Evidence for Under Nutrition in Adolescent Females using Routine Dieting Practices

Running Title: Under Nutrition in Dieting Adolescent Females

Jade Guest,[1] MPH; Ayse Bilgin,[2] PhD; Robyn Pearce,[3] PhD; Surinder Baines,[4] PhD; Carol Zeuschner,[5] MSc; Corilda Le Rossignol-Grant,[1] DipNursing; Margaret J Morris,[6] PhD; Ross Grant,[1, 6]* PhD

1. *Australasian Research Institute, Sydney Adventist Hospital, 185 Fox Valley Rd, Wahroonga, NSW, 2076 Australia.*
2. *Dept. Statistics, Macquarie University, Nth Ryde, NSW 2109 Australia*
3. *Faculty of Education, Avondale College, Cooranbong, NSW, 2265 Australia.*
4. *School of Health Sciences, Faculty of Health, University of Newcastle, Callaghan, NSW, 2308 Australia.*
5. *Dept. Dietetics, Sydney Adventist Hospital, 185 Fox Valley Rd, Wahroonga, NSW, 2076 Australia.*
6. *School of Medical Sciences, Faculty of Medicine, University of New South Wales, Sydney, NSW, 2052 Australia.*

*Corresponding author Dr Ross Grant, *Australasian Research Institute, Sydney Adventist Hospital, 185 Fox Valley Rd, Wahroonga, NSW, 2076 Australia*, email: rossg@sah.org.au Telephone: +612 94879602, Facsimile: +612 9487 9626.

Author Contributions:

Jade Guest: jade.guest@sah.org.au
Analysis and interpretation of data, Drafting of the manuscript, Critical revision of the manuscript for important intellectual content, Administrative, technical, and material support.

Ayse Bilgin: bilgina@efs.mq.edu.au
Acquisition of data, Analysis and interpretation of data, Statistical expertise, Critical revision of the manuscript for important intellectual content.

Robyn Pearce: robyn.pearce@avondale.edu.au
Study concept and design, Acquisition of data, Critical revision of the manuscript for important intellectual content.

Surinder Baines: surinder.baines@newcastle.edu.au
Analysis and interpretation of data, Critical revision of the manuscript for important intellectual content, Administrative, technical, and material support.

Carol Zeuschner: carol.zeuschner@sah.org.au
Study concept and design, Critical revision of the manuscript for important intellectual content.

Corilda Le Rossignol-Grant: corilda@sah.org.au
Acquisition of data, Critical revision of the manuscript for important intellectual content, Administrative, technical, and material support.

Margaret J Morri: m.morris@unsw.edu.au
Analysis and interpretation of data, Critical revision of the manuscript for important intellectual content, Obtained funding, Study supervision.

Ross Grant: rossg@sah.org.au
Study concept and design, Acquisition of data, Analysis and interpretation of data, Drafting of the manuscript, Critical revision of the manuscript for important intellectual content, Obtained funding, Study supervision.

ABSTRACT

In Western countries the increasing prevalence of obesity in young people is a major public health concern. While the focus has been on reducing obesity, paradoxically the success of these campaigns may result in unhealthy nutritional practices. The aim of this study was to investigate the use and impact of weight control techniques on the health of adolescent females. Using Analysis of Variance we compared physiological and biochemical markers of health against responses to a modified, Schools Physical Activity and Nutrition Survey (SPANS) in 482 adolescent females (14-17yrs) from secondary schools in the northern Sydney and Central Coast regions of New South Wales, Australia. Participants who '*often*' used weight control methods had, on average, a healthy BMI of 22.5 (σ=3.7). However, comparison of blood derived markers between participants who *'never', 'occasionally' or 'often'* used weight reduction techniques showed that, those who '*often*' used weight control methods had significantly lower haemoglobin (p<0.05), alkaline phosphatase (p<0.001), bilirubin (p<0.05), albumin (p<0.05), total protein (p<0.05), and calcium (p<0.05), but higher blood levels of creatinine (p<0.05) and potassium (p<0.05). These data suggest that the use of common weight control techniques by healthy weight adolescent females can produce a metabolically divergent group whose biochemical markers are consistent with subtle levels of chronic under-nutrition.

KEYWORDS

Adolescent, nutrition, diet fads, BMI, alkaline phosphatase

INTRODUCTION

In Western countries the increasing prevalence of obesity in young adults is a major public health concern due to its role in the pathophysiology of conditions such as metabolic syndrome and type 2 diabetes.[1, 2] While the focus has been on reducing obesity, paradoxically the success of these campaigns may result in the use of unhealthy nutritional practices. A number of studies conducted internationally have shown that a substantial percentage of healthy-weight adolescent females regard themselves as overweight.[3-5] Considering oneself as overweight has been shown to correlate with low self esteem and body dissatisfaction.[6, 7] Body image perceptions are influenced by a number of factors, but have been consistently linked to the development of unrealistic ideals of beauty. Such ideals are readily integrated into the psyche due to widespread media portrayals, and may be amplified by the pressures and perception of family and peers.[8-11] In order to reach the ideal standard of beauty, many adolescent females who are dissatisfied with their bodies commonly resort to the use of weight control techniques.[3-6, 12-15]

Weight control techniques reported to be employed by teenagers include dieting, excessive exercise and purging via either laxative misuse or vomiting, as well as the use of diet pills, cigarettes and caffeine.[4] Abraham found that in an effort to control or reduce weight 48% of young Australian women restricted their food intake whilst 7% reported the use of self-induced vomiting, 2% reported laxative misuse and 15% reported excessive exercise. A further 14% reported smoking cigarettes or drinking coffee to control their weight.[3] The

practice of dieting, and other weight control techniques as described above may compromise the health of users and lead to eating disorders such as anorexia nervosa.[16]

The physiological injury caused by the extreme malnutrition in disorders such as anorexia nervosa has been well documented.[17-22] In such disorders most, if not all, body systems are adversely affected.[19] However metabolic dysregulation may be occurring in individuals with more subtle levels of under-nutrition. Benzera et al reported that persons on a carefully planned, energy controlled diet had a reduced intake of calcium, zinc, iron and vitamin E.[23] Fogelholm et al also showed that "yo-yo" dieting can cause adverse effects on bone density and mineralisation in premenopausal women.[24] Turner et al reported similar results, observing that adolescent females with a diet-related disorder were at risk of low bone density.[25]

During adolescence when height should increase by approximately 25% and weight should almost double, the deprivation of essential nutrients may impact negatively upon sexual maturation, skeletal mineralisation and overall growth.[21] Therefore a chronic reduction in overall energy and nutrient intake by adolescents is a potential cause for reduced cellular metabolism leading to growth impairment. This may occur even within the community's normal spectrum of dieting practices. With evidence that eating patterns established in youth persist into adulthood,[26] this presents a worrying trend for the high percentage of Australian adolescent females that report the use of weight control techniques.[3-6, 12-15]

Few studies have investigated the physiological/biochemical consequences of healthy weight females utilising weight control techniques, particularly in the Australian female adolescent population. This study therefore aimed to investigate the physiological health profile of a cohort of 14-17 year old females attending schools within the northern Sydney and Central Coast regions who self reported regular use of weight control techniques.

MATERIALS & METHODS

Participants.

As part of a wider diet and lifestyle study females aged 14-17yrs were recruited from seven schools in the northern Sydney and Central Coast regions of Australia,. This study was approved by the Sydney Adventist Hospital Human Research Ethics Committee (SAH HREC) number 04/07.

All subjects considered themselves to be in general good health at the time of the study. The total sample size for this study was 482.

Exclusions.

Participants were not actively prevented from participating in the study. However on the basis of responses to the questionnaire, participants with diabetes or those on lipid or cholesterol lowering medications were excluded during data analysis.

Sample collection.

Between 08:00am and 10:30am on the morning of the study, fasting blood samples were collected via normal venipuncture.

Serum samples for biochemical analyses were stored at -80^{o}C until analysis. Whole blood samples for haemoglobin and red cell quantitation were analysed within 4 hours of collection. All assays were performed by the pathology department at the Sydney Adventist Hospital using routine methods.

Height .

Height was measured using a standard height bar after participants had removed their shoes.

Fat Mass, Muscle Mass and Weight.

Fat mass, muscle mass and weight were measured using the Tanita Body Composition Analyser model BC420-MA. This system measures fat and muscle mass based on the principles of bioelectrical impedance, a validated measure of body composition.[27-29] Weight was measured to point one of a kilogram, with light clothing and no shoes. To account for clothing, 500 g was deducted from the weight of each participant.

Body mass index (BMI).

BMI was calculated using the standard formula of net weight in kg divided by the height in meters squared.

Waist circumference.

The waist circumference of each participant was measured midway between the top of the ileac crest and the lowest rib using a standard tape measure.

Hip circumference.

The hip circumference of each participant was measured around the largest portion of the buttocks using a standard tape measure.

Weight Control Behaviours.

Self reports of weight control methods were obtained using a modified version of Booth et al NSW Schools Physical Activity and Nutrition Survey (SPANS).[30] This survey contained specific questions relating to the use of weight control behaviours and body perception. The section of the SPANS survey relating to fundamental movement skill proficiency was not used.

Specific questions defining weight control behaviour included; *'a) do you ever skip meals in order to lose weight, b) do you ever make yourself sick (vomit) in an attempt to manage your weight and c) how often do you diet; that is deliberately control how much you eat in order to keep your weight the same or lose weight?'*

Data Analysis.

Comparisons between weight control technique groups were performed by using a parametric analysis of variance (ANOVA) and a non-parametric Kruskal-Wallis test. Although 95% confidence intervals are only meaningful when a variable is normally distributed we have presented all the means and 95% confidence intervals for simplicity of the presentation regardless of whether parametric or non-parametric tests were performed (Table 3 and Table 4). For comparison of categorical variables chi-square tests were used. The statistical significance levels are reported as significant at the 5% ($p<0.05$), 1% ($p<0.01$), 0.1% ($p<0.001$) and highly significant ($p<0.000$) levels. The statistical analyses were performed using SPSS 16.0 for Windows.

RESULTS

Body perception.

The majority of participants reported being '*a fair bit'* or '*very much'* happy with their weight (86%), body shape (91%) and fitness levels (91%) (Table 1).

Weight Control Behaviours.

Of the 482 participants surveyed, 7% reported using self induced vomiting to control or reduce their weight, with 1% of participants reporting their use of this technique as '*often'*. Dieting was practiced by 54% of participants, with 11% of participants reporting their use of

this technique as '*often*'. 28% of participants surveyed reported skipping meals to control their weight, with 3% of participants using this weight control behaviour '*often*'.

Body Perception and the use of Weight Control Techniques.

We found a significant association between body shape satisfaction and frequency of weight control method use ($p<0.001$). Forty percent (40%) of participants who were *'a fair bit'* to '*very much'* satisfied with their body shape reported using weight control methods. In comparison 77% of participants who were dissatisfied with their body shape reported using weight control methods. (Table 2)

We also observed a significant association between body weight satisfaction and frequency of use of weight control methods . Thirty nine percent (39%) of the participants who reported feeling *'a fair bit'* to '*very much'* satisfied with their weight reported using weight control methods compared to 79% of participants who were not satisfied with their body weight ($p<0.001$, Table 2).

No significant association was found between participant level of satisfaction with their fitness level and frequency of weight control method use ($p=0.075$).

BMI and Body Perception.

The participants who were not satisfied with their body shape had a higher BMI (mean=23.6, $\sigma=4.1$) than participants who were *'a little bit'* to *'somewhat'* satisfied (mean=22.0, $\sigma=3.4$) or '*a fair bit'* to '*very much'* satisfied (mean=20.3, $\sigma=2.7$) with their body shape. Differences in BMI between these categories were significant (Kruskal-Wallis; $p<0.001$). Similar results were obtained for the satisfaction with weight categories where the average BMI declined from 24.3 ($\sigma=4.1$) to 21.8 ($\sigma=3.3$) and then 19.8 ($\sigma=1.9$) (Kruskal-Wallis; $p<0.001$); and for

the satisfaction with the fitness level categories where the average BMI declined from 23.1 (σ=4.5) to 21.8 (σ=3.5) and then 20.5 (σ=2.3) (Kruskal-Wallis; p<0.001).

Morphological and Physiological Markers.

Participants who *'never'* used weight control methods had lower BMI, WHR, fat mass, muscle mass and fat to muscle ratio compared to the participants who used weight control methods '*occasionally'* and '*often'* (Table 3). There was considerable overlap between confidence intervals (CI) of those who used weight control methods '*occasionally'* and '*often'* (Table 3). The prevalence of overweight and obesity within this sample was 12.3% and 1.3% respectively based on the CDC 2000 BMI age specific percentile charts.[31]

Blood Derived Health Markers.

To investigate the impact of weight control behaviours on biochemical health we looked at differences in blood derived health markers between those who '*never', 'occasionally' or 'often'* used weight control techniques.

Participants who used weight control methods '*often'* had significantly lower blood levels of haemoglobin, alkaline phosphatase (ALP), bilirubin, albumin, total protein and calcium, but higher blood levels of creatinine and potassium (Table 4). The largest differences were observed in ALP (95 IU/L for 'often' vs 124 IU/L for 'never') and bilirubin (9.7 μM for 'often' and 12.3 μM for 'never'). Overlap was observed between confidence intervals (CI) of those who used weight control methods '*occasionally'* and '*often'*.

DISCUSSION

In this study the average BMI of the sampled population was within the healthy range (16.8-24.8).[31, 32] However, those with higher BMI and fat/muscle ratios were more likely to be

unhappy with their body shape or weight and more likely to use weight control techniques. This supports the observation by others that adolescent body weight perceptions do not coincide with actual weight or a healthy BMI.[4, 5, 14, 33] Striegel-Moore et al proposed that the reason for this misconception is that girls are being conditioned to equate underweight as normal weight.[34]

A unique finding of the present study was that participants who reported using common weight control techniques '*often*' exhibited a biochemical health profile suggestive of chronic under nutrition.

Importantly we noted that confidence intervals for individual health markers in the '*occasionally*' and '*often*' weight control categories generally overlapped (Table 3 & 4). Apart from creatinine and calcium all other variables were analysed using the non-parametric Kruskal Wallis test. Therefore confidence intervals for these dieting groups are not directly comparable.[35] However clear differences were observable for selected parameters between the lowest use (*never*) and highest use (*often*) categories.

No difference was found for red cell count, mean red cell volume (data not shown), B12 and folate between dieting groups. However participants who frequently used weight control techniques had lower bilirubin, albumin and total protein (Table 4). As albumin is used commonly to assess adequate protein and nutrition this observation strongly suggests that the nutritional quality and quantity for this group is lower than that of their school peers who do not frequently diet.

Furthermore, those who reported using weight control methods '*often*' also had reduced serum calcium and ALP levels.

ALP is a zinc dependant enzyme whose activity is consistently elevated during the adolescent years. The reduction in ALP activity may therefore reflect the reduced blood calcium and/or decreased zinc intake. Though blood zinc levels were not measured in this study, Gibson et al

noted that reduced zinc intake in adolescents may be due to a decline in red meat consumption.[36] Indeed in this study a higher proportion of those who reported using weight control techniques '*often*' also reported lower meat consumption (i.e. less than once a week); 13% vs 6% for those who '*never*' use weight control methods. Weight loss studies have shown that low zinc intake may lead to a decrease in bone content and/or density.[37-40] During adolescence, deprivation of essential elements such as calcium and zinc, may impact negatively upon skeletal mineralisation, possibly reducing growth potential and/or bone density.[21, 37-40]

In this study we have shown that high frequency dieting practices in the adolescent population can result in a subtle but significant reduction in important nutrients such as protein, calcium, iron, and potentially zinc. This chronic under-nutrition may lead to a reduction in key metabolic processes resulting in reduced bone mineralisation and growth potential. Consequently detrimental health effects may be occurring earlier in the weight loss spectrum than previously thought.[13, 37, 41] Even though the blood results of those who '*often'* used diet control measures fell within their age specific reference range , they do form an identifiable group that is negatively diverging from the ideal. If this practice is not remediated at this early stage it may contribute to more serious health issues in the future.

STUDY LIMITATIONS

It is relevant to note that the proportion of adolescent females found to be overweight (12.3%) and obese (1.3%) in this study differs from the national average (20% & 5.7% respectively).[42] This likely reflects the predominant recruitment of participants from areas of above average income (i.e. Sydney's upper North Shore and private schools on the Central Coast) and is consistent with research by O'Dea showing that families of higher socioeconomic status are at reduced risk of obesity.[43]

Though the proportion of children experiencing obesity may differ in this cohort, the perceptions leading to, and the biological impact of, heavy dieting is likely to be transferable across other population groups. Additionally while the conclusions from this study are based on blood derived data and appear to be robust the reliance on self-reported information for key study variables is a recognised limitation.

CONCLUSION

Evidence from this study suggests that the use of common weight reduction and weight control techniques by healthy weight adolescent females results in a metabolically identifiable group whose results are consistent with subtle levels of chronic under-nutrition. This early negative biochemical divergence may predispose these individuals to adverse health outcomes such as osteoporosis, during the later years. These likely consequences highlight the need for education in nutritionally safe dieting practises that ensure adequate nutritional quality.

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AUTHOR DISCLOSURES

Authors have no conflict of interest.

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TABLES

Table 1. Female adolescent participants reported degree of satisfaction with their own body weight, shape and fitness level.

Body Satisfaction Category	Weight (%)*	Body shape (%)**	Fitness(%)***
Not at all happy	14	9	9
A little to somewhat happy	49	49	58
Fair bit to very happy	37	42	34
Total	100	100	100

The distribution of participants between all three categories of satisfaction (not at all happy, a little to somewhat happy and fair bit to very happy) is significantly different for weight (χ^2 = 89, df=2, *p<0.000), body shape (χ^2 = 129, df=2, **p<0.000) and fitness (χ^2 = 171, df=2, ***p<0.000).

Table 2: Comparison of Body Perception and the use of Weight Control Methods.

	Body Perception Category	**Use of Weight Control Methods (%)**		
		Never	Occasionally	Often
Body Shape *	Not at all happy	23	49	28
	A little to somewhat happy	30	56	14
	A fair bit to very happy	60	34	6
Weight**	Not at all happy	21	52	27
	A little to somewhat happy	35	51	14
	A fair bit to very happy	61	37	2

The association between all three satisfaction categories (not at all happy, a little to somewhat happy, and fair bit to very happy) and the use of weight control techniques is significantly different for weight ($\chi^2 = 58$, df=4, $^{**}p<0.000$) and body shape ($\chi^2 = 54$, df=4, $^{*}p<0.000$).

Table 3. Comparison of key morphological health markers in adolescent females who self reported never, occasionally or often using weight control techniques.[†]

Physiological Health Marker	Use of Weight Control Techniques	Mean (95%CI)	Min	Max
BMI (kg/m^2)*	Never	20.7 (20.3, 21.2)	15.4	35.8
	Occasionally	21.9 (21.4, 22.3)	16.8	35.8
	Often	22.5 (21.5, 23.5)	16.5	31.7
Waist/hip ratio*	Never	0.77 (0.76, 0.78)	0.62	0.96
	Occasionally	0.79 (0.78, 0.80)	0.66	1.03
	Often	0.80 (0.78, 0.82)	0.69	0.94
Fat Mass (kg)*	Never	13.9 (13.0, 14.7)	1.10	41.9
	Occasionally	15.9 (15.0, 16.8)	1.60	45.4
	Often	16.6 (14.6, 18.6)	6.50	36.5
Muscle Mass (kg)*	Never	39.5 (38.9, 40.2)	23.6	51.6
	Occasionally	41.2 (40.5, 41.8)	17.5	62.6
	Often	41.9 (40.7, 43.1)	29.4	51.6
Fat/Muscle ratio*	Never	0.34 (0.33, 0.36)	0.03	0.81
	Occasionally	0.38 (0.36, 0.40)	0.03	1.66
	Often	0.39 (0.35, 0.43)	0.16	0.76

[†] The sample distribution is (n=199 never; n=217 occasionally and n=54 often).

* The nonparametric Kruskal–Wallis tests showed that at least one of the medians is statistically significantly different from the other medians for each variable ($p<0.01$).

Table 4. Comparison of blood derived health markers between adolescents who *never*, *occasionally* or *often* use weight control techniques.

Health Marker	Reference Range	Category‡	Mean (95%CI)	Min	Max
Red Cell Count (n/µL)	3.80-5.80	Never	4.89 (4.85, 4.94)	4.20	6.20
		Occasionally	4.86 (4.81, 4.90)	4.10	6.30
		Often	4.77 (4.68, 4.87)	4.10	5.90
Haemoglobin (g/L) **	115-160	Never	141 (140, 143)	116	163
		Occasionally	140 (138, 141)	96	160
		Often	138 (135, 141)	78	162
Alkaline phosphatase (IU/L)*	47-132	Never	124 (117, 132)	52	349
		Occasionally	107 (102, 112)	47	287
		Often	95 (86, 105)	35	275
Aspartate amino transferase (IU/L)	0-35	Never	26 (24, 28)	10	190
		Occasionally	25 (24, 26)	11	52
		Often	25 (23, 27)	14	54
Alanine amino transferase (IU/L)	0-35	Never	19 (16, 22)	10	279
		Occasionally	18 (17, 19)	7	50
		Often	19 (17, 21)	10	62
γ-Glutamyl transferase (IU/L)	5-36	Never	13 (13, 14)	3	27
		Occasionally	13 (13, 14)	5	34
		Often	13 (12, 14)	4	31
Bilirubin (µmol/L) **	1.0-19.0	Never	12.3 (11.2, 13.3)	3.0	48.0
		Occasionally	11.9 (10.9, 12.8)	3.0	55.0
		Often	9.7 (8.5, 10.9)	4.0	23.0
Albumin (g/L) **	35.0-51.0	Never	50.2 (49.8, 50.6)	43.0	58.0
		Occasionally	50.0 (49.6, 50.3)	43.0	59.0
		Often	48.6 (47.8, 49.4)	41.0	56.0
Total Protein (g/L) **	60.0-81.0	Never	80.4 (79.8, 81.0)	69.0	96.0
		Occasionally	80.8 (80.2, 81.4)	69.0	96.0
		Often	78.9 (77.8, 80.0)	68.0	87.0
Calcium (mmol/L) **, †	2.10-2.55	Never	2.45 (2.44, 2.46)	2.17	2.67

		Occasionally	2.45 (2.44, 2.46)	2.25	2.66
		Often	2.42 (2.39, 2.45)	2.25	2.66
Creatinine (μmol/L) **, †	50.0-100.0	Never	62.2 (61.1, 63.3)	42.0	86.0
		Occasionally	63.1 (62.0, 64.2)	36.0	88.0
		Often	65.4 (62.9, 68.0)	48.0	88.0
Urea (mmol/L)	2.1-100.0	Never	4.35 (4.21, 4.50)	2.0	8.8
		Occasionally	4.34 (4.23, 4.46)	2.2	7.2
		Often	4.64 (4.30, 4.98)	2.4	7.6
Potassium (mmol/L)**	3.4-5.5	Never	4.4 (4.3, 4.4)	3.6	5.8
		Occasionally	4.4 (4.4, 4.4)	3.7	5.6
		Often	4.5 (4.4, 4.6)	3.8	5.5
Folate (nmol/L)	9.1-78.9	Never	27.9 (26.2, 29.6)	2.7	77.0
		Occasionally	28.8 (27.1, 30.5)	4.7	82.3
		Often	28.0 (24.5, 31.5)	11.9	61.2
Vitamin B12 (pmol/L)	200-725	Never	422 (399, 444)	132	1220
		Occasionally	415 (378, 452)	133	3690
		Often	446 (384, 509)	155	1300

*p<0.001, **p<0.05 at least one of the means or the medians is significantly different from the others within the frequency of weight control techniques.
† These variables are normally distributed therefore ANOVA was performed. All other variables were tested with the nonparametric Kruskal-Wallis test.
‡ The sample distribution is (n=198 *never*; n=214 *occasionally* and n=55 *often*).