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Physiological and anthropometrical comparisons between the triathlete and the runner, cyclist and swimmer

Zetisky, Jonathan V

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CHAPTER 3

MATERIALS AND METHODS

Chapter 3 highlights the subjects of the study and the ways in which the various tests were conducted. In depth information is provided on the testing protocol as well as on the research methodology and statistical analysis. The tests carried out are crucial to obtaining the required information in order to compare triathletes with their single sport counterparts.

3.1 Subjects

Thirty-four well-trained 'elite' endurance athletes volunteered for this study. For the purposes of this study, the minimum criteria to be considered elite are the following:

- triathletes must have completed at least a standard triathlon in 2:10 or less
- runners must have run a 21km in 80 minutes or less
- cyclists must have completed 50km in less than 75 minutes
- swimmers must be able to swim 1500m in less than 18.5 minutes

These criteria were used in order to define an elite athlete and to differentiate them from recreational athletes. All of the triathletes tested complied with the criteria to be considered elite by Triathlon SA (finishing within 5% and 8% of the first South African male for selected drafting and non-drafting events respectively). (Triathlon SA: www.triathlonsa.co.za).

Athletes were divided into four groups:

Group T consisted of twelve triathletes (27.5 years ± 5)

Group R consisted of eight runners (25.5 years ± 5.1)

Group C consisted of eight cyclists (26.75 years ± 7.3)

Group S consisted of six swimmers (22.5 years ± 7.3)

3.2 Procedure

The study was approved by the Committee for Research on Human Subjects of the University of the Witwatersrand (Protocol Number 26/6/92). Each athlete gave written informed consent before testing procedures commenced. Anthropometric measurements were taken on Day 1 prior to a stress ECG test. On Day 2, $VO_{2max.}$ and running economy measurements were made and on Day 3 muscle strength and muscle endurance measurements were performed. Physiological and anthropometrical assessments were carried out at the exercise laboratory in the School of Physiology at the University of the Witwatersrand in Johannesburg at an altitude of approximately 1800m above sea level. Muscle dynamometry was carried out at the Johannesburg Cardiac Centre.

3.3 Techniques

3.3.1 Stress ECG

Each subject first performed a twelve lead stress ECG assessment to test cardiac response to strenuous exercise (Hewlett Packard 4700, Andover, USA). The Bruce Protocol was used as the model for graded exercise (Table 2) on a motorised treadmill (Powerjog EJ20, Sports Engineering Ltd, Birmingham, UK).

TABLE 2: Duration, Speed and Elevation in the Bruce Protocol

STAGE	TIME	SPEED	ELEVATION
One	0 – 3min.	2,74km/h	10%
Two	3 – 6min.	4,02km/h	12%
Three	6 – 9min.	5,47km/h	14%
Four	9 – 12min.	6,75km/h	16%
Five	12 – 15min.	8,046km/h	18%
Six	15 – 18min.	8,85km/h	20%

(From Astrand and Rodahl 1986)

ECG readings were taken at 15 second intervals before the third minute of each workload. At exhaustion, ECG recordings were taken at one minute, two minutes, five minutes and ten minutes post exercise.

Ratings of perceived exertion (Borg Scale)(Borg, G. A. V., 1982, Garcin, M, et al 2003), blood pressures (using a sphygmomanometer and stethoscope) and heart rates (by means of ECG electrodes) were measured at the same times as the ECG recordings.

3.3.2 Anthropometrical Evaluation

The anthropometric measurements were administered according to the procedures formulated by Heath and Carter (1990) and Durnin and Rahaman (1967). Height and girths were read to the nearest mm, biepicondylar diameters to the nearest 0.5mm and skinfolds to the nearest 0.1mm. Each measurement was repeated three times and mean values were used in further calculations.

i. *Body Mass (kg)*

Subjects were weighed using an electronic scale (Mettler TE/J, Mettler Instruments, Zurich, Switzerland) and mass recorded to the nearest 50 grams.

ii. Height (cm)

Height was measured to the nearest millimetre with the subject standing straight against an upright wall, touching the wall with heels, buttocks and back, with the heels together and the head placed in the Frankfort plane.

iii. Skinfolds (mm)

Skinfold thickness was measured at five sites ie, biceps, triceps, subscapular, suprailiac and medial calf (the Harpenden Skinfold Calliper, British Indicators Ltd, Herts, UK). All skinfolds were taken on the right hand side of the body and the sum of the skinfold thickness was calculated. The athlete stands relaxed (except for the calf which was taken with the athlete seated). Three independent measurements were taken at each fold. A fold of skin and subcutaneous tissue held firmly between the thumb and forefinger of the left hand was raised and pulled away from the underlying muscle. The edge of the plates on the Harpenden calliper branches was applied 1cm below the fingers of the left hand and they were allowed to exert their full pressure before reading the thickness of the fold.

- The triceps skinfold

The athlete stood with his arm hanging loose. A fold at the back of the arm was raised at a level half way along a line connecting the acromion and olecranon process.

- Subscapular skinfold

The athlete stood with his back to the observer, shoulders relaxed and arms hanging loosely at the sides. The subscapular skinfold was raised immediately below the inferior angle of the scapular in a direction that was obliquely upward and lateral (at 45°).

- Suprailiac skinfold

The athlete stood facing the observer. The skinfold is 1cm above and 2cm medial to the anterior superior iliac spine. The skinfold was picked up with a sweep of the index finger and the thumb so that it was directed vertically.

- Biceps skinfold

The biceps skinfold is on the anterior aspect of the arm, at the same midpoint level as the triceps skinfold. The biceps skinfold was picked up with the athlete facing the observer, the arm hanging relaxed and the palm facing forwards.

- Medial calf skinfold

A vertical skinfold on the medial side of the leg was raised at the level of the maximum girth of the calf with the athlete seated and the legs hanging over the edge of the table.

iv. Diameters (cm)

Biepicondylar diameters of the humerus and femur were measured using a Harpenden Anthropometer. These measurements are the diameters between the medial and lateral epicondyles of the humerus and femur respectively.

- Biepicondylar diameter of the humerus

The shoulder and elbow of the athlete was flexed to 90°. The calliper was placed at an angle approximately bisecting the angle of the elbow. Firm pressure was placed on the crossbars in order to compress the subcutaneous tissue.

- Biepicondylar diameter of the femur

The athlete was seated with the knee bent at an angle. The greatest distance between the medial and lateral epicondyles of the femur was measured with firm pressure on the crossbars.

v. Girths (cm)

Upper arm (biceps, flexed) and calf girth were measured using a metal anthropometer tape measure to an accuracy of 1mm.

- Upper arm girth, flexed and tensed

The athlete was instructed to flex the shoulder to 90° and the elbow to 45°. The athlete was instructed to clench his hand so as to maximally contract the elbow flexors and extensors. The measurement of the greatest girth of the arm was taken.

- Calf Girth

The athlete was instructed to stand with the feet slightly apart. The tape was placed around the calf and the maximum circumference was measured.

vi. Percentage Body Fat

Body fat was calculated from density using Siri's (1956) Equation (Durnin, J. V. G. A and Womersley, J, 1974; Brodie, D. A. 1988, Lohman, T. G., 1982).

$$\textbf{Percentage Fat} = \frac{4{,}95 - 4{,}5}{\text{Density}} * 100 \qquad \textbf{(Siri's Equation)}$$

Four skinfold measurements (biceps, triceps, subscapula and suprailiac) (Durnin, J. V. G. A. and Rahaman, M, M, 1967; Durnin, J. V. G. A. and Womersley, J. 1974), were used to calculate body density (DB) using one of the following age adjusted equations:

TABLE 3: Formula for Body Density according to Age

AGE (Years)	FORMULA
<20	DB = 1.162 – 0,0632 X
20 – 29	DB = 1.162 – 0,0632 X
30 – 39	DB = 1,1422 – 0,0544X

(Durnin and Rahaman 1974)

3.3.3 Somatotyping

The Heath – Carter somatotype rating form was used to calculate the somatotype (endomorph, mesomorph and ectomorph ratings) using the anthropometric data obtained.

The following equations were used to plot the somatopoint on the somatochart (Carter, J. E. L., Heath, B. H. 1990):

'X' co-ordinate = ectomorphy – endomorphy

'Y' co-ordinate = 2 (mesomorphy) – (endomorphy + ectomorphy)

3.3.4 *Physiological Assessment*

Maximal Aerobic Capacity ($VO_{2max.}$) and Running Economy (RE)

After familiarising with the equipment and techniques, a direct intermittent incremental method was used to determine $VO_{2max.}$ using a motorised treadmill (Powerjog). Work intensity was altered by maintaining the speed at 13 km/h and increasing elevation by 1.5% for successive 3 minute work periods. Oxygen consumption was measured using a pre-calibrated online system (Oxycon 4, Mijnhardt, Netherlands). Steady state oxygen consumption measurements were made at 2 – 3 minutes of maximal exercise. $VO_{2max.}$ was taken as the average of two successive steady state oxygen consumption measurements which differed by less than 1.0 $ml.min.kg^{-1}$.

Running Economy was determined at a speed of $12km.h^{-1}$ (5 $min.km^{-1}$) and 0% elevation. Oxygen consumption was recorded at 30 second intervals for a period of five minutes. The VO_2 measurements made at 2.5 – 5 min was averaged to give a measure of the steady state energy cost of performing the exercise. RE ($ml.kg.km^{-1}$) was calculated using the following formula:

$$\mathbf{RE = \frac{(Exercise\ VO_2 - Resting\ VO_2)\ ml.min.kg^{-1}}{0.2km.m^{-1}}}$$

3.3.5 Muscle Strength and Endurance

Muscle strength and endurance was measured using an Akron isokinetic dynamometer and Akron computer software version V2.30. The dominant limb of each subject was tested for strength and endurance. The muscle groups tested were knee flexors and extensors and shoulder flexors and

extensors at speeds of 60, 160 and 245º/s in order to simulate the actual activity more closely. An angular velocity of 60º/s was used to measure strength or peak torque, 160º/s to measure the level of work output at functional velocities and 245º/s to assess muscle endurance. The latter was measured by observing the change in work output expressed as a percentage during a 25 second period of sustained muscle activity.

Positioning and stabilisation for knee flexor and extensor assessment

The subjects were seated on the Akron testing table with the back rest inclined backward to an angle of about 95 degrees from horizontal, depending on the size of the subject. The subject's knee joint axis was then aligned with the mechanical axis of the dynamometer. A shin pad was placed superior to the subject's medial malleolus by adjusting the lever length. Two stabilisation straps were placed across each subject's thorax. A second strap was positioned across the lower abdomen, over the anterior superior iliac spinae and a fourth strap proximal to the superior border of the patella on the anterior thigh. Subjects were instructed to keep their arms folded across their chests during the test.

<u>The testing protocol was as follows</u>:

i) The subjects performed a number of submaximal trial repetitions at 245, 150 and 60°/s respectively, as part of a familiarisation and warm up procedure.

ii) A one minute rest interval.

iii) The muscle strength test consisting of maximal repetitions of knee flexion and extension for a period of 15 seconds at a speed of 60°/s.

iv) A two minute rest interval.

v) A measure of work output and power consisting of maximal repetitions of knee flexion and extension for a period of 20 seconds at a velocity of 160°/s.

vi) A two minute rest interval.

vii) A measure of endurance consisting of maximal repetitions of knee flexion and extension for a period of 25 seconds at a speed of 245°/s.

viii) The subjects were verbally encouraged to perform maximal isokinetic contractions.

One repetition was considered to be a movement from full extension to full flexion and vice versa.

Positioning for the testing of shoulder flexion and extension

The subject was positioned supine on the Akron testing table with the relevant shoulder closest to the dynamometer. The lever length was adjusted in such a way that the subject had a firm grip on the lever handle with his elbow in full extension. The mechanical axis of the dynamometer was aligned with the subjects shoulder joint axis (mid point of the shoulder joint). The testing protocol was exactly the same as for the knee test.

The research conducted was exploratory in nature to obtain new information in order to compile a profile of an elite South African triathlete. The research technique was however quantitative (eg. VO_{2max}, running economy, somatotype rating, muscle strength etc) as the information required to compile this research is based solely on physiological and anthropometric measurements.

3.3.6 Statistical Analysis

A one-way analysis of variance procedure was applied to determine whether the mean scores for the various 'measurement' variables were significantly different for the four groups of athletes. Where differences were observed, a Bonferroni multiple comparison test was applied at a pairwise level, to identify where the differences lay. A non-parametric Kruskal-Wallis test was also applied to the data in order to confirm the results obtained by the analysis of variance procedure. The same results were obtained. (Ferguson, G. A. 1986).