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Characterization of Obesity in the Prader-Labhart-Willi Syndrome: Fatness Patterning

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Abstract

A multidisciplinary study involving cytogenetic, clinical, and anthropometric assessments of Prader-Labhart-Willi Syndrome (PLWS) has focused on improving diagnosis and prognosis in this complex condition. Since one of the major features of PLWS is obesity, 7 of the 26 measurements in the anthropometric evaluation were skinfold thicknesses at different body sites. Forty individuals with PLWS have been assessed. *Z*-scores were computed for skinfold measurements to examine quantitative differences for fatness at different sites. Data on PLWS individuals, grouped by age, sex, and chromosome type, were compared with normative data for skinfolds. The results suggest that males with PLWS have three times the fatness scores of other males their age, while scores for PLWS females average only twice those of normals. Our research illustrates the utility of anthropometry in the evaluation of patients in clinical genetics and offers a comprehensive approach to the heterogeneity observed in PLWS.

Anthropometric methods have been applied increasingly in the clinical evaluation and diagnosis of individuals with genetic disorders and other dysmorphic conditions. Meaney and Fairer (1986) have reviewed more than 40 hereditary and congenital disorders for which published anthropometric data are now available. One of these conditions is Prader-Labhart-Willi syndrome (PLWS), an obesity disorder that has received attention during the 1980s following the discovery of a chromosome deletion in some PLWS individuals.[1] Our current research focuses on the development of obesity in PLWS and attempts to characterize the patterning of fatness in afflicted individuals through a comprehensive assessment of skinfold measurements at several standard body sites.

More than 700 cases of PLWS have been reported in the literature since the disorder was first described by Prader and his colleagues (1956). Later Zellweger (1979, 1981) described two phases in the development of the syndrome. The first may begin at the age of a few months to two years, with the following early diagnostic features: decreased muscle tone

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[1]Deletions occur during cell division when there is breakage of a chromosome and subsequent loss of a part. The resulting "new" chromosome is structurally abnormal and lacks whatever genetic information was present in the lost portion of the chromosome. In PLWS, it has been demonstrated that 50–60% of individuals with the condition have a deletion in the long arm of chromosome 15 (Butler and Palmer 1983; Ledbetter et al. 1981).

(hypotonia) and feeding problems (and usually failure-to-thrive). In PLWS males, micropenis, underdeveloped scrotum, and undescended testicles are also included. The second phase of PLWS, as described by Zellweger, includes obesity with accompanying reports of excessive eating, mental deficiency, behavioral problems, short stature, small genitalia and gonads (hypogonadism), muscular hypotonia, a characteristic face, and retardation in the growth of the hands and/or feet. Recently, however, Butler, Butler, and Meaney (1988) provided evidence that obesity in PLWS infants, as judged by skinfolds, may occur earlier than previously thought, despite reduced caloric intake. The PLWS infants followed by Butler and his colleagues achieved obesity before they were considered heavy by weight-for-length criteria.

How obesity manifests itself during childhood and adolescence and into childhood in PLWS individuals has not been investigated to date through comprehensive, longitudinal anthropometric evaluation. Some of the early clinical reports for the disorder suggested that subcutaneous fat is deposited chiefly on the trunk, buttocks (Dunn 1968; Evans 1964; Pipes and Holm 1973; Zellweger and Schneider 1968), and proximal parts of the limbs. Zellweger (1979) qualified this assessment by adding that the forearms and lower legs also become obese in some children. In general, however, fatness distribution in PLWS individuals has merely been described impressionistically by clinicians as atypical, or unusual, or as resembling the distribution of adipose tissue in females (Holm and Pipes 1981). Few clinical studies have incorporated skinfold assessments of PLWS individuals. We report here the first comprehensive assessment of skinfolds and fatness patterning in a clinical population of PLWS individuals.

Materials and Methods

Forty individuals diagnosed with PLWS were assessed clinically and anthropometrically by a multidisciplinary biomedical research group consisting of cytogeneticists, clinical geneticists, pediatricians, and an anthropometrist trained in biological anthropology and medical genetics. Diagnosis of subjects was based on the following specific criteria: infantile hypotonia, hypogonadism, delayed developmental milestones and/or mental retardation, early childhood obesity, small hands and feet, and short stature. The clinical population consisted of 23 males and 17 females ranging in age from 2 weeks to 39 years at time of first examination. Anthropometric and clinical assessments of 16 of the 40 PLWS individuals have been made on more than one occasion.

All measurements were carried out by one of the authors (F. J. M.) according to standard techniques (Cameron 1984; Weiner and Lourie 1969). The anthropometric evaluation consisted of 26 measurements in total, including skinfold thicknesses at seven body sites: triceps, forearm, subscapular, abdomen, suprailiac, thigh, and medial calf. In addition, medical histories, hand x-rays, hand and foot prints, and blood for chromosome tests were obtained. Analyses of these data have been reported elsewhere (Butler and Meaney 1985; Butler, Meaney, and Palmer 1986; Reed and Butler 1984). Of the 40 PLWS individuals, 23 (58%) were found to have a deletion of the proximal long arm of chromosome 15 (Butler and Meaney 1987).

For certain analyses of the skinfold data, measurements were converted to *Z*-scores to control for age and sex effects.[2] *Z*-score variables were then plotted against age to determine whether there was any residual effect of age. Correlations were computed for each of the comparisons between a *Z*-score variable and age. The raw skinfold measurements were plotted against standards obtained from available published sources for those skinfolds. PLWS individuals, grouped by results of chromosome analysis (deletion versus non-deletion)[3] and sex, were compared using percent change from the overall mean, and results were then plotted. These group comparisons matched for age and sex in the chromosome group and for age and chromosome status in the sex comparisons. Percent body fat was determined by using either the triceps alone or triceps and medial calf skinfolds as predictors.

Results

A summary of the average *Z*-scores for skinfold thicknesses in PLWS individuals is shown in Table 1. Also shown for comparison are the *Z*-scores for height and weight. The highest mean *Z*-score is for the medial calf skinfold, and the triceps skinfold has the lowest average value. Unfortunately, standards are not available for skinfold measurements covering the full age range of individuals for all skinfold sites (Jackson, Pollock, and Ward 1980; Lohman 1981; Malina and Roche 1983; National Center for Health Statistics 1970, 1972, 1974, 1977; Tanner and Whitehouse 1975).

Correlation values of the *Z*-scores for height, weight, and triceps and subscapular skinfolds with age (Meaney and Butler 1988) reveal a negative correlation between the height *Z*-score and age, suggesting a relative slowing down of linear growth compared with normal individuals. There was no tendency for weight or skinfolds to increase or decrease relative to age, as shown by a lack of correlation between the respective *Z*-scores and age.

Figure 1 shows the raw values for triceps and subscapular skinfolds, plotted against standards for these measurements (National Center for Health Statistics 1970, 1972, 1974; Tanner and Whitehouse 1975). Individuals with PLWS are characteristically unable to exert self-control over food intake, and thus strict intervention is required to achieve any control over developing obesity. As may be seen in the figure, the triceps skinfold measurements for PLWS individuals fall almost consistently above the 90th percentile after age three. Exceptions include several males whose dietary intakes had been strictly controlled, as well

[2] *Z*-scores are used so that subjects (Ss) of different ages and sex may be compared in standard units. They are computed as follows for each measurement:

$$\frac{(\text{observed value for each S}) - (\text{expected value for normal Ss of same age and sex})}{\text{SD from table of appropriate anthropometric standards}}$$

A subject's measurement is thus expressed as a ratio of the difference between his or her measurement and the mean value for his or her age and sex to the appropriate standard deviation. Individual *Z*-scores will have values either greater than or less than zero unless, of course, the subject's measurement is the same as the mean value for his or her age and sex.

[3] A PLWS individual was placed in the deletion subgroup if it was determined in high-resolution microscopic studies of chromosome 15 that the individual was missing bands q11–q13 of chromosome 15. Nondeletion individuals were those who demonstrated no cytogenetically detectable deletion.

as several teenage and adult females whose diets were similarly well controlled. The results for subscapular skinfold are similar to those for triceps. Plots of medial calf (Malina and Roche 1983), abdomen (Jackson, Pollock, and Ward 1980;Lohman 1981; Malina and Roche 1983), suprailiac (Jackson, Pollock, and Ward 1980; Lohman 1981; Malina and Roche 1983), and forearm (Malina and Roche 1983) skinfolds repeat this pattern (Figures 2 and 3).

Figure 4 displays an anthropometric profile indicating the percent difference from the overall mean comparing the PLWS individuals grouped by chromosome status. The deletion group consisted of 15 PLWS individuals (9 males and 6 females) with an average age of 12.2 years and age range of 2.2–22.8 years. The nondeletion group consisted of 15 PLWS individuals (9 males and 6 females) with an average age of 11.9 years and age range of 2.5–25.0 years. No clear pattern emerges from these data. A discriminant analysis utilizing the full set of anthropometric *Z*-scores also failed to detect differences between the deletion and non-deletion groups.

The anthropometric profile for percent differences from the overall mean for 14 PLWS males (average age, 13.3 years; age range of 2.5–23.6 years) versus 14 PLWS females (average age, 13.7 years; age range of 2.6–22.8 years) does reveal a pattern, however (Figure 4). First of all, males are consistently larger on all dimensions, including each of the skinfolds. Male-female differences are greatest for limb skinfold thicknesses (e.g., average triceps skinfold in our PLWS males is 27.5 mm and 25.9 mm in females, while the average for normal males is 9.4 mm and 12.7 mm for normal females at 13 years of age—National Center for Health Statistics 1974) and least for the three truncal sites. The pattern is similar for the circumferences but not as accentuated.

An equation for the prediction of percent body fat in adults (defined as > 18 years of age) based on triceps skinfold thickness alone (Schemmel 1980) estimates a mean of 29.0% body fat for a group consisting of five males (average age, 24.9 years) and four females (average age, 24.6 years), with a range of 19 to 38.5 years of age for the total group. For the four females, the mean estimated percent body fat was 37.5, while in the males it was 22.3. Using an equation for the prediction of percent body fat in children 8–18 years of age based on both triceps and medial calf skinfolds (Slaughter et al. 1988), we found the mean estimate for percent body fat to be 47.0 for a group consisting of 12 males (average age, 13.0 years) and 8 females (average age, 14.3 years). The age range for this second group was from 7.5–18.2 years of age. The mean estimated body fat of the 12 males was 50.8%, while in the females it was 41.5%. The mean estimated percent body fat for the total of 29 PLWS individuals was 41.5 (42.4% for the 17 males and 40.2% for the 12 females).

Discussion

The *Z*-score variables for skinfolds demonstrate abnormally high values for the seven assessed body sites. The results for skinfolds in this sample of PLWS individuals certainly support the reported clinical observations of heavy deposition of subcutaneous fat in the truncal region and in the limbs. In this group of PLWS individuals the skinfold thickness at the medial calf has the largest *Z*-score value (6.01), thus supporting Zellweger's observation (1979) of excess fatness in the distal limbs of some individuals with the disorder.

The sex differences for fatness that have been observed in this clinical population of PLWS individuals are intriguing. In the matched comparison between PLWS males and females for skinfolds and circumferences, males are consistently larger than females on all measurements, a striking contrast to normals, among whom females have larger skinfolds than males even before puberty (National Center for Health Statistics 1970, 1972, 1974). Comparisons with normative data for skinfolds suggest that our PLWS males have fatness scores (e.g., average triceps skinfold of 27.5 mm) averaging three times those for normal males of their age (average triceps skinfold is 9.4 mm for 13-year-old males, according to National Center for Health Statistics figures [1974]), while females with PLWS (e.g., average triceps skinfold of 25.9 mm) average two times higher than the standards for normal females (average triceps skinfold of 12.7 mm for 13-year-old females [National Center for Health Statistics 1974]). Sex differences in PLWS are especially pronounced in the limbs, particularly the distal limbs, and are less apparent in measures of truncal fat.

The explanation for the larger skinfold measurements in males with PLWS compared with females is not clear, although it may be due to a hormone imbalance. Clinically, PLWS individuals have delayed sexual development, small gonads, and decreased testosterone levels in males. This hormone abnormality, along with decreased physical activity, may interfere with muscle growth and subsequent loss of subcutaneous fat which normally occurs in adolescent boys. Possibly, PLWS males may be more efficient at fat deposition with subsequently larger skinfold measurements than normal individuals, but additional research is needed with a larger sample size at various ages to confirm the atypical fatness pattern seen in these PLWS individuals.

Levels of adipose tissue lipoprotein lipase, an enzyme that regulates uptake and storage of triglycerides, were tenfold higher in fat biopsy specimens from seven PLWS patients compared with control individuals when adjusted for percent ideal body weight and fat cell size (Schwartz, Brunzell, and Bierman 1981). Thus, this enzyme is apparently elevated in PLWS individuals, but again additional research is needed, this time to determine whether the elevation is a primary defect or a response to other metabolic derangements. Recently, derangements of steroid metabolism in PLWS were reported by Chasalow et al. (1987), but these abnormalities and their role, if any, in the clinical manifestations seen in PLWS individuals (e.g., obesity, mental deficiency, small gonads) are not understood.

The overall body fat estimate is 41.5% for 29 PLWS individuals in this study. This value is considerably lower than the 52% total body fat reported by Nelson et al. (1981) in a study of the body composition of seven individuals with PLWS, though Nelson and his colleagues also reported that some children with PLWS had more than 60% of their body weight containing adipose tissue. Values of 60% are among the highest reported for obese individuals (Nelson et al. 1981).

The use of anthropometric measurements like skinfolds to predict body fatness is not without problems and limitations, as reviewed recently by Lohman (1988). The problem may be compounded when equations based on a sample of normal subjects are used to predict body fatness in obese individuals. By using prediction equations based on one or two skinfolds, we are probably underestimating body fatness in our subjects, especially in the

adult PLWS individuals, for whom triceps skinfold alone was used as a predictor of total body fat. Among the PLWS individuals in our study, triceps skinfold had the lowest mean *Z*-score value of all skinfolds and thus may be a poor predictor of total body fat in PLWS, since we observed more aberrant subcutaneous fat deposition at other body sites. The equation based on triceps and medial calf in 8–18-year-old subjects produced values for total body fat that were closer to those reported by Nelson et al. (1981). These estimates may reflect body fatness in PLWS more accurately, since the medial calf skinfold had the highest mean *Z*-score among the seven skinfold sites. The estimates of body fatness reported here, however, represent initial attempts to study body composition in our clinical population of PLWS individuals. Further studies are planned using prediction equations that include other measurements such as circumferences and skeletal breadths.

No differences in anthropometric measurements have been substantiated between the deletion and nondeletion subgroups of PLWS individuals (Meaney and Butler 1988). Larger surveys of PLWS individuals, longitudinal studies, and DNA investigations to characterize the chromosome 15 deletion will be required before any final conclusions are reached concerning clinical and anthropometric differences between the two chromosome subgroups, however. Research in progress using DNA probes for bands q11–q13 on chromosome 15 to confirm the deletion may eventually offer an opportunity to study the size of the deletion in relation to clinical and anthropometric findings. It is hoped that further collaborative efforts between cytogeneticists, molecular geneticists, clinicians, and anthropometrists will eventually solve the problem of heterogeneity in both this disorder and other genetic diseases.

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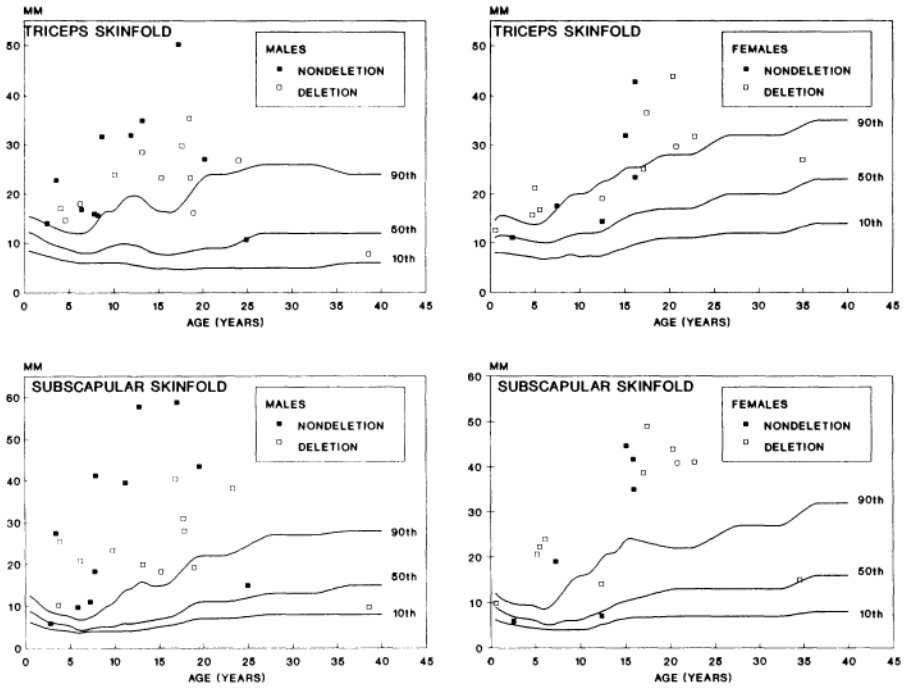

Figure 1.

Triceps and subscapular skinfold measurements in male and female deletion and non-deletion PLWS individuals plotted on standardized curves (National Center for Health Statistics 1970, 1972, 1974; Tanner and Whitehouse 1975).

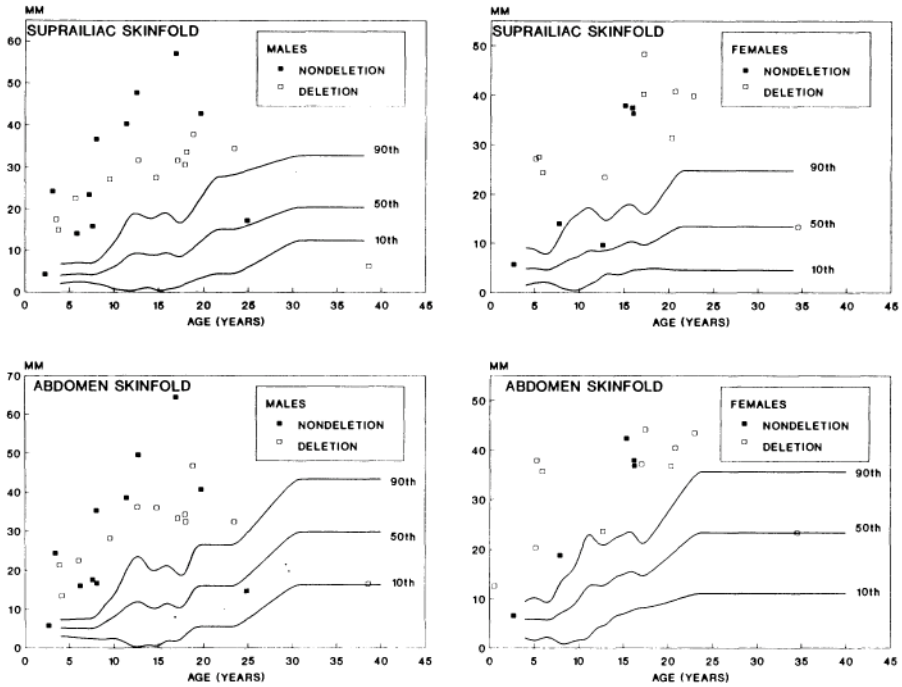

Figure 2.

Suprailiac and abdomen skinfold measurements in male and female deletion and non-deletion PLWS individuals plotted on standardized curves (Jackson, Pollock, and Ward 1980; Lohman 1981; Malina and Roche 1983).

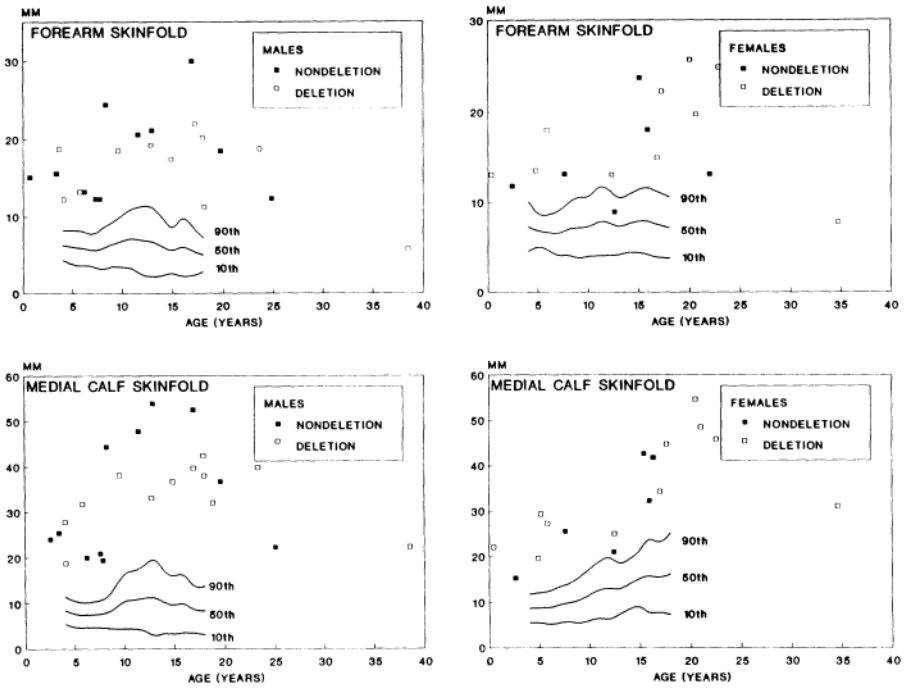

Figure 3.

Forearm and medial calf skinfold measurements in male and female deletion and non-deletion PLWS individuals plotted on standardized curves (Molina and Roche 1983).

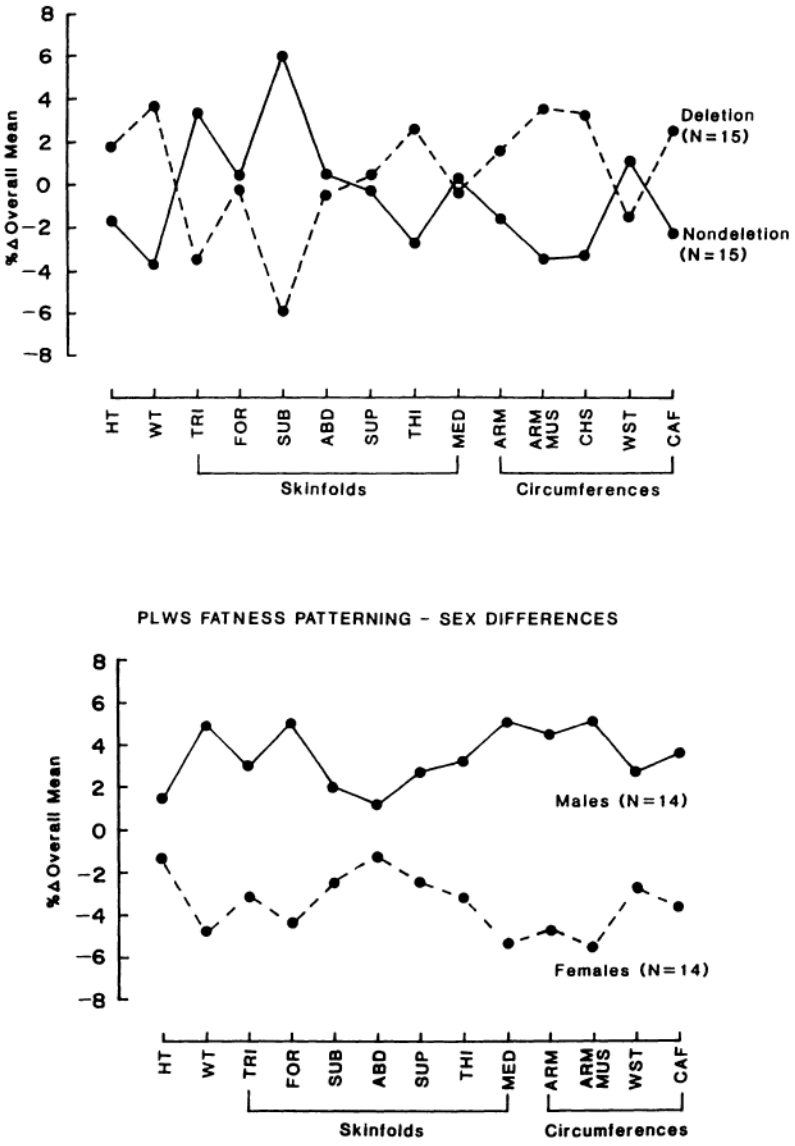

Figure 4.

Anthropometric profile indicating percent difference from overall means for chromosome groups (deletion and nondeletion), matched for sex and age, and for sex differences (males and females), matched for age and chromosome group.

Table 1

***Z*-score means, ranges, and standard deviations for height, weight, and skinfolds in Prader-Labhart-Willi Syndrome**

Variable	Males *(N)*	Females *(N)*	Mean range	SD
Height	23	17	−2.17 (−4.77–0.79)	1.32
Weight	23	17	1.96 (−2.66–10.83)	2.89
Triceps skinfold	23	17	2.44 (−0.40–8.10)	1.61
Subscapular skinfold	23	17	3.45 (−1.30–12.24)	2.94
Abdomen skinfold	21	14	4.97 (−0.10–19.02)	4.22
Suprailiac skinfold	21	15	5.69 (−1.67–18.98)	4.07
Medial calf skinfold	20	11	6.01 (1.29–15.89)	3.24
Forearm skinfold	17	10	4.92 (0.41–10.37)	2.34
Thigh skinfold	8	4	4.62 (0.29–9.70)	2.55