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Ponderal Somatogram Analysis of Girth Measurements by Position in Division III College Football Players

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Abstract
Ponderal somatograms assessed body compositions in four groups of Division III collegiate football players: offensive line (OL), defensive line (DL), offensive backs (OB), and defensive backs (DB). Ponderal somatograms evaluate body size and shape by converting muscular (shoulders, chest, biceps, forearm, thigh, and calf) and nonmuscular (abdomen, hips knee, ankle, and wrist) girths into ponderal equivalent (PE) values. Anthropometric measurements, including stature, body mass, girths, and percent body fat by densitometry were collected in 82 players (22 OL, 12 DL, 20 OB, and 28 DB) during preseason camp. PE values were calculated for each girth as PE, kilograms = (girth, cm / k)sq. x stature, decimeters, where k=k constant from Behnke's reference man. PE values were compared to body mass to indicate overdevelopment (PE greater than body mass) and underdevelopment (PE less than body mass). OL was significantly heavier than DL (+15.6 kg), OB (+25.2 kg), and DB (+22.4 kg). OL percent fat as significantly greater than DL (+5.9%), OB (+9.0%), and DB (+9.3%). Similar differences occurred in girths and PE values by position. Muscular components were generally overdeveloped, with the greatest overdevelopment in the biceps (OL + 16.0 kg, DL + 19 kg, OB + 14.2 kg, and DB + 16.2 kg). Nonmuscular abdomen, hips, and knee were generally overdeveloped, with the greatest overdevelopment in the OL abdomen (+19.3 kg). Nonmuscular ankle and wrist were underdeveloped. Ponderal somatograms provide a relatively quick and simple method to translate girth measurements into ponderal equivalent values that seem to be position-specific among offensive and defensive linemen and backs. Somatograms provide an appraisal of body composition that helps coaches and athletes monitor the effectiveness of strength and conditioning programs.

Keywords
body composition, anthropometry, body profile

Disciplines
Other Medicine and Health Sciences | Sports Sciences

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Abstract

Stuempfle, KJ, Drury, DG, Petrie, DF, and Katch, FI. Ponderal somatogram analysis of girth measurements by position in Division III college football players. *J Strength Cond Res* 23(3): 788–799, 2009—Ponderal somatograms assessed body composition in four groups of Division III collegiate football players: offensive line (OL), defensive line (DL), offensive backs (OB), and defensive backs (DB). Ponderal somatograms evaluate body size and shape by converting muscular (shoulders, chest, biceps, forearm, thigh, and calf) and nonmuscular (abdomen, hips, knee, ankle, and wrist) girths into ponderal equivalent (PE) values. Anthropometric measurements, including stature, body mass, girths, and percent body fat by densitometry were collected in 82 players (22 OL, 12 DL, 20 OB, and 28 DB) during preseason camp. PE values were calculated for each girth as PE, kilograms = (girth, cm ÷ k)^2 × stature, decimeters, 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). OL was significantly heavier than DL (+15.6 kg), OB (+25.2 kg), and DB (+22.4 kg). OL percent fat was significantly greater than DL (+5.9%), OB (+9.0%), and DB (+9.3%). Similar differences occurred in girths and PE values by position. Muscular components were generally overdeveloped, with the greatest overdevelopment in the biceps (OL + 16.0 kg, DL + 19 kg, OB + 14.2 kg, and DB + 16.2 kg). Nonmuscular abdomen, hips, and knee were generally overdeveloped, with the greatest overdevelopment in the OL abdomen (+19.3 kg). Nonmuscular ankle and wrist were underdeveloped. Ponderal somatograms provide a relatively quick and simple method to translate girth measurements into ponderal equivalent values that seem to be position-specific among offensive and defensive linemen and backs. Somatograms provide an appraisal of body composition that helps coaches and athletes monitor the effectiveness of strength and conditioning programs.

Key Words body composition, anthropometry, body profile.

Introduction

Techniques for measuring body composition in football players and other athletes are well developed (6,16), yet their practical application has been less well demonstrated. It is not unusual for a plethora of body composition measurements to be taken, only to have them become meaningless statistics lost in a file cabinet. However, it is possible to translate body composition data into a meaningful and practical application for both coaches and athletes.

Hydrostatic weighing, bioelectrical impedance, and skinfold and girth measurements are frequently used to assess body composition in football players (6,16). Hydrostatic weighing is usually the criterion method (16) but requires specialized laboratory equipment and is a time consuming procedure. In contrast, girth measurements are relatively simple and quick to obtain and can produce a somatogram, a graphic representation of girth measurements that provides a practical method to communicate body composition data to coaches and athletes (1,10).

In 1959, Behnke (1) introduced the concept of the somatogram based on 11 girth measurements to quantitatively describe body shape expressed in percent deviation units from a reference standard. If the girth measurements for a given individual conform precisely to the reference values, no deviations occur and the somatogram plots as a vertical line.

In 1987, Katch (10) presented an extension of the original Behnke somatogram, termed the ponderal somatogram. In this enhancement, the girth measurements were placed into muscular (shoulders, chest, biceps, forearm, thigh, and calf) and nonmuscular (abdomen average, hips, knee, ankle, and wrist) components. Additionally, individual girth measurements were converted into ponderal equivalent (PE) values to allow for comparison of individual girths to body mass as

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Table 1. Strength training program.

	Week (sets × repetitions)					
	1	2	3	4	5	6
Monday						
Squat	3 × 10	3 × 10	3 × 8	3 × 8	3 × 6	3 × 6
1 leg squat	3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Squat jumps	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Leg curl	3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Incline press	3 × 10	3 × 10	3 × 8	3 × 8	3 × 6	3 × 6
Ball push ups	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Dumbbell bench press	3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Dumbbell fly	3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Inverted dumbbell shoulder press	3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Tricep exercise	3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Abdominal exercise	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30
Tuesday						
Overhead squat	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Drop squat	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Trap clean	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Pull floor	3 × 10	3 × 10	3 × 6	3 × 6	3 × 5	3 × 5
Pull thigh	3 × 10	3 × 10	3 × 6	3 × 6	3 × 5	3 × 5
Push jerk	3 × 6	3 × 6	3 × 4	3 × 6	3 × 3	3 × 3
Pull up	3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Dumbbell shrug	3 × 20	3 × 20	3 × 20	3 × 20	3 × 15	3 × 15
Bicep exercise	3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Wrist roller	3 × 3	3 × 3	3 × 3	3 × 3	3 × 3	3 × 3
Back extensions	3 × 15	3 × 15	3 × 15	3 × 15	3 × 12	3 × 12
4 way neck	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10
Abdominal exercise	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30
Thursday						
Squat	3 × 10	3 × 10	3 × 8	3 × 8	3 × 6	3 × 6
Step up	3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Jump tucks	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Romanian dead lift	3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Bench press	3 × 10	3 × 10	3 × 8	3 × 8	3 × 6	3 × 6
Push ups	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Dumbbell incline press	3 × 12	3 × 12	3 × 12	3 × 12	3 × 12	3 × 10
Shoulder combo	3 × 12	3 × 12	3 × 12	3 × 12	3 × 12	3 × 12
Tricep exercise	3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Abdominal exercise	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30
Friday						
Overhead squat	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Drop squat	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Power snatch	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10

(*Continued on next page*)

Pull floor		3 × 10	3 × 10	3 × 6	3 × 6	3 × 5	3 × 5
Pull thigh		3 × 10	3 × 10	3 × 6	3 × 6	3 × 5	3 × 5
Back combo		3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Shrug combo		3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Bicep exercise		3 × 12	3 × 12	3 × 12	3 × 12	3 × 10	3 × 10
Wrist roller		3 × 3	3 × 3	3 × 3	3 × 3	3 × 3	3 × 3
Back extensions		3 × 15	3 × 15	3 × 15	3 × 15	3 × 12	3 × 12
4 way neck		2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10

	Week (sets × repetitions)						
	7	8	9	10	11	12	13
Abdominal exercises	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30	
Monday							
Squat	3 × 6	3 × 5	3 × 5	3 × 3	3 × 3	5 × 10, 8, 6, 3, 1	5 × 10, 8, 6, 3, 1
Squat jumps	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8
One leg squat	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8	3 × 6	3 × 6
Good mornings	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 6	3 × 6
Incline press	3 × 6	3 × 5	3 × 5	3 × 3	3 × 3	5 × 10, 8, 6, 3, 1	5 × 10, 8, 6, 3, 1
Push ups	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Seated military press	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 6	3 × 6
Dumbbell upright row	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 6	3 × 6
Tricep exercise	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 8	3 × 8
Abdominal exercises	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30
Tuesday							
Overhead squat	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Drop clean	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Trap clean	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Hang clean	3 × 3	3 × 3	3 × 3	3 × 2	3 × 2	3 × 2	3 × 2
Pull ups	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 6	3 × 6
Bar shrug	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 6	3 × 6
Heavy bar curls	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 8	3 × 8
Wrist roller	3 × 3	3 × 3	3 × 3	3 × 3	3 × 3	3 × 3	3 × 3
Back extensions	3 × 12	3 × 12	3 × 10	3 × 10	3 × 10	3 × 8	3 × 8
4 way neck	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10
Abdominal exercises	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30
Thursday							
Squat	3 × 6	3 × 5	3 × 5	3 × 3	3 × 3	5 × 10, 8, 6, 3, 1	5 × 10, 8, 6, 3, 1
Russian hops	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Lunges	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 6	3 × 6
Romanian dead lift	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 6	3 × 6
Bench press	3 × 6	3 × 5	3 × 5	3 × 3	3 × 3	5 × 10, 8, 6, 3, 1	5 × 10, 8, 6, 3, 1
Push ups	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Dumbbell flys	3 × 10	3 × 8	3 × 8	3 × 8	3 × 8	3 × 8	3 × 6
Shoulder combo	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Tricep exercise	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 8	3 × 8
Abdominal exercise	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30

Friday						
Overhead squat	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Drop squat	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Power snatch	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Hang snatch	3 × 3	3 × 3	3 × 2	3 × 2	3 × 2	3 × 2
Pull ups	3 × 10	3 × 8	3 × 8	3 × 6	3 × 6	3 × 6
Curls	3 × 10	3 × 10	3 × 10	3 × 8	3 × 8	3 × 8
Shrug combo	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10	3 × 10
Wrist roller	3 × 3	3 × 3	3 × 3	3 × 3	3 × 3	3 × 3
Back extensions	3 × 12	3 × 10	3 × 10	3 × 10	3 × 8	3 × 8
4 way neck	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10
Abdominal exercise	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30	3 × 30

mass equivalents. These conversions indicate overdevelopment or underdevelopment at a given site. For example, if the PE value at a given site exceeds body mass, this region is considered overdeveloped. If the PE value is less than body mass, it indicates underdevelopment at this site. The ratio of the PE muscular components (PE-M) to the PE nonmuscular components (PE-NM) serves as useful, relative index of muscularity and adiposity. For the graphical representation of the ponderal somatogram, the deviation of each PE girth from the reference is computed as the percentage deviation from the opposite PE component. A report by Sinning and Moore (17) provided evidence for the validity of the ponderal somatogram.

In the present study, body composition was assessed in Division III college football players separated into four groups by position: offensive line (OL), defensive line (DL), offensive backs (OB), and defensive backs (DB). Body mass and percent fat by densitometry (including fat mass and fat-free mass) were compared among the groups and ponderal somatograms assessed girth deviations. The following was calculated for each group: (1) muscular and nonmuscular PE values compared with body mass, (2) PE-M/PE-NM ratio, and (3) graphic display of each PE value as a percentage deviation from the opposite PE component.

Methods

Experimental Approach to the Problem

Analysis of variance detected anthropometric differences in four groups of Division III college football players: OL, DL, OB, and DB. Anthropometric measurements, including stature, body mass, girths, and percent body fat by densitometry were collected during preseason camp. Girth measurements were used to construct ponderal somatograms that divide girth measurements into muscular (shoulders, chest, biceps, forearm, thigh, and calf) and nonmuscular (abdomen average, hips, knee, ankle, and wrist) components and convert the girth measurements into PE values. PE values were compared to body mass to indicate overdevelopment (PE > body mass) or underdevelopment (PE < body mass) at specific girth locations. The ratio of PE muscular components to PE nonmuscular components was calculated as an indication of muscularity and adiposity. A graphic representation of the deviation of each PE value as a percentage deviation from the opposite PE component provided visual representation of body size and shape.

Subjects

Anthropometric characteristics were assessed in 82 Division III football players from Gettysburg College, Gettysburg, Pa., a NCAA Division III school with a 114-year history of competition in football at this level. The subjects were placed into four groups by position: OL ($N = 22$), DL ($N = 12$), OB ($N = 20$), and DB ($N = 28$). Subjects were tested during the 2002 preseason camp. Before reporting to preseason camp, all subjects participated in a 13-week mandatory team

Table 2. Running program.

	Week (repetitions × meters)												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Tuesday	3 × 300	3 × 300	1 × 400	2 × 400	1 × 400	8 × 200	4 × 200	2 × 200	10 × 150	5 × 150	8 × 60	12 × 40	10 × 40
	5 × 200	5 × 200	3 × 300	4 × 200	1 × 350		4 × 150	6 × 150		4 × 100	8 × 40		
			3 × 200	4 × 150	2 × 200		4 × 100	6 × 100		2 × 60			
Thursday					2 × 150								
						5 × 300							
Friday	8 × 150	8 × 150	10 × 150	2 × 200	3 × 200			5 × 300		1 × 400	10 × 100	4 × 100	12 × 60
				6 × 150	4 × 150					6 × 200		4 × 60	
Saturday				4 × 100	4 × 100								
						2 × 200	1 × 200	2 × 200	4 × 100	2 × 100			
						4 × 100	4 × 100	4 × 100	4 × 60	4 × 60			
						6 × 60	6 × 60	3 × 60	4 × 40	8 × 40			
							4 × 40	3 × 40					

Table 3. Agility drills and flexibility exercises.

Agility drills	Flexibility exercises
1 step shuffle over bags	Calf/hamstring stretch
2 step shuffle over bags	Hip stretch
Pro shuttle	Quad stretch
Shuffle through bags	Groin stretch
Back pedal and sprint	Arm pulls
Jump rope routine	Hip flexor stretch
Square drills	
Quick carioca	

strength and conditioning program. The program included upper-extremity, lower-extremity, and core strength training exercises, running, agility drills, and flexibility exercises (Tables 1–3). The team was not ranked in NCAA Division III rankings during the 2002 season and finished the season with a 4–6 record. The school's Institutional Review Board approved the study, and subjects were fully informed of the purpose and nature of the study and provided informed consent.

Procedures

Measurements. Anthropometric measurements included stature, body mass, 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 lbs. Girth measurements were taken using a calibrated cloth

Table 4. k Constants from reference man (12).

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 ave.	39.20
Hips	46.70
Knee	18.30
Ankle	11.25
Wrist	8.65

TABLE 5. Stature, body mass, and % body fat by position; values expressed as mean ± *SD*.

	Team	OL	DL	OB	DB	$p < 0.05$
Height, cm	179.4 ± 5.4	182.6 ± 5.6	180.9 ± 4.9	176.9 ± 5.5	177.9 ± 3.9	OL > OB, DB
Body mass, kg	92.5 ± 13.3	108.6 ± 8.0	93.0 ± 9.9	83.4 ± 7.9	86.2 ± 9.3	OL > DL, OB, DB; DL > OB
% fat	18.0 ± 6.4	24.2 ± 5.0	18.3 ± 6.0	15.2 ± 4.9	14.9 ± 5.1	OL > DL, OB, DB
Fat mass, kg	17.3 ± 8.3	26.6 ± 7.0	17.4 ± 6.5	12.9 ± 5.0	13.1 ± 5.5	OL > DL, OB, DB
Fat-free mass, kg	75.2 ± 7.3	82.0 ± 4.6	75.6 ± 6.3	70.5 ± 5.8	73.1 ± 6.6	OL > DL, OB, DB

OL = offensive line; DL = defensive line; OB = offensive back; DB = defensive back.

tape to ±0.1 cm. All girth measurements were taken by the same investigator (KS) who was experienced with this technique. Test-retest reliabilities of girth measurements at all sites average approximately 0.95 or higher (2,7) with validity verified during pilot testing (FK). 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 follow (7):

Anatomical Landmarks for Muscular Girth Sites

- 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 degrees
- Forearm: maximal girth with elbow extended and hand supinated
- Thigh: maximal girth
- Calf: maximal girth
- Anatomical Landmarks for Nonmuscular Girth Sites

TABLE 6. Girth measurements by position; values expressed as mean ± *SD*.

	Girth, cm					
	Team	OL	DL	OB	DB	$p < 0.05$
Muscular component						
Shoulders	125.1 ± 7.0	132.2 ± 5.3	126.0 ± 5.3	121.5 ± 5.3	121.8 ± 5.6	OL > DL, OB, DB
Chest	107.3 ± 8.4	116.7 ± 6.1	108.6 ± 5.4	100.9 ± 6.0	103.9 ± 5.5	OL > DL, OB, DB; DL > OB
Biceps	38.9 ± 2.9	41.4 ± 2.0	39.4 ± 2.2	37.1 ± 2.7	37.9 ± 2.7	OL > OB, DB
Forearm	31.0 ± 1.7	32.5 ± 1.0	31.4 ± 1.5	30.0 ± 1.2	30.3 ± 1.7	OL > OB, DB; DL > OB
Thigh	64.6 ± 4.8	69.5 ± 3.1	65.1 ± 3.1	61.6 ± 3.0	62.5 ± 4.7	OL > DL, OB, DB
Calf	40.7 ± 2.5	42.9 ± 1.9	40.4 ± 1.7	39.9 ± 1.6	39.4 ± 2.8	OL > DL, OB, DB
Nonmuscular component						
Abdomen ave.	91.8 ± 10.1	103.5 ± 8.1	92.6 ± 6.7	85.3 ± 6.0	87.1 ± 6.5	OL > DL, OB, DB; DL > OB
Hips	107.4 ± 6.8	115.2 ± 4.2	108.0 ± 3.4	103.1 ± 4.8	104.0 ± 5.4	OL > DL, OB, DB; DL > OB
Knee	41.7 ± 2.5	44.1 ± 1.7	42.3 ± 1.5	40.6 ± 1.9	40.3 ± 2.2	OL > DL, OB, DB; DL > DB
Ankle	24.7 ± 1.4	26.0 ± 1.2	24.8 ± 1.1	24.3 ± 1.0	24.0 ± 1.3	OL > DL, OB, DB
Wrist	18.4 ± 0.8	18.9 ± 0.7	18.6 ± 0.5	17.9 ± 0.7	18.2 ± 0.7	OL > OB, DB; DL > OB

OL = offensive line; DL = defensive line; OB = offensive back; DB = defensive back.

Table 7. Ponderal equivalent values by position; values expressed as mean ± *SD*.

	Ponderal equivalent, kg					
	Team	OL	DL	OB	DB	$p < 0.05$
Muscular component						
Shoulders	91.8 ± 11.1	104.1 ± 8.0	93.6 ± 6.7	85.3 ± 8.5	86.1 ± 8.0	OL > DL, OB, DB; DL > OB, DB
Chest	98.8 ± 16.6	118.3 ± 11.8	101.4 ± 9.8	85.9 ± 11.3	91.4 ± 9.9	OL > DL, OB, DB; DL > OB, DB
Biceps	108.6 ± 16.8	124.6 ± 12.4	112.0 ± 10.1	97.6 ± 14.5	102.4 ± 13.8	OL > DL, OB, DB; DL > OB
Forearm	95.5 ± 11.3	106.4 ± 7.3	98.7 ± 7.9	88.1 ± 8.6	90.8 ± 9.8	OL > OB, DB; DL > OB, DB
Thigh	100.2 ± 15.7	117.6 ± 9.9	102.3 ± 9.1	89.8 ± 9.4	92.9 ± 13.5	OL > DL, OB, DB; DL > OB
Calf	93.8 ± 12.5	105.0 ± 9.7	92.3 ± 7.6	88.2 ± 8.1	86.7 ± 12.2	OL > DL, OB, DB
Mean PE-M	97.9	112.7	100.1	89.2	91.7	
Nonmuscular Component						
Abdomen ave.	99.8 ± 23.4	127.9 ± 19.4	101.3 ± 14.3	84.2 ± 13.4	88.2 ± 13.4	OL > DL, OB, DB; DL > OB
Hips	95.3 ± 13.4	111.2 ± 8.7	96.8 ± 6.7	86.5 ± 9.5	88.5 ± 9.4	OL > DL, OB, DB; DL > OB, DB
Knee	93.5 ± 12.6	106.3 ± 9.9	96.6 ± 7.5	87.4 ± 9.8	86.5 ± 9.8	OL > DL, OB, DB; DL > OB, DB
Ankle	87.1 ± 11.4	97.9 ± 10.2	88.2 ± 8.0	83.1 ± 8.3	81.0 ± 9.3	OL > DL, OB, DB
Wrist	81.0 ± 8.3	87.5 ± 8.0	83.6 ± 5.6	76.0 ± 7.3	78.3 ± 6.5	OL > OB, DB; DL > OB
Mean PE - NM	91.3	106.2	93.3	83.4	84.5	
PE-M/PE-NM	1.074	1.063	1.074	1.070	1.086	

OL = offensive line; DL = defensive line; OB = offensive back; DB = defensive back.

- 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

Before hydrostatic weighing, a Medgraphics metabolic cart analyzed 3 trials of seated vital capacity to estimate residual lung volume computed as vital capacity × 0.24 (23). Hydrostatic weighing assessed body mass in water 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 after procedures, described previously (9). Ten repeated weighings (using an average of the last 3 trials) computed the underwater weight score (8). For white players, percent fat was calculated with the Siri equation (18), where % fat = 495 ÷ density (g/mL) − 450; for black players, the Schutte equation (15) computed body fat where % fat = 437.4 ÷ density (g/mL) − 392.8.

Ponderal Somatogram. Ponderal somatograms described body size and shape using muscular (shoulders, chest, biceps, forearm, thigh, calf) and nonmuscular (abdomen 1, abdomen 2, hips, knee, wrist, and ankle) girth measurements converted into ponderal (or mass) equivalent values expressed in kilograms (10). This allowed comparison of individual girths as PE values to body mass to provide an assessment of overdevelopment (PE value > body mass) or underdevelopment (PE value < body mass) for each of the muscular and nonmuscular girth measurements. The PE value for each girth measurement was calculated as follows (10):

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

In this equation, k = k constant from reference man (Table 4)

For example, if PE = 100 kg for abdomen, this means the person (or group) has an abdominal girth of a person

Table 8. Comparison of ponderal equivalent (PE) value to body mass by position: positive value (PE value > body weight) indicates overdevelopment of region; negative value (PE value < body weight) indicates underdevelopment of region; Values expressed in kilograms.

	Team	OL	DL	OB	DB
Muscular component					
Shoulders	−0.7	−4.5	+0.6	+1.9	−0.1
Chest	+6.3	+9.7	+8.4	+2.5	+5.2
Biceps	+16.1	+16.0	+19.0	+14.2	+16.2
Forearm	+3.0	−2.2	+5.7	+4.7	+4.6
Thigh	+7.7	+9.0	+9.3	+6.4	+6.7
Calf	+1.3	−3.6	−0.7	+4.8	+0.5
Nonmuscular Component					
Abdomen ave.	+7.3	+19.3	+8.3	+0.8	+2.0
Hips	+2.8	+2.6	+3.8	+3.1	+2.3
Knee	+1.0	−2.3	+3.6	+4.0	+0.3
Ankle	−5.4	−10.7	−4.8	−0.3	−5.2
Wrist	−11.5	−21.1	−9.4	−7.4	−7.9

OL = offensive line; DL = defensive line; OB = offensive back; DB = defensive back.

(or group) who weighs 100 kg. If the person (or group) weighs 93 kg, the person (or group) is overdeveloped in this region by 7 kg.

The ratio of the PE muscular components to the PE nonmuscular components (PE-M/PE-NM) provides a relative indication of muscularity and adiposity. A high ratio reflects an oversized muscular component or an undersized nonmuscular component. In contrast, a low ratio reflects an undersized muscular component or an oversized nonmuscular component. The ratio would be less than one for individuals with excessive fat and greater than one for individuals with excessive muscle (10).

Ponderal somatograms produce a visual appraisal of body size and shape by expressing the deviation of each ponderal equivalent value from the reference as the percent deviation from the opposite ponderal equivalent component. For the muscular ponderal equivalent values, a positive deviation indicates overdevelopment and a negative deviation indicates underdevelopment of that region compared with the nonmuscular components. For the nonmuscular ponderal equivalent values, a positive deviation indicates overdevelopment and a negative deviation indicates an underdevelopment of that region compared with the muscular component. The percent (%) deviations were calculated as described below (10):

Muscular Component Ponderal Equivalent Values

$$\%\,\text{Deviation} = \frac{(\text{PE muscular value} - \text{average PE muscular components}) \times 100}{\text{Average PE Nonmuscular Components}}$$

Nonmuscular Component Ponderal Equivalent Values

$$\%\,\text{Deviation} = \frac{(\text{PE nonmuscular value} - \text{average PE muscular components}) \times 100}{\text{Average PE Muscular Components}}$$

Table 9. Comparison of ponderal equivalent (PE) muscular and PE nonmuscular values by position. For PE muscular components, value indicates % deviation from the PE nonmuscular average; a positive deviation indicates an overdevelopment compared with the nonmuscular components. For PE nonmuscular components, value indicates % deviation from the PE muscular average; a negative deviation indicates an underdevelopment compared with the muscular components.

	Team	OL	DL	OB	DB
Muscular component					
Shoulders	+0.7	−1.8	+0.4	+2.4	+1.9
Chest	+8.0	+11.5	+8.7	+2.9	+8.0
Biceps	+19.0	+17.7	+20.0	+16.7	+20.5
Forearm	+4.9	+0.7	+5.8	+5.9	+7.0
Thigh	+9.8	+11.0	+9.6	+7.6	+9.7
Calf	+2.1	−0.9	−1.1	+5.8	+2.1
Nonmuscular component					
Abdomen ave.	+0.8	+13.1	+1.0	−5.7	−3.8
Hips	−2.7	−1.3	−3.2	−2.9	−3.4
Knee	−4.5	−5.8	−3.3	−1.9	−5.5
Ankle	−11.4	−13.4	−12.0	−7.1	−11.3
Wrist	−16.8	−22.6	−16.3	−14.7	−13.8

OL = offensive line; DL = defensive line; OB = offensive back; DB = defensive back.

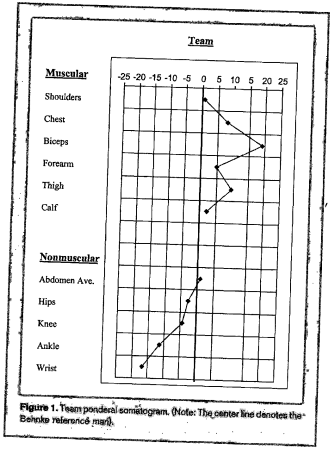

Figure 1. Team ponderal somatogram. (Note: The center line denotes the Behnke reference man).

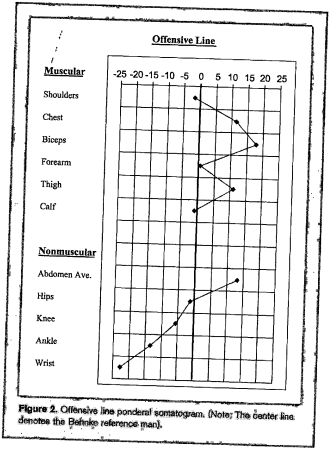

Figure 2. Offensive line ponderal somatogram. (Note: The center line denotes the Behnke reference man).

Statistical Analyses

An analysis of variance compared body mass, percent fat, fat mass, fat-free mass, girth measurements, and PE values by position (OL, DL, OB, and DB). Tukey-Kramer's post-hoc test assessed statistically significant main effects at $p \leq 0.05$.

Results

Table 5 displays the differences in body composition among OL, DL, OB, and DB. The most consistent differences occurred between OL and the other players. OL were significantly heavier than DL (+15.6 kg), OB (+25.2 kg), and DB (+22.4 kg). Percent body fat was significantly greater in OL compared with DL (+5.9%), OB (+9.0%), and DB (+9.3%). OL also had significantly greater fat mass (+9.2 kg, +13.7 kg, +13.5 kg, respectively) and fat-free mass (+6.4 kg, +11.5 kg, +8.9 kg, respectively) compared to DL, OB, and DB.

Table 6 presents differences by position in girth measurements, and Table 7 shows the corresponding differences in PE values. The differences in girth measurements and PE values between OL and the other three players groups were similar to the body composition differences. The muscular shoulders, chest, biceps, thigh, and calf girth measurements and PE values were significantly greater in OL compared with DL, OB and DB (except for no difference between OL and DL in biceps girth). Forearm girth measurements and PE values were significantly greater for OL compared with OB and DB. The nonmuscular abdominal, hips, knee, and ankle girth measurements and PE values were significantly greater for OL compared with DL, OB, and DB. Wrist girth measurements and PE values were significantly larger in OL compared with OB and DB.

Table 8 compares PE values to body mass by position. The ponderal somatogram muscular components were generally overdeveloped (PE value > body mass). The greatest overdevelopment occurred in the biceps. The biceps ponderal equivalent (112.0 kg) for DL was 19.0 kg greater than body mass (93.0 kg). The same trend occurred for OL (+16.0 kg), OB (+14.2 kg), and DB (+16.2 kg). In the nonmuscular component, the abdominal, hips, and knee ponderal equivalents were generally positive, indicating overdevelopment. The greatest overdevelopment occurred for the abdominal ponderal equivalent value for OL (+19.3 kg). The ankle and wrist ponderal equivalent values were negative for all 4 groups (PE value < body mass), which suggests underdevelopment relative to other body sites.

The last row of Table 7 displays the ratio of the PE muscular to PE nonmuscular components (PE-M/PE-NM

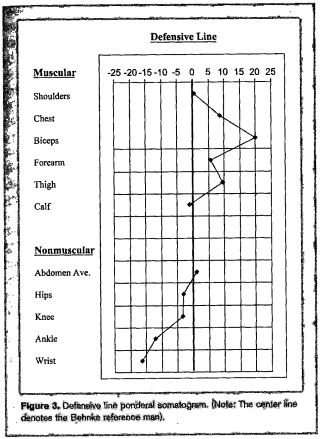

Figure 3. Defensive line ponderal somatogram. (Note: The center line denotes the Behnke reference man).

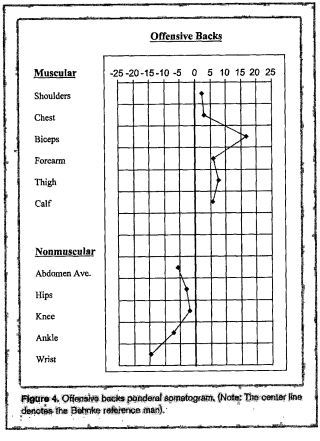

Figure 4. Offensive backs ponderal somatogram. (Note: The center line denotes the Behnke reference man).

ratio). All 4 groups had a PE-M/PE-NM ratio greater than 1.0. DB had the highest PE-M/PE-NM ratio (1.086) and OL the lowest ratio (1.063).

Table 9 and Figures 1–5 compare the PE muscular values with the average of the PE nonmuscular values by position (values expressed as a percent deviation). The deviations for the muscular component were generally positive, indicating overdevelopment of the muscular compared with the nonmuscular component. The greatest overdevelopment occurred in the biceps in all four groups (OL = 17.7, DL = 20.0, OB = 16.7, and DB = 20.5%).

Table 9 and Figures 1–5 also compare the PE nonmuscular values to the average of the PE muscular values by position. The deviations for the nonmuscular component were generally negative, indicating underdevelopment of the nonmuscular compared with the muscular component. The obvious exception was the +13.1% abdominal value for OL, suggesting an overdevelopment of this area compared with the muscular component.

Table 9 and Figures 4 and 5 reveal that OB and DB exhibited the most desirable profiles. Both groups had all positive deviations (overdevelopment) for the muscular component and all negative deviations (underdevelopment) for the nonmuscular components.

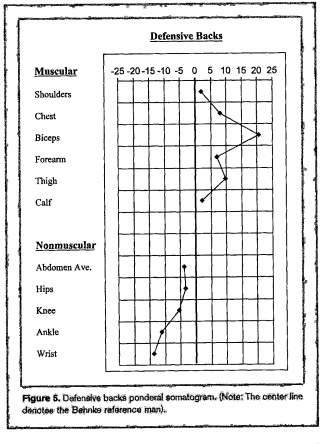

Figure 5. Defensive backs ponderal somatogram. (Note: The center line denotes the Behnke reference man).

Discussion

The most prominent differences in body composition and anthropometry occurred between OL and the 3 other groups. These findings are consistent with NFL and Division I football players. For example, in the 1970s, Wilmore (24,25) reported that professional OL and DL had a higher percent body fat than OB and DB. In 1998, Snow (19) reported that OL at the professional level had a higher percent body fat than DL, OB, and DB. At the Division I level, Wickkiser (22) reported that OL had a greater percent body fat than DL, OB, and DB. The pattern of percent body fat differences by position in the present study was similar to that reported in previous studies, yet the absolute percent body fat by position was higher for the athletes in the current study. This is not surprising because the athletes were competing at the Division III level compared to Division I athletes (22) or National Football League (NFL) professionals (19,24,25).

The present study is unique in documenting body composition differences by position in Division III football players, yet perhaps more importantly, the methodology serves as an example of the usefulness of ponderal somatograms to interpret girth measurements. The original Behnke somatogram and current ponderal somatogram methods quantify the relative proportions of the body's girth dimensions for charting changes in these physical dimensions over time or to quantify differences in physique between individuals or groups (10,11). Katch (12) charted changes in Dr. Behnke's somatogram over a span of 28 years, and college men were compared in anthropometry over their 4-year collegiate education (10). Buskirk (3) suggested that the Behnke and ponderal somatograms methods were useful to document changes in wasting from starvation, bed rest, disabling injury, and weightlessness. Most recently, ponderal somatograms have monitored changes in football players during their 4-year collegiate careers (20). The Behnke and ponderal somatogram approach also can compare individuals or groups to the reference man or woman to quantify differences in physique between individuals and groups. Behnke somatograms have compared anorexic women (4) and ballet dancers (5) to the reference woman and anthropometric differences between white and Hispanic women (14). Ponderal somatograms have compared 9th- and 12th-grade boys, college men from the 1890s to current college men (10), and obese and nonobese male and female adolescents (13).

A beneficial feature of ponderal somatograms is converting individual girth measurements into PE values. This allows individual girth comparisons to body mass as mass equivalents to illuminate overdevelopment (PE value > body mass) or underdevelopment (PE value < body mass) at each site. In this study, the football players generally had overdeveloped muscular and nonmuscular ponderal somatograms (Table 8). This is not surprising because this sport encourages large body size and strength. The biceps showed the greatest overdevelopment in the muscular component. For DL, the PE value was 112.0 kg, suggesting these athletes had the biceps girth similar to a group that would weigh 112.0 kg. Body mass averaged only 93.0 kg, meaning that DL had overdeveloped biceps by 19.0 kg. Similar overdevelopment of the biceps was evident in OL (+16.0 kg), OB (+14.2 kg), and DB (+16.2 kg). This is not unexpected because football strength training and conditioning programs typically emphasize biceps curls and other upper-arm resistance exercises. The abdomen in OL (+19.3 kg) showed the greatest overdevelopment in the nonmuscular component. These findings coincide with the significantly greater body mass and percent fat observed in OL, as was the case for Division I (22) and NFL (19,24,25) players.

The PE-M/PE-NM ratio provides another useful feature of the ponderal somatogram approach. The PE-M/PE-NM ratio exceeded 1.0 in all 4 groups, indicating an oversized muscular component expected for football players. The lowest ratio occurred for OL (1.063) and the highest ratio for DB (1.086). Interestingly, highest percent body fat occurred in OL and lowest in DB. Others reported PE-M/PE-NM ratios of 0.993 for obese adolescent boys (13), 1.019 for Berkley male college students (10), 1.055 for Eastern Oregon male college students (10), and 1.396 for professional male body builders (10).

The visual appraisal of body size and shape provides an additional valuable feature of the ponderal somatogram by expressing the deviation of each ponderal equivalent girth from the reference values (Table 9 and Figures 1–5). Generally, overdevelopment occurred in muscular components and underdevelopment in nonmuscular components (except OL abdomen). Interestingly, both OB and DB exhibited all positive deviations for the muscular component (overdevelopment) and all negative deviations for the nonmuscular component (underdevelopment). Professional male body builders exhibited this same pattern (10).

Practical Applications

Techniques for measuring body composition are well established, yet is remains a challenge to translate this data into a meaningful format. Somatograms help resolve this dilemma. The original Behnke or improved ponderal somatograms translate girth measurements into a visual representation of body size and shape easily understood by coaches and athletes. Somatograms track individuals or groups over time or compare individuals or groups for differences in anthropometric dimensions. We believe the somatogram approach provides a convenient visual appraisal of body composition differences that can help motivate athletes adhere to strength and conditioning programs and monitor the effectiveness of these programs.

Advantages of ponderal versus Behnke somatograms, include dividing 11 girth measurements into muscular and nonmuscular components and converting girth

measurements into PE values. PE values allow comparison of individual girth measurements to body mass; this provides an indication of overdevelopment (PE value > body mass) or underdevelopment (PE value < body mass) at a given girth site. The PE-M/PE-NM ratio estimates relative muscularity and adiposity, which has important health implications. Muscular individuals (or groups) have a PE-M/PE-NM ratio that exceeds 1.000, and obese individuals (or groups) have a PE-M/PE-NM ratio less than 1.000. For the latter, Healthy People 2010 (21) identifies obesity as a major public health concern in the United States. Overweight and obesity substantially increase the risk of hypertension, type II diabetes, heart disease, stroke, and other conditions. The ponderal somatogram approach can help to monitor overweight and obesity status in both nonathletes and athletes, especially in sports where a premium is placed on large body size as in football or power events in track and field (shot, discus, and hammer). The ponderal somatogram approach also could monitor changes in an athlete's body proportions for years (and decades) after their competitive seasons.

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