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

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

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 cm), 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

Authors
Kristin J. Stuempfe, Daniel G. Drury, David F. Petrie, and Frank I. Katch

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PONDERAL SOMATOGRAHS ASSESS CHANGES IN ANTHROPOMETRIC MEASUREMENTS OVER AN ACADEMIC YEAR IN DIVISION III COLLEGIATE FOOTBALL PLAYERS

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1Department of Health Sciences, Gettysburg College, Gettysburg, Pennsylvania 17325; 2Retired Santa Barbara, California and International Research Scholar, Faculty of Health and Sport, Agder University College, Kristiansand, Norway.

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 + k3)/ 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 (+3.3 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, 28). 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), win-
ter (January), and spring (May). Anthropometric measurements were used to construct pectoral somatograms that evaluate body size and shape by averaging muscular (shoulders, chest, hips, forearms, thigh), calf, and non-muscular (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 underdevelopment (negative deviation) at that location for a person (or group).

Subjects

Anthropometric characteristics were assessed in 56 Division III football players from Gannon College, Grafton, PA, a National Collegiate Athletic Association (NCAA) Division III school with a 12-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 13-week, 4-days weekly mandatory team strength and conditioning program from August through April. The program included upper extremity, lower extremity, and core weight training ex-

rsiones, upper and lower body plyometrics, agility drills, and flexibility exercises (see Tables 1 and 2).

Measures. Anthropometric measures included stature, body mass, selected girths, vital capacity, and body mass in water. All data on an individual were obtained on the same day. Height was measured using a standard structure to ± 0.1 cm, and body mass was measured on a balance beam to ± 0.05 kg. Girth measurements were taken by the same investigator throughout the study of the investigation using a calibrated cloth tape to ± 0.1 cm. The 13 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 an-

atomical landmarks for the muscular and nonmuscular girth sites were as follows:

Anatomical landmarks for muscular component:

- Shoulders: latissimus dorsi muscle of the deltoid and shoulder and, anteriorly at the prominence of the sternum at the junction of the second rib
- Chest: nipple line at midclavicular volume of respiration
- Hips: flexed: maximal girth with elbow flexed to 90°
- Forearm: maximal girth with elbow extended and hand epicondyle
- 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 lateral margins of the rectus and the umbilicus
- Abdomen 2 (umbilicus): laterally at the level of the iliac crest, and anteriorly at the umbilicus
- Hips: posteriorly at the maximal projection of the gluteal muscles, and anteriorly at the level of the symphysis pubis
- Knees: 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 extended
- Ankle: maximal 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 Micromedica metabolic cart. Residual lung volume was estimated from vital capacity (body temperature and pressure, saturated with water vapor [BTPS]) (residual lung volume = vital capacity × 0.21 according to Wilmore's data (31)) that showed close agreement between body composition measure-

ments using measured vs. estimated residual lung volume. Body mass in water was assessed by hydrostatic weighing in the seated position (49.9 ± 5.3 kg ± 30.8 kg aluminum tank. Subjects performed 10 successive under-

water weighing trials, with approximately a 1-minute rest interval among trials following procedures described previously (31). Ten repeated weighings being an aver-

age of the last 3 trials produced a true underwater weight score (14). For white players, percent fat was calcu-

lated with the Siri equation (29), where % fat = 445.9 - 10.8 H - 6.7 W, for black players, the Siri equation (24) was used where % fat = [447.6 - density of body water] × 0.943. The pondural somatogram. The pondural somatogram was used to describe the body profile (14). Muscular (shoulder) and nonmuscular (abdomen 1, abdomen 2, hips, knee, wrist, ankle) girth measurements were converted into pondural (or mass) equivalent values expressed in kg. This allowed compar-

isons of body shape and 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 measure-

ments. Percent deviation from the reference man or group for each girth measurement was calculated as follows (14):

PE kg = (girth, cm · kg/m² · stature, dm where L 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) weight 94 kg, if the person (or group) weight 80 kg, the person (or group) is overdeveloped in this region by 14 kg.

Pondural somatograms provided 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.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Reps</th>
<th>Sets</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squats</td>
<td>10</td>
<td>5</td>
<td>Barbell</td>
</tr>
<tr>
<td>Press</td>
<td>8</td>
<td>3</td>
<td>Dumbbells</td>
</tr>
<tr>
<td>Deadlifts</td>
<td>6</td>
<td>4</td>
<td>Weight plate</td>
</tr>
</tbody>
</table>

Table 2. Anthropometric measures.

<table>
<thead>
<tr>
<th>Site</th>
<th>Measurement</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder</td>
<td>Height</td>
<td>183 cm</td>
</tr>
<tr>
<td>Hips</td>
<td>Girth</td>
<td>40 cm</td>
</tr>
<tr>
<td>Knees</td>
<td>Distance</td>
<td>35 cm</td>
</tr>
<tr>
<td>Wrist</td>
<td>Girth</td>
<td>20 cm</td>
</tr>
<tr>
<td>Ankle</td>
<td>Girth</td>
<td>15 cm</td>
</tr>
</tbody>
</table>

Figure 1. Pondural somatogram for football players.
ter (January), and spring (May). Anthropometric measurements were used to construct pioral somatograms that evaluate body size and shape by comparing muscular (shoulders, chest, hips, forearm, thigh, calf) and non-muscular (abdomen, hips, knees, 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 underdevelopment (negative deviation) at that location for a person (or group).

Subjects

Anthropometric characteristics were assessed in 54 Division III soccer players from Frostburg College, Frostburg, PA, a National Collegiate Athletic Association (NCAA) Division III school with a 125-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 pre-season 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 August 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. 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 ± 0.1 kg. Girth measurements were taken by the same investigator throughout the study. Measurements were taken using a calibrated cloth tape to ± 0.1 cm. The 13 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 described.

Anatomical landmarks for muscular component:

- Shoulders: laterally at the maximum projection of the deltoid muscles, and anteriorly at the prominence of the sternum at the junction of the second rib
- Chest: nipple line at midlateral volume of respiration
- Hips: maximal girth with elbow flexed to 90°
- Forearm: maximal girth with elbow extended and hand maximally pronated
- 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 lateral margins of the rectus abdominis
- Abdomen 2 (umbilicus): laterally at the level of the iliac crest, and anteriorly at the umbilicus
- Hips: posteriorly at the maximal projection of the gluteal muscles, and anteriorly at the level of the symphysis pubis
- Knee: midpoint of the tibia, 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 extended
- Ankle: maximal girth, superior to malleoli

Prior to hydrostatic weighing, 3 trials of seated vital capacity (ambient temperature and pressure, saturated with water vapor [AETPD]) were determined according to manufacturer's directions using a Microlab metabolic cart. Residual lung volume was estimated from vital capacity (body temperature and pressure saturated with water vapor [BTPS]) residual lung volume = vital capacity × 0.205 according to Wilmore's data (33) 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 (n = 3) using a Polaris underwater scale and calculated with the Siri equation (33), where %fat = 495 × density - 848 for black players, the Siri equation (34) was used for white players, person fat = ± 848 for black players, the Siri equation (34) was used for white players, person fat = ± 848 for black players, the Siri equation (34) was used for white players, person fat = ± 848 for white players.

Pectoral Somatogram. The pectoral somatogram was used to describe the body profile (14). Muscular (abdomen 1, abdomen 2, hips, knees, wrist, ankle) girth measurements were converted to pectoral (or mass) equivalent values expressed in kg. This allowed comparison of the abdominal measurements with 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.

For each girth measurement was calculated as follows (14):

\[ \text{PE} = \frac{\text{girth, cm} \times \text{Kg} \times \text{cm}}{\text{ stature, cm}} \]

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) weight 94 kg. If the person (or group) weight 90 kg, the person (or group) is overweight in this region by 14 kg.

Pectoral 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

<table>
<thead>
<tr>
<th>Module</th>
<th>Exercise</th>
<th>Reps</th>
<th>Sets</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Squats</td>
<td>10</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>Lunges</td>
<td>15</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>Pushups</td>
<td>20</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>Bicep curls</td>
<td>12</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>Tricep dips</td>
<td>12</td>
<td>3</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 2. Anthropometric measurements

<table>
<thead>
<tr>
<th>Measurement Site</th>
<th>PE (kg)</th>
<th>PE (cm)</th>
<th>PE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdomen 1</td>
<td>85</td>
<td>80</td>
<td>10</td>
</tr>
<tr>
<td>Abdomen 2</td>
<td>75</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>Hips</td>
<td>65</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>Forearm</td>
<td>55</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Thigh</td>
<td>45</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>Calf</td>
<td>35</td>
<td>30</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 3. Siri equation constants

<table>
<thead>
<tr>
<th>Body Fat (%)</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>495</td>
</tr>
<tr>
<td>20</td>
<td>495</td>
</tr>
<tr>
<td>30</td>
<td>495</td>
</tr>
<tr>
<td>40</td>
<td>495</td>
</tr>
<tr>
<td>50</td>
<td>495</td>
</tr>
<tr>
<td>60</td>
<td>495</td>
</tr>
<tr>
<td>70</td>
<td>495</td>
</tr>
<tr>
<td>80</td>
<td>495</td>
</tr>
</tbody>
</table>

Figure 1. Pectoral somatogram for football players.
**Table 3.** Pyrotechnics program, agility drills, and flexibility exercises.

<table>
<thead>
<tr>
<th>Pyrotechnics program</th>
<th>Agility drills</th>
<th>Flexibility exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Callisthenics &amp; stretch</td>
<td>1 step drink over bags</td>
<td>Hip flexor stretch</td>
</tr>
<tr>
<td>Push-ups (floor)</td>
<td>2 step drink over bags</td>
<td>Hip flexor stretch</td>
</tr>
<tr>
<td>Jump-shots (floor)</td>
<td>2 step drink over bags</td>
<td>Hip flexor stretch</td>
</tr>
<tr>
<td>Jump-shots (on bags)</td>
<td>2 step drink over bags</td>
<td>Hip flexor stretch</td>
</tr>
<tr>
<td>Squats (male)</td>
<td>2 step drink over bags</td>
<td>Hip flexor stretch</td>
</tr>
<tr>
<td>Squats (female)</td>
<td>2 step drink over bags</td>
<td>Hip flexor stretch</td>
</tr>
<tr>
<td>Squats (male)</td>
<td></td>
<td>Hip flexor stretch</td>
</tr>
<tr>
<td>Squats (female)</td>
<td></td>
<td>Hip flexor stretch</td>
</tr>
</tbody>
</table>

**Muscular component girths:**

- **% Deviation**
  - (PE girth - average PE nonmuscular component) / average PE nonmuscular component × 100

**Nonmuscular component girths:**

- **% Deviation**
  - (PE girth - average PE nonmuscular component) / average PE nonmuscular component × 100

**Statistical Analyses**

One-way analysis of variance with repeated measures examined changes in anthropomorphic characteristics throughout the year. When statistically significant main effect results were obtained, Tukey-Kramer's post hoc test was used to assess where the differences occurred. Statistical significance was set at p < 0.05.

**RESULTS**

Table 4 presents the changes in body composition for the fall, winter, and spring testing, while Table 5 displays the proportional changes in girth measurements and proportional changes in girth measurements and proportional changes in girth measurements and proportional changes in girth measurements and proportional changes in girth measurements and proportional changes in girth measurements.

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Fall  (P)</th>
<th>Winter (W)</th>
<th>Spring (S)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass, kg</td>
<td>79.0 ± 1.9</td>
<td>79.0 ± 1.9</td>
<td>79.0 ± 1.9</td>
<td><em>&lt; 0.05</em></td>
</tr>
<tr>
<td>Fat-free mass, kg</td>
<td>71.5 ± 7.4</td>
<td>71.5 ± 7.4</td>
<td>71.5 ± 7.4</td>
<td><em>&lt; 0.05</em></td>
</tr>
</tbody>
</table>

**DISCUSSION**

The construction of a ponderal somatogram or body figure is a practical application of the relative representation of the body's mass-girth measurements. The ponderal somatogram (16) differs from the original Biehlke somatogram (21) in that 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 overdeveloped or underdeveloped girths at each girth location.

The ponderal somatogram (or Biehlke somatogram) quantifies the relative proportions of the body's girth dimensions, and charts changes in these physical dimensions as a function of time from such factors as training diet, dietary interventions, or influences of aging (16, 18). For example, changes in Dr. Biehlke's body profile over a span of 20 years have been published (17), and the ponderal somatogram can document changes during or after training from starvation, bed rest, disabling injury, or weightlessness (15, 16). The ponderal or Biehlke somatogram also can compare individuals or groups with the reference man, or reference woman, and permit quantification of differences in physique between individuals or groups (16, 18). For example, Biehlke somatograms have compared women with amenorrhea (6), and adolescent and prepubescent boys to the reference woman (17), while 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 position and performance test data for American football players at the professional (23, 24), college (25, 26), and Division III (27, 28) levels.

The few studies have reported body composition position and performance test results for football players at different time points throughout the season. Geitner et al. (29) 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 Kung (31) 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. (32) reported that performance in the power clean, bench press, squat, and squat jumped increased over a season in Division I football players participating in the team's strength and conditioning program. The present study documents longitudinal changes in the body composition of Division III football players. These findings are important, particularly, in that they assist in understanding the implications of using ponderal somatograms to track changes in body composition over a 3-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 ponderal somatograms, which quantifies the relative proportions of the body's girth dimensions, and charts changes in these physical dimensions as a function of time from such factors as training diet, dietary interventions, or influences of aging (16, 18).

The fall and winter seasons were characterized by increased training and competition, which resulted in increased body mass and fat mass. The spring season was characterized by decreased training and competition, which resulted in decreased body mass and fat mass. The fall-to-winter transition was characterized by increased training and competition, which resulted in increased body mass and fat mass. The winter-to-spring transition was characterized by decreased training and competition, which resulted in decreased body mass and fat mass.

**Table 5.** Proportional changes in girth measurements and proportional changes in girth measurements and proportional changes in girth measurements and proportional changes in girth measurements and proportional changes in girth measurements and proportional changes in girth measurements.

<table>
<thead>
<tr>
<th>Proportional change</th>
<th>Fall-Winter</th>
<th>Winter-Spring</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torso</td>
<td>0.0</td>
<td>0.0</td>
<td><em>&lt; 0.05</em></td>
</tr>
<tr>
<td>Arms</td>
<td>0.0</td>
<td>0.0</td>
<td><em>&lt; 0.05</em></td>
</tr>
<tr>
<td>Legs</td>
<td>0.0</td>
<td>0.0</td>
<td><em>&lt; 0.05</em></td>
</tr>
</tbody>
</table>

**Conclusions**

It is certain that more than body mass and fat mass changes may have occurred gradually from the August to January testing. It is certainly more than 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.

Additional 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 3. Physiological program, agility drills, and flexibility exercises.

<table>
<thead>
<tr>
<th>Physiological program</th>
<th>Agility drills</th>
<th>Flexibility exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall push-up</td>
<td>1-step squats over bags</td>
<td>Elevated stretch</td>
</tr>
<tr>
<td>Fast punishes</td>
<td>2-stop squats over bags</td>
<td>Hip flexion stretch</td>
</tr>
<tr>
<td>Cut over the line</td>
<td>2-step squats over bags</td>
<td>Hip flexion stretch</td>
</tr>
<tr>
<td>Push-up (no bags)</td>
<td>Squat jumps over bags</td>
<td>Glute stretch</td>
</tr>
<tr>
<td>Jump tasks</td>
<td>Jump squats over bags</td>
<td>Arm pull</td>
</tr>
<tr>
<td>Box jumps</td>
<td>Squat jumps</td>
<td>Hip flexion stretch</td>
</tr>
<tr>
<td>Squat jumps</td>
<td>Quick starts</td>
<td></td>
</tr>
</tbody>
</table>

Muscular component girths:

- % Deviation
  - (PE girth - average PE nonmuscular components) / average PE nonmuscular components × 100

Nonmuscular component girths:

- % Deviation
  - (PE girth - average PE nonmuscular components) / average PE nonmuscular components × 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 was conducted to assess where the differences occurred. Statistical significance was established at p < 0.05.

RESULTS

Table 4 presents the changes in body composition for the fall, winter, and spring testing, while Table 5 displays the percent change in girth measurements and percent change in body mass. From fall to winter, a significant increase occurred in body mass (+1.6%), percent fat (+1.3%), and fat mass (+1.6%). These body composition changes were matched by significant increases in the nonmuscular abdominal (+2.1 cm) and hips (+1.1 cm) girths. The abdominal and hips percentative equivalents also increased significantly during this time interval (+0.3% and +2.6%, respectively).

From fall to winter, percent fat (+1.3%) and fat mass (+1.4 kg) decreased significantly. This was accompanied by a significant decrease in the nonmuscular abdominal girth (-1.9 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 biomass girth (+0.4 cm) and hips percentoidal equivalent (+0.9 kg).

The ponderal somatogram components were generally overdeveloped (PF > body mass) in the football players in this study. The greatest overdevelopment occurred in the hips. In the fall, the hips ponderal equivalent (90.9 kg) was 14.7 kg greater than body mass (96.9 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 (PF < 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 abdominal ponderal equivalent (99.7 kg) was 6.8 kg greater than body mass (92.9 kg). This discrepancy increased to 10.8 kg in the winter and decreased to 7.9 kg in the spring.

Figure 1-3 displays the percent deviation from the reference man for each ponderal equivalent at the 3 testing times. Placing 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 hips (+17.9%), followed by the abdomen (+17.6%). Hip and abdominal values were less extreme in the spring. 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 (17.9%) increased to 4.6% in the winter, and decreased to 1.6% in the spring.

DISCUSSION

The construction of a ponderal somatagram or body profile is a practical application of the relative representation of the body's mass girth measurements. The ponderal somatogram (36) differs from the original Behnke somatogram (25) by separating the girth measurements into muscular and nonmuscular components, and by converting girth measurements into ponderal equivalents to allow comparison to body mass to indicate overdeveloped or underdeveloped 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 dimensions as a function of time from such factors as training dietary intervention, or influences of aging (34, 38). For example, changes in Dr. Behnke's body profile over a span of 26 years have been published (17), and the ponderal somatograms can document changes during or after training from starvation, bed rest, disability injury, or weightlossanesthesia (34). The ponderal or Behnke somatogram can also compare individuals or groups with the reference man, or reference woman, and permit quantification of differences in physique between individuals or groups (34, 35). For example, Behnke somatograms have compared women with amenorrhea (4), and adolescent and professional football players to the reference woman (7). While with Hispanic women (22), and somatographic differences between obese and nonobese individuals (35). In the present study, ponderal somatograms tracked changes that occurred in the body profile of Division 1 football players over the course of an academic year. Numerous studies have been published describing body composition position and/or performance test data for American football players at the professional (22, 23), Division I (22, 23), Division II (1, 10, 29), and Division III (23, 29) levels. Few studies have reported body composition position test results for football players at different time points throughout the year. Connor et al. (4) reported that body composition, cardiopulmonary 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 Huffman and Kamps (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 in 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 I 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 is certainly 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. Table 5 also reveals 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 biomass 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 Gotten et al. (4), who reported that body composition in professional football players improved significantly following a 14-week preseason strength and conditioning program (12).

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 (PF > body mass) or underdeveloped (PF < body mass) compared to the muscular ponderal equivalent values in Table 4 (1). In general, the muscular components of the ponderal somatogram were underdeveloped, while the nonmuscular components were overdeveloped. As an example of the usefulness of ponderal somatograms, Table 5 provides body composition values for athletes with a relatively high degree of size and strength. The biopsy exhibited the greatest overdevelopment of the muscular components. In the fall, the hips ponderal equivalent value was 107.2 kg, meaning that the football players had hips of a girth that weighed 107.2 kg. Body mass averaged only 90.9 kg, indicating the players had overdereveloped hips by 14.7 kg. This extent of overderevelopment was maintained in the winter (+14.9 kg) but increased to 17.4 kg in the spring testing following the mandatory team strength and conditioning program. This was not unexpected because hip circumference 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 an abdominal girth of a group that weighed 99.7 kg. The actual body mass averaged only 90.9 kg, indicating players were overdereveloped in the abdominal region by 60 kg. This overderevelopment increased to 10.8 kg in the winter testing, but decreased to 7.6 kg in the spring testing following the mandatory team strength and conditioning program. Above, these findings are similar to Gotten et al. (4), who reported a decrease in percent body fat in American professional football players following a 14-week preseason strength and conditioning program (12).

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-
Figure 1. Ponderal somatogram for fall 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 too common for a plethora of body composition measurements to be taken, only to be lost as meaningless data in the file cabinet 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 hip component) also can graphically monitor the "obesity status" of individuals, of which course has important health implications.

REFERENCES

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

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

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REFERENCES


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