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Associations between serum lipids and indicators of adiposity in men with spinal cord injury

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Several reports indicate that dyslipidemia, primarily depressed high density lipoprotein cholesterol, is common in persons with spinal cord injury. The purpose of this study was to assess the relationships between anthropometric and near infrared interactance measurements to the serum lipoprotein profiles of 46 men with spinal cord injury of >6 months duration. Mean age ($\pm$ SD) was 49.5 ± 15.0 y and duration of injury was 17.5 ± 13.0 y. Forty-one percent of the subjects had low high density lipoprotein cholesterol ($<35\ mg\ dl^{-1}$) and 57% had elevated total cholesterol to high density lipoprotein cholesterol ratios (>4.5). Abdominal circumference was most closely associated with the overall lipid profile and abdominal circumference/height ratio was the second strongest correlate. Body mass index, conicity index, and percent body fat estimated by near infrared interactance were significantly related to some lipid parameters; however, the relationships were weaker than for abdominal circumference or abdominal circumference/height. Significant correlations were found between abdominal circumference and serum high density lipoprotein cholesterol ($r = -0.421$, $P < 0.01$) and $\log_{10}$ triglyceride ($r = 0.587$, $P < 0.001$) concentrations as well as the total cholesterol:high density lipoprotein cholesterol ($r = 0.482$, $P < 0.01$) and low density lipoprotein cholesterol-to-high density lipoprotein cholesterol ($r = 0.387$, $P < 0.05$) ratios. Based on these findings, the sample was partitioned by abdominal circumference into low (<95 cm), moderate, and high ($\geqslant 102$ cm) risk subgroups. Compared to the low risk group the high risk subjects had lower high density lipoprotein cholesterol (35 ± 9 *vs* 44 ± 9, $P < 0.03$) and higher triglyceride (173 ± 71 *vs* $101 \pm 30.4\ mg\ dl^{-1}$, $P < 0.003$ for $\log_{10}$ triglyceride, non-transformed values shown) and total cholesterol:high density lipoprotein cholesterol (5.6 ± 1.8 *vs* 4.2 ± 1.1, $P < 0.03$). Our results confirm those of earlier investigators who found a high prevalence of depressed high density lipoprotein cholesterol in men with spinal cord injury. In addition, these findings suggest that abdominal adiposity, as indicated by abdominal circumference or abdominal circumference/height ratio, is an important correlate of the dyslipidemia associated with SCI.

Keywords: spinal cord injury; cardiovascular disease; lipoproteins; obesity; body fat distribution

Introduction

Previous investigators have found that persons with spinal cord injury (SCI) have a high prevalence of some cardiovascular disease (CVD) risk factors including depressed levels of high density lipoprotein cholesterol (HDL-C),[1–8] sedentary lifestyle,[9] impaired glucose tolerance and non-insulin-dependent diabetes mellitus.[2,10,11] Additionally, recent evidence suggests that men with SCI may be at elevated risk for CVD when compared to able bodied men or the general population.[12–14]

Obesity occurs frequently in persons with SCI,[15] and may be an important contributing factor in the development of CVD in this population. The adverse health effects of the obese condition relate not only to the degree of adiposity, but also to the regional distribution of body fat.[16–22] Obese persons with a central (abdominal) distribution of body fat are at high risk for CVD, non-insulin dependent diabetes, hypertension, insulin resistance and dyslipidemia.[16–22]

Epidemiological and clinical studies have shown that anthropometric measurements such as body mass index (BMI) and waist-to-hip ratio are useful for identifying persons at risk for CVD.[16–22] However, changes in body composition secondary to long term paralysis make interpretation of these parameters problematic in persons with SCI.[15,23] Moreover, some anthropometric measurements that are commonly utilized in the able bodied population are difficult to perform on SCI patients in a clinical setting. Therefore, the present study was undertaken to assess the relationships be-

tween clinically practical anthropometric measurements and the serum lipid profiles of men with chronic SCI.

Subjects and methods

Subjects

Subjects included 49 men with SCI of >6 months' duration cared for by the Hines VA Hospital SCI Service. The sample included 32 outpatient and 17 inpatient volunteers. The inpatients were undergoing rehabilitation or were in the latter stages of decubitis ulcer healing. None of the subjects were known to be malnourished or suffering from acute infections or chronic diseases other than hypertension. Individuals taking medications for hyperlipidemia, diabetes mellitus or other endocrine disorders were not enrolled. Data from three subjects were excluded from all analyses, two because of HDL-C concentrations >4 SD above the group mean (77 and 114 mg dl^{-1}) and one due to elevated serum triglycerides (TG; 930 mg dl^{-1}). Serum TG concentration >400 mg dl^{-1} was established *a priori* as an exclusion criterion.

Study protocol

The protocol for this investigation was approved by the Hines VA Hospital Human Subjects Subcommittee. Subjects reported to the laboratory after an overnight fast of at least 10 h. After completing informed consent procedures, a venous blood sample was drawn for determination of the serum lipid profile. Anthropometric and near infrared interactance (NIR) measurements were taken as described below. In most subjects these were done on the same morning that the blood sample was drawn. However, in a few subjects these measurements were completed in the afternoon or on a separate day within 1 week of the blood sample. In these cases the measurements were taken at least 4 h postprandially.

Anthropometric and near infrared interactance (NIR) measurements

Body weight was measured on a balance beam scale designed to accommodate wheelchairs. Subjects' weights were recorded as the difference between the weight of the subjects in light clothing in his wheelchair and the weight of the wheelchair alone. Since all of our subjects became paralyzed in adulthood, height was determined by self-report of the pre-injury height. In instances where a subject was not sure of his height, body length was measured to the nearest centimeter in a supine position using a metal measuring tape. Abdominal circumference (AC) was measured with a non-stretch anthropometric tape in duplicate. If the values differed by >1 cm a third measurement was taken and the results of the two or three trials were averaged. Measurements were made at umbilicus after a normal expiration with subjects supine.

NIR determinations were completed with a Futrex 5000 body composition analysis system (Futrex Inc, Gaithersburg, MD, USA) according to the instructions outlined in the manual provided by the manufacturer, using the equations programmed into the device. Percent body fat (%BF NIR) was recorded as the average of two readings from the device output.

It should be emphasized that body composition estimations generated from NIR have not been validated in persons with SCI. Therefore, these values should be viewed with caution. However, NIR is a simple method that is practical for use in a clinical setting, and thus our purpose for including it was only to compare its usefulness for predicting lipid abnormalities with that of other simple measurements.

Laboratory analysis

Serum lipid profiles were completed by the Hines VA Laboratory Service using a Paramax^{TM} analyzer (Baxter Diagnostics, Deerfield, IL). Briefly, total cholesterol (TC) and triglycerides (TG) were determined enzymatically and HDL-C was measured after precipitation of lower density lipoproteins by phosphotungstate. Low density lipoprotein cholesterol (LDL-C) in mg dl^{-1} was calculated according to the Friedewald equation[24] as shown below.

$$\text{LDL-C} = \text{TC} - (\text{HDL-C} + \text{TG}/5) \quad [1]$$

Calculations

BMI was calculated as the weight in kg divided by the squared height in meters. AC/height (cm cm^{-1}) ratio and conicity index were also calculated. Conicity index is a newly proposed index of abdominal adiposity which has been shown to correlate with the lipid profile in epidemiologic studies[25] and was calculated according to the following formula:

$$\text{Conicity index} = \text{AC}/0.109\sqrt{(\text{weight}/\text{height})} \quad [2]$$

where AC is the abdominal circumference in m and weight and height are in kg and m, respectively. Lean body mass and fat mass (FM NIR) were calculated from total body mass and the %BF estimated by NIR.

Statistical analysis

Log_{10} transformation of serum TG concentration was used because of skewness in the distribution. TG concentrations in the text and tables are presented as the actual rather than log transformed values for clarity. Non-paired *t* tests were performed to compare continuous variables (lipid parameters, BMI, AC, AC/height, conicity index, %BF NIR) between persons with quadriplegia and paraplegia. Pearson correlation coefficients were calculated to show the relationships between the anthropometric and body composition parameters. Univariate and multivariate regression was used to assess the relationships between anthropometric parameters, %BF NIR, FM NIR, and level of injury as independent variables, and lipid and lipoprotein parameters as dependent variables (Pearson *r* values are reported). One-way analysis of variance, followed by Scheffe's procedure where

appropriate, was performed to compare continuous variables between subjects classified by AC category as described below. The Fisher exact test was used to compare the distribution of nominal variables between subjects grouped by AC category. All analyses were completed using the Statview II statistical package (Abacus Concepts, Calabasas, CA), with the exception of the Fisher exact test which was calculated by the Primer for Biostatistics program (copyright S Glantz), on a Macintosh SE/30 computer. Two-tailed P values ≤ 0.05 were considered statistically significant. Results are reported as mean ± SD unless otherwise noted.

Results

Clinical characteristics of the 46 subjects included in the analyses are shown in Table 1. Age ranged from 18 to 75 years (mean age 49.5 ± 15.0 year). Most subjects had long standing paralysis with the mean duration of SCI being 17.5 ± 13.0 years. Fourteen subjects were taking antihypertensive medications. Five of these persons were taking beta adrenergic blockers or diuretics which may have adverse effects on the blood lipid profile.[26] Six other subjects were taking alpha adrenergic blockers which have been reported to have favorable effects on the lipid profile.[26]

Means and standard deviations for lipid and lipoprotein parameters as well as the proportion of subjects falling outside the 'desirable range' for these parameters are shown in Table 2. It should be noted that there was a high prevalence of elevated TC:HDL-C ratio with 57% of the subjects exceeding 4.5, primarily due to a high prevalence of reduced HDL-C (57% $< 40\ mg\ dl^{-1}$).

Tables 3 and 4 show the mean values for the anthropometric and body composition parameters and the correlations between these variables, respectively. AC could not be measured in three men because of unwillingness to transfer to an examination table or use of an orthotic device that could not be easily removed. As expected, the measurements were all significantly correlated ($P < 0.01$). However, the correlation coefficients between the conicity index and BMI ($r = 0.458$) as well as FM NIR ($r = 0.505$) and %BF NIR ($r = 0.558$) were notably lower than the others, which all exceeded 0.75. We compared the BMI and AC values for our group to those published by Jakicic *et al*[20] for 324 able bodied men (Table 5). (The AC was measured in their study with the subjects in a standing position.) Our sample had lower BMIs at the mean as well as the 25th, 50th and 75th percentiles. In contrast, the mean AC of our group was slightly higher as were the values at the 50th and 75th percentiles. Because AC and total adiposity are highly correlated in able bodied men,[19,27] it is likely that our sample had a greater %BF as a group, particularly since BMI was lower which probably reflects the loss of lean body mass secondary to paralysis.[15]

Table 1 Clinical characteristics of subjects

	Number of subjects
Level of SCI	
Tetraplegia	23
Paraplegia	23
Cigarette smokers	11
Taking antihypertensive medication	14
Beta adrenergic blockers or diuretics	5
Alpha adrenergic blockers	6

Table 3 Anthropometric and body composition parameters (mean ± SD)

Abdominal circumference (cm)	97.3 ± 13.7
AC/height ($cm\ cm^{-1}$)	0.55 ± 0.08
Conicity index	1.32 ± 0.10
Body mass index ($kg\ m^{-2}$)	25.6 ± 4.5
Fat mass by near infrared interactance (Kg)	18.2 ± 8.7
Lean mass by near infrared interactance (Kg)	63.1 ± 10.0
% Body fat by near infrared interactance	21.5 ± 7.6

Table 4 Pearson correlation matrix showing the relationships between various anthropometric variables and estimated fat mass and percent body fat by near infrared interactance[a]

	BMI	*AC*	*AC/ height*	*Conicity index*	*Fat mass NIR*
AC	0.870				
AC/height	0.859	0.953			
Conicity index	0.458	0.802	0.803		
Fat mass NIR	0.927	0.854	0.825	0.505	
% BF NIR	0.800	0.754	0.803	0.558	0.914

[a]All were significant with $P < 0.01$

Table 2 Lipid and lipoprotein parameters ($n = 46$)

Lipid parameter	*Mean ± SD ($mg\ dl^{-1}$)*	*Desirable range ($mg\ dl^{-1}$)*	*% outside the desirable range*
Total cholesterol	186 ± 37	< 200	26
LDL cholesterol	120 ± 35	< 130	33
HDL cholesterol	39 ± 9	> 39	57
Triglycerides	136 ± 61	< 150	32
TC:HDL-C ratio	5.04 ± 1.53	≤ 4.5	57
LDL-C:HDL-C ratio	3.27 ± 1.26	≤ 3.0	56

Table 5 Comparison between body mass index and abdominal circumference values in our SCI subjects with published values for 324 able-bodied men[20]

	Mean ± SD	*Percentiles*		
		25th	*50th*	*75th*
BMI ($kg\,m^{-2}$)				
Present	25.6 ± 4.5	23.70	25.40	27.50
Jakicic	27.4 ± 3.4	24.93	27.16	29.60
Difference	−6.6%	−4.9%	−6.5%	−7.1%
AC (cm)				
Present	97.3 ± 13.7	88.01	99.10	105.05
Jakicic	95.3 ± 10.0	88.45	95.00	102.00
Difference	+2.1%	−0.5%	+4.3%	+3.0%

Difference = ((Present − Jakicic)/Jakicic) × 100

Neither the anthropometric nor NIR variables were significantly related to the TC or LDL-C concentrations (Table 6). HDL-C was significantly inversely correlated with the three anthropometric variables which included AC in their calculation (AC, AC/height, and conicity index). Log_{10} TG and TC:HDL-C ratio correlated significantly with all measures while LDL-C:HDL-C ratio was significantly correlated with AC, AC/height, BMI, and FM NIR. In agreement with several reports in able bodied and SCI groups,[1,2,28] there was a significant inverse correlation between HDL-C and serum (log transformed) TG ($r = -0.408$, $P < 0.01$).

Persons with paraplegia and tetraplegia were found to have similar values for lipid parameters and anthropometric measures. However, since AC was the variable with the strongest relationship to the lipid profile, we examined the level of SCI in relation to lipid variables while controlling for AC by multiple regression. After taking AC into account, persons with tetraplegia had HDL-C that was $6\,mg\,dl^{-1}$ lower than persons with paraplegia ($P < 0.03$). Level of injury explained an additional 10% of the variance in HDL-C after AC was accounted for ($R^2 = 0.28$ *vs* 0.18). Other lipid variables did not differ between those with paraplegia or tetraplegia.

We also divided our sample into risk categories based on AC using the percentile ranks of the 324 able bodied subjects in the study by Jakicic *et al*.[20] A 'high risk' AC was considered to be the 75th percentile or higher (≥ 102.0 cm), 'moderate risk' constituted the 50th to the 74th percentiles (95.0–101.9 cm), and 'low risk' was less than the 50th percentile.[20]

The characteristics of the subjects in the different risk categories are shown in Table 7. As expected, the groups differed significantly in AC, BMI, and FM NIR. No significant difference was found between groups in age, although the low risk group was significantly different from the high risk group in duration of SCI (10.8 ± 8.4 *vs* 21.8 ± 14.5 y). No significant relationships between age or duration of injury and any lipid or lipoprotein parameter were noted; however, a significant correlation was found between AC and duration of injury ($r = 0.315$, $P < 0.05$).

The high risk group had lower mean HDL-C ($P < 0.03$) and higher TG concentrations (log_{10}, $P < 0.003$) than the low risk group (Figure 1). These men also had an elevated mean TC:HDL-C ratio ($P < 0.03$; Figure 2). No significant differences were detected between groups for TC, LDL-C or the LDL-C:HDL-C ratio. It is of interest to note that the low risk group had a higher proportion of smokers than the high risk group (7/16 *vs* 2/17), but this trend did not reach statistical significance. Cigarette smoking is associated with reduced HDL-C and increased TG,[29] but is also associated with a lower tendency toward the development of obesity.

Discussion

As preventative and treatment strategies have improved over the past several decades, the life expectancy of persons with SCI has increased steadily.[12,13] Along with this has come an increase in the incidence of CVD and other diseases associated with advanced age.[13] A recent study found that CVDs were the

Table 6 Pearson correlation coefficients between anthropometric variables, estimates of body composition by near infrared interactance and lipid and lipoprotein parameters

	AC $n = 43$	*AC/ht* $n = 43$	*Conicity* $n = 43$	*BMI* $n = 46$	*FM NIR* $n = 46$	*% BF NIR* $n = 46$
TC	0.198	0.217	0.053	0.284	0.283	0.289
LDL-C	0.136	0.159	0.048	0.265	0.265	0.255
HDL-C	−0.421**	−0.400**	−0.360*	−0.286	−0.277	−0.171
Log_{10} TG	0.587***	0.565***	0.596***	0.412**	0.410**	0.391**
TC: HDL-C	0.482**	0.437**	0.326*	0.437**	0.389**	0.321*
LDL-C HDL-C	0.387*	0.385*	0.191	0.401**	0.425**	0.289

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 7 Characteristics of subjects grouped by abdominal circumference risk category

	High risk (*n* = 17)	*Moderate risk* (*n* = 10)	*Low risk* (*n* = 16)
Tetraplegia (*n*)	8	4	9
Paraplegia (*n*)	9	6	7
Age (y)	53.6 ± 12.1	47.7 ± 16.4	47.6 ± 17.6
Duration of injury (y)	21.8 ± 14.5*	17.8 ± 12.6	10.8 ± 8.4
AC (cm)	110.1 ± 7.0**,***	98.3 ± 2.1**	83.1 ± 8.0
BMI (kg m^{-2})	28.9 ± 4.4**	26.0 ± 1.4*	22.0 ± 3.2
Fat mass by NIR	24.5 ± 8.9**	18.9 ± 2.5*	11.7 ± 5.4
Cigarette smokers (*n*)	2	1	7
Taking antihypertensives (*n*)	3	6	5
Beta blockers/diuretics (*n*)	1	3	1
Alpha blockers (*n*)	2	2	2

*$P < 0.05$ *vs* low risk group, **$P < 0.001$ *vs* low risk group, ***$P < 0.001$ *vs* moderate risk group

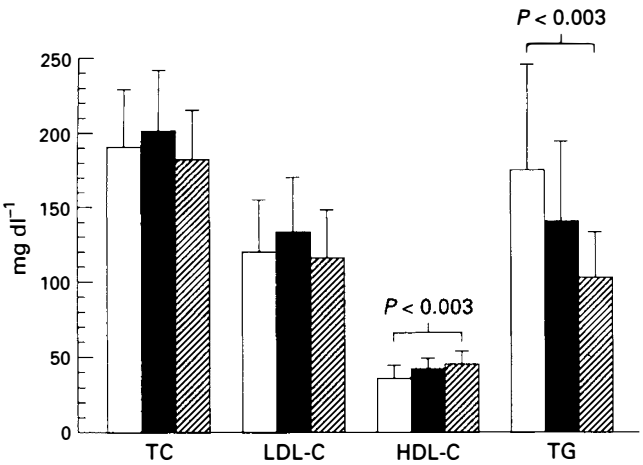

Figure 1 Lipid and lipoprotein levels in subjects grouped by abdominal circumference (AC). Risk categories were assigned according to percentile rankings for 324 able bodied men published by Jakicic *et al*.[20] □ High risk (≥ 75th; AC ≥ 102 cm), ■ moderate risk (50–74th), ▨ low risk (< 50th; AC < 95 cm).

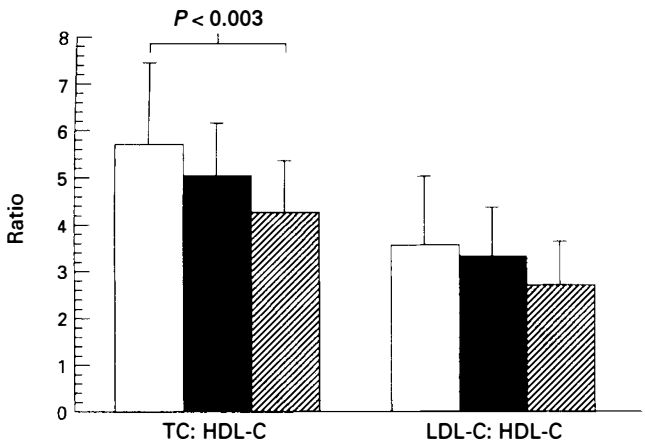

Figure 2 Lipid risk ratios in subjects grouped by abdominal circumference (AC). Risk categories were assigned according to percentile rankings for 324 able bodied men published by Jakicic *et al*.[20] □ High risk (≥ 75th; AC ≥ 102 cm), ■ moderate risk (50–74th), ▨ low risk (< 50th; AC < 95 cm).

leading causes of death in persons with long standing SCI (> 30 y) and among those over 60 y.[13] DiVivo and colleagues[12] reported that standardized mortality ratios for 'diseases of the arteries' and 'non-ischemic heart disease' (primarily cardiac arrest) were significantly elevated in the first 12 years after SCI. A common underlying cause of fatal cardiac arrest is coronary atherosclerosis.[30] Yekutiel *et al*,[14] in a retrospective chart review, reported that patients with SCI had a significantly elevated prevalence of diagnosed ischemic heart disease and hypertension as compared to age-matched able bodied controls. Additionally, CVD mortality has been found to be increased in persons with traumatic leg amputation, particularly those affected bilaterally, who have mobility restrictions similar to those imposed by SCI.[31]

Several publications have documented the high prevalence of depressed HDL-C concentrations in the SCI population,[1–8] though a recent publication has disputed this.[32] Mean HDL-C values have generally been reported to be 5–15 mg dl^{-1} below that of age-matched able bodied subjects. This has substantial clinical significance because epidemiologic studies have found a 2–3% increase in CVD incidence and mortality for each 1 mg dl^{-1} reduction in HDL-C.[33] Bauman *et al*[1] studied a group of 100 veterans with SCI who were very similar to our sample in age, duration of injury and BMI. The mean values for the lipid parameters in our study were not substantially different from those reported by Bauman's group. In particular, the mean HDL-C concentrations were similar (39 *vs* 38.5 mg dl^{-1}) as was the prevalence of HDL-C levels below 35 mg dl^{-1} (41 *vs* 37%).

Our results, therefore, support the findings of other investigators who reported high prevalence rates of depressed HDL-C in men with SCI.[1–8] We have also extended the previous work by clearly implicating abdominal adiposity as an important determinant of dyslipidemia in this group. Increasing AC was significantly and inversely correlated with HDL-C, and directly with TG, and the TC:HDL-C and LDL-C:HDL-C ratios. Furthermore, when subjects were categorized according to AC, the low risk group (AC < 95 cm) had a mean HDL-C level 9 mg dl^{-1} (26%)

greater than the high risk (AC $\geq$ 102 cm) group. Relative to the low risk group, the high risk group also had substantially increased TC:HDL-C (5.6 *vs* 4.2), and TG (173 *vs* 101 mg dl^{-1}).

The mean HDL-C in 45–54 year old men in the second National Health and Nutrition Examination Survey was 47 mg dl^{-1} [34] which is only slightly higher (6%) than the mean level for our low risk group (44 mg dl^{-1}). The TC (179 mg dl^{-1}) and LDL-C (115 mg dl^{-1}) levels of the low risk group were 17–18% below the mean values for 45–54 year old men (218 and 138 mg dl^{-1}, respectively). Furthermore, the TC:HDL-C ratio (4.2) was within the desirable range. Thus, the lipid profile of the low risk group suggests that these men would be at somewhat lower CVD risk than the general population.

In contrast, the high risk group would be at increased risk due to low mean HLD-C (35 mg dl^{-1}) with a TC:HDL-C ratio of 5.6, despite normal TC (188 mg dl^{-1}) and LDL-C (118 mg dl^{-1}). A report from the Physicians Health Study indicated that each one unit increase in TC:HDL-C was associated with a 53% increase in the incidence of myocardial infarction after adjustment for other risk factors.[35] This translates into a 74% increase in risk of CVD for our high risk as compared to our low risk group.

Despres[17,18] has suggested that the waist circumference (which correlates highly with the AC[19,20]) may be a useful anthropometric measurement for assessing regional body fat distribution in the clinical setting. Approximately 90% of the variance in this measurement can be accounted for by differences in total body-, abdominal subcutaneous-, and deep abdominal fat.[17] In contrast, only ~50% of the variance in waist-to-hip ratio was explained by these factors.[17] Thus, waist circumference (and presumably AC) is determined by the three major adipose components related to CVD risk in able bodied men.[17] Increased abdominal adiposity as measured by waist circumference, waist-to-hip ratio, computed tomography or magnetic resonance imaging is associated with dyslipidemia, insulin resistance and hyperinsulinemia, and elevated risk of non-insulin dependent diabetes mellitus and CVD.[16–22] These relationships and the underlying mechanisms have been recently reviewed in detail.[16–18,21] Indeed, the Framingham Heart Study employed the same methods used in the present investigation to measure the AC/height ratio as an indication of regional body fat distribution.[36] In 20-year follow-up CVD mortality was increased by 40% and coronary artery disease mortality elevated by 60% in the highest as compared to the lowest AC/height quintile after adjustment for other risk factors.[36]

One might speculate that loss of tone and atrophy of the abdominal muscles may influence the AC in persons with high level SCI in such a way that the relationships between adipose stores and AC would be altered. We do not believe that this is the case when AC is measured with the subject in a supine position. The relationships between blood lipid and lipoprotein values and AC were compared between persons with cervical spinal cord lesions to those of subjects with lesions below T_{11}. There were no statistically significant differences between the slopes of the regression lines (data not shown). Moreover, the correlation coefficients relating AC to lipid parameters were very similar to those reported for able bodied men.[19,20] Nevertheless, studies using computed tomography or magnetic resonance imaging would be necessary to quantify the relationships between anthropometric measurements and fat depots in persons with SCI.

Based on the results of our study and numerous others in able bodied persons,[16–22] we propose that AC (or AC/height) may be a useful clinical indicator for CVD risk assessment in men with SCI. A reasonable cut-off for a high risk AC/height ratio might be $\geq$ 0.58 which includes the top third of our sample (AC and AC/height were highly correlated $r = 0.953$). The subjects with AC/height ratios above this level had mean lipid values similar to the high risk AC group (data not shown). This would correspond to an AC of ~102 cm in a man with a height of 175 cm (5 ft, 9 in). BMI, FM NIR, %BF NIR and conicity index did correlate with some of the lipid parameters, but were not as closely related to dyslipidemia as were AC or AC/height.

In addition to increased adiposity, several other factors might be important determinants of the depressed HDL-C levels in persons with SCI. Chief among these is physical inactivity.[6,37] It is well known that persons who engage in regular physical activity have increased HDL-C relative to sedentary persons.[6,38] While this relationship may be partially accounted for by differences in body fat,[38] exercise conditioning and/or physical activity may have a modest influence on HDL-C independent of any effect on body composition.[38,39] Cross-sectional data suggest that physically active persons with SCI have higher HDL-C concentrations than those who are inactive.[3,4,6,37] Limited data on exercise training by persons with SCI support this notion.[40]

Duckworth *et al*[10,11] and Bauman *et al*[2] have reported a high prevalence of non-insulin dependent diabetes mellitus and impaired glucose tolerance in men with SCI. Glucose intolerance and insulin resistance (even with normal glucose tolerance) are also associated with reduced HDL-C and increased TG.[41] Physical inactivity and increased adiposity are both associated with insulin resistance and an increased risk for the development of glucose intolerance.[42] However, alterations in the neural control mechanisms and loss of lean tissue (particularly skeletal muscle) secondary to paralysis may also play important roles in the etiology of these conditions in SCI.

After adjustment for AC by multiple regression, HDL-C was 6 mg dl^{-1} higher in men with paraplegia than those with tetraplegia. This suggests the possibility that the greater proportion of paralytic muscle tissue and/or lower physical activity may have contributed to the depression of HDL-C in these individuals.

Dietary practices, alcohol consumption and cigarette smoking are additional factors which influence HDL-C

and other lipid and lipoprotein concentrations.[43] The influence of these factors in the SCI population deserve further study.

Conclusions

Our results suggest that AC or AC/height ratio are useful for identifying men with SCI at risk for dyslipidemia. Categorization by AC avoids, to a large extent, the potential confounding effect of loss of lean body mass after SCI on anthropometric measurements, is practical for use in the clinical setting, and requires no special equipment other than an inexpensive anthropometric measuring tape. Further study will be required in larger groups of persons with SCI to determine the relationship of these measurements to other risk factors, as well as CVD morbidity and mortality. Finally, these results suggest that efforts toward prevention of obesity by promotion of increased physical activity and improved dietary patterns may be effective means for reducing the incidence of dyslipidemia in this population.

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