A PHYSIOLOGICAL EVALUATION OF PROFESSIONAL SOCCER PLAYERS

P. B. RAVEN, Ph.D., L. R. GETTMAN, Ph.D.,
M. L. POLLOCK, Ph.D., and K. H. COOPER, M.D.

Institute for Aerobics Research, 11811 Preston Road, Dallas, Texas 75230

ABSTRACT

The purpose of this study was to evaluate the physiological functions of a professional soccer team in the North American Soccer League (NASL). Eighteen players were evaluated on cardiorespiratory function, endurance performance, body composition, blood chemistry, and motor fitness measures near the end of their competitive season. The following means were observed: age, 26 yrs; height, 176 cm; weight 75.5 kg; resting heart rate, 50 beats/min; maximum heart rate (MHR), 188 beats/min; maximum oxygen intake ($\dot{V}O_2$ max), 58.4 ml/kg·min^{-1}; maximum ventilation (V̇Emax BTPS), 154 L/min; body fat, 9.59%; 12-min run, 1.86 miles; and Illinois agility run, 15.6 secs. Results on resting blood pressure, serum lipids, vital capacity, flexibility, upper body strength, and vertical jump tests were comparable to values found for the sedentary population. Comparing the results with previously collected data on professional American football backs indicated that the soccer players were shorter; lighter in body weight; higher in $\dot{V}O_2$ max (4 ml/kg·min^{-1}) and body fat (1.8%); and similar in MHR, V̇E max, and VC. The 12-min run scores were similar to the initial values observed for the 1970 Brazilian World Cup Team. The agility run results were superior to data collected from other groups. Their endurance capabilities, agility, and low percent of body fat clearly differentiate them from the sedentary population and show them to be similar to that of professional American football backs.

INTRODUCTION

Despite the world-wide popularity of the game of association football (soccer), comparatively little scientific information is available concerning the physiological characteristics of the professional participant; although, some information is available concerning the amateur player (Bell and Rhodes, 1975; Caru *et al.*, 1970; Fardy, 1969). Soccer players must combine speed, strength, agility, power, and endurance as basic qualities before the individual skills inherent to the playing of soccer can be utilized. The understanding of the physical and the mental demands of the sport will enable a more scientific approach to the training of soccer players than has been prevalent heretofore.

This study represents an initial attempt to define the physical and physiological characteristics of soccer players performing at the professional level, thereby establishing a base line to which future investigations can be compared.

METHODS

The subjects consisted of 18 professional soccer players from the Dallas Tornado Soccer Club and represented 100 percent of the playing staff. The Dallas club is one of the founder members of the North American Soccer League (NASL). The Dallas club failed to reach the championship play-offs during the 1975 season; yet, it performed moderately well throughout the league. The playing staff consisted of 13 English league soccer players and 5 United States trained players. All positions, offensive, midfield, and defensive, were represented in this sample. The head coach designated each positional classification regardless of the numbered position for that player on the field of play.

Each player was scheduled for four days of testing during the latter half of the 1975 season. On day one of testing, following a 14-hour fast, each player underwent a preliminary screening examination which consisted of a resting 12-lead electrocardiogram (ECG), a medical examination, a review of a medical history questionnaire with a physician. Following the examination, each player was informed of the purposes and the risks of the study and was requested to sign the informed consent form. Before beginning the testing on day one, a 15 ml blood sample was taken from the antecubital vein, and resting heart rate and blood pressure were determined. These preliminaries were performed after a five-minute sitting rest and in the post-absorptive state. Then the player was tested for body composition, pulmonary function, and endurance capacity. A second 15 ml blood sample was taken on day two after another 14-hour fast. This second sample was used to verify the values obtained on the first test.

Days three and four of testing were utilized to determine values of strength, agility, power, and endurance. Maximum aerobic capacity was determined on a motor-driven treadmill utilizing a modified Åstrand running test (Pollock *et al.* 1976). This protocol included a five-minute warmup walk at 3.5 mph, 2.5 percent grade followed by a continuous, multi-stage, voluntary run to exhaustion followed by a five-minute seated recovery.

Treadmill speed was adjusted to exhaust each individual subject within a seven to ten minute time period. ECG and heart rates were monitored continuously via the Hewlett-Packard direct-lead ECG recording system and cardiotachometer (Quinton Instruments, Model 611). The V5 lead was monitored during exercise; leads II, III, AVL, AVF, and V5, immediately following, and during 1, 3, and 5 minutes of recovery. Blood pressure was determined by auscultation prior to exercise, immediately following, and at 1, 3, and 5 minutes of recovery. During the third minute of recovery, a 3 ml venous blood sample was obtained from the antecubital vein for the determination of blood lactate.

Expired air samples were collected continuously each minute, beginning with the third minute, until the end of the test. Aliquots were analyzed for O_2 and CO_2 content using a Beckman polarographic O_2 (OM-11) and infrared CO_2 (LB-2) analyzers. Calibration gases and analyzers were checked by a modified Lloyd Haldane gas analyzer. Pulmonary ventilation ($\dot{V}E$) was determined by means of a Parkinson-Cowan gas meter (Model CD_4) connected on the inspired side, which was previously calibrated by a Collins 150 L Tissot gasometer. The metabolic techniques and procedures of Consolazio *et al.* 1963 were followed.

The subjects were measured for standing height to the nearest 0.25 inch on a standard physician's scale and for body weight to the nearest 10 g on an Acme Scale (Model ACSMIN). Anthropometric determinations included 7 skinfold (S), 11 girth (G), and 7 diameter (D) measures. Then vital capacity (VC), residual volume (RV), and body density (BD) by hydrostatic weighing were determined. Experienced technicians administered all tests. Sessions were organized so that the same investigator measured all subjects on the same tests; i.e., one investigator always was assigned to each of the following three stations: anthropometry, spirometry, and hydrostatic weighing.

Skinfold fat was measured at the chest, axilla, triceps, subscapula, abdomen, suprailium, and thigh with a Lange skinfold fat calliper. The calliper had a constant pressure of 10 g/mm^2, and measures were taken on the right side. Recommendations published by the Committee on Nutritional Anthropometry of the Food and Nutrition Board of the National Research Council were followed in obtaining skinfold fat data (Keys, 1956). Girth measures were taken with a Lufkin steel tape at the following 11 sites: shoulder, chest (normal), abdomen, waist, gluteus, thigh, calf, ankle, arm, forearm, and wrist. Body diameters were determined with a GPM Swiss-made anthropometer and included the following measures: bideltoid, biacromion, chest width, bi-ilium, bitrochanter, knee and wrist. Skinfold fat data were measured and recorded to the nearest 0.5 mm; and G and D measures, to the nearest 0.1 cm. The location and procedures of anthropometric sites measured were shown and described respectively by Hertzberg *et al.* (1963) and by Behnke and Wilmore (1974).

Vital capacity was determined using a rolling seal spirometer (Ohio Medical Model 842) according to the procedures outlined by Kory *et al.* (1961). Residual volume was determined by the nitrogen washout technique described by Wilmore (1964) using a nitrogen analyzer (Ohio Medical Model 700). Although RV and hydrostatic weighing determinations were administered separately, the same postural positions (sitting) were used for both.

Hydrostatic weighing was conducted in a 4 x 6 x 5 ft fibreglass tank in which a chair seat was suspended from a Chatillon 15 kg scale. The hydrostatic weighing procedure was repeated six to ten times until three similar readings to the nearest 20 g were obtained (Katch, 1968). Water temperature was recorded after each trial. The technique for determining BD followed the method outlined by Goldman and Buskirk (1961); and the calculation of BD, from the formula of Brozek *et al.* (1963). The percent fat was calculated according to the Siri formula, 1961.

The resting blood samples were analyzed[1] for SMA-12 on a Technicon 12-60 autoanalyzer (Model 133-A014-01). The data reported here are those observed for serum cholesterol, glucose, and total proteins. A separate determination of serum triglycerides was made. In addition, a complete blood count (CBC) was run on a Coulter Counter (Model S). The recovery blood sample was analyzed for blood lactate according to the enzymatic method of Sigma Chemical Co.[2]

The field test evaluations consisted of an endurance run, the Cooper 12-min run-walk test for distance (1968), Illinois agility run (Cureton, 1970), Sargent Jump for power (Adams *et al.* 1963; Cureton, 1970; Johnson and Nelson 1971), sit and reach test of flexibility, and one repetition maximum bench press for strength (DeLorme and Watson – 1948). The endurance run was conducted outdoors on a tartan-surfaced, one-half mile track while the other tests were conducted in the air-conditioned environment of the Aerobics Activity Center.

Means and standard errors were calculated for each subgroup and for the total group of players. Further subgroup analysis was not attempted because of the small numbers in two of the groups: midfield players (n

1. Blood analysis was carried out each day of collection at the Ford, Lynn and Associates, Anatomic and Clinical Pathology Laboratory, Denton, Texas 76201.

2. Lactic acid enzyme analysis kits are obtainable from Sigma Chemical Co., P.O. Box 14508, Saint Louis, Missouri 63178.

= 2), goalkeepers (n = 2), defensive players (n = 9), and attacking players (n = 5).

RESULTS

Table I summarizes the group means and variability of selected resting physiological parameters and demonstrates the absence of any manifest clinical problems. In addition, the results of the SMA-12 screening verified the normality of the subject population. The resting heart rates were markedly lower than those observed for healthy sedentary populations, and serum triglycerides and cholesterol were below normal for the age group (Cooper *et al.* 1976).

The results of the endurance capacity tests, as measured by $\dot{V}O_2$ max and the 12-min run for distance, are outlined in Table II. Designation of the players into attacking, midfield, and defensive players along with goalkeepers as subgroups within the total population suggested that both attacking and defensive players had a greater endurance capacity than the midfield players and goalkeepers and that the two midfield players had greater endurance than the two goalkeepers.

Anthropometric differences among the positional groupings can be observed in Table III. The attacking and defensive players were lighter than the midfield players and goalkeepers, but the goalkeepers were approximately 10 kg heavier than the midfield players. Many of these differences were reflected in terms of body composition as measured by percent body fat and the sum of six skinfold measures. However, both the mid-

TABLE I

Resting Physiological Parameters of Professional Soccer Players (N — 18)

Variable	Sitting Heart Rate (beats/min)	Sitting Blood Pressure Systolic (mm/Hg)	Diastolic (mm/Hg)	14 Hours Post Absorptive Blood Parameters Total Protein (gm%)	Hemoglobin (gm%)	Hematocrit (%)	Glucose (mg%)	Triglycerides (mg%)	Cholesterol (mg%)
$\bar{X}$,SE	50±1	121±1	77±2	7.15±.08	14.6±0.2	41.9±0.5	94.5±1.2	90.8±5.3	174.8±6.9

TABLE II

Endurance Capacity of Professional Soccer Players*

Subjects (Soccer Players)	N	$\dot{V}O_2$ max (ml O_2/kg-min^{-1})	$\dot{V}E$ max (l/min-BTPS)	max HR (beats/min)	3 min Post-Max Lactate (mgm%)	Distance in 12 min** (mi)
Attacking Players (Forwards)	5	59.6 ± 1.2 (63.1 — 57.2)	153.1 ± 9.5 (170.7 — 125.5)	186 ± 3 (194 — 180)	127 ± 10 (158 — 108)	1.90 ± 0.08 (2.03 — 1.77)
Midfield Players (Playmakers)	2	56.1 ± 1.4 (57.1 — 55.1)	152.0 ± 16.0 (162.7 — 140.31)	182 ± 11 (190 — 175)	113 ± 23 (129 — 97)	1.76 ± 0.06 (1.81 — 1.85)
Defensive Players (Backs)	9	59.3 ± 1.3 (66.7 — 55.0)	154.0 ± 6.0 (173.4 — 136.35)	190 ± 3 (203 — 173)	123 ± 5.7 (138 — 88)	1.95 ± 0.04 (2.02 — 1.85)
Goalkeepers	2	53.7 ± 1 (54.4 — 53.0)	154.0 ± 27.0 (172.6 — 134.8)	194 ± 1 (194 — 193)	88 ± 13 (97 — 79)	1.64 ± 0.03 (1.67 — 1.62)
Total Mean	18	58.4 ± 0.83 (66.7 — 53.0)	153.6 ± 4.1 (173.4 — 125.5)	188 ± 2 (203 — 173)	119.3 ± 4.9 (158 — 79)	1.86 ± 0.04 (2.03 — 1.62)

** Values are means ± S.E. The range is bracketed.*

*** Due to injuries and time schedules, only 4 forwards and 5 backs were able to perform the 12-min run for distance during the testing period. All N's were adjusted accordingly.*

TABLE III

Body Composition of Professional Soccer Players*

Subjects (Soccer Players)	N	Age (yrs)	Height (cm)	Weight (kg)	Body Fat (%)	Lean Body Wt. (kg)	Sum of 6 Skinfolds (mm)
Attacking Players (Forwards)	5	25.6±1.7 (31–23)	176.3±2.9 (182.9–170.2)	74.5±5.5 (91.6–65.4)	10.7±0.85 (12.5–7.78)	66.7±4.5 (80.1–60.3)	55.0±7.0 (70–37)
Midfield Players (Playmakers)	2	26.5±7.8 (32–21)	175.0±2.9 (177.8–172.1)	77.3±3.6 (79.7–74.7)	10.6±2.3 (12.3–9.0)	69.1±4.9 (72.5–65.5)	58.0±1.0 (58.5–56.6)
Defensive Players (Backs)	9	25.5±1.5 (31–19)	176.0±1.9 (184.2–168.3)	73.6±1.8 (82.4–63.3)	8.1±1.16 (12.5–2.44)	67.5±1.7 (74.3–58.7)	52.0±3.89 (67.5–36.5)
Goalkeepers	2	25.5±4.9 (29–22)	178.0±2.2 (180.3–175.9)	86.4±4.5 (89.7–83.5)	13.3±0 (13.2–13.3)	75.1±3.8 (77.8–72.4)	82.0±17.0 (94.5–80)
Total Mean	18	25.6±1.0 (32–19)	176.3±1.2 (184.2–168.3)	75.7±1.9 (91.5–63.3)	9.59±0.73 (13.26–2.44)	68.3±1.5 (80.1–60.3)	56.6±3.58 (94.5–36.5)

**Values are means ± S.E. The range is bracketed.*

TABLE IV

Lung Capacities of Professional Soccer Players*

Subjects (Soccer Players)	N	Vital Capacity (Litres-BTPS)	Residual Volume (Litres–BTPS)	Total Lung Capacity (Litres–BTPS)
Attacking Players (Forwards)	5	5.47±0.25 (5.88–4.68)	1.422±0.067 (1.587–1.296)	6.890±0.229 (7.419–6.267)
Midfield Players (Playmakers)	2	5.38±0.80 (5.95–4.08)	1.554±0.940 (2.217–1.891)	6.934±1.751 (8.167–5.691)
Defensive Players (Backs)	9	5.16±0.32 (6.58–3.80)	1.341±0.097 (1.898–1.018)	6.501±0.383 (7.903–4.818)
Goalkeepers	2	5.40±0.49 (5.74–5.05)	1.822±0.530 (2.197–1.447)	7.220±0.040 (7.247–7.187)
Total Mean	18	5.29±0.174 (6.58–3.80)	1.385±0.117 (2.217–0.891)	6.735±0.224 (8.167–4.818)

**Values are means ± S.E. The range is bracketed.*

field players and goalkeepers appeared to have a greater lean body mass than the attacking and defensive players.

Comparison of lung capacities (Table IV) indicated no obvious differences. The field test scores (Table V) indicated a trend towards the midfield players and goalkeepers having greater flexibility and strength than the defensive and attacking players with little or no difference between the groups for agility and power.

DISCUSSION

The average $\dot{V}O_2$ max of this group of soccer players was 58.4 ml O_2/kg·min^{-1} which was above those values reported for sedentary populations of a similar age (Shephard 1966; Taguchi, *et al.* 1975). Comparison of

TABLE V

Field Test Scores of Professional Soccer Players*

Subjects (Soccer Players)	N	Flexibility Reach (in)	Hand Grip Strength (lb)	Bench Press Maximum (lb)	Vertical Jump Height (in)	Agility Run Time (sec)
Attacking Players (Forwards)	4	18.4±2.6 (22–12)	103±4 (112–97)	148±13 (180–130)	21.6±3 (26–16)	15.40±.05 (16.1–14.2)
Midfield Players (Playmakers)	2	22.2±1.1 (23–21)	108±6 (112–103)	165** (165)	16.0** (16)	16.00** (16.0)
Defensive Players (Backs)	9	19.9±0.67 (23–17)	100±5 (112–73)	163±14 (225–120)	21.1±1 (25–17)	15.50±0.11 (16.1–15.2)
Goalkeepers	2	22.9±1.2 (23–22)	107±24 (124–90)	180±21 (195–165)	20.2±1 (21–19)	16.00±0.85 (16.6–15.4)
Total Mean	17	20.2±0.7 (23–12)	102±3 (124–73)	161±9 (224–120)	20.8±1 (26–16)	15.56±0.14 (16.6–14.2)

** Values are means ± S.E. The range is bracketed.*

***One player was unable to perform the field test, thereby reducing group N and total N by 1.*

the $\dot{V}O_2$ max data for the soccer players with those for athletes in other specialized sports showed them to have a relatively moderate level of endurance capacity. Saltin and Åstrand (1967) reported $\dot{V}O_2$ max values ranging from 57 ml $O_2/kg{\cdot}min^{-1}$ for weight lifters to 82 ml $O_2/kg{\cdot}min^{-1}$ for cross country skiers. More recently, Pollock *et al.* (1975) described the capacities of elite-distance runners to average 78.5 ml $O_2/kg{\cdot}min^{-1}$ for middle distance runners and 74.4 ml $O_2/kg{\cdot}min^{-1}$ for marathon runners. In addition, Novak *et al.* (1969) as well as Wilmore and Haskell (1972) reported 51.3 ml $O_2/kg{\cdot}min^{-1}$ and 50.1 ml $O_2/kg{\cdot}min^{-1}$ respectively for professional American football players. Comparing their values with those for the soccer players suggested that the latter, on the average, had greater cardiorespiratory capacity. Fardy (1969) showed, in amateur players, that five weeks of soccer training was capable of increasing $\dot{V}O_2$ max from 2.90 l O_2/min by 14.6% in U.S. college players. Hence, it was not surprising to find a relatively high level of cardiorespiratory fitness in this group of professional soccer players, most of whom are involved in playing all year in the professional and semi-professional leagues of the United Kingdom.

Without special training, it appears that the aerobic capacity of professional soccer players averages above 56 ml $O_2/kg\ min^{-1}$. Caru *et al.* (1970) in their investigation of 95 Italian amateur soccer players, aged 14-18 years, in the midst of a competitive season had similar findings to the present investigation. They observed that attacking and defensive players had the greatest level of aerobic power and that goalkeepers had the lowest values.

A group having similar training for comparative purposes is the Brazilian National Soccer Team. In 1969, Cooper[3] used the 12-min run for distance to test the Brazilian team for endurance capacity. The Cooper 12-min run-walk test has been shown to be a reliable measure of endurance performance for large populations (Cooper, 1968; Doolittle and Bigby 1968; Maksud and Coults, 1971). The Brazilian National Soccer Team averaged 1.86 miles in 1969, one year before the 1970 World Cup Finals in Mexico City. The NASL players of this study also averaged 1.86 miles (Table II). The attacking and defensive players in the present study attained the greatest distance, 1.96 miles; and as expected from the $\dot{V}O_2$ max results, the midfield players and goalkeepers ran the least distance. In the pre-World Cup final year of 1969, the Brazilians underwent an aerobic-type conditioning programme in addition to their regular intensive soccer training and raised their average distance to 2.20 miles. Unfortunately, the lack of knowledge concerning the role of the endurance capacity in the make-up of a successful soccer team and the lack of comparable $\dot{V}O_2$ max or endurance capacity data for the other teams in the World Cup competition of 1970 precludes further interpretation.

The professional soccer players of this study had a much greater percent of body fat than the elite-distance runners (Pollock *et al.* 1975) in spite of the supposed training effect from the sport. Obviously the training

3. Unpublished data collected by K. H. Cooper, M.D., during personal tours of Brazil.

distances for the elite runners (75-100 miles/week) exceeded those of the soccer players and probably accounted for their greater degree of leanness. The goalkeepers were heavier in whole body weight and lean body mass and had a greater percent of body weight as fat and fat thickness than the other players. In addition, the goalkeepers were taller than the other players, which probably accounted for their greater residual volumes and total lung capacity. Dividing total lung capacity by height, the average ratio of each group was 39.1 ml/cm, and only the defensive players had a lower ratio, 36.9 ml/cm. The defensive and attacking players were similar in height, weight, and lean body weight although the attacking players had a slightly greater percent body fat.

The overall group average of percent body fat, 9.59%, was slightly less than the average of 10.65% body fat obtained from 400 Brazilian professional soccer players found by DeRose (1975) but was significantly less than that found by Bell and Rhodes (1975), in their morphologic evaluation of English college players. In addition, they had slightly greater percent fat than the 8.3% reported for attacking and defensive professional American football backs by Wilmore and Haskell (1972). However, the lean body weight of the professional American football players was markedly greater than that of the soccer players and probably reflects the different requirements of the two games. As the national level soccer players of Brazil and those players investigated in this study had similar levels of percent body fat, it appears that the percent body fat of soccer players is approximately 10%.

The field tests for strength, power, and flexibility indicated that the soccer players ranged from average to excellent in comparison to a normal population[4] and that the goalkeepers performed better than all other groups. The field test that distinguished soccer players as a group from the normal population, was the Illinois agility run. All groups scored above the 99.95 percentile, and the average for the players was above 99.99 percentile of the standard scores established by Cureton (1970). The agility of these players proved to be their greatest asset and to set them apart from the normal population.

In summary, the playing of soccer appears to require a high degree of cardiorespiratory endurance. The required values are significantly higher than the normal sedentary standards, but lower than those found among world-class distance runners. The body fat percentage of soccer players is equivalent to that of running backs in professional American football; yet, the lean body weight requirements for soccer are less than those for professional American football. One of the most outstanding attributes of the soccer player is his high level of agility.

ACKNOWLEDGEMENTS

The authors greatly appreciate the efforts of Ron Newman, Coach of the Dallas Tornado Soccer Team, in scheduling the players for testing. Also, they would like to thank the players for their time and our technical assistants, John Ayers, Ann Ward, Larry Durstine, Mike Bah, and Jean Sass, for their help in collecting the data. Finally, we would like to acknowledge the generous support of Mr. Lamar Hunt, owner of the Dallas Tornado Soccer Club.

4. Unpublished data handouts by R. A. Berger, Temple University.

REFERENCES

ADAMS, W. C., W. L. HASKELL, W. L. HOLTINGER, R. D. LEIGHT, and W. J. PENNY, 1963. *Foundations of Physical Activity.* Champaign, Ill.: Stipes Publishing Company.

BEHNKE, A. R. and J. H. WILMORE, 1974. *Evaluation and Regulations of Body Build and Composition.* Englewood Cliffs, N.J.: Prentice-Hall.

BELL, W. and G. RHODES, 1975. "The morphological characteristics of the association football player." *British J.Sports Med.* 9: 196-200.

BROZEK, J., LeGRANDE, J., ANDERSON, T. and KEYS, A. 1963. "Densitometric analysis of body composition: revision of some quantitative assumptions." *Ann.N.Y.Acad.Sci.* 110: 113-140.

CARU, B., L. LeCOULTRE, P. AGHENIS and F. PINERA LIMAS, 1970. "Maximal aerobic and anaerobic muscular power in football players." *J.Sports Med.Phys.Fitness,* 10: 100-103.

CONSOLAZIO, F., R. JOHNSON, and L. PECORA, 1963. *Physiological Measurements of Metabolic Functions in Man.* New York: McGraw-Hill Book Company.

COOPER, K. H. 1968. "A means of assessing maximal oxygen intake: correlation between field and treadmill testing." *J.A.M.A.,* **203**: 201-204.

COOPER, K. H., M. L. POLLOCK, R. P. MARTIN, and S. R. WHITE, 1976. "Levels of physical fitness versus selected coronary risk factors; a cross sectional study". *J.A.M.A.* (in press).

CURETON, T. K. 1970. "Illinois agility run." In: *Physical Fitness Workbook for Adults.* Champaign, Ill.: Stipes Publishing Company. pp. 105-118.

DeLORME, T. L. and A. L. WATKINS, 1948. "Techniques of progressive resistance exercise." *Arch.Phys.Med.Rehabil.* **29**: 263-273.

DeROSE, E. H. 1975. "Determinaticn of the ideal body weight and corporal composition of the professional soccer player." Abstract In: *Questions of Athletes Nutrition; Abstracts of the Reports of the International Symposium.* Leningrad: Leningrad Research Institute of Physical Culture, p. 123. *(Further information can be obtained from E. H. DeRose, School of Physical Education, Federal University of Rio Grande du Sul, Porto Alegre, Brazil.)*

DOOLITTLE, T. L. and R. BIGBEE, 1968. "The twelve-minute run-walk: a test of cardiorespiratory fitness of adolescent boys." *Res.Q.Am.Assoc.Health Phys.Educ.,* **39**: 491-495.

FARDY, P. S. 1969. "Effects of soccer training and detraining upon selected cardiac and metabolic measures." *Res.Q.Am.Assoc.Health Phys.Educ.,* **40**: 502-508.

GOLDMAN, R. F. and E. R. BUSKIRK, 1961. "Body volume measurement by underwater weighing: description of a method." In: *Techniques for Measuring Body Composition,* edited by J. Brozek and A. Henschel. Washington, D.C.: Natl.Acad.Sci., pp. 78-89.

HERTZBERG, H. T. E., E. CHURCHILL, C. W. DUPERTUIS, R. M. WHITE, and A. DAMON, 1963. *Anthropometric Survey of Turkey, Greece and Italy.* New York: MacMillan Co.

JOHNSON, B. and J. NELSON, 1971. *Practical Measurement for Evaluation In Physical Education.* Minneapolis: Burgess Publishing Company.

KATCH, F. E. 1968. "Apparent body density and variability during underwater weighing." *Res.Q.Am.Assoc.Health Phys.Educ.,* **39**: 993-999.

KEYS, A. (Chairman). 1956. "Recommendations concerning body measurements for the characterization of nutritional status." *Hum.Biol.* **28**: 111-123.

KORY, R., R. CALLAHAN, and H. COREN, 1961. "The veterans administration-army cooperative study of pulmonary function." *Am.J.Med.,* **30**: 243-258.

MAKSUD, M. G. and R. D. COULTS, 1971. "Application of the Cooper twelve-minute run-walk test to young males." *Res.Q.Am.Assoc.Health Phys.Educ.,* **42**: 54-59.

MEYERS, C. R., L. A. GOLDING, and W. E. Sinning, 1973. *The Y's Way to Physical Fitness.* Emmaus, Pa: Rodale Press, Inc.

NOVAK, L. P., R. E. HYATT, and J. F. ALEXANDER, 1969. "Body composition and physiologic function of athletes." *J.A.M.A.* **205**: 764-770.

POLLOCK, M. L., J. AYRES, A. WARD, J. SASS, and S. WHITE, 1975. "Working capacity, cardiorespiratory, and body composition, characteristics of world class middle and long distance runners." *The Physiologist* **18**(3): 355.

POLLOCK, M. L., R. L. BOHANNON, K. H. COOPER, J. J. AYRES, A. WARD, S. R. WHITE, and A. C. LINNERUD, 1976. "A Comparative analysis of four protocols for maximal treadmill stress testing." *Am.Heart J.* (in press).

SALTIN, B. and P. O. ÅSTRAND, 1967. "Maximal oxygen uptake in athletes." *J.Appl.Physiol.* **23**: 353-385.

SHEPHARD, R. J. 1966. "World standards of cardiorespiratory performance." *Arch.Environ.Health,* **13**: 664-672.

SIRI, W. E. 1961. "Body composition from fluid spaces and density." In: *Techniques for Measuring Body Composition,* edited by J. Brozek and A. Henschel. Washington, D.C.: Natl. Acad. Sci.

TAGUCHI, S., P. B. RAVEN, M. KANEKO, H. MATSUI, and S. M. HORVATH, 1975. "Comparative studies of maximal aerobic capacity." In: *J.I.B.P. Synthesis: Human Adaptability,* edited by S. M. Horvath, S. Kondo, H. Matsui and H. Yoshimura. Tokyo: University of Tokyo Press, Vol. 1, pp. 55-68.

WILMORE, J.HH. 1964. "A simplified method for determination of residual lung volumes." *J.Appl.Physiol.* **27**: 96-100.

WILMORE, J. H. and W. L. HASKELL, 1972. "Body composition and endurance capacity of professional football players." *J.Appl.Physiol.* **33**: 564-567.