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Ponderal Somatograms Assess Changes in Anthropometric Measurements Over an Academic Year in Division III Collegiate Football Players

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Abstract

Ponderal somatograms evaluate body size and shape by converting muscular (shoulders, chest, biceps, forearm, thigh, calf) and nonmuscular (abdomen, hips, knee, ankle, wrist) girths into ponderal equivalent (PE) values. Anthropometric measurements, including stature, body mass, girths, and percent body fat by densitometry were collected in 54 Division III football players in preseason camp (fall) and at the beginning (winter) and end (spring) of the team strength and conditioning program. PE values were calculated for each girth as PE, kg = (girth, cm / k) squared x stature, dm, where k = k constant from Behnke's reference man. PE values were compared to body mass to indicate overdevelopment (PE is greater than body mass) and underdevelopment (PE is less than body mass) at specific girth sites. From fall to winter, body mass (+1.6 kg), percent fat (+1.3%), fat mass (+1.6 kg), nonmuscular abdominal and hip girths (+2.1 cm, +1.5 cm), and PE values (+5.3 kg, +2.6 kg) increased significantly (*p* is less than 0.05). From winter to spring, percent fat (-1.5%), fat mass (-1.4 kg), nonmuscular abdominal girth (-1.0 co), and PE value (-2.5 kg) decreased significantly (*p* is less than 0.05) from winter to spring. Fat-free mass (+1.5 kg), muscular biceps girth (+0.4 cm), and PE value (+2.6 kg) increased significantly (*p* is less than 0.05) from winter to spring. Ponderal somatograms muscular components were generally overdeveloped, with the greatest overdevelopment at the biceps in the fall (+14.7 kg), winter (+14.9 kg), and spring (+17.4 kg). Nonmuscular components generally were underdeveloped, except abdomen and hips that were overdeveloped. The abdomen remained the greatest nonmuscular overdevelopment in fall (+6.8 kg), winter (+10.5 kg), and spring (+7.9 kg). Ponderal somatograms provide a relatively simple, practical method to track specific changes in body size and shape over time.

Keywords

body composition, anthropometry, body profile

Disciplines

Other Medicine and Health Sciences | Sports Sciences

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Ponderal Somatograms Assess Changes in Anthropometric Measurements Over an Academic Year in Division III Collegiate Football Players

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Abstract. Stuempfle, K.J., D.G. Drury, D.F. Petrie, and F.I. Katch. Ponderal somatograms assess changes in anthropometric measurements over an academic year in Division III collegiate football players. *J. Strength Cond. Res. 21(3):689–696. 2007.*—Ponderal somatograms evaluate body size and shape by converting muscular (shoulders, chest, biceps, forearm, thigh, calf) and nonmuscular (abdomen, hips, knee, ankle, wrist) girths into ponderal equivalent (PE) values. Anthropometric measurements, including stature, body mass, girths, and percent body fat by densitometry were collected in 54 Division III football players in preseason camp (fall) and at the beginning (winter) and end (spring) of the team strength and conditioning program. PE values were calculated for each girth as PE, kg = (girth, cm ÷ k)^2 × stature, dm, where k = k constant from Behnke's reference man. PE values were compared to body mass to indicate overdevelopment (PE > body mass) and underdevelopment (PE < body mass) at specific girth sites. From fall to winter, body mass (+1.6 kg), percent fat (+1.3%), fat mass (+1.6 kg), nonmuscular abdominal and hip girths (+2.1 cm, +1.5 cm), and PE values (+5.3 kg, +2.6 kg) increased significantly ($p < 0.05$). From winter to spring, percent fat (−1.5%), fat mass (−1.4 kg), nonmuscular abdominal girth (−1.0 cm), and PE value (−2.5 kg) decreased significantly ($p < 0.05$). Fat-free mass (+1.5 kg), muscular biceps girth (+0.4 cm), and PE value (+2.6 kg) increased significantly ($p < 0.05$) from winter to spring. Ponderal somatogram muscular components were generally overdeveloped, with the greatest overdevelopment at the biceps in fall (+14.7 kg), winter (+14.9 kg), and spring (+17.4 kg). Nonmuscular components generally were underdeveloped, except abdomen and hips that were overdeveloped. The abdomen remained the greatest nonmuscular overdevelopment in fall (+6.8 kg), winter (+10.5 kg), and spring (+7.9 kg). Ponderal somatograms provide a relatively simple, practical method to track specific changes in body size and shape over time.

Key Words. body profile, body composition, anthropometry

Introduction

A great deal of time and effort is typically devoted to development and implementation of strength and conditioning programs for football players. These programs are designed to improve factors believed important for success on the football field, including strength, power, speed, agility, flexibility, and body composition (8, 9, 21). Testing can quantify individual and team physical progress in these components (8, 9).

Body composition assessment in football players typically includes hydrostatic weighing, skinfold and girth assessment, and bioelectrical impedance (11, 26). Hydrostatic weighing serves as the criterion method for determining body composition (26), but the procedure is time consuming and requires specialized laboratory equipment and expertise. In contrast, girth measurements are relatively simple to obtain, and can be useful for producing a ponderal somatogram or body profile. The ponderal somatogram was devised by Katch et al. (16) as an extension of the original Behnke somatogram (2). In the ponderal somatogram, girth measurements are differentiated into muscular (shoulders, chest, biceps, forearm, thigh, calf) and nonmuscular (abdomen 1, abdomen 2, hips, knee, wrist, ankle) components. Individual girth measurements are converted into ponderal (or mass) equivalent values expressed in kg. This allows comparison of individual girths as ponderal equivalent (PE) values to body mass. PE values provide an appraisal of overdevelopment (PE > body mass) and underdevelopment (PE < body mass) for specific girth measurement regions. The ponderal somatogram also produces a visual appraisal of body size and shape when PE values are expressed as percent deviations from the reference man. In the reference man, all of the girth measurements plot as a vertical line. Deviation of a girth measurement from the vertical line indicates overdevelopment (positive deviation) or underdevelopment (negative deviation) at that location for a person (or group). A report by Sinning and Moore (27) provided evidence for the validity of the ponderal somatogram.

In the present study, ponderal somatograms evaluated changes in body size and shape in Division III football players over the course of an academic year. Anthropometric characteristics were assessed in the fall at the start of preseason camp (August), in winter at the start of the mandatory team strength and conditioning program (January), and in spring at the conclusion of the mandatory team strength and conditioning program (May). The muscular and nonmuscular PE values were compared to body mass at each of the 3 testing times. Additionally, the muscular and nonmuscular PE values were graphically represented as percent deviations from the reference man at each of the 3 testing times.

Methods

Experimental Approach to the Problem

A repeated-measures experimental design tracked the anthropometric changes in Division III football players during an academic year. Anthropometric measurements including stature, body mass, girths, and percent body fat by densitometry were collected in the fall (August), winter (January), and spring (May). Anthropometric measurements were used to construct ponderal somatograms that evaluate body size and shape by converting muscular (shoulders, chest, biceps, forearm, thigh, calf) and nonmuscular (abdomen, hips, knee, wrist, ankle) girths into PE values. PE values were compared to body mass to indicate overdevelopment (PE > body mass) and underdevelopment (PE < body mass) at specific girth sites. PE values also were expressed as percent deviations from the reference man to provide a visual appraisal of body shape and size. In the reference man, all of the girth measurements plot as a vertical line. Deviation of a girth measurement from the vertical line indicates an overdevelopment (positive deviation) or an underdevelopment (negative deviation) at that location for a person (or group).

Subjects

Anthropometric characteristics were assessed in 54 Division III football players from Gettysburg College, Gettysburg, PA, a National Collegiate Athletic Association (NCAA) Division III school with a 112-year history of competition in football at this level. Subjects were tested during the 2002–2003 academic year. The team was not ranked in NCAA Division III during the 2002 season. The school's Institutional Review Board approved the study. Subjects were fully informed of the purpose and nature of the study and provided informed consent.

Procedures

Subjects were tested in the fall (August) during preseason camp, in the winter (January) at the beginning of the mandatory team strength and conditioning program, and in the spring (May) at the end of the mandatory strength and conditioning program.

All subjects participated in the 12-week, 4 days weekly mandatory team strength and conditioning program from January through April. The program included upper extremity, lower extremity, and core weight training exercises, upper and lower body plyometrics, agility drills, and flexibility exercises (see Tables 1 and 2).

Measurements. Anthropometric measurements included stature, body mass, selected girths, vital capacity, and body mass in water. All data on an individual were collected on the same day. Height was measured using a stadiometer to ± 0.1 cm, and body mass was measured on a balance beam scale to ± 0.25 lb. Girth measurements were taken by the same investigator throughout the investigation using a calibrated cloth tape to ± 0.1 cm. The 12 measurement sites included 6 muscular sites and 6 nonmuscular sites. Bilateral paired measurements were made for the extremities, and an average of the paired scores served as the criterion score for those sites. The abdomen 1 and abdomen 2 measurements were averaged to produce an abdominal average criterion score. The anatomical landmarks for the muscular and nonmuscular girth sites were (13):

Anatomical landmarks for muscular component:

- Shoulders: laterally at the maximum protrusion of the deltoid muscles, and anteriorly at the prominence of the sternum at the junction of the second rib
- Chest: nipple line at midtidal volume of respiration
- Biceps flexed: maximal girth with elbow flexed to 90°
- Forearm: maximal girth with elbow extended and hand supinated
- Thigh: maximal girth
- Calf: maximal girth

Anatomical landmarks for nonmuscular component:

- Abdomen 1 (waist): laterally midway between the lowest rib and the iliac crest, and anteriorly midway between the xiphoid process of the sternum and the umbilicus
- Abdomen 2 (umbilicus): laterally at the level of the iliac crests, and anteriorly at the umbilicus
- Hips: posteriorly at the maximal protrusion of the gluteal muscles, and anteriorly at the level of the symphysis pubis
- Knee: midpatellar level, with the knee slightly flexed and weight transferred to the opposite leg
- Wrist: maximal girth just distal to the styloid process of the radius and ulna with the hand supinated
- Ankle: minimal girth, superior to malleoli

Prior to hydrostatic weighing, 3 trials of seated vital capacity (ambient temperature and pressure, saturated with water vapor [ATPS]) were determined according to manufacturer's directions using a Medgraphics metabolic cart. Residual lung volume was estimated from vital capacity (body temperature and pressure saturated with water vapor [BTPS]) (residual lung volume = vital capacity × 0.24) according to Wilmore's data (31) that showed close agreement between body composition measurements using measured vs. estimated residual lung volume. Body mass in water was assessed by hydrostatic weighing in the seated position in a 91 × 91 × 183 cm aluminum tank. Subjects performed 10 successive underwater weighing trials, with approximately a 1-minute rest interval among trials following procedures described previously (15). Ten repeated weighings (using an average of the last 3 trials) produced a true underwater weight score (14). For white players, percent fat was calculated with the Siri equation (28), where % fat = (495 ÷ density $g \cdot ml^{-1}$) − 450; for black players, the Schutte equation (24) was used where % fat = (437.4 ÷ density $g \cdot ml^{-1}$) − 392.8.

Ponderal Somatogram. The ponderal somatogram was used to describe the body profile (14). Muscular (shoulders, chest, biceps, forearm, thigh, calf) and nonmuscular (abdomen 1, abdomen 2, hips, knee, wrist, ankle) girth measurements were converted into ponderal (or mass) equivalent values expressed in kg. This allowed comparison of individual girths as PE values to body mass. PE values provided an indication of overdevelopment (PE > body mass) or underdevelopment (PE < body mass) for each of the muscular and nonmuscular girth measurements. The PE value for each girth measurement was calculated as follows (14):

$$\text{PE, kg} = (\text{girth, cm} \div k)^2 \times \text{stature, dm}$$

where k is a constant from the reference man (see Table 3).

For example, if PE = 94 kg for abdomen, this means the person (or group) has an abdominal girth of a person (or group) who weighs 94 kg. If the person (or group) weighs 80 kg, the person (or group) is overdeveloped in this region by 14 kg.

Ponderal somatograms produced a visual appraisal of body size and shape by expressing PE values as percent deviations from the reference man. In the reference man, all of the girth measurements plot as a vertical line. The percent deviation from the reference man for each girth measurement was calculated as described below (16):

TABLE 1. Strength and conditioning program.

	Week (sets × repetitions)											
	1	2	3	4	5	6	7	8	9	10	11	12
Monday												
Squat	3 × 6	3 × 6	3 × 3	3 × 3	3 × 3	5 × 10, 8, 6, 3, 1	4 × 8	4 × 8	4 × 6	4 × 6	4 × 3	5 × 10, 8, 6, 3, 1
1 leg squat	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 12	3 × 12	3 × 12	3 × 12	3 × 12	3 × 12
Unilateral leg curl	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 12	3 × 12	3 × 12	3 × 12	3 × 12	3 × 12
Bench press	3 × 6	3 × 6	3 × 3	3 × 3	3 × 3	3 × 2	4 × 8	4 × 8	4 × 6	4 × 6	4 × 3	3 × 2
4 way neck	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10
Inverted dumbbell shoulder press	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	4 × 6	4 × 6	3 × 8	3 × 8
Dumbbell front raise	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	4 × 6	4 × 6	3 × 8	3 × 8
Tricep exercise	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8
Abdominal exercise	3 × 25	3 × 25	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20
Tuesday												
Overhead squat	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10
Drop squat	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10
Trap clean	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10
Pull floor	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6
Pull thigh	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6
Power clean	3 × 5	3 × 5	3 × 5	3 × 4	3 × 3	3 × 2	3 × 8	3 × 8	3 × 6	3 × 6	3 × 3	3 × 3
Incline bench press	3 × 6	3 × 6	3 × 8	3 × 8	3 × 8	5 × 10, 8, 6, 3, 1	3 × 6	3 × 6	3 × 8	3 × 8	3 × 8	5 × 10, 8, 6, 3, 1
Pull up	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	2 × 10	2 × 10	2 × 12	2 × 12	2 × 15	2 × 15
Dumbbell shrug	3 × 20	3 × 20	3 × 15	3 × 15	3 × 15	3 × 15	3 × 20	3 × 20	3 × 20	3 × 20	3 × 15	3 × 15
Bicep exercise	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Abdominal exercise	3 × 25	3 × 25	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20
Thursday												
Squat	3 × 6	3 × 6	3 × 3	3 × 3	3 × 3	3 × 2	4 × 8	4 × 8	4 × 6	4 × 6	4 × 3	4 × 2
Lunge	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 12	3 × 12	3 × 12	3 × 12	3 × 12	3 × 12
Romanian dead lift	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 12	3 × 12	3 × 12	3 × 12	3 × 12	3 × 12
Bench press	3 × 6	3 × 6	3 × 3	3 × 3	3 × 3	5 × 10, 8, 6, 3, 1	4 × 8	4 × 8	4 × 6	4 × 6	4 × 3	5 × 10, 8, 6, 3, 1
4 way neck	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10
Shoulder combo	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 12	3 × 12	3 × 12	3 × 12	3 × 12	3 × 12
Dumbbell front raise	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	4 × 6	4 × 6	3 × 8	3 × 8
Tricep exercise	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8
Abdominal exercise	3 × 25	3 × 25	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20	4 × 20
Friday												
Overhead squat	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10
Drop squat	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10
Power snatch	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10	1 × 10
Pull floor	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6
Pull thigh	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6	3 × 6
Snatch	3 × 5	3 × 5	3 × 5	3 × 4	3 × 3	3 × 2	3 × 8	3 × 8	3 × 6	3 × 6	3 × 6	3 × 6
Dumbbell incline	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8	5 × 10, 8, 6, 3, 1	3 × 10	3 × 10	3 × 8	3 × 6	3 × 3	3 × 3
Pull up	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	5 × 10, 8, 6, 3, 1
Shoulder shrug combo	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 12	3 × 12	3 × 12	3 × 8	3 × 8	3 × 8
Bicep exercise	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 12	3 × 12	3 × 12
Abdominal circuit	3 × 30	3 × 30	4 × 30	4 × 30	4 × 30	4 × 30	4 × 30	4 × 30	4 × 30	3 × 10	3 × 10	3 × 10

TABLE 2. Plyometrics program, agility drills, and flexibility exercises.

Plyometrics program	Agility drills	Flexibility exercises
Ball push-ups	1 step shuffle over bags	Calf/hamstring stretch
Plate punches	2 step shuffle over bags	Hip stretch
Cross over the line	Pro shuttle	Quad stretch
Push-ups (seal clap)	Shuffle through bags	Groin stretch
Jump tucks	Back pedal and sprint	Arm pulls
Bench jumps	Jump rope routine	Hip flexor stretch
Russian hops	Square drills	
Squat jumps	Quick carioca	

Muscular component girths:

$$\% \text{ Deviation} = \frac{(\text{PE girth} - \text{average PE nonmuscular components})}{\text{average PE nonmuscular components}} \times 100$$

Nonmuscular component girths:

$$\% \text{ Deviation} = \frac{(\text{PE girth} - \text{average PE muscular components})}{\text{average PE muscular components}} \times 100$$

Statistical Analyses

One-way analysis of variance with repeated measures examined changes in anthropometric characteristics throughout the year. When statistically significant main effect results were obtained, Tukey-Kramer's post hoc test assessed where the differences occurred. Statistical significance was established at $p \leq 0.05$.

RESULTS

Table 4 presents the changes in body composition for the fall, winter, and spring tests, while Table 5 displays the triannual changes in girth measurements and ponderal equivalents.

From fall to winter, a significant increase occurred in body mass (+1.6 kg), percent fat (+1.3%), and fat mass (+1.6 kg). These body composition changes were matched by significant increases in the nonmuscular abdominal (+2.1 cm) and hips (+1.5 cm) girths. The abdominal and hips ponderal equivalents also increased significantly during this time interval (+5.3 and +2.6 kg, respectively).

From winter to spring, percent fat (−1.5%) and fat mass (−1.4 kg) decreased significantly. This was accompanied by a significant decrease in the nonmuscular abdominal girth (−1.0 cm) and PE value (−2.5 kg). Fat-free mass increased significantly from winter to spring (+1.5 kg), matched by a significant increase in the muscular biceps girth (+0.4 cm) and biceps ponderal equivalent (+2.6 kg).

The ponderal somatogram muscular components were generally overdeveloped (PE > body mass) in the football players in this study. The greatest overdevelopment occurred in the biceps. In the fall, the biceps ponderal equivalent (107.6 kg) was 14.7 kg greater than body mass (92.9 kg). The discrepancy was similar in the winter (+14.9 kg), but increased in the spring to 17.4 kg. The nonmuscular components remained generally underdeveloped (PE < body mass), with the notable exceptions of the abdomen and hips at all 3 testing times. Of the nonmuscular components, the greatest overdevelopment occurred in the abdomen. In the fall, the abdomen ponderal equivalent (99.7 kg) was 6.8 kg greater than body mass (92.9 kg). This discrepancy increased to 10.5 kg in the winter and decreased to 7.9 kg in the spring.

Figures 1–3 display the percent deviation from the reference man for each ponderal equivalent at the 3 testing times. Plotting the muscular and nonmuscular ponderal equivalents as percent deviations from the reference man is a useful graphical representation of girth data. The muscular components were generally overdeveloped (positive deviation) compared to the reference man at all 3 testing times. The greatest deviation was for the biceps (+17.1% fall, +17.8% winter, +21.4% spring). With the exception of the abdomen, the nonmuscular components were generally underdeveloped (negative deviation) compared to the reference man at all 3 testing intervals. The positive deviation for the abdomen in the fall (1.3%) increased to 4.6% in the winter, and decreased to 1.6% in the spring.

TABLE 3. k Constants from reference man (17).

Site	k Constant
Muscular component	
Shoulders	55.40
Chest	45.90
Biceps	15.85
Forearm	13.45
Thigh	27.40
Calf	17.90
Nonmuscular component	
Abdomen average	39.20
Hips	46.70
Knee	18.30
Ankle	11.25
Wrist	8.65

DISCUSSION

The construction of a ponderal somatogram or body profile is a practical application of the relative representation of the body's main girth measurements. The ponderal somatogram (16) differs from the original Behnke somatogram (2) by separating the girth measurements into muscular and nonmuscular components, and by converting girth measurements into ponderal equivalent values to allow comparison to body mass to indicate overdevelopment or underdevelopment at each girth location.

The ponderal somatogram (or Behnke somatogram) quantifies the relative proportions of the body's girth dimensions, and charts changes in these physical dimen-

TABLE 4. Stature, body mass, and percent body fat for the fall, winter, and spring testing; values expressed as mean ± *SD*.

	Fall (F)	Winter (W)	Spring (S)	$p < 0.05$
Stature, cm	179.7 ± 5.0	179.8 ± 5.0	180.0 ± 5.0	F < S
Body mass, kg	92.9 ± 14.1	94.5 ± 15.1	94.6 ± 14.4	F < W; F < S
% Fat	18.0 ± 6.4	19.3 ± 6.2	17.8 ± 6.3	F < W; W > S
Fat mass, kg	17.4 ± 8.5	19.0 ± 8.8	17.6 ± 8.7	F < W; W > S
Fat-free mass, kg	75.5 ± 7.4	75.5 ± 8.1	77.0 ± 7.8	F < S; W < S

sions as a function of time from such factors as training, dietary intervention, or influence of aging (16, 18). For example, changes in Dr. Behnke's body profile over a span of 28 years have been published (17), and the ponderal somatogram can document changes during or after wasting from starvation, bed rest, disabling injury, or weightlessness (5). The ponderal or Behnke somatogram also can compare individuals or groups with the reference man or reference woman, and permits quantification of differences in physique between individuals or groups (16, 18). For example, Behnke somatograms have compared women with anorexia (6), and adolescent and professional ballet dancers to the reference woman (7), white with Hispanic women (22), and somatographic differences between obese and nonobese adolescents (19).

In the present study, ponderal somatograms tracked changes that occurred in the body profile of Division III football players over the course of an academic year. Numerous studies have been published describing body composition and/or performance test data for American football players at the professional (25, 32), and Division I (3, 4), Division II (1, 20), and Division III (23, 29) levels, yet few studies have reported body composition or performance test results for football players at different time points throughout the year. Gettman et al. (10) reported that body composition, cardiorespiratory fitness, leg power, and agility of American professional football players improved following a 14-week preseason training program. Thompson (30) reported that fat mass decreased and fat-free mass increased during the season in Division I football players, and Hoffman and Kang (12) revealed that strength improved in Division III football players during the season when players adhered to a 2 days per week in-season resistance training program. Miller et al. (21) reported that performance in the power clean, bench press, and squat increased over time as Division I football players participated in the team's strength and conditioning program. The present study documents longitudinal changes in the body composition of Division III football players, but perhaps more importantly, provides an example of the usefulness of ponderal somatograms to track changes in physical dimensions over a 9-month interval.

As documented in Tables 4 and 5, significant increases occurred in body mass, percent fat, and fat mass from the fall to winter testing. These body composition changes were accompanied by significant increases in the nonmuscular abdominal and hip girths and ponderal equivalent values. We acknowledge that these changes may have occurred gradually from the August to January testing. It certainly is more probable that these body composition changes primarily occurred between the end of the football season in mid-November and the start of January's mandatory team strength and conditioning program. During this time, players were not required to participate in a formal strength and conditioning program. Tables 4 and 5 also reveal that from the winter to spring testing, percent fat and fat mass decreased significantly, accompanied by a significant decrease in the nonmuscular abdominal girth and PE value. During this interval, fat-free mass increased significantly matched by a significant increase in the muscular biceps girth and ponderal equivalent value. The results suggest that the mandatory team strength and conditioning program positively impacted fat-free mass development. These findings agree with Gettman et al., who reported that body composition in professional football players improved significantly following a 14-week preseason strength and conditioning program (10).

One particularly useful feature of the ponderal somatogram approach is the conversion of muscular and nonmuscular girth measurements into ponderal equivalent values to allow comparison of individual girth measurements to body mass. This provides an indication of whether an individual muscular or nonmuscular component is either overdeveloped (PE > body mass) or underdeveloped (PE < body mass). A comparison of the muscular ponderal equivalent values in Table 5 to body mass values in Table 4 indicates that, in general, the muscular components of the ponderal somatogram were overdeveloped in these football players. This is not surprising for athletes with a relatively high degree of size and strength. The biceps exhibited the greatest overdevelopment of the muscular components. In the fall, the biceps ponderal equivalent value was 107.6 kg, meaning that the football players had the biceps girth of a group that weighs 107.6 kg. Body mass averaged only 92.9 kg, indicating the players had overdeveloped biceps by 14.7 kg. This extent of overdevelopment was similar in the winter testing (14.9 kg) but increased to 17.4 kg in the spring testing following the mandatory team strength and conditioning regimen. This was not unexpected because biceps curls were included in workouts. Comparing the nonmuscular ponderal equivalent values in Table 5 to body mass values in Table 4 indicates that the nonmuscular components of the ponderal somatogram generally remained underdeveloped. The notable exception was overdevelopment of the abdomen and hips at all 3 testing times. The abdomen exhibited the greatest overdevelopment of the nonmuscular components. In the fall, the abdomen ponderal equivalent value averaged 99.7 kg, meaning the football players had the abdominal girth of a group that weighs 99.7 kg. The actual body mass averaged only 92.9 kg, indicating players were overdeveloped in the abdominal region by 6.8 kg. This overdevelopment increased to 10.5 kg in the winter testing, but decreased to 7.6 kg in the spring testing following the mandatory team strength and conditioning program. As above, these findings are similar to Gettman et al., who reported a decrease in percent body fat in American professional football players following a 14-week preseason strength and conditioning program (10).

Another beneficial feature of the ponderal somatogram approach is the construction of a visual appraisal of body size and shape by expressing the ponderal equiv-

TABLE 5. Girth measurements and ponderal equivalent values for the fall, winter, and spring testing; values expressed as mean ± *SD*.

	Girth, cm				Ponderal equivalent, kg			
	Fall (F)	Winter (W)	Spring (S)	$p < 0.05$	Fall (F)	Winter (W)	Spring (S)	$p < 0.05$
Muscular component								
Shoulders	124.6 ± 6.9	126.8 ± 7.7	125.5 ± 6.4	F < W; W > S	91.3 ± 11.0	94.7 ± 12.4	92.7 ± 10.4	F < W; W > S
Chest	106.7 ± 8.5	108.4 ± 9.2	108.6 ± 9.0	F < W; F < S	97.9 ± 16.8	101.2 ± 18.4	101.6 ± 18.2	F < W; F < S
Biceps	38.6 ± 3.0	39.0 ± 3.0	39.4 ± 3.0	F < S; W < S	107.6 ± 17.5	109.4 ± 17.7	112.0 ± 17.9	F < S; W < S
Forearm	30.8 ± 1.7	30.9 ± 1.7	31.0 ± 1.6	F < S	94.5 ± 11.5	95.2 ± 11.5	96.1 ± 11.3	F < S
Thigh	64.3 ± 5.4	64.9 ± 5.5	65.2 ± 5.4	F < S	99.9 ± 18.0	101.8 ± 18.7	102.8 ± 18.3	F < S
Calf	40.8 ± 2.9	40.6 ± 3.0	40.7 ± 2.8	F > W	94.0 ± 14.2	93.2 ± 14.7	93.5 ± 14.0	—
Nonmuscular component								
Abdomen average	91.7 ± 10.3	93.8 ± 11.2	92.8 ± 10.5	F < W; F < S; W > S	99.7 ± 23.8	105.0 ± 26.5	102.5 ± 25.1	F < W; F < S; W > S
Hips	107.5 ± 8.0	109.0 ± 8.2	108.1 ± 7.5	F < W	96.0 ± 15.9	98.6 ± 16.4	97.2 ± 15.1	F < W
Knee	41.8 ± 3.0	41.7 ± 2.9	41.7 ± 2.7	—	94.6 ± 15.4	93.8 ± 14.7	94.2 ± 14.0	—
Ankle	24.9 ± 1.6	24.7 ± 1.6	24.6 ± 1.5	F > W; F > S	88.2 ± 12.2	87.1 ± 12.2	86.6 ± 11.5	F > W; F > S
Wrist	18.4 ± 0.8	18.3 ± 0.8	18.3 ± 0.8	—	81.4 ± 8.6	80.6 ± 8.4	80.9 ± 8.1	—

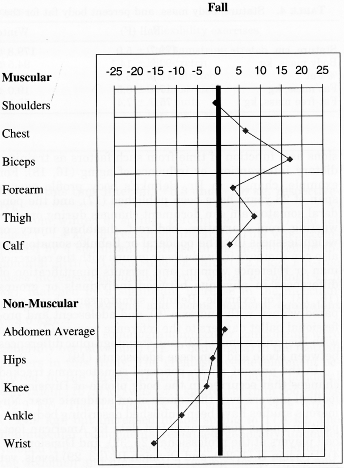

FIGURE 1. Ponderal somatogram for fall testing. (Note: The center line denotes the reference man.)

alent values as percent deviations from the reference man. All of the reference man girth measurements plot as a vertical line. A positive deviation of the ponderal equivalent value from the vertical line indicates an overdevelopment at that specific girth location, and a negative deviation of the ponderal equivalent value from the vertical line represents and underdevelopment at that specific girth measurement. Figures 1–3 graphically represent the girth data for the muscular and nonmuscular components of the ponderal somatogram at the fall, winter, and spring testing. Compared to the reference man, the muscular components were generally overdeveloped (positive deviation), while the nonmuscular components (with the exception of the abdomen) were generally underdeveloped at all 3 testing times. The greatest deviation was for the biceps, which was similar in fall (+17.1%) and winter testing (+17.8%), but increased to 21.4% in the spring testing following the mandatory team strength and conditioning workouts. The 1.3% positive deviation for the abdomen in the fall testing increased to 4.6% in the winter testing, but decreased to 1.6% in the spring testing. Plotting the percent deviation of the ponderal equivalent values from the reference man to graphically demonstrate overdevelopment and underdevelopment at specific girth measurements reveals a similar pattern to comparing the muscular and nonmuscular ponderal equivalent values to body mass to determine overdevelopment and underdevelopment at specific girth locations. The graphical representation of the girth data provides a meaningful way to easily share (and interpret) body composition changes with players and coaching staff.

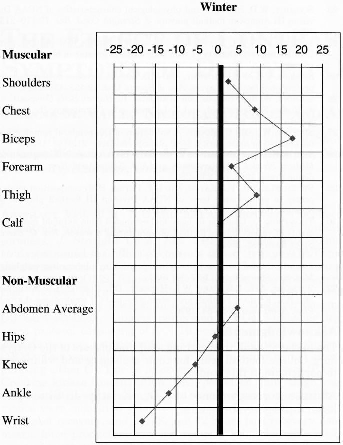

FIGURE 2. Ponderal somatogram for winter testing. (Note: The center line denotes the reference man.)

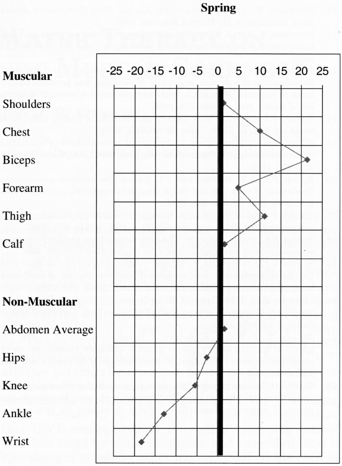

FIGURE 3. Ponderal somatogram for spring testing. (Note: The center line denotes the reference man.)

PRACTICAL APPLICATIONS

The ponderal somatogram offers a simple, practical anthropometric method to track specific changes in body size and shape over a defined time period. Girth measurements are a reliable alternative to other anthropometric techniques (e.g., skinfolds) to evaluate changes in the body profile. The ponderal somatogram is unique because it partitions the body into muscular and nonmuscular components. Ponderal equivalent values provide an indication of overdevelopment (ponderal equivalent > body mass) and underdevelopment (ponderal equivalent < body mass) at specific girth measurement locations. The ponderal somatogram produces a visual appraisal of body size and shape when ponderal equivalent values are expressed as percent deviations from the reference standard.

The techniques for measuring body composition in American football players (and other individuals) are well established, yet the practical application of this information is less well developed. Indeed, it is all too common for a plethora of body composition measurements to be taken, only to be lost as meaningless data in the file cabinets of overworked strength and conditioning coaches, athletic trainers, and other athletic and allied-health care professionals. With minimal effort, it is possible to translate girth measurements into ponderal somatograms. Plotting ponderal equivalent values as percent deviations from the reference man provide a simple and powerful visual representation of an individual's or a group's body composition status. Tracking changes in individual and group ponderal somatograms over time can provide motivation for players to adhere to strength and conditioning programs, and can help coaches to assess the effectiveness of these programs. Ponderal somatograms (especially the nonmuscular abdomen 1, abdomen 2, and hips components) also can graphically monitor the "obesity status" of individuals, which of course has important health implications.

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