses necessitated by the work-intensity, the intensity found in training in this study would require a recovery time 200% of the active time to avoid undue physiolcgical stress. This means that training could be prolonged for a further 95 minutes each day. Though the calculations have limited direct applicability because of the assumption that the work is spread over an eight-hour shift and no allowance is made for the occurrence of peak loads, the indication is that the duration of training at the intensity found could be doubled without undue distress.

For the purpose of evaluation, training may be viewed from a slightly different perspective. The analogy with the acting profession implies that the motives of training incorporate a preparation of individuals for their public performances. The parallelism may be extended to evaluate the training objective as preparation for competition. This investigation was in terms of adaptive physiological responses. This requires summary statements on training dimensions that elicit adaptations.

The search for an optimum training programme on sound scientific principles has attracted many investigators. Shephard (1968 op cit) concluded that the adaptive response to a training regime is determined largely by the intensity of effort demanded and the initial fitness of the subjects. The findings of Davies and Knibbs (1971) and Fox et al (1975) suggest the intensity of effort is the most important dimension effecting changes in maximum aerobic power. Karvonen (1959 op cit), describing the advantages of a trained cardiovascular system, concluded that to attain all major effects of training it is necessary to train at high pulse rate levels. Karvonen et al (1957) stressed the existence of a threshold of about 135 beats/min below which no training will occur. Roskamm (1967) placed the threshold at 130 beats/min, adding the qualification that this rate must be maintained for 30 min on five days a week. Ogirimah et al (1974) assumed the training threshold was at 130 beats/min. Karlsson et al (1967) predicated that to elicit a maximal training effect on the circulatory system, the demand on the O_2 transport system should probably be maximum, though this could be effected at a submaximal rate of work as measured by running speed. Faria (1970) and Sharkey and Holleman (1967 op cit) emphasised intensity rather than duration as the important factor in endurance training with uninterrupted work. Fox et al (1973 op cit) arrived at a similar conclusion for interval training programmes.

Over a season of competitive soccer the objective of fitness training can well be seen as retention of a high level of circulatory efficiency acquired during a pre-season physical conditioning programme. Results of Brynteson and Sinning (1973 op cit) show that once cardiovascular fitness is acquired it may be maintained for an appreciable time with a reduction in frequency of training. Training was not monitored during the pre-season regime beyond the observation that training sessions were generally held twice a day. The generalisation of the training objective to one of fitness maintenance cannot apply to individuals disabled for a period and in whom disuse effects would be expected or to players joining the club who might not have had a strenuous physical conditioning programme prior to commencement of the competitive season. The data obtained allows a description of the comparative severity of the training routines over a 23 week period during the competitive season and the comparison of individual routines with the severity of 'games' which in the training programme constitute simulated competition.

The intensity of work during 'games' was similar to that reported by Seliger (1968) using heart rate as the parameter. The simulation of competition stress is likely to have been good since movement activity in 'games' and competition bore close resemblance in the one S observed under both conditions. No routine other than 'games' presented the work-intensity expected in competition. Of the remaining routines, only running and 'drills' exceeded the training stimulus threshold. The three routines accounted for 53% of training time. Only in 'games' and running did heart rates transiently approach maximum values. Where running was comprised of interval training the durations of the active and interval rest periods were not monitored. The routine was generally performed in three sub-groups with one sub-group only active at the one time. This indicates that the rest periods were about twice as long as the work periods. The amount of time devoted to running was 10•5 min when the routine was performed. Within this time it is hardly likely that training effects of interval training as outlined by Bloomfield (1969) and Bonen (1973) would occur. The value of this routine as employed is questionable in view of the limited period in which the intensity of competition stress was presented.

'Drills' were performed at a mean heart rate of 137 beats/min for 19•75 min. This is likely to represent a training stimuls to the circulatory system. The routine was not performed at the degree of intensity expected in competition. It is possible that drills rehearsed at lower degrees of physiological stress cannot be efficiently performed under competition stress because of the physiological load imposed by competition. The incorporation of a degree of 'pressure-training' to increase intensity in this routine is recommended.

The value of warm-up and calisthenics as preparation for future exercise and as safeguard against injury is recognised by many authors (e.g. Williams, 1962; Jensen and Fisher, 1972) and sports practitioners. The work intensity during these routines was 'moderate'. Both routines were always performed to initiate the training session. The combined durations of the two routines was 14•9 min, which is close to the time devoted to pre-competition limbering up by the majority of athletes at major international competitions as reported by Williams (1962 op cit). The observation of Adams (1973 op cit) that little time is devoted to mobility exercises in training for soccer was substantiated in the training programme studied here.

The heart rates during skills-practice and circuit training indicated these routines were close to the margin of 'moderate' to 'heavy' work. High heart rates were not recorded during these activities. The purposive basis of the skills-practice routine may supercede adaptation but it seems advisable that the intensity of work be raised during the routine to represent the competition stress in which the skills are intended to be employed. The objective of the circuit training was general physical conditioning as connoted by Adamson (1958) and the series of resistance exercises conformed to Adamson's model. Results indicate that objectives were not achieved as the mean heart rate was below the training threshold level. The circuit was performed in 10•3 min. Exercises alternated between small and large muscle groups. It is probable that the loads used were too light and the rate of performing each exercise too slow. These could have been artefacts of the imposition of a fixed routine on the whole group without allowance for individual differences. In effect the loads were determined by the weakest member of the group and were too light to evoke a training stimulus to the circulatory system. The routine was infrequently performed more than once a week. In the light of these observations, improvements in muscular strength or muscular power should not be expected as a result of performing the circuit (McQueen, 1954).

Apart from 'games', no training routine produced the stress intensity expected in competition. One third of the training session was devoted to this routine which is likely to have constituted most of the adaptation training stimulus. A controlled experimental situation is required to ascertain the type of game that produces the highest work intensity. This information could be used to apply the overload principle to preparation for competition. Running and circuit-training as employed probably do not achieve their objectives while the value of the skills-practice and drills routines could be enhanced by raising the intensity of work. In general the duration of the training session should be extended as temporal constraints limit the effectiveness of most of the routines.

Evaluation of performance tests conducted during training suggest that when endurance is a factor required, the test is unreliable. It is likely that many Ss performed below maximum effort, particularly on initial testing in the 4-lap run. This may have reflected a distrust of the way the test results might be interpreted by coaching staff. It is more likely that test performances were inhibited by training routines to follow — skills-practice, 'drills' and 'games' — in which their soccer skills are being subject to on-going subjective evaluation.

Zelenka (personal communication, 1975, February 25th) described the use of a specific function test for the evaluation of young football players. The test requires repetitive slalom runs with the ball, with a rest interval of 1 min between runs of ∿ 35-40 s. Results in the present study suggest that tests resembling Zelenka's would be of dubious value with English professional footballers and should not be substituted for evaluation of fitness in laboratory conditions.

6.4. Physical stress

Injuries incurred in competition were the greatest cause of absences from training. The incidence rate for First Team players was similar to the frequency reported by Adams (1973 op cit) for Leeds United F.C. of one injury for every 12·6 player exposures. It seems this figure approximates the current probability of injury in top-class competitive soccer. Injuries among Reserves players were only 44% as frequent as at the higher level of competition. It appears the superior skill expected in First Team players does not ensure protection against injury and that the risk factor is greater at the higher level of competition.

The figures corroborate the findings of other investigators in emphasising the vulnerability of the lower limb in soccer. The absence of relationships between physical attributes and injuries does not necessarily imply that injuries should be accepted as an occupational hazard and that precautionary procedures are futile. More detailed information collected according to conventional epidemiological procedures, comprising extant and concurrent data is required for statements of causal inferences to be made. The predictability of injury in any individual on the basis of the present injury records in conjunction with physical fitness test data is unlikely to be high.

The significant correlations between Factor O and joint injuries lend some support to the hypothesis that the more apprehensive individuals are more injury prone. The more apprehensive tend to have a greater severity of joint injuries (as reflected in the significant correlations between both visits for physiotherapy and days disabled through joint injuries and Factor O) but not a greater frequency of separate joint injuries. The results indicate that apprehensiveness may be a predisposing factor to joint injury but not to soft-tissue injury. It may be that soft-tissue and joint injuries differ in terms of the situational features of their occurrence and that behavioural differences in operational competitive contexts are to some extent determined by differences in apprehensiveness. The data analysed in this study did not indicate whether injuries were as a result of physical contact with opposing players, or with the ground, or whether they were self-induced through lapses in skill and ensuing errors of omission or commission. It may be that the apprehensive individual is susceptible to injury because of his tendency to a particular type of error in critical situations or because of behavioural characteristics in contact situations. A relationship between joint injuries and apprehensiveness has been established. It is contentious whether apprehensiveness can be assuaged in an individual by specific coaching techniques. It would be necessary to identify the predominant cause of injury from patterns of overt behaviour during competition before practical advice likely to reduce the injury-risk in an apprehensive individual could usefully be given.

The direction recommended for further research into injuries should incorporate:

(a) more detailed recording of information on historicity and diagnostic conclusions of injuries for retrospective analysis.

(b) behavioural characterisation during competition with an identification of critical incidents.

(c) further analysis of the dimension of 'apprehensiveness' by factor analysis or alternative inventories (e.g. Taylor, 1953) to increase the power of predictability.

6.5. Habitual activity and daily energy expenditure

The estimated level of daily energy expenditure in the population studied was greater than the value computed for the 'reference man' by a margin of 250 kcal/day. The mean daily energy requirement of 3447 kcal does not indicate that peculiar dietary requirements obtain for professional footballers. The daily demands are below the 3600 kcal quoted by Edholm (1967) for coal-miners and well below the demands computed by Grafe (1971 op cit) for top-class sportsmen in full training. There was however a wide fluctuation between days which was largely determined by variations in the training regime. Daily energy expenditure exceeded 4000 kcal on Wednesdays when the duration of training was longest. The lowest values were found on Sunday, which typically is a day of rest following Saturday competition. The daily rates through the week reflect the patterned build-up towards week-end competition.

In the present study, no information was obtainable on the reserves of muscle glycogen at the conclusion of competition. In the light of Saltin's findings (1973, personal communication, op cit) of the complete depletion of thigh muscle glycogen stores in 4 out of 9 subjects at the end of a football game, dietary means of boosting glycogen reserves as recommended by Thomas (1971a op cit) seem advisable. The present results indicate that professional footballers do not have exceptional daily calorific requirements.

The amount of energy expended during professional life-space (18•5 hours per week) was approximately 1300 kcal/day. This is well below Edholm's (1967) guide of 2000 kcal/day during work as representing the maximum that may be expected for work continued over a period of months or years. This guide referred to normal workers and to shifts of longer duration than the temporal occupational commitments of footballers. The estimated rate of energy expenditure of the footballers over their working hours was 6•9 kcal/min, which means the occupation can be described as 'moderate' work according to the classification of Christensen (1953 op cit).

A striking feature of the habitual activity of the group studied was the high proportion of time spent in sedentary and recumbent postures. Time spent lying (including sleeping) and sitting (including driving) amounted to 19•5 hours per day. This exceeds the range for lying and sitting quoted for military cadets and for coal-miners but is less than the 21-22 hours a day for laboratory workers (Edholm, 1967 op cit). It seems that the professional footballer can be described in Edholm's (1970) terminology as 'homo sedentarius'.

It is apparent that daily energy demands are not excessive in the occupation here studied. The rates found were considerably less than reported by other investigators for top-class athletes in full training. It is likely that the current population could, without undue strain, tolerate an increased daily energy demand effected by a more extensive training programme. The four individuals who undertook voluntary training away from the club's training environment all consolidated their position as regular First Team members during the 1974-75 season. Their success in occupational terms offers substance to the recommendation that daily energy expenditure could be raised by a more extensive training regime without resultant duress.

SECTION SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. Fitness

It was earlier emphasised that the study of fitness profiles of professional footballers was a specific objective of this thesis. The laboratory tests indicated that high scores on certain test items tended to be associated with particular playing positions. Muscular power tended to be greatest in centre-backs and goalkeepers, while mid-fielders were superior in circulatory efficiency. This exemplifies the specificity element of fitness required to accomplish the range of tasks imposed by a positional role. Requirements could be evaluated by administration of the test battery analysed in this study and short-comings in any one individual remedied by adoption of appropriate training methods. Additionally the test-items might usefully suggest the position most suited to the fitness profile of a particular individual.

A programme of pre-season training significantly altered fitness profiles. Effects were largely confined to training of the circulatory system. The only individuals found to exhibit pre-conditioning profiles at the end of the training period were two goalkeepers. In general, endurance was poor at initial testing, while leg power was below maximum potential at the end of pre-season training. It is recommended that the performance of some endurance training during the off-season be encouraged and that strength and power training be included in the pre-season training programme.

As changes in fitness during the season could be a function of disuse due to injury or of the training regimes employed, it seems important that fitness tests should be administered regularly throughout the season. Performance tests conducted in the training environment were unreliable when endurance was a test requirement and it seems fitness is best evaluated in the laboratory. The battery could be administered in full at initial testing. Anthropometric variables, e.g. height, limb length, limb circumference, in which little or no test-retest variability is expected, could be excluded from subsequent tests, reducing the duration of Ss laboratory visits. Measurement of muscular strength should be retained in the test battery in view of its utility in identifying individuals lacking strength and its established discriminant function. Because of the motivational requirements of the test procedure, the use of cable tensiometry could be limited to the pre-competitive season tests. Exceptions could be made in particular individuals considered to require more regular assessment of muscle strength.

Though intra-seasonal tests suggested the current population were excellent in circulatory efficiency, the same degree of supra-normality as found in the treadmill test was not evident in the Harvard Step Test. Ss, particularly mid-fielders, compared very favourably with international endurance athletes in predicted $\dot{V}O_{2\,max}$ but were below the HI scores of Olympic Games soccer players. Because of the importance of $\dot{V}O_{2\,max}$ in endurance exercise, it seems advisable that this parameter be measured directly in the laboratory.

Personality assessments indicated that, though Ss differed in many respects from the normal population means, they did not exhibit profiles consistent with that typical of successful teams as found by other investigators. The neuroticism, submissiveness, suspicion, apprehensiveness, and self-sufficiency found during the season are likely to have induced specific coaching difficulties. It is possible that changes in personality observed during the season were a product of team performances. The 1972-73 season was an unusually poor season for the club in terms of competitive results. The effect of performance on personality could not be evaluated in one team only and was outside the scope of this investigation. The utility of personality assessment was supported by the forecast of misclassifications in group membership. Additionally the 16 P.F. provides information on unique individual characteristics as well as group profiles. In view of the profiles exhibited by the current population, the assessment of personality could be supplemented by administration of a temperament inventory (e.g. Taylor, 1953 op cit) and measurement of transient affective states. These tests could be applied at the training environs for the convenience of Ss.

It seems that discrimination between the First Team and Reserves is possible on the basis of fitness profiles. Univariate analysis indicated that the First Team was in general superior in leg power and circulatory efficiency during the season. The personality profiles of the groups differed in some aspects, the factors which showed between-groups differences changing between tests. This may have been to some extent a result of changes in group membership, as the constitution of the First Team was frequently altered during the season. Discrimination was improved when multivariate procedures were employed. Group separation was achieved either by ordering test-items into four groups for separate analysis or using individuals' scores on the principal components of the original test battery. Group separations are summarised in Table 8. Discrimination was possible at each test on either muscular strength and power items or on cardiac variables. Significant group separation on the basis of principal components' scores was achieved at all except the mid-season test. Where group separation was non-significant, identification of group misplacements was shown to have pragmatic potentialities. Predictions in all instances studied were found to have authentic validity. This statistical procedure of analysing fitness test data would seem to be of immense assistance to coaching staff in the identification of individuals in the First Team with possible susceptibility to trauma or losses in playing form or of individuals in the Reserves exhibiting First Team fitness profiles.

Table 8. Bases for separation of First Team and Reserves using Functional Discriminant Analysis

Basis of discrimination	T1	T2	T3	T4
Anthropometry and blood pressure	-	-	NS	-
Muscular strength and power	NS	**	NS	**
Cardiac variables	**	NS	**	NS
Personality factors	NS	NS	NS	NS
Principal component scores	**	**	NS	**

** indicates significant group separation

NS indicates non-significant group separation

Independent components of fitness were found to underlie the domain of variables in the test battery. The component accounting for the greatest proportion of the total variance was identified as 'size' at each test. A cluster analysis of principal component scores showed a degree of clustering according to positional roles but congregation on the basis of playing position was sometimes disjoined. This is likely to have been due to the presence of a number of individuals who, though tied to a specific role in any one game, alternated between positional roles over the period of this study. The effectiveness of cluster analysis was limited in the present study by the sample size and in some instances to indistinctness of positional groupings. The congruence of individuals who did not play for the First Team over the duration of this study substantiated the utility of this statistical procedure. The technique could have added usefulness with Ss clearly defined as regards playing positions. Its value could be further augmented with the addition of competitive behavioural characteristics. An avenue meriting investigation might be the relationship between clustering on component scores and efficiency of tackling, passing, jumping, and efficiency and frequency of shooting at goal. Clustering according to different combinations of components was not analysed with the present data. This is another direction in which further research might profitably be undertaken.

When rotational procedures of factor analysis were employed, extraction and identification of factors was facilitated. A number of similar factors of physical fitness was consistently found during the season. The preliminary solution indicated that psychological components of fitness coexisted with physical and physiological components in the test battery. The interplay between the variables could be further explored by factor analysis with oblique rotation of all original pure items in the test battery including personality factors. Ideally the sample size should be considerably increased. The exploration is made possible with extended SPSS computer programming facilities. It is this author's intention to pursue this direction of research.

7.2. Competition

Pre-match levels of arousal were equated with anxiety reactions and except for the goalkeeper were found to be low. Results suggest that habituation to competitive stress occurs. The fH acceleration in the 40 min period before leaving the dressing room showed differences between individuals. The substitute had a lower pre-match fH than the players. Except for the substitute the tachycardia was more pronounced at home matches, indicating greater emotional stress prior to playing before the home supporters. Arousal levels did not correlate with spectator attendances. In individuals the pre-match fH was not significantly correlated with work-rate. A more meaningful assessment of performance efficiency might be achieved by analysis of skilled characteristics of soccer performance. This would necessitate monitoring all eleven players during competition and assessing the performance of each S from a filmed or video-taped record of the game. This seems to be an avenue meriting further investigation. Additionally the inverted U-shaped curve relating arousal to performance efficiency need not be abandoned because of the non-significance of the relationship between mean fH and match result found in this study. It is empirically well founded that goals scored or conceded do not always accurately reflect trends in skilled soccer performance of individual team members or of the group as a whole. A qualitiative evaluation of competitive performance was not an objective of this thesis. Further research could investigate criteria for evaluating team performance and re-assess the inverted U-shaped arousal/performance efficiency relationship.

A methodology, which incorporated motion analysis, for the assessment of work-rate during competition was devised and validated. The technique can be employed to evaluate the movement behaviour of an individual during match-play. It could also be used to assess the temporal distribution of movement intensities during competition to examine how individuals pace their work-rate over the playing duration. The method could also be applied to measure the movement behaviour of opposition players or prospective club players when not directly involved in play. The importance of running when not in possession of the ball as a factor contributing to overall team performance is denoted by the small proportion of distance that is covered while in possession. Additionally the methodology could be applied to assess the accuracy of various forms of games in simulating competition stress in training conditions.

Work-rate as measured by total distance covered per game was greatest in mid-fielders and least among outfield players in centre-backs. Strikers and centre-backs were most frequently involved in aerial possession of the ball. Fitness profiles tended in general to match positional movement behaviours, the mid-fielders having high $\dot{V}O_{2\,max}$ values, with goalkeepers and centre-backs having great muscular power. Alterations in movement intensities were frequent and rest pauses infrequent in all outfield players. The pattern of movement activity during match-play suggested that endurance, speed-endurance and speed are required in all outfielders, endurance being critical in mid-fielders. It is recommended that specific functional training of these aspects be incorporated into the weekly training programme.

Work-rate was found to deteriorate over the second period of play. It is likely that this decrement in performance is attributable to hypoglycaemia. This could be obviated by boosting of glycogen stores prior to competition. Manipulation of the weekly training programme as a method of augmenting muscle glycogen stores is impracticable in professional footballers. The recommendation is made that glucose syrup be ingested prior to competition and during the intermission.

7.3. Training

Training 'games' were found in the one S examined to replicate the work-rate of match-play. This was taken as evidence supporting the successful simulation of competition stress in training conditions. Heart rate, monitored for a complete week in 23 Ss, indicated the degree of physiological strain and facilitated the critical examination of the training routines as preparation for competition. Energy expenditures were predicted using the training heart rate data and the heart rate-$\dot{V}O_2$ relationship obtained for each S using the Åstrand/Rhyming nomogram.

The only routine which could be described as 'very heavy work' was 'games' with a mean fH of 157 beats/min in outfield players. The energy expenditure during 'games' was estimated to be 16•4 kcal/min. Outfielders were working at about 75%, while goalkeepers (mean fH 125 beats/min) were working at less than 50% of their aerobic capacity. This routine consumed 25% of total training time. The routine nearest in intensity to 'games' was running, with mean fH 144 beats/min and estimated energy expenditure 14 kcal/min. Mean fH during 'drills' was 137 beats/min. In these three routines the work intensity was sufficiently high to elicit adaptive physiological responses. The duration of running was probably too short and the intervals between running efforts too long for effective training of the O_2 transport system. The routine needs careful re-evaluation. To extend running prior to the performance of skills, 'drills' and 'games' might impose an extra motivational burden on players. Two methods are suggested to circumvent this problem:

1. Running could be performed as the last of the training routines. This might eliminate any inhibitions about inducing fatigue which might be operable prior to ball-playing routines.

2. Players would be required to dribble a ball during running efforts. This is unlikely to reduce work intensity and would intrude a functional skills element into the routine.

It seems the major training stimulus to the O_2 transport system is provided by 'games' and by competition. 'Drills' were not performed at the intensity of competition. It is recommended that pressure-training be incorporated in this routine to elevate the intensity of work to the level expected in competition.

The physiological strain during skills practice and circuit-training was below the threshold of a training stimulus to the circulatory system. The circuit training was unlikely to achieve its objective of providing general conditioning. Improvement in muscle strength or power could not be expected from the routine as performed. The fitness data suggested that some strength and power training is needed and this could usefully be a specific objective of a weight-training programme, in which case a regime could be formulated on principles outlined e.g. by McQueen, 1954 op cit, or Murray, 1963 op cit. In addition the frequency of performing the regime needs to be increased and the load should be tailored to match individual needs. The problem of accommodating a group of the size of one training squad could be overcome by expediential utilisation of a multi-station exercise machine.

Mean fH over the training session as a whole was 132 beats/min. This merits the description of 'heavy' work according to Christensen's method of classifying industrial work. The calculated gross energy expenditure in training had a mean value of 4784 kcal per week. This could be considerably increased without risk of physiological duress to Ss.

The mean duration of a training session was 75 min. Time spent training showed a patterned build up to mid-week and a subsequent tapering off in preparation for Saturday competition. The intensity as well as the duration of training was greatest on Wednesday. The duration of training at the intensities found could have been doubled without physiological risk to Ss. In an extension of training duration the patterned distribution throughout the week could be retained.

7.4. Physical Stress

The major cause of absences from training was injuries received in competition. The incidence of injury in First Team competition was 237% greater than that incurred in Reserves matches. The injury frequency of one per 11·7 player exposures is probably a true approximation of the risk factor currently involved in playing top-class soccer.

The data emphasise the vulnerability of the lower limb in this occupation. The most frequent site of severe injury was the knee-joint. Injuries to the foot and ankle were as frequent as knee injuries but were less severe. Eight separate injuries brought disability for a period of at least three weeks during the competitive season, the most severe injury causing disability for 60% of the total working year.

No physical factors were identified which could be used as indicants of injury proneness. A significant correlation was demonstrated between apprehensiveness and joint injuries. Methods of reducing the injury risk in apprehensive individuals require further investigation. In addition the dimension of apprehensiveness as well as the behavioural context mediating between the physiological state and the event evoking trauma need to be studied. It is also recommended that a more detailed recording of injury data be executed to improve the sensitivity of retrospective analysis.

7.5. Habitual activity and daily energy expenditure

Mean daily expenditure in the footballers studied was 3447 kcal. This figure slightly exceeds normal values but lies below that reported for coal-miners and international standard sportsmen in full training in other sports. Variations between days were found which were largely attributable to the distribution of the training load throughout the week. Mean daily energy expenditure exceeded 4000 kcal on Wednesday, the day the training load was greatest. The footballers had no exceptional calorific requirements and daily energy transformations could be raised without imminent physiological endangerment.

Temporal work commitment amounted to 18•5 hours per week. Over the time the estimated rate of energy expenditure was 6•9 kcal/min. On this basis the occupation could be described as 'moderate' work. On average 19•5 hours were spent each day in sedentary or recumbent postures. Only in the case of four Ss, who performed extra voluntary training away from the club's environment, was hard work undertaken outside of working hours. It seems daily energy metabolism could be raised by extending the training period without precipitating excessive strain.

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APPENDICES

Appendix I. Anthropometric and Resting Blood Pressure Data (Mean ± S.D.)

	Pre-Season (TI)	Start of Season (T2)	Mid-Season (T3)	End of Season (T4)
Age (years)	22·4 ± 3·3	22·6 ± 3·2	22·9 ± 3·4	23·5 ± 3·3
Height (cm)	176 ± 6	176 ± 6	176 ± 6	176 ± 6
Weight (kg)	73·2 ± 8·2	73·3 ± 7·9	73·3 ± 8·3	74·7 ± 8·7
Ponderal Index	12·8 ± 0·3	12·7 ± 0·3	12·7 ± 0·3	12·7 ± 0·2
Body Surface Area (m^2)	1·87 ± 0·1	1·87 ± 0·1	1·86 ± 0·1	1·88 ± 0·1
Triceps Fat (mm)	9·3 ± 3·4	8·3 ± 2·8	8·1 ± 2·3	8·1 ± 3·0
Sub-scapular Fat (mm)	9·1 ± 2·9	8·5 ± 2·5	8·5 ± 2·3	8·2 ± 2·2
Supra-iliac Fat (mm)	10·1 ± 4·4	8·8 ± 3·9	8·6 ± 4·0	9·3 ± 4·0
Summated Fatfolds (mm)	28·2 ± 9·4	25·5 ± 8·4	25·7 ± 8·6	25·6 ± 8·8
Endomorphy	2·8 ± 0·8	2·6 ± 0·8	2·6 ± 0·7	2·6 ± 0·8
Arm Girth (cm)	31 ± 2·1	31 ± 2·1	31 ± 2·1	31 ± 4·8
Chest Girth (deflated) (cm)	90 ± 4·5	91 ± 4·5	90 ± 4·9	91 ± 5·0
Chest Girth (inflated) (cm)	97 ± 3·1	97 ± 4·4	97 ± 4·6	98 ± 5·0
Chest Expansion (%)	7·9 ± 2·0	7·1 ± 1·7	7·4 ± 2·0	8·2 ± 1·6
Hip Girth (cm)	94 ± 1·3	94 ± 3·9	--	--
Thigh Girth (cm)	55 ± 3·1	55 ± 3·2	57 ± 5·0	56 ± 3·9
Calf Girth (cm)	37 ± 1·3	37 ± 1·9	37 ± 2·0	37 ± 2·2
Pelvic Girth (cm)	288 ± 15	--	--	288 ± 12·5
Ankle Girth (cm)	74 ± 4·6	--	--	74 ± 4·0
Ankle Mobility (°)	62 ± 8·5	--	55 ± 7·6	54 ± 6·5
Humerus Length (cm)	71 ± 4·2	--	--	69 ± 12·8
Thigh Length (cm)	99 ± 4·8	--	--	98 ± 5·1
Vital Capacity (ℓ - B.T.P.S.)	5·8 ± 1·0	5·9 ± 0·9	5·7 ± 0·9	6·0 ± 0·9
FEV_1 (ℓ - B.T.P.S.)	4·95 ± 0·9	5·0 ± 0·8	4·85 ± 0·7	5·05 ± 0·8
FEV_1 % VC	86 ± 1·3	86 ± 4·7	85 ± 5·3	84 ± 5·5
FEF (ℓ/s)	10·6 ± 1·8	10·6 ± 1·8	9·3 ± 1·8	9·3 ± 1·9
Reaction Time (ms)	178 ± 19	149 ± 14	150 ± 18	147 ± 18
Blood Pressure (mm/Hg) Systolic	132 ± 13	120 ± 12	122 ± 14	119 ± 15
Blood Pressure (mm/Hg) Diastolic	72 ± 11	66 ± 11	70 ± 10	65 ± 11
Pulse Pressure (mm/Hg)	60 ± 13	53 ± 11	52 ± 14	54 ± 12

Appendix 2. Muscular Strength and Power Variables (Mean ± S.D.)

	Pre-season (T1)	Start of Season (T2)	Mid-season (T3)	End of Season (T4)
Grip (Right) (kg)	50·4 ± 6·5	49·1 ± 6·6	47·8 ± 6·4	47·0 ± 6·7
Grip (Left) (kg)	47·4 ± 5·1	47·7 ± 6·2	47·2 ± 5·6	45·6 ± 6·0
Neck Flexion (kg)	42·8 ± 12·2	36·6 ± 11·2	19·8 ± 10·0	13·9 ± 7·4
Trunk Extension (kg)	43·3 ± 11·7	44·4 ± 11·6	----	----
Trunk Flexion (kg)	47·8 ± 13·0	44·3 ± 14·0	34·9 ± 11·1	21·8 ± 10·0
Overhead Pull (kg)	42·8 ± 10·2	34·6 ± 13·8	25·3 ± 9·1	16·2 ± 9·7
Hip Flexion (Right) (kg)	47·7 ± 6·8	43·9 ± 9·2	22·8 ± 6·9	18·1 ± 7·1
Hip Flexion (Left) (kg)	----	43·4 ± 7·0	23·7 ± 7·2	19·2 ± 7·0
Hip Extension (Right) (kg)	47·2 ± 7·4	53·9 ± 15·6	28·0 ± 9·2	26·3 ± 10·7
Hip Extension (Left) (kg)	----	49·1 ± 13·1	25·4 ± 9·2	20·7 ± 9·4
Knee Flexion (Right) (kg)	32·0 ± 2·0	24·0 ± 10·2	7·2 ± 5·2	7·6 ± 5·8
Knee Flexion (Left) (kg)	----	23·2 ± 9·4	6·6 ± 4·9	7·6 ± 7·8
Knee Extension (Right) (kg)	47·8 ± 6·8	37·0 ± 12·8	21·9 ± 9·7	13·2 ± 9·2
Knee Extension (Left) (kg)	----	34·3 ± 11·2	19·7 ± 9·5	12·6 ± 7·5
Ankle Extension (Right) (kg)	114·0 ± 17·0	110·0 ± 13·6	----	----
Ankle Extension (Left) (kg)	----	109·7 ± 13·7	----	----
Vertical Jump (cm)	58·0 ± 6·2	55·6 ± 6·0	54·0 ± 6·3	54·3 ± 7·0
Standing Broad Jump (cm)	219·0 ± 16·5	211·0 ± 17·4	225·0 ± 11·6	225·0 ± 15·2

Appendix 3. Cardiac Variables (Mean ± S.D.)

	Pre-season (T1)	Start of Season (T2)	Mid-season (T3)	End of Season (T4)
Basal Pulse Rate (beats/min)	48 ± 5•5	48 ± 7•3	48 ± 5•5	50 ± 7•0
Sitting Heart Rate (beats/min)	65 ± 12•0	54 ± 9•6	65 ± 14•2	59 ± 8•3
Maximum Heart Rate (beats/min)	198 ± 7•8	196 ± 12•6	195 ± 19•8	196 ± 11•2
C.A.F.	40•6 ± 3•3	41•8 ± 6•7	41•4 ± 5•4	39•9 ± 5•4
Treadmill Heart Rate (beats/min)	158 ± 15•7	132 ± 14•4	137 ± 15•2	139 ± 13•4
Harvard Index	78•8 ± 7•1	99•5 ± 12•3	97•6 ± 14•3	96•9 ± 12•0

Appendix 4. The Sixteen Personality Factors.

	High Score Description	Low Score Description
A.	Extraverted, Sociable	Aloof, introverted
B.	Intelligent	Dull
C.	Emotionally stable	Neurotic
E.	Dominant, Aggressive	Submissive
F.	Cheerful, Happy-go-lucky	Serious
G.	Conscientious	Undependable
H.	Adventurous, Carefree	Withdrawn
I.	Sensitive, Gentle	Realistic, Tough
L.	Suspicious	Trustful
M.	Bohemian	Practical
N.	Ambitious	Unpretentious
O.	Apprehensive	Secure
Q1	Radical	Conservative
Q2	Self-sufficient	Group-dependent
Q3	Controlled, Exacting will-power	Lax
Q4	High Ergic Tension, Driven	Phlegmatic, Composed

Appendix 4A.

Personality Factors (mean ± S.D.)

	Pre Season (T1)	Start of Season (T2)	Mid-Season (T3)	End of Season (T4)
A	6•5 ± 1•2	6•2 ± 1•8	6•0 ± 1•5	6•4 ± 1•4
B	5•8 ± 1•7	6•3 ± 1•9	5•9 ± 1•6	5•1 ± 1•7
C	4•4 ± 1•8	4•5 ± 1•6	4•5 ± 1•6	4•4 ± 1•6
E	5•5 ± 1•8	5•5 ± 1•7	4•9 ± 1•5	7•0 ± 2•4
F	5•8 ± 1•7	6•2 ± 1•7	5•5 ± 1•6	5•8 ± 2•0
G	4•6 ± 1•6	4•5 ± 1•6	4•3 ± 1•6	4•1 ± 1•4
H	5•0 ± 1•4	5•0 ± 1•5	4•7 ± 1•4	5•4 ± 1•7
I	5•2 ± 1•5	5•5 ± 1•5	4•9 ± 1•5	4•4 ± 1•7
L	5•9 ± 1•8	6•2 ± 1•7	6•0 ± 1•9	6•3 ± 2•0
M	5•7 ± 1•7	6•0 ± 2•0	5•5 ± 1•5	6•8 ± 1•7
N	4•9 ± 1•8	5•0 ± 2•4	5•1 ± 2•1	5•9 ± 2•0
O	6•6 ± 1•9	6•6 ± 1•7	6•8 ± 1•8	5•1 ± 1•8
Q1	6•0 ± 1•7	5•8 ± 1•9	5•6 ± 1•9	5•4 ± 1•8
Q2	6•3 ± 1•9	6•4 ± 1•7	6•2 ± 1•5	6•4 ± 2•3
Q3	5•2 ± 1•6	5•0 ± 1•4	5•2 ± 1•9	4•7 ± 1•8
Q4	6•2 ± 1•9	6•2 ± 2•0	6•0 ± 1•8	5•1 ± 1•8

Appendix 5

ANOVA for T1/T2 - differences significant at the levels of probability quoted

Test Item	Between Subjects	Between Squads	Between Tests	Squad/Test Interaction
Body Surface Area	•05			
Triceps Fat	•01			
Sub-scapular Fat	•05			
Supra-iliac Fat	•05			
Summated Fatfolds	•05			
Hip Girth	•01			
Thigh Girth	•01			
Calf Girth	•01			
VC	•01			
FEV_1	•01			
FBF	•05			
Reaction Time			•01	
Systolic B.P.		•05	•01	
Diastolic B.P.		•01	•05	
Pulse Pressure			•05	
Grip Strength (Right)	•01			
Neck Flexion			•01	
Trunk Flexion	•01			•05
Trunk Extension				
Overhead Pull				
Hip Flexion (Right)				
Hip Extension (Right)				
Knee Flexion (Right)				
Knee Extension (Right)				
Ankle Extension (Right)				
Vertical Jump				
Standing Broad Jump	•01	•05		
Sitting Heart Rate			•01	•05
Maximum Heart Rate	•01			
C.A.F.	•01			
Treadmill Heart Rate	•01		•05	
Harvard Index	•05		•01	
Factor A	•01			
Factor B				
Factor C	•05			
Factor E	•05	•01		
Factor F	•05			
Factor G				
Factor H	•01			
Factor I				
Factor L	•05			
Factor M				
Factor N				
Factor O	•01			
Factor Q1	•01	•01		
Factor Q2	•01	•05		
Factor Q3				
Factor Q4				

Appendix 6

ANOVA for T2/T3 - differences significant at the levels of probability quoted

Test Item	Between Subjects	Between Squads	Between Tests	Squad/Test Interaction
Triceps Fat	•01	•05		
Sub-scapular Fat	•05			
Supra-iliac Fat	•01			
Summated Fatfolds	•01			
Calf Girth	•01			
VC	•05			
FEV_1	•01			
FEF				
Reaction Time				
Systolic B.P.				
Diastolic B.P.				
Pulse Pressure	•01			
Grip Strength (Right)	•05			
Neck Flexion	•01		•01	
Trunk Flexion			•01	
Vertical Jump				
Standing Broad Jump	•01		•01	•05
Sitting Heart Rate	•01	•01	•01	
Maximum Heart Rate	•05	•05		
C.A.F.	•01	•05		
Treadmill Heart Rate	•01	•01		
Harvard Index	•05	•01		
Factor A				
Factor B		•05		
Factor C				
Factor E	•05			
Factor F				
Factor G	•05			
Factor H				
Factor I				
Factor L		•05		
Factor M				
Factor N				
Factor O				
Factor Q1				
Factor Q2	•05			
Factor Q3				
Factor Q4				

Appendix 7

ANOVA for T3/T4 - differences significant at the levels of probability quoted

Test Item	Between Subjects	Between Squads	Between Tests	Squad/Test Interaction
Triceps Fat				
Sub-scapular Fat	·05			
Supra-Iliac Fat	·01			
Summated Fatfolds				
Ankle Mobility		·01		
VC	·01			
FEV_1	·01			
FEF	·05			
Calf Girth	·01			
Systolic B.P.				
Diastolic B.P.				
Pulse Pressure				
Grip Strength (Right)	·05			
Neck Flexion			·05	
Trunk Flexion (Right)			·01	
Hip Flexion (Right)			·01	
Knee Extension (Right)			·01	
Vertical Jump		·01		
Standing Broad Jump	·05	·05		
Sitting Heart Rate	·01			
Maximum Heart Rate	·01			
C.A.F.	·01			
Treadmill Heart Rate	·01			
Harvard Index				
Factor A				
Factor B				
Factor C				
Factor E			·01	
Factor F	·05			
Factor G				
Factor H		·05		
Factor I				
Factor L				
Factor M				
Factor N				
Factor O			·01	
Factor Q1	·05			
Factor Q2	·01			
Factor Q3	·01			
Factor Q4	·01			

Appendix 8. Intercorrelations of Strength Variables at T1

	1	2	3	4	5	6	7	8	9	10	11
1. Neck Flexion	1·00										
2. Trunk Flexion	·31	1·00									
3. Trunk Flexion	·34	·35	1·00								
4. Overhead Pull	·49**	·06	·46***	1·00							
5. Hip Flexion	·49***	·26	·47***	·55***	1·00						
6. Hip Extension	·53***	·25	·35*	·48***	·62***	1·00					
7. Knee Flexion	·51***	·17	·40*	·50***	·67***	·57***	1·00				
8. Knee Extension	·39*	·28	·21	·27	·35*	·15	·46***	1·00			
9. Ankle Extension	·14	·17	·39*	·39*	·47***	·20	·42**	·10	1·00		
10. Grip Right	·32	·18	·41**	·27	·33	·29	·36*	·43**	·27	1·00	
11. Grip Left	·36*	·16	·44**	·40*	·52***	·40*	·53***	·40*	·43**	·84***	1·00

* R ⩾ ·35 = P < ·05
** R ⩾ ·41 = P < ·01
*** R ⩾ ·45 = P < ·001

Appendix 9. Intercorrelations of Strength Variables at T2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Neck Flexion	1·00															
2. Trunk Extension	·46***	1·00														
3. Trunk Flexion	·36*	·21	1·00													
4. Overhead Pull	·64***	·18	·53***	1·00												
5. Hip Flexion Right	·62***	·66***	·36*	·43**	1·00											
6. Hip Flexion Left	·42**	·50***	·37*	·31	·70***	1·00										
7. Hip Extension Right	·29	·45***	·42**	·09	·41**	·41**	1·00									
8. Hip Extension Left	·57***	·20	·26	·39*	·50***	·46***	·63***	1·00								
9. Knee Flexion Right	·56***	·49***	·63***	·52***	·58***	·49***	·63***	·46***	1·00							
10. Knee Flexion Left	·53***	·29	·41**	·62***	·55***	·35*	·30	·42**	·71***	1·00						
11. Knee Extension Right	·63***	·33	·53***	·72***	·62***	·47***	·10	·30	·68***	·70***	1·00					
12. Knee Extension Left	·64***	·27	·35*	·67***	·64***	·45***	·12	·37*	·58***	·61***	·84***	1·00				
13. Ankle Extension Right	·14	·32	·26	·10	·28	·01	·26	·09	·39*	·16	·21	·16	1·00			
14. Ankle Extension Left	·02	·04	·12	·03	·10	·03	-·01	-·02	·14	·17	·11	·24	·60***	1·00		
15. Grip Right	·43**	·27	·63***	·38*	·48***	·31	·40*	·41**	·60***	·67***	·57***	·51***	·38*	·37*	1·00	
16. Grip Left	·26	·14	·57***	·28	·34	·19	·27	·27	·56***	·56***	·49**	·42**	·31	·34	·82***	1·00

* R ≥ ·35 = P < ·05
** R ≥ ·41 = P < ·01
*** R ≥ ·45 = P < ·001

Appendix 10. Intercorrelations of Strength Variables at T3

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Neck Flexion	1·00												
2. Trunk Flexion	·41**	1·00											
3. Overhead Pull	·47***	·25	1·00										
4. Hip Flexion Right	·47***	-·05	·33	1·00									
5. Hip Flexion Left	·48***	·13	·45***	·49***	1·00								
6. Hip Extension Right	·32	·32	·27	·21	·25	1·00							
7. Hip Extension Left	·21	·15	·23	·18	·23	·57***	1·00						
8. Knee Flexion Right	·48***	·09	·58***	·52***	·58***	·46***	·22	1·00					
9. Knee Flexion Left	·30	-·19	·73***	·58***	·44**	·15	·27	·68***	1·00				
10. Knee Extension Right	·20	-·11	·46***	·28	·33	·25	·34	·56***	·73***	1·00			
11. Knee Extension Left	·27	-·20	·29	·44**	·43**	·07	·25	·56***	·69***	·75***	1·00		
12. Grip Right	·40*	·15	·39*	·50***	·28	·27	·23	·45***	·49***	·46***	·33	1·00	
13. Grip Left	·33	·19	·37*	·54***	·22	·32	·42**	·39*	·48***	·37*	·33	·82***	1·00

* $R \geq ·35 = P < ·05$
** $R \geq ·41 = P < ·01$
*** $R \geq ·45 = P < ·001$

Appendix II. Intercorrelations of Strength Variables at T4

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Neck Flexion	1·00												
2. Trunk Flexion	·50***	1·00											
3. Overhead Pull	·00	·14	1·00										
4. Hip Flexion Right	·39*	·33	·26	1·00									
5. Hip Flexion Left	·40*	·44**	·24	·53***	1·00								
6. Hip Extension Right	-·01	-·05	-·24	·10	·14	1·00							
7. Hip Extension Left	·12	·18	·01	·37*	·33	·27	1·00						
8. Knee Flexion Right	·06	·11	·05	·35*	·27	·02	·43**	1·00					
9. Knee Flexion Left	-·01	·11	·11	·07	-·06	·22	-·14	·23	1·00				
10. Knee Extension Right	·22	·28	·55***	·50***	·20	·09	·20	-·10	·15	1·00			
11. Knee Extension Left	·00	-·02	·28	·37*	·15	·07	·17	·00	·27	·69***	1·00		
12. Grip Right	·30	·40*	·35*	·31	·03	-·09	·07	·30	·27	·54***	·39*	1·00	
13. Grip Left	·33	·42**	·18	·38*	·30	·18	·19	·36*	·26	·33	·16	·68***	1·00

* R ≥ ·35 = P < ·05
** R ≥ ·42 = P < ·01
*** R ≥ ·46 = P < ·001

Appendix 12. Abbreviated terms for test items employed in the Multi-Variate Analyses

SYST	Systolic Blood Pressure
DIAST	Diastolic Blood Pressure
PP	Pulse Pressure
SITHR	Sitting Heart Rate
RT	Reaction Time
VC	Vital Capacity
FEV	Forced Expiratory Volume in one second (FEV_1)
FVPN	FEV_1 as percentage of VC
FEF	Forced Expiratory Flow
NECK	Neck Flexion (Strength)
TRE	Trunk Extension (Strength)
TRF	Trunk Flexion (Strength)
OP	Overhead Pull (Strength)
HFR and HFL	Hip Flexion Right and Hip Flexion Left (Strength)
HER and HEL	Hip Extension Right and Hip Extension Left (Strength)
KFR and KFL	Knee Flexion Right and Knee Flexion Left (Strength)
KER and KEL	Knee Extension Right and Knee Extension Left (Strength)
AKER and AKEL	Ankle Extension Right and Ankle Extension Left (Strength)
GRIPR and GRIPL	Grip Strength - Right and Left Hands
VERT	Vertical Jump
SBJ	Standing Broad Jump
HT	Height
WT	Weight
LIN	Ponderal Index (PI)
BSA	Body Surface Area
TRIC	Triceps Skinfold Thickness
SCAP	Sub-scapular Skinfold Thickness
ILIAF	Supra-iliac Skinfold Thickness
TFAT	Summated Fatfolds
ENDO	Endomorphy
ARM	Arm Circumference
DEFL	Chest Circumference (Deflated)
INFL	Chest Circumference (Inflated)
EXPAN	$\frac{100\ (Infl-Defl)}{Defl}$
HIP	Hip Circumference
THIGH	Thigh Circumference
CALF	Calf Circumference
PELV	Pelvic Circumference
ANKLE	Ankle Circumference
HUMER	Length of Humerus
FEMUR	Length of Thigh
MOBIL	Ankle Mobility
TT	Treadmill Test
HI	Harvard Index
HRMAX	Maximum Heart Rate
HRMIN	Basal Pulse Rate
CAF	Cardiac Assessment Factor
A	Personality Factor A
B	Personality Factor B
C	Personality Factor C
E	Personality Factor E
F	Personality Factor F
G	Personality Factor G
H	Personality Factor H

continued...

I	Personality Factor I
L	Personality Factor L
M	Personality Factor M
N	Personality Factor N
O	Personality Factor O
Q1	Personality Factor Q1
Q2	Personality Factor Q2
Q3	Personality Factor Q3
Q4	Personality Factor Q4

Appendix 13. Principal Component Analysis (TI) - Component Variance

Component Number	Eigenvalue	Accumulated Value as % of Total Variance
1	12•25	23•46
2	7•53	35•04
3	6•14	44•49
4	4•28	51•07
5	3•48	56•42
6	3•17	61•30
7	2•71	65•48
8	2•62	69•51
9	2•36	73•13
10	1•98	76•18
11	1•82	78•98
12	1•72	81•62

	Component Number											
	1	2	3	4	5	6	7	8	9	10	11	12
ACC	.09	.16	.21	.06	.21	.07	.12	.18	.06	.05	.04	.06
SYST	.02	.17	-.01	-.16	.26	-.12	.16	-.05	.04	.10	.12	.20
DIAST	.10	.10	.11	.04	.11	-.29	-.02	.02	-.26	-.01	.02	.10
FP	-.07	.09	-.10	-.20	.17	.15	.18	-.07	.26	.11	.10	.11
SITHR	-.01	.09	.10	-.36	00	-.11	-.02	-.04	-.17	00	.13	-.20
RT	-.09	.05	.13	-.02	.06	.17	.17	-.09	-.11	-.04	-.11	.13
VC	.12	-.27	-.01	.03	.11	-.05	.05	.05	-.03	.04	.16	.04
FEV	.11	-.28	-.06	-.05	.08	.01	-.01	.13	-.08	.03	.13	.07
FVPN	-.05	-.03	-.13	-.22	-.06	.14	-.14	.22	-.11	00	-.07	.04
PEF	-.02	-.11	-.22	.05	.09	.20	-.08	.23	.04	-.07	.14	.21
NECK	.14	.06	-.12	-.14	.07	-.10	-.09	.10	.06	.29	-.05	.05
TRE	.10	-.12	-.10	.08	.07	.17	-.25	.09	.14	-.01	.04	-.08
TRF	.15	-.07	-.13	-.07	-.04	.25	00	-.09	.06	.09	.04	-.01
OP	.12	.06	-.12	-.06	-.22	.03	-.06	.06	.02	.13	-.20	.25
HFR	.14	.02	-.21	-.15	-.07	-.04	-.02	.07	-.01	-.12	-.02	-.06
HER	.13	00	-.13	-.25	-.01	-.10	-.02	-.08	.08	-.02	-.14	.16
KFR	.16	-.03	-.17	-.07	-.10	-.17	-.05	.02	-.07	-.06	-.21	.01
KER	.13	-.08	.02	-.03	-.05	-.10	-.11	.24	.25	.07	.01	-.23
AKER	.12	-.12	00	-.10	-.18	.06	00	.05	-.31	-.12	-.05	.08
GRIPR	.18	-.08	.03	.06	.11	-.01	.18	-.07	.12	.03	-.13	-.11
GRIPL	.20	-.03	00	-.01	.05	.02	.17	.04	-.05	-.07	-.23	-.16
VERTJ	.03	-.12	.06	-.14	-.15	.33	.15	.20	-.02	-.02	.05	-.02
SBJ	.07	-.08	.12	-.15	-.19	.16	.28	.22	-.01	-.08	-.01	.12
HT	.19	-.16	.08	-.09	-.07	.04	.04	-.14	.01	-.06	.06	.06
WT	.25	-.01	.06	.05	00	.01	.02	-.03	-.01	-.02	.06	.02
LIN	-.09	-.22	.03	-.19	-.12	.03	-.02	-.23	00	-.06	-.02	.03
BSA	.24	-.04	.07	.01	-.03	.01	.07	-.08	.03	.01	.06	.04
TRIC	.10	.25	00	.05	-.19	-.01	-.03	-.01	-.16	.11	-.06	-.07
SCAP	.13	.25	.01	.08	-.13	.11	-.06	-.08	-.03	.02	-.06	-.08
ILIAF	.11	.23	-.01	.09	-.22	.06	.03	00	.07	-.07	.04	.10
TFAT	.12	.27	-.01	.08	-.19	.07	-.02	-.03	-.05	.02	-.02	-.01
ENDO	.08	.25	-.11	.06	-.24	.06	-.04	-.09	-.05	-.01	.05	.01
ARM	.21	.09	.01	.06	.03	.04	-.03	.06	00	-.01	-.03	.20
DEFL	.23	.04	.04	.08	.08	.08	00	.03	.04	-.06	.15	.02
INFL	.22	-.03	.02	.11	.07	.04	-.02	.02	-.07	-.13	.15	.08
EXPAN	-.09	-.19	-.06	.05	-.09	-.12	-.05	-.05	-.26	-.15	-.02	.14
HIP	.22	-.02	.15	.02	.01	.03	-.05	.05	.09	-.05	.04	-.06
THIGH	.23	.03	-.02	.05	00	.02	-.01	.04	-.02	-.06	.08	-.05
CALF	.21	-.04	.05	.03	-.01	-.02	.05	-.17	-.06	-.11	-.05	-.05
PELV	.17	-.12	.04	.08	.13	.03	.14	.01	.13	-.06	-.14	.11
ANKLE	.16	.09	.05	-.06	.07	-.12	.14	-.07	-.07	.14	.22	-.06
HUMER	.20	-.02	-.06	-.02	.11	-.03	.08	-.17	-.10	-.19	.02	-.02
FEMUR	.18	-.07	-.03	-.05	.13	-.15	-.02	00	.07	.05	-.17	-.11
MOBIL	.06	-.05	-.07	-.06	-.09	-.02	.14	-.16	.26	-.01	-.16	-.30
TT	-.03	.11	.16	-.21	-.09	-.07	-.07	.16	.07	-.22	.27	-.10
HI	00	-.16	-.15	.21	-.01	.02	-.08	-.18	-.02	.19	-.23	.17
HR MAX	-.03	.11	-.09	-.27	.05	-.09	.02	.03	.02	-.40	-.09	-.03
HR MIN	.01	-.02	.24	-.28	.04	-.09	-.03	.01	-.18	.17	-.15	00
CAF	-.03	.05	-.25	.16	-.02	.06	.06	.01	.18	-.36	.10	00
A	00	-.17	-.15	.01	-.13	-.03	.28	.14	-.12	.06	-.04	-.10
B	.06	-.12	.24	.02	-.03	.13	-.11	-.13	-.11	00	.02	.14
C	-.04	-.17	.16	.08	-.22	.08	-.14	00	.06	.09	.03	-.23
E	.03	-.08	-.19	-.06	-.19	-.25	.16	-.11	.10	.06	.20	.04
F	-.03	-.04	-.17	.07	.02	.02	.27	00	-.30	.23	.15	-.07
G	-.05	-.07	.11	.15	-.07	-.20	.15	.12	.08	-.14	-.24	-.11
H	-.02	.03	-.07	.23	-.16	-.22	.22	.08	00	.21	.21	-.01
I	.02	-.07	-.07	-.19	00	.25	.05	-.29	.10	.19	.12	-.16
L	.03	-.01	-.26	.06	.07	-.08	-.15	.05	-.19	-.08	.14	-.22
M	.02	.16	-.07	-.15	-.14	.09	.14	.27	.08	.14	-.08	.03
N	-.10	-.08	.04	.08	-.08	-.17	.32	.19	.02	-.07	-.05	.07
O	-.10	.15	-.10	.01	.20	.13	.09	-.04	-.01	-.11	-.15	.12
Q1	00	-.05	-.16	-.13	-.20	-.21	-.01	-.18	.18	-.04	.17	.20
Q2	.09	-.06	.18	-.06	-.05	-.15	-.25	.12	.14	.07	.06	.23
Q3	-.06	.02	.18	.01	-.10	.10	.13	-.24	-.01	-.18	.14	.03
Q4	.05	.03	-.24	-.07	.25	.06	-.02	.04	-.20	-.05	-.06	-.15

Appendix 15. Principal Component Analysis (T2) - Component Variance

Component Number	Eigenvalue	Accumulated Value as % of Total Variance
1	14•70	22•62
2	6•89	33•21
3	5•12	41•09
4	4•54	48•08
5	4•18	54•52
6	2•98	59•09
7	2•80	63•40
8	2•56	67•34
9	2•49	71•16
10	2•25	74•63
11	1•91	77•56
12	1•77	80•29

	Component Number											
	1	2	3	4	5	6	7	8	9	10	11	12
AGE	·17	·13	·21	·08	·16	·12	·09	00	·12	·10	·05	·01
SYST	·02	·01	·18	·16	·15	·01	-·20	-·32	-·07	·10	·14	-·01
DIAST	·06	·01	·05	·11	·29	·18	·16	-·16	-·08	-·02	-·07	·03
FP	-·04	00	·15	·06	-·15	-·18	-·39	-·17	00	·13	-·08	-·05
SITHR	-·03	-·16	-·19	·21	·01	·01	-·12	-·21	-·19	·01	·10	-·04
RT	·06	·07	-·21	·15	·12	-·01	-·17	·13	-·09	00	·03	-·05
VC	·13	-·27	-·00	·01	·03	-·11	-·02	·05	·09	-·11	·06	-·01
FEV	·10	-·29	-·02	-·03	-·01	-·08	-·01	·12	·03	-·11	·15	-·11
FVPN	-·01	-·00	-·04	·08	-·21	·17	·11	-·02	-·05	·06	·51	·03
PEF	-·02	·13	-·15	-·21	-·04	-·13	-·14	-·08	·02	-·04	·19	·11
NECK	·17	-·02	·17	·07	-·11	·09	-·11	·08	-·10	-·04	-·03	·02
TRE	·11	·04	·08	·10	-·18	-·12	-·05	-·12	·04	-·25	-·14	-·22
TRF	·17	-·04	·06	-·06	-·07	·06	·27	-·01	·06	·09	·10	-·19
OP	·15	-·01	·23	·06	-·03	·18	·08	·15	-·08	·05	·20	·01
HFR	·18	·03	·08	·09	-·15	-·04	-·09	00	-·02	-·20	-·08	-·05
HFL	·13	·06	·09	·04	-·23	-·03	-·05	-·06	·07	-·15	-·07	-·09
HER	·02	-·12	-·01	-·10	-·33	·01	·10	-·15	·01	-·17	-·09	·01
HEL	·12	-·04	·02	-·00	-·26	·14	·03	-·01	-·18	-·01	-·11	·12
KFR	·18	-·09	·11	-·08	-·14	·12	·01	-·16	-·02	-·11	·07	00
KFL	·19	-·06	·07	-·04	-·01	·17	-·09	·02	-·02	-·07	·13	·09
KER	·19	·02	·19	00	-·03	·08	-·11	-·06	-·07	·09	·16	·05
KEL	·18	-·01	·21	·02	-·01	-·03	-·16	-·03	-·03	·05	·13	·16
AKER	·10	-·18	-·06	-·02	·09	-·17	·03	-·09	-·18	-·14	-·04	-·14
AKEL	·09	-·09	-·00	-·09	·24	-·25	00	-·15	-·13	-·11	·05	-·10
GRIPR	·22	-·08	-·03	-·04	·02	·03	-·05	-·17	·02	·13	-·05	-·01
GRIPL	·19	-·01	-·07	-·13	·04	00	-·07	-·13	-·02	·21	·02	-·08
VERTJ	·06	-·11	·09	-·04	-·16	-·13	-·00	·17	-·06	·30	-·06	-·29
SBJ	·08	-·10	·15	-·06	·09	-·24	-·04	·10	·07	·27	·04	-·28
HT	·17	-·16	-·19	·12	·03	-·06	-·01	·10	·04	·08	-·07	·01
WT	·04	-·01	-·11	·03	·07	-·04	·04	·02	·05	-·03	-·05	·05
LIN	-·11	-·23	-·15	·15	-·05	-·04	-·04	·11	-·01	·14	-·06	-·09
BSA	·23	-·04	-·12	·07	·05	-·04	·02	·02	·03	·06	-·09	·08
TRIC	·10	·26	-·13	-·01	-·06	-·13	-·06	·04	-·06	·01	00	·07
SCAP	·16	·25	-·14	·04	-·04	·03	·03	·09	-·01	·10	-·03	·03
ILIAF	·07	·31	-·15	-·02	-·08	-·09	·01	-·01	·06	·03	·06	-·11
TFAT	·11	·30	-·15	-·00	-·06	-·07	-·01	·04	00	·05	·02	-·02
ENDO	·07	·28	-·17	-·05	-·14	-·12	-·04	·09	-·02	·03	-·05	-·05
ARM	·21	·09	-·03	·04	·08	·05	-·01	-·02	-·03	-·02	·04	·02
DEFL	·22	-·01	-·04	00	·12	-·04	·01	·02	·07	-·02	·02	-·04
INFL	·22	-·05	-·04	00	·14	-·04	-·03	·09	·06	-·05	·05	-·06
EXPAN	-·05	-·13	-·01	·02	·02	00	-·10	·22	-·04	-·06	·17	-·06
HIP	·23	·06	-·09	·06	·04	·10	-·05	-·01	·08	-·06	·05	·05
THIGH	·22	·08	-·08	-·04	·02	·02	·15	-·11	-·04	·05	·03	00
CALF	·21	-·02	-·12	-·03	·10	-·08	·07	-·07	·02	·03	-·08	·10
TT	-·05	·02	-·02	·29	00	-·15	·13	-·05	-·25	·07	·19	-·20
HI	·01	-·12	·03	-·25	·03	·10	·01	·09	·25	-·01	-·27	·14
HR MAX	-·05	·09	·11	-·02	·19	-·13	·10	·07	-·36	·10	·02	-·01
HR MIN	-·02	-·09	-·26	·22	·11	·16	-·23	·01	-·02	00	·06	·02
CAF	-·02	·11	·27	-·19	00	-·18	·21	·03	-·05	·08	-·12	-·07
A	-·05	-·07	-·07	-·17	-·07	-·23	-·04	-·13	·30	·05	·29	·03
B	00	-·09	-·16	·05	-·04	·24	·19	-·07	·08	·31	-·13	-·07
C	00	-·10	-·01	·19	-·28	-·05	·23	·06	-·16	·03	-·08	·07
E	00	-·06	-·22	-·16	-·07	·12	-·05	-·02	-·12	·20	-·21	-·05
F	- 03	-·10	-·08	-·26	-·13	-·14	-·03	-·10	-·22	-·02	·14	·03
G	-·10	·11	·05	·22	-·01	-·02	·28	-·08	·12	-·15	·10	·03
H	00	-·04	00	-·11	-·08	-·15	·04	00	-·38	·13	-·10	·38
I	·05	-·06	-·09	-·03	-·21	·19	-·16	·12	-·06	·07	·01	-·04
L	·03	-·01	-·06	-·23	·09	00	·15	·27	-·21	-·16	·14	·13
M	·01	·05	·12	-·16	·01	·17	-·26	·06	·08	·28	·15	-·12
N	·02	-·17	-·01	-·05	·04	-·11	·02	-·23	·08	·20	·08	·41
O	-·02	·08	·04	-·16	·17	·15	-·05	-·18	-·20	-·15	-·01	-·12
Q1	-·05	·12	-·02	·03	-·11	·07	·03	-·36	-·05	·15	·07	-·03
Q2	·08	·03	·19	·09	·01	-·01	-·17	·20	-·16	·04	-·10	·11
Q3	·02	·06	·14	·20	·01	-·21	-·04	·14	·15	·11	·01	·27
Q4	·02	·06	-·05	-·27	·10	·26	-·14	·02	-·09	-·06	00	-·12

Appendix 17. Oblique Factor Structure Matrix (TI)

	Factor Number									
	1	2	3	4	5	6	7	8	9	10
SYST	•01	•10	•21	•18	- •14	•10	•03	•09	•11	•76
DIAST	•35	•07	•04	•08	- •14	•25	•30	•06	- •18	•64
SITHR	- •15	•03	•66	•26	•09	•35	•31	•28	•09	•24
RT	- •22	- •02	•14	- •31	•17	•23	•15	•21	•69	- •02
VC	•52	- •71	- •32	•18	•28	- •15	•03	- •32	- •43	- •04
FEV	•43	- •67	- •26	•30	•33	- •06	- •13	- •30	- •40	- •15
FEF	- •03	- •19	- •28	•05	•10	•01	- •91	- •19	- •12	- •21
VERT	•07	- •16	•08	- •01	•82	•01	- •13	- •14	- •11	- •27
SBJ	•21	- •07	•14	•15	•88	- •02	•13	- •24	- •08	00
HT	•71	- •29	- •18	•47	•44	- •07	•38	- •14	- •37	- •04
WT	•97	•02	- •21	•34	•26	- •08	•32	•02	- •49	•19
TFAT	•40	•85	•06	•11	- •01	- •03	•16	•05	- •13	•21
ENDO	•25	•86	•05	•22	- •12	- •11	•04	- •03	- •08	•11
ARM	•83	•24	- •19	•27	•14	•10	•11	•07	- •29	•20
DEFL	•95	•10	- •12	•22	•17	- •18	•12	- •11	- •41	•23
INFL	•91	- •04	- •22	•23	•16	- •16	•11	- •19	- •43	•19
HIP	•66	- •02	- •01	•19	•25	- •19	•35	- •06	- •51	•07
THIGH	•90	•12	- •15	•40	•13	- •07	•11	•11	- •45	•12
CALF	•72	•03	- •29	•37	•19	- •17	•34	•11	- •47	•28
HUMER	•71	- •34	- •40	•19	•36	- •20	•17	•04	- •29	•08
PELV	•08	•08	- •05	•05	- •21	- •01	•15	•76	- •02	•07
FEMUR	•71	- •07	- •18	•54	•09	- •12	•20	•03	- •37	•34
ANKLE	•59	- •28	- •25	•48	•12	- •12	•22	•28	- •57	•21
MOBIL	•10	- •15	- •08	•19	•22	- •74	•25	•14	- •33	- •05
TT	- •10	•10	•91	•08	•12	•11	•17	- •03	•05	•04
HI	- •01	- •14	- •88	- •05	- •21	- •01	- •15	- •11	- •04	- •37
HRMAX	- •20	•07	•45	•41	•02	•10	- •16	•55	•12	•20
HRMIN	00	- •29	•06	•14	•27	•67	•22	•18	- •03	•17
TRE	•49	- •21	- •24	•26	- •09	- •27	- •35	- •21	- •29	- •38
OP	•24	•45	- •28	•46	•23	- •01	•01	- •19	- •45	•12
HF	•33	•23	- •08	•73	•13	- •19	- •14	•01	- •53	•23
HE	•31	•05	- •08	•85	•09	- •03	•08	•09	- •27	•21
KF	•39	•10	- •32	•65	•14	- •03	•08	•17	- •63	•15
KE	•36	- •15	- •01	•14	•28	- •20	•08	•05	- •85	- •08
GRIP	•60	- •20	- •39	•21	•27	- •38	•34	•07	- •49	•33
Percent contribution	39•2	14•9	10•5	7•9	7•4	5•4	4•7	3•8	3•2	2•9

Appendix 18. Varimax rotated factor matrix (T2)

Variable	Factor Number							
	1	2	3	4	5	6	7	8
AGE	·32	-·17	·30	·41	·02	·57	-·19	·02
SYST	-·03	-·01	-·05	·75	·23	·14	-·17	·10
DIAST	·28	-·06	-·04	·74	-·20	·11	-·04	·01
SITHR	-·03	·22	-·64	·15	-·08	-·24	·18	·49
RT	·38	-·15	-·44	-·13	·07	-·04	·26	·16
VC	·40	·74	-·18	-·00	·01	·09	·14	-·16
FEV	·27	·84	-·16	-·17	-·03	·10	·16	-·11
FEF	-·08	·52	·28	-·09	·22	-·03	·21	·01
VERT	·05	·47	·27	-·26	·15	·19	-·02	·14
SBJ	·22	·54	·47	·03	·06	·14	-·31	·05
HT	·68	·44	-·35	-·10	·01	·04	-·01	·04
WT	·95	·12	-·10	·02	·12	·16	·06	-·08
TFAT	·57	-·66	·10	-·30	·24	·01	-·10	·16
ENDO	·43	-·60	·13	-·48	·25	-·13	-·08	·11
ARM	·76	-·10	-·03	·06	·13	·36	·03	·07
DEFL	·81	·18	-·03	·02	·11	·25	-·04	-·09
INFL	·82	·30	-·10	-·01	·08	·26	-·07	-·12
HIP	·87	-·02	-·10	-·01	·27	·16	·01	-·01
THIGH	·87	-·12	·15	·03	-·00	·14	·28	·07
CALF	·87	·11	-·03	·13	·02	-·04	·14	-·13
TT	-·12	·05	-·08	·03	-·02	-·03	-·10	·93
HI	·02	·19	·12	-·04	-·14	-·06	·13	-·71
HRMAX	-·16	-·03	·21	·32	-·13	-·23	-·52	·19
HRMIN	·06	·06	-·89	·09	-·07	-·11	-·19	·12
CAF	-·13	-·04	·92	·02	-·02	·03	-·09	-·01
NECK	·32	·15	-·01	·01	·36	·63	·11	-·06
TRE	·19	·08	·06	-·01	·79	·13	·22	·12
TRF	·53	·25	·35	-·06	-·12	·31	·44	·06
OP	·23	·14	·16	·09	-·01	·89	·11	·03
HFR	·42	·06	·00	-·00	·63	·31	·22	·02
HER	·10	·25	·08	-·24	·32	-·05	·74	-·12
KFR	·36	·24	·09	·10	·29	·35	·67	-·15
KER	·40	·03	·11	·18	·23	·63	·21	-·01
AKE	·36	·53	-·11	·12	·19	-·12	·13	·06
GRIP	·72	·25	·02	·15	·09	·18	·30	-·08
Percent Contribution	40·0	14·7	14·2	9·9	7·4	6·3	4·0	3·5

Appendix 19. Oblique Factor Structure Matrix (T2)

	1	2	3	4	5	6	7	8
AGE	•29	•19	- •23	•46	- •03	•24	- •68	•05
SYST	- •01	- •09	•05	•75	•16	•14	- •17	•11
DIAST	•30	- •08	•07	•71	•04	•02	- •22	- •17
SITHR	•05	- •32	•57	•06	•57	- •21	•30	00
RT	•29	•27	•55	- •04	•20	•19	00	•04
VC	•56	- •67	•16	- •26	- •17	•10	- •22	•34
FEV	•45	- •75	•13	- •43	- •12	•10	- •18	•33
FEF	•05	- •45	- •35	- •28	- •03	•01	- •03	•39
VERT	•12	- •31	- •28	- •37	•09	•24	- •23	•32
SBJ	•27	- •34	- •41	- •08	•01	•57	- •26	•20
HT	•74	- •28	•43	- •24	•04	•18	- •22	•30
WT	•96	•05	•24	- •06	- •15	•11	- •47	•40
TFAT	•39	•85	•08	- •11	•08	•06	- •18	•18
ENDO	•25	•81	•02	- •29	•03	•04	00	•17
ARM	•74	•23	•14	•05	- •01	•09	- •59	•33
DEFL	•83	00	•15	- •06	- •14	•22	- •50	•36
INFL	•85	- •11	•22	- •11	- •17	•26	- •50	•36
HIP	•85	•20	•25	- •04	- •07	•13	- •44	•47
THIGH	•86	•22	- •04	- •03	- •04	- •12	- •45	•29
CALF	•88	00	•15	•02	- •18	•03	- •26	•29
TT	- •12	00	•07	•06	•94	•13	•09	- •03
HI	•07	- •24	- •15	- •14	- •72	- •10	•03	- •06
HRMAX	- •24	•05	- •14	•41	•24	•47	•27	- •34
HRMIN	•05	- •11	•90	•13	•25	•02	•22	- •13
CAF	- •16	•12	- •89	•02	- •11	•23	- •10	- •05
NECK	•38	- •07	•02	- •04	- •11	•03	- •72	•53
TRE	•23	•05	- •06	- •09	•08	- •06	- •28	•85
TRF	•64	- •19	- •35	- •24	- •08	- •18	- •53	•28
OP	•31	- •13	- •19	•04	- •05	•02	- •94	•22
HFR	•47	•06	•03	- •07	- •04	- •05	- •50	•77
HER	•24	- •26	- •18	- •46	- •20	- •56	- •08	•58
KFR	•52	- •28	- •16	- •11	- •25	- •46	- •55	•62
KER	•46	00	- •10	•12	- •09	- •07	- •78	•43
AKE	•47	- •45	•11	- •08	•06	•08	- •04	•41
GRIP	•81	- •18	•03	- •02	- •15	- •08	- •45	•42
Percent Contribution	40•0	14•7	14•2	9•9	7•4	6•3	4•0	3•5

Appendix 20. Varimax rotated factor matrix (T3)

Variable	Factor Number							
	1	2	3	4	5	6	7	8
AGE	•36	- •41	- •35	- •06	•42	•04	•29	- •21
SYST	•05	•02	- •01	- •01	•73	- •00	•02	- •04
DIAST	•39	•16	- •15	- •13	•39	- •19	- •15	- •05
SITHR	•09	•74	- •00	- •17	•07	- •02	•04	•08
RT	•15	•30	•25	•05	•07	•05	•07	- •33
VC	•22	- •17	•87	- •13	- •05	•20	•12	- •04
FEV	•16	- •01	•96	- •07	•00	•16	•05	•05
FEF	•06	- •07	•46	•43	- •11	•02	•16	•01
VERT	- •07	•13	•11	•08	- •10	•74	•05	•01
SBJ	•22	•33	•26	•02	•12	•81	•08	•09
HT	•61	•11	•43	- •30	- •01	•31	•05	•05
WT	•96	- •05	•18	- •13	•02	•10	•11	- •01
TFAT	•74	•43	- •36	•15	- •04	- •04	- •15	- •05
ENDO	•55	•59	- •27	•29	- •17	- •10	- •36	•05
ARM	•86	•12	•04	- •06	•15	- •08	•22	- •01
DEFL	•80	- •12	•24	•10	•09	- •17	•32	- •10
INFL	•79	- •12	•40	•09	•05	- •17	•28	- •08
THIGH	•62	- •18	- •04	•03	•28	•06	•23	•01
CALF	•83	- •06	•15	- •06	- •12	•23	- •05	- •02
MOBIL	•10	•43	- •22	- •12	- •04	•16	- •03	- •11
RT	- •16	•84	•04	- •04	•06	•13	•01	- •25
HI	- •04	- •88	•03	•13	•03	- •17	•04	•01
HRMAX	- •30	•61	- •05	- •05	•12	•18	- •11	- •05
HRMIN	- •00	•36	- •05	- •93	•02	- •03	•01	- •06
CAF	- •12	- •07	- •09	•86	•01	•06	- •00	•02
NECK	•36	•18	•01	- •06	•12	- •14	•69	•33
TRF	•03	•22	•16	•12	•45	- •01	•26	•52
CP	•24	- •15	•13	•07	•12	•22	•56	•10
HFR	•57	- •02	•07	•10	- •39	- •12	•43	•00
HER	- •00	- •25	•04	•07	- •16	•13	•26	•71
RFR	•24	- •27	•32	- •01	- •38	•11	•63	•18
KER	•27	- •61	•04	•13	- •03	•24	•44	- •05
GRIP	•68	- •24	•02	- •17	•04	•25	•24	•22
Percent Contribution	34•2	20•8	13•5	8•9	7•3	6•1	5•7	3•5

Appendix 21. Oblique Factor Structure Matrix (T3)

	Factor Number							
	1	2	3	4	5	6	7	8
AGE	•29	- •30	- •14	- •06	•01	•33	•15	•69
SYST	•05	•07	•01	- •05	•13	•69	•05	•20
DIAST	•43	•16	- •11	- •21	•02	•44	•21	•06
SITHR	•20	•68	- •09	- •28	•24	•11	- •10	- •26
RT	•18	•40	•27	- •01	- •11	•06	- •07	•09
VC	•12	- •11	•93	- •13	•10	- •19	- •25	•26
FEV	•08	•01	•96	- •08	•18	- •12	- •25	•10
FEF	•02	- •04	•49	•43	•14	- •23	- •04	•14
VERT	- •05	•14	•12	•06	•02	- •13	- •75	•02
SBJ	•25	•31	•31	- •07	•23	•05	- •86	•10
HT	•58	•09	•55	- •39	•19	- •08	- •35	•26
WT	•91	- •05	•41	- •24	•19	- •07	- •06	•51
TFAT	•84	•38	- •26	00	•02	•05	•04	•01
ENDO	•69	•48	- •27	•13	- •02	- •02	•03	- •35
ARM	•84	•12	•24	- •19	•28	•05	•10	•49
DEFL	•73	- •06	•46	•02	•23	- •06	•23	•63
INFL	•71	- •06	•61	•01	•23	- •11	•20	•59
THIGH	•56	- •15	•16	- •03	•24	•16	•03	•56
CALF	•79	- •07	•34	- •15	•04	- •15	- •21	•33
MOBIL	•18	•42	- •23	- •19	- •06	•03	- •18	- •12
TT	- •02	•88	- •09	- •15	- •06	•14	- •23	- •33
HI	- •18	- •83	•14	•26	- •11	- •06	•31	•38
HRMAX	- •19	•60	- •20	- •10	- •02	•21	- •27	- •40
HRMIN	•02	•35	- •01	- •96	- •02	•09	- •05	- •13
CAF	- •09	- •06	- •09	•87	•02	- •04	- •03	- •02
NECK	•33	•13	•13	- •14	•73	- •11	•11	•49
TRF	•05	•11	•13	•06	•70	•29	- •07	•06
OP	•17	- •11	•29	•05	•41	- •11	- •17	•59
HFR	•53	- •01	•25	•05	•24	- •53	•13	•45
HER	- •06	- •43	•06	•10	•62	- •33	- •18	•08
KFR	•13	- •27	•47	•01	•42	- •62	- •11	•55
KER	•14	- •53	•27	•18	•12	- •22	- •10	•72
GRIP	•60	•29	•24	- •23	•34	- •10	- •20	•54
Percent contribution	34•2	20•8	13•5	8•9	7•3	6•1	5•7	3•5

Appendix 22. Oblique Factor Structure Matrix (T4)

	Factor Number									
	1	2	3	4	5	6	7	8	9	10
AGE	- ·03	·10	- ·32	- ·19	- ·51	- ·44	·22	- ·58	·22	·25
SYST	- ·05	·57	- ·18	- ·15	- ·11	- ·25	·73	·32	·05	- ·08
DIAST	·22	·41	- ·10	- ·16	- ·18	- ·59	·63	·24	- ·02	·55
SITHR	·03	·16	- ·07	·33	- ·83	·05	- ·05	- ·02	·08	·09
RT	·03	·14	·13	- ·01	- ·07	- ·13	·27	·79	- ·16	00
VC	·87	- ·31	- ·17	- ·04	·06	- ·11	- ·19	·09	00	·25
FEV	·80	- ·31	- ·18	- ·03	·23	00	- ·18	·07	·10	·09
FEF	00	·03	- ·24	- ·20	·51	·25	·26	- ·20	·17	- ·22
VERT	·12	- ·01	- ·76	·02	00	- ·02	- ·10	- ·06	·25	·01
SBJ	·27	·06	- ·93	·18	- ·10	- ·07	- ·03	- ·18	·04	·08
HT	·73	·21	- ·40	·15	- ·27	- ·24	- ·08	·18	·22	·58
WT	·58	·31	- ·45	- ·08	- ·37	- ·46	·14	·21	·15	·40
TFAT	·12	·90	- ·10	00	- ·33	- ·33	·20	·05	·32	·26
ENDO	·04	·88	- ·02	·12	- ·11	- ·20	·13	·24	·31	·06
ARM	·38	·50	- ·14	00	·02	- ·29	·13	·08	- ·01	·67
DEFL	·68	·43	- ·28	- ·25	- ·38	- ·58	·07	·07	·31	·47
INFL	·70	·37	- ·23	- ·25	- ·32	- ·59	·08	·09	·30	·41
THIGH	·57	·72	- ·17	- ·14	- ·31	- ·33	·29	·19	·39	·62
CALF	·74	·49	- ·17	- ·06	- ·20	- ·33	·12	·27	·11	·44
HUMER	·78	·09	- ·25	- ·02	- ·05	- ·22	·32	·04	- ·15	·23
PELV	·56	·41	- ·49	- ·21	- ·08	- ·27	·30	·26	- ·05	·32
FEMUR	·77	·30	- ·33	·04	- ·17	- ·08	·08	- ·04	·19	·55
ANKLE	·71	·24	·04	00	·02	- ·05	·32	·08	·08	·30
MOBIL	·24	·01	·14	·14	·16	00	·82	·20	·14	- ·03
TT	·03	·05	- ·18	·90	- ·27	·05	00	·04	·07	·03
HI	- ·10	- ·45	·18	- ·58	·40	·41	- ·30	·28	·10	- ·14
HRMAX	- ·32	·14	- ·05	·50	- ·16	·19	·25	·01	- ·18	- ·38
HRMIN	- ·04	·39	- ·11	·29	·24	- ·13	·15	- ·30	·61	·22
TRE	·09	·27	- ·28	·03	- ·23	- ·14	·22	- ·23	·84	·21
OP	·18	·16	- ·13	- ·09	- ·09	- ·96	·12	·03	·03	·18
HF	·29	·34	00	00	- ·15	- ·29	- ·03	·20	·47	·51
HE	·07	·03	·51	- ·03	·12	·23	- ·16	·32	·22	·06
KF	·11	- ·10	·02	- ·07	- ·14	- ·06	- ·11	- ·05	·17	·60
KE	·03	·32	- ·15	- ·36	- ·08	- ·50	·10	·19	·31	·25
GRIP	·44	·40	- ·26	- ·20	- ·27	- ·45	·42	- ·15	·26	·64
Percent Contribution	36·6	14·9	10·2	8·6	7·3	6·6	5·2	3·6	3·6	3·3

Appendix 23. Homogeneity of Group Means (T3) - Anthropometry and Blood Pressure

Variables	Mean Squares Within Groups	Among Groups	F Ratio	Normal Deviate	Probability
SYST	207•60	145•20	0•70	0•22	0•415
DIAST	112•48	22•53	0•20	- 0•42	0•661
RT	342•95	149•63	0•44	- 0•05	0•521
VC	0•74	0•60	0•81	0•31	0•379
FEV	0•45	0•39	0•86	0•34	0•365
FEF	3•52	7•91	2•24	1•07	0•142
HT	38•74	0•41	0•01	- 1•18	0•882
WT	71•38	13•13	0•18	- 0•45	0•674
TRIC	8•65	9•35	1•08	0•50	0•308
SCAP	5•13	4•18	0•81	0•31	0•378
ILIAC	16•06	19•36	1•21	0•58	0•282
ARM	4•46	0•41	0•09	- 0•70	0•758
DEFL	23•30	35•21	1•51	0•75	0•227
INFL	20•84	22•71	1•09	0•51	0•306
THIGH	23•72	52•01	2•19	1•05	0•146
CALF	4•23	0•83	0•20	- 0•42	0•666
MOBIL	46•44	388•80	8•37	2•45	0•007 *

* Indicates significant result

Appendix 24. Homogeneity of Group Means (TI) - Strength and Muscular Power

Variables	Mean Squares Within Groups	Mean Squares Among Groups	F Ratio	Normal Deviate	Probability
NECK	105•80	4•50	0•04	- 0•91	0•82
TRE	137•47	131•20	0•95	0•42	0•34
TRF	169•05	129•09	0•76	0•27	0•39
OP	106•07	18•90	0•18	- 0•46	0•68
HF	44•56	109•60	2•46	1•16	0•12
HE	52•83	90•16	1•71	0•85	0•20
KF	77•73	144•82	1•86	0•92	0•18
KE	46•74	15•36	0•33	- 0•20	0•58
AKE	315•92	71•23	0•23	- 0•37	0•64
GRIPR	41•97	35•93	0•86	0•34	0•37
GRIPL	25•37	47•58	1•88	0•92	0•18
VERT	38•55	17•13	0•44	- 0•04	0•52
SBJ	264•41	511•09	1•93	- 0•95	0•17

Appendix 25. Homogeneity of Group Means (T2) - Strength and Muscular Power

Variables	Mean Squares Within Groups	Among Groups	F Ratio	Normal Deviate	Probability
NECK	115•26	394•87	3•43	1•47	0•071
TRE	140•05	5•76	0•40	- 0•92	0•822
TRF	187•05	451•60	2•41	1•14	0•127
OP	91•98	3016•02	32•79	4•37	0•000 006*
HFR	80•87	176•52	2•18	1•05	0•147
HFL	50•28	19•20	0•38	- 0•12	0•548
HER	243•89	233•84	0•96	0•42	0•338
HEL	175•01	74•60	0•43	- 0•07	0•526
KFR	115•36	186•52	1•62	0•80	0•211
KFL	71•07	590•49	8•31	2•45	0•007 *
KER	81•32	2531•67	31•13	4•29	0•000 009 *
KEL	64•04	1927•60	30•10	4•24	0•000 011 *
AKER	190•30	0•28	0•00	- 1•41	0•921
AKEL	192•81	67•37	0•35	- 0•17	0•566
GRIPR	42•03	77•84	1•85	0•91	0•181
GRIPL	38•73	36•76	0•95	0•41	0•340
VERT	37•30	1•43	0•04	- 0•94	0•826
SBJ	1439•17	99•64	0•07	- 0•78	0•783

* Indicates significant result

Appendix 26. Homogeneity of Group Means (T3) - Strength and Muscular Power

Variables	Mean Squares Within Groups	Mean Squares Among Groups	F Ratio	Normal Deviate	Probability
NECK	96•20	105•75	1•10	0•51	0•304
TRF	121•98	42•15	0•38	- 0•17	0•567
OP	82•78	14•82	0•18	- 0•46	0•677
HFR	51•59	15•45	0•30	- 0•24	0•595
HFL	51•85	2•20	0•40	- 0•91	0•820
HER	86•37	0•74	0•01	- 1•22	0•889
HEL	77•33	250•80	3•24	1•41	0•079
KFR	27•26	0•88	0•03	- 0•98	0•836
KFL	20•52	38•18	1•86	0•92	0•180
KER	64•57	847•46	13•12	3•04	0•001 *
KEL	73•51	496•00	6•75	2•20	0•014 *
GRIPR	40•24	39•19	0•97	0•43	0•334
GRIPL	30•41	16•00	0•53	0•05	0•481
VERT	39•31	9•37	0•24	- 0•34	0•634
SBJ	133•82	52•17	0•39	- 0•11	0•544

* Indicates significant result

Appendix 27. Homogeneity of Group Means (T4) - Strength and Muscular Power

Variables	Mean Squares Within Groups	Mean Squares Among Groups	F Ratio	Normal Deviate	Probability
NECK	53•81	82•29	1•53	0•75	0•225
TRF	81•96	594•32	7•25	2•26	0•011 *
OP	86•02	302•29	3•51	1•48	0•069
HFR	59•20	1•75	0•03	- 1•00	0•840
HFL	45•62	20•57	0•45	- 0•04	0•515
HER	107•36	57•14	0•53	0•05	0•479
HEL	101•00	30•04	0•30	- 0•24	0•596
KFR	30•34	60•04	1•98	0•96	0•168
KFL	64•08	3•57	0•06	- 0•84	0•801
KER	76•26	175•00	2•29	1•09	0•138
KEL	46•52	371•57	7•99	2•38	0•009 *
GRIPR	46•29	20•57	0•44	- 0•04	0•518
GRIPL	33•11	30•04	0•91	0•38	0•352
VERT	37•64	357•14	9•49	2•59	0•005 *
SBJ	206•68	825•14	3•99	1•61	0•054

* Indicates significant result

Appendix 28. Homogeneity of Group Means (T1) - Cardiac Variables

Variables	Mean Squares Within Groups	Mean Squares Among Groups	F Ratio	Normal Deviate	Probability
SITHR	152•91	5•11	0•03	- 0•97	0•83
TT	251•81	62•88	0•25	- 0•32	0•63
HI	45•86	125•83	2•74	1•26	0•10
HRMAX	59•00	121•30	2•06	1•00	0•16
CAF	10•38	35•54	3•42	1•47	0•07

Appeneix 29. Homogeneity of Group Means (T2) - Cardiac Variables

Variables	Mean Squares Within Groups	Mean Squares Among Groups	F Ratio	Normal Deviate	Probability
SITHR	88•61	203•35	2•29	1•09	0•14
TT	214•18	3•44	0•02	- 1•12	0•87
HI	155•02	68•48	0•44	- 0•05	0•52
HRMAX	163•50	6•39	0•04	- 0•93	0•82
CAF	44•10	81•86	1•86	0•91	0•18

Appendix 30. Homogeneity of Group Means (T3) - Cardiac Variables

Variables	Mean Squares Within Groups	Mean Squares Among Groups	F Ratio	Normal Deviate	Probability
SITHR	40•57	270•00	6•66	2•18	0•015 *
TT	184•31	1526•53	8•28	2•44	0•007 *
HI	126•21	2376•30	18•83	3•53	0•0002 *
HRMAX	84•78	418•13	4•93	1•84	0•03 *
CAF	27•88	79•05	2•84	1•28	0•10

* Indicates significant result

Appendix 31. Homogeneity of Group Means (T4) - Cardiac Variables

Variables	Mean Squares Within Groups	Mean Squares Among Groups	F Ratio	Normal Deviate	Probability
SITHR	67•41	104•14	1•54	0•76	0•22
TT	184•25	46•29	0•25	- 0•32	0•63
HI	148•77	0•21	0•00	- 1•41	0•92
HRMAX	129•27	0•03	0•00	- 1•51	0•93
CAF	29•53	32•49	1•11	0•52	0•30

Appendix 32. Homogeneity of Group Means (TI) - The Sixteen Personality Factors

Factors	Mean Squares Within Groups	Among Groups	F Ratio	Normal Deviate	Probability
A	1•53	1•37	0•90	0•37	0•35
B	2•69	5•27	1•96	0•96	0•17
C	3•22	0•22	0•07	- 0•79	0•79
E	2•85	11•07	3•88	1•59	0•06
F	2•83	0•04	0•02	- 1•13	0•87
G	2•79	0•06	0•02	- 1•07	0•86
H	2•08	2•60	1•25	0•60	0•27
I	2•13	3•11	1•46	0•72	0•24
L	3•13	4•75	1•52	0•75	0•22
M	3•03	2•45	0•81	0•31	0•38
N	3•24	0•78	0•24	- 0•34	0•63
O	3•64	0•07	0•02	- 1•10	0•86
Q1	2•26	23•48	10•40	2•73	0•003 *
Q2	3•37	4•90	1•45	0•72	0•24
Q3	2•58	0•001	0•00	- 1•49	0•93
Q4	3•70	0•25	0•07	- 0•79	0•79

* Indicates significant result

Appendix 33. Homogeneity of Group Means (T2) - The Sixteen Personality Factors

Factors	Mean Squares Within Groups	Mean Squares Among Groups	F Ratio	Normal Deviate	Probability
A	3•13	1•51	0•48	0•002	0•50
B	3•57	0•45	0•13	- 0•59	0•72
C	2•74	0•19	0•07	- 0•77	0•78
E	2•86	8•81	3•08	1•36	0•86
F	3•07	2•49	0•81	0•31	0•38
G	2•54	0•08	0•03	- 0•99	0•84
H	2•19	1•60	0•73	0•24	0•40
I	2•46	0•19	0•08	- 0•75	0•77
L	2•78	1•66	0•60	0•12	0•45
M	3•71	8•27	2•23	1•07	0•14
N	5•57	8•33	1•50	0•74	0•23
O	3•00	0•42	0•14	- 0•55	0•71
Q1	3•52	4•02	1•14	0•54	0•29
Q2	2•74	7•61	2•78	1•27	0•10
Q3	2•08	2•60	1•25	0•60	0•27
Q4	3•99	1•69	0•42	- 0•07	0•53

Appendix 34. Homogeneity of Group Means (T3) - The Sixteen Personality Factors

Factors	Mean Squares Within Groups	Among Groups	F Ratio	Normal Deviate	Probability
A	2•29	0•83	0•36	- 0•15	0•56
B	2•52	1•20	0•48	- 0•01	0•50
C	2•42	9•63	3•97	1•61	0•053
E	2•30	0•30	0•13	- 0•58	0•72
F	2•75	0•53	0•19	- 0•43	0•67
G	2•62	3•33	1•27	0•62	0•27
H	1•99	0•13	0•07	- 0•79	0•79
I	2•38	1•20	0•50	0•02	0•49
L	3•47	4•80	1•38	0•68	0•25
M	2•20	0•00	0•00	0•45	0•33
N	4•51	0•30	0•07	- 0•80	0•79
O	3•33	0•03	0•01	- 1•20	0•88
Q1	3•61	0•13	0•04	- 0•95	0•83
Q2	2•33	0•03	0•01	- 1•14	0•87
Q3	3•63	1•20	0•33	- 0•19	0•58
Q4	3•38	0•30	0•09	- 0•71	0•76

Appendix 35. Homogeneity of Group Means (T4) - The Sixteen Personality Factors

Factors	Mean Squares Within Groups	Mean Squares Among Groups	F Ratio	Normal Deviate	Probability
A	2•03	0•14	0•07	- 0•78	0•78
B	2•99	0•89	0•30	- 0•24	0•60
C	2•73	1•75	0•64	0•16	0•44
E	5•86	3•57	0•61	0•13	0•45
F	4•29	1•75	0•41	- 0•09	0•54
G	1•95	5•14	2•64	1•21	0•11
H	2•80	3•57	1•27	0•62	0•27
I	2•66	5•14	1•93	0•94	0•17
L	3•84	4•32	1•13	0•53	0•30
M	2•87	0•00	0•00	0•44	0•33
N	3•86	4•32	1•12	0•52	0•30
O	2•86	9•14	3•20	1•39	0•08
Q1	3•20	1•29	0•40	- 0•10	0•54
Q2	5•26	11•57	2•19	1•05	0•15
Q3	3•32	1•29	0•39	- 0•12	0•55
Q4	3•32	0•32	0•10	- 0•68	0•75

Appendix 36. Homogeneity of Group Means (T1) - The Eight Principal Components

Component Number	Mean Squares Within Groups	Among Groups	F Ratio	Normal Deviate	Probability
1	15·12	6·13	0·41	- 0·09	0·54
2	7·50	8·14	1·09	0·50	0·31
3	4·83	44·80	9·28	2·58	0·005 *
4	4·34	2·62	0·60	0·13	0·45
5	3·23	10·58	3·27	1·42	0·08
6	3·27	0·23	0·07	- 0·78	0·78
7	2·69	3·48	1·29	0·63	0·26
8	2·30	11·62	5·04	1·87	0·03 *

* Indicates significant result

Appendix 37. Homogeneity of Group Means (T2) - The Six Principal Components

Component Number	Mean Squares Within Groups	Among Groups	F Ratio	Normal Deviate	Probability
1	13·25	56·58	4·27	1·69	0·045 *
2	7·37	1·59	0·22	- 0·38	0·65
3	3·38	55·54	16·44	3·35	0·0004 *
4	4·70	0·00	0·00	- 1·52	0·94
5	4·19	4·04	0·96	0·42	0·33
6	3·01	1·95	0·65	0·17	0·43

* Indicates significant result

Appendix 38. Homogeneity of Group Means (T3) - The Six Principal Components

Component Number	Mean Squares Within Groups	Among Groups	F Ratio	Normal Deviate	Probability
1	11•18	33•94	3•04	1•35	0•09
2	5•98	59•53	9•96	2•67	0•004 *
3	5•87	11•72	2•00	0•97	0•17
4	4•02	0•64	0•16	- 0•51	0•69
5	3•13	0•20	0•06	- 0•80	0•79
6	3•31	0•93	0•28	- 0•27	0•61

* Indicates significant result

Appendix 39. Homogeneity of Group Means (T4) - The Six Principal Components

Component Number	Mean Squares Within Groups	Among Groups	F Ratio	Normal Deviate	Probability
1	14•74	3•72	0•25	- 0•32	0•63
2	6•67	3•98	0•60	0•12	0•45
3	5•03	9•32	1•85	0•91	0•18
4	4•60	5•08	1•11	0•51	0•30
5	3•89	9•84	2•53	1•17	0•12
6	2•68	36•48	13•62	3•05	0•001 *

* Indicates significant result

Appendix 40. Homogeneity of Group Means - T1/T2 discriminability

Variables	Mean Squares Within Groups	Among Groups	F Ratio	Normal Deviate	Probability
SYST	167•48	2440•66	14•57	3•35	0•0004 *
DIAST	132•17	546•06	4•13	1•71	0•044 *
SITHR	118•52	2090•32	17•64	3•65	0•0001 *
NECK	113•51	600•79	5•29	1•98	0•023 *
TRE	136•42	18•65	0•14	- 0•56	0•712
TRF	181•79	191•63	1•05	0•50	0•310
OP	146•40	1040•58	7•11	2•34	0•010 *
HF	65•50	224•58	3•43	1•51	0•065
HE	148•82	704•53	4•73	1•86	0•032 *
KF	92•37	992•00	10•74	2•90	0•002 *
KE	104•35	1810•08	17•35	3•62	0•0001 *
AKE	234•49	19•76	0•08	- 0•72	0•765
GRIPR	42•50	24•53	0•58	0•11	0•457
GRIPL	48•16	27•11	0•56	0•09	0•462
VERT	36•97	88•32	2•39	1•16	0•123
SBJ	288•81	831•11	2•88	1•33	0•091
WT	64•61	0•15	0•00	- 1•37	0•914
TFAT	81•55	124•62	1•53	0•78	0•219
DEFL	21•13	2•94	0•14	- 0•55	0•710
TT	226•34	10845•16	47•92	5•46	0•0000 *
HI	100•33	6434•14	64•13	6•05	0•0000 *
HRMAX	109•67	48•79	0•44	- 0•03	0•515
CAF	28•29	853•96	30•19	4•58	0•000 *

* Indicates significant result

Appendix 41. Distances covered according to types of activities and frequency of movement activities per game (n = 40).

Activity	Overall Distance (m)		Frequency	
	Mean	S.D.	Mean	S.D.
Jog	3187	746	239	48
Cruise	1810	411	114	16
Sprint	974	246	62	15
Walk	2150	471	308	49
Back	559	247	120	37
Overall Distance Covered	8680	1011	853	--
Distance in Possession of Ball	158	85	--	--

Appendix 42. Distances covered in various positional roles according to types of activities and frequency of movement activities per game.

	Activity	Distance (m)		Frequency of movements	
		Mean	S.D.	Mean	S.D.
MID-FIELD (n = 11)	Jog	4042	540	288	30
	Cruise	2159	314	118	20
	Sprint	1063	162	68	15
	Walk	2034	368	315	51
	Back	507	295	106	39
	Overall Distance	9805	787	895	--
FULL-BACK (n = 8)	Jog	2907	431	226	50
	Cruise	1588	281	109	15
	Sprint	787	284	52	11
	Walk	2293	388	331	28
	Back	670	208	138	38
	Overall Distance	8245	816	856	--
STRIKER (n = 14)	Jog	2769	616	210	32
	Cruise	1752	437	114	14
	Sprint	1068	252	65	17
	Walk	2310	558	304	58
	Back	498	167	117	31
	Overall Distance	8397	710	810	--
CENTRE-BACK (n = 7)	Jog	2908	346	225	37
	Cruise	1596	254	110	14
	Sprint	829	113	59	10
	Walk	1774	316	276	25
	Back	652	305	131	41
	Overall Distance	7759	521	801	--