

Maximal voluntary contraction as a functional indicator of adult chronic undernutrition

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(Received 12 May 1995 – Accepted 10 November 1995)

Maximal voluntary contraction (MVC) using a handgrip dynamometer was assessed in seventy-two young adult males. The subjects were divided into two groups on the basis of a BMI of 18.5 kg/m². The subjects with a BMI < 18.5 kg/m² (*n* 38) were further divided into an underweight (UW; *n* 20) group and a chronically energy-deficient (CED; *n* 18) group. The CED subjects had significantly lower MVC (30.1, SD 5.9 kg) than either the well-nourished controls (BMI > 18.5 kg/m²: 39.8, SD 5.8 kg) or the underweight group (37.6, SD 4.9 kg). The differences between the CED and UW groups persisted even after the MVC were corrected for forearm muscle area and stature. The results suggest that MVC may be a useful functional indicator of nutritional status particularly in differentiating subjects with chronic undernutrition from individuals who are underweight and not undernourished but have similar BMI.

Body mass index: Chronic energy deficiency: Handgrip dynamometry: Maximal voluntary contraction

Body mass index (BMI; weight (kg)/height (m)²), in conjunction with indices of energy turnover, has been proposed as a suitable indicator for the classification of chronic energy deficiency (CED) among adults (James *et al.* 1988). Subsequently it has been shown that an adult BMI of < 18.5 kg/m² alone is sufficient for the diagnosis of CED in adults (Ferro-Luzzi *et al.* 1992) and that the earlier concerns regarding the potential for misclassification of healthy, very active and thin or underweight individuals as CED was largely unwarranted. A low BMI in an adult is indicative of a reduction in body energy stores. This reduction manifests as a decrease in fat mass as well as lean body mass including muscle. Studies from our laboratory have shown that individuals with BMI < 18.5 kg/m² can be subdivided into two groups, i.e. those who are chronically undernourished or CED and those who are underweight (UW). UW subjects in general have characteristics that are similar to those of well-nourished subjects (WN) in terms of their daily energy intakes (Kurpad *et al.* 1989*a*), metabolic characteristics (Kurpad *et al.* 1989*b*; Soares & Shetty, 1991) and cardiovascular responses (Kulkarni *et al.* 1988) which are different from those seen in chronically undernourished or CED subjects. Since both UW and CED adults have BMI < 18.5 kg/m² it is essential to distinguish between CED and UW subjects using easily measurable physiological or anthropometric variables.

Skeletal muscle function indices have been advocated for the assessment of nutritional status (Nicks & Fleishman, 1962; Brozek, 1984). Changes in muscle function such as contractility, relaxation rate and endurance may precede body composition changes and may help detect functional impairment at subclinical levels (Lopes *et al.* 1982). Muscle function as measured by maximal momentary grip strength has been used as an indicator of pre-operative nutritional status capable of predicting the likelihood of complications

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after gastrointestinal surgery (Klidjian *et al.* 1980, 1982). Muscle function changes have also been assessed by measuring the strength of contraction of the *abductor pollicis* during electrode stimulation in patients on diets designed to alter body weight and composition (Lopes *et al.* 1982; Russell *et al.* 1983*b*). In order to be truly useful, however, muscle function indices should not merely reflect anthropometry but should also be able to distinguish between anthropometrically similar groups who may have different nutritional states as is the case between individuals who are UW and those who are CED. The present study was designed to measure and compare one index of muscle function (maximal voluntary contraction; MVC) using a handgrip dynamometer, in WN, UW and CED subjects and to evaluate the usefulness of muscle function in distinguishing UW from undernourished individuals who may have similar BMI.

MATERIALS AND METHODS

Subjects

A total of seventy-two healthy, adult male subjects between the ages of 18 and 35 years were studied after obtaining fully informed consent. These were divided into two groups on the basis of their BMI: $> 18.5 \text{ kg/m}^2$ (n 34) and $< 18.5 \text{ kg/m}^2$ (n 38). The group with BMI $< 18.5 \text{ kg/m}^2$ was further subdivided into an UW group (n 20) and a CED group (n 18). The WN group (BMI $> 18.5 \text{ kg/m}^2$) and the UW group were recruited from among the staff and students of the Medical College while the undernourished or CED group was studied at a rurally-based community hospital and consisted largely of rural, agricultural labourers. The UW and CED groups were differentiated on the basis of their socio-economic status (Pareek & Trivedi, 1964; Kuppaswamy, 1984) and short stature; the latter probably indicative of undernutrition since childhood (Waterlow, 1988).

Anthropometry

All subjects underwent a detailed anthropometric assessment that included height (m) and weight (kg) and mid-upper-arm circumference (MAC). Skinfold measurements were obtained from four sites, i.e. triceps, biceps, subscapular and suprailiac, on the same side of the body with the subject standing, using Holtain (Crymmych, Dyfed) skinfold calipers. Percentage fat and fat-free mass (FFM) were estimated from the sum of four skinfolds using the age- and sex-specific equations of Durnin & Womersley (1974). In addition maximal forearm circumference (FAMC) was also determined and the forearm muscle area (FAMA) calculated as described for the arm (Heymsfield *et al.* 1979). Muscle mass was derived from corrected arm muscle area (CAMA) using the equation of Heymsfield *et al.* (1982).

Maximal voluntary contraction

MVC were obtained on both the dominant and non-dominant sides using a Harpenden handgrip dynamometer (CMS Weighing Equipment Ltd, London), with the arm by the side of the body and the forearm stretched to an angle of 90° . Three measurements were taken at intervals of at least 1 min. The highest of the three measurements was taken as the MVC. For the purpose of analysis MVC are expressed in absolute terms as well as corrected for FAMA and for stature.

Statistical analysis and ethical approval

All data were analysed for statistical significance between the two BMI groups (> 18.5 and $< 18.5 \text{ kg/m}^2$) using an independent *t* test. In addition the data were analysed for differences between WN, UW and CED groups using a one-way ANOVA with multiple

Table 1. *A comparison of anthropometric characteristics of well-nourished (WN), underweight (UW) and chronically energy-deficient (CED) subjects*†

(Mean values and standard deviations)

	BMI > 18.5 kg/m ² (WN; n 34)		BMI < 18.5 kg/m ² (pooled; n 38)		UW (n 20)		CED (n 18)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
BMI (kg/m ²)	20.7	1.7	17.1*	1.0	17.3*	1.2	16.9*	0.8
Height (m)	1.722	0.054	1.683*	0.066	1.718	0.062	1.641*†	0.045
Weight (kg)	61.2	7.5	48.6*	4.8	51.1*	4.3	45.6*†	3.4
MAC (cm)	27.4	2.3	24.2*	1.6	24.6*	1.3	23.4*	1.5
CAMA (cm ²)	35.8	6.9	28.9*	5.1	28.8*	4.8	28.3*	4.9
Muscle mass (kg)	20.7	2.9	17.5*	2.4	17.6*	2.4	17.1*	2.3
Body fat (%)	18.1	5.3	11.4*	2.7	12.4*	2.6	10.2*	2.5
FFM (kg)	49.9	4.9	43.0*	3.8	44.7*	3.6	40.7*†	2.6

MAC, mid-upper-arm circumference; CAMA, corrected arm muscle area; FFM, fat-free mass.

* Mean values were significantly different from those for WN controls, $P < 0.05$.

† Mean values were significantly different from those for UW subjects, $P < 0.05$.

‡ Differences between WN controls and the pooled data for BMI < 18.5 kg/m² were assessed by independent t test; differences between WN controls, UW and CED subjects were assessed by one-way ANOVA with multiple comparisons by the Scheffé test.

comparisons (Scheffé), results being considered significant at $P < 0.05$. All results are expressed as means and standard deviations.

The experimental protocol was approved by the Human Investigation and Ethical Committee of the Medical College and fully informed consent was obtained from each subject who participated in the study.

RESULTS

Comparison of anthropometric and forearm characteristics across the study groups

A comparison of the anthropometric differences between the various study groups is summarized in Table 1. The CED group had significantly lower height, weight, fat mass and FFM than the WN controls, and was also significantly different from the UW group in all of these variables. MAC, CAMA and muscle mass were significantly lower in both UW and CED groups than in the WN group and there were no differences between the UW and CED groups (Table 1). FAMC and FAMA were comparable in the CED and UW groups for both dominant and non-dominant sides and were significantly lower than the WN controls (Table 2). Measurements taken on the dominant side were significantly higher than the corresponding measurements taken on the non-dominant side within any of the three study groups.

Variability of maximal voluntary contractions and comparison across study groups

The interindividual and intraindividual variabilities in MVC were 16.3 and 5.7 respectively. Interindividual variability was higher in the CED group for both dominant and non-dominant sides while intraindividual variability was similar across groups. MVC on both dominant and non-dominant sides had similar statistically significant correlations with several anthropometric indices such as FFM (r 0.66), body weight (r 0.63), muscle mass

Table 2. A comparison of forearm anthropometric characteristics of well-nourished (WN), underweight (UW) and chronically energy-deficient (CED) subjects; the effect of dominance and differences between the study groups

(Mean values and standard deviations)

	WN (n 34)		UW (n 20)		CED (n 18)	
	Mean	SD	Mean	SD	Mean	SD
FAMC						
Dominant†	24.2	1.5	23.0*	0.8	22.2*	0.8
Non-dominant	23.2	1.4	22.1*	0.9	21.7*	0.9
FAMA						
Dominant†	46.7	5.8	42.1*	3.0	39.4*	2.7
Non-dominant	43.0	4.9	38.8*	3.3	37.6*	3.2

FAMC, forearm muscle circumference; FAMA, forearm muscle area.

* Mean values were significantly different from those for WN: $P < 0.05$.

† The dominant side was significantly ($P < 0.05$) greater than the non-dominant side in all three groups.

Table 3. A comparison of maximal voluntary contraction (MVC) in well-nourished (WN), underweight (UW) and chronically energy-deficient (CED) subjects

(Mean values and standard deviations)

	BMI > 18.5 kg/m ² (WN; n 34)		BMI < 18.5 kg/m ² (pooled; n 38)		UW (n 20)		CED (n 18)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
MVC								
Dominant	40.1	5.3	34.6*	7.0	38.3	5.3	30.1*†	6.2
Non-dominant	39.8	5.8	34.3*	6.6	37.6	4.9	30.1*†	5.9
MVC/FAMA								
Dominant	0.86	0.10	0.83	0.15	0.91	0.11	0.74*†	0.15
Non-dominant	0.93‡	0.12	0.89‡	0.17	0.97‡	0.11	0.78*†	0.16
MVC/(FAMA × HT)								
Dominant	0.50	0.06	0.49	0.08	0.53	0.06	0.45†	0.09
Non-dominant	0.54‡	0.08	0.53‡	0.09	0.57‡	0.07	0.48*†	0.10

FAMA, forearm muscle area; HT, height (m).

* Mean values were significantly different from those for WN: $P < 0.05$.

† Mean values were significantly different from those for UW: $P < 0.05$.

‡ Mean values were significantly different from those for the dominant arm: $P < 0.05$.

(r 0.55) and BMI (r 0.46). Table 3 highlights the comparative results of the MVC in the three groups. The CED group had significantly lower MVC both in absolute terms as well as when corrected for stature and FAMA than the WN group. This was largely true irrespective of whether the measurements were made on the dominant or non-dominant side. In contrast, the MVC of the UW group were comparable to the MVC of the WN controls despite significant differences in other anthropometric indices (Table 1), and were significantly higher than those of the CED group although the measured forearm anthropometric indices were similar in both groups (Table 2).

DISCUSSION

It is important to diagnose the chronically undernourished or energy-deficient (CED) state in a community as well as a clinical set-up. In the community it allows for the description of the overall nutritional status as a necessary measure prior to the formulation of nutritional policy and the introduction and evaluation of intervention programmes (Shetty & James, 1994). In a clinical situation the CED patient needs to be identified in view of special nutritional requirements (Fernandez *et al.* 1993), drug-nutrient interactions (Krishnaswamy, 1978) and a possible altered sensitivity to drugs in the undernourished state (Jayarajan & Shetty, 1987; Kulkarni *et al.* 1988; Vaz *et al.* 1992). In addition, the clinician needs to assess prognosis taking into account the undernourished state (Klidjian *et al.* 1980).

The classification of adult CED is based on the use of BMI and energy turnover as recommended by the International Dietary Energy Consultancy Group working party (James *et al.* 1988). The determination of energy turnover requires the estimation of daily energy intake or energy expenditure which limits its applicability on an epidemiological scale. It has therefore been suggested that BMI alone be used for the diagnosis of CED in adults (Ferro-Luzzi *et al.* 1992). However, BMI used alone may be associated with considerable misclassification errors since even the National Centre for Health Statistics data on adults indicate the presence of a reasonable number of underweight but not necessarily undernourished individuals in a community (Abraham *et al.* 1979).

The results of the present study suggest that MVC may help to delineate the CED state. Methodologically it appears to make little difference whether the dominant or non-dominant side is measured in terms of differentiating between groups. MVC was corrected for FAMA in an attempt to express muscle strength per unit muscle mass. If in fact FAMA was a major determinant of handgrip strength it would seem plausible that correcting MVC for FAMA might reduce the differences in MVC between the three groups. This does not, in fact, occur (Table 3) and might be related to the fact that strength of the handgrip involves only a part of the forearm muscle mass; an explanation that may also account for the higher MVC/FAMA in the non-dominant side of all the groups. Since muscle development, and therefore muscle strength, is dependent on the growth of the long bones, the lower MVC in the CED subjects may be attributed to their shorter stature. However, the similar MAC, CAMA and the statistically insignificant differences in FAMA between the UW and CED groups with significant differences in stature do not support this. When MVC were expressed to correct for differences in stature (Ghesquiere & Eekels, 1984) between the CED group and the rest, the differences between the CED subjects and the other groups persisted despite this correction (Table 3).

MVC has been found to be useful in the assessment of nutritional status, particularly in states of acute weight loss (Lopes *et al.* 1982) and in evaluating prognosis of nutritionally depleted patients (Klidjian *et al.* 1980). It has also been shown to be more sensitive to changes in dietary patterns than many traditionally measured nutritional variables (Russell *et al.* 1983*a*). On the other hand, however, muscle function may be dissimilar across different muscle groups in the same individual (Lambert, 1965). A drawback in the testing of muscle strength with a dynamometer is the dependence on motivation of the subject to exert maximal effort. It is encouraging that there were no large differences in the intraindividual variability in MVC across groups in the present study suggesting that motivation may not have been a factor contributing to these differences. The interpretation of MVC is also confounded by genetic influences (Reed *et al.* 1991), the effect of training (Hakkinen *et al.* 1985) and age (Larsson & Karlsson, 1978). It would therefore be necessary to determine the cut-offs for undernutrition across different age ranges.

The present study demonstrates that the testing of muscle function, in the form of maximal grip strength, is a simple but useful functional variable that can be used to delineate the undernourished state both at the bedside and in the community and may form a valuable adjunct to BMI.

This study was supported by the Nestlé Foundation, Switzerland. The authors would like to thank Drs A. J. W. Jacob and Mario Soares for their help and useful discussions.

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