Wellcome Film Project

Nutritional Requirements

Uptodate: Clinical Nutrition

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<**Opening titles**>

<**Narrated by Durnin to camera**>

Now in this presentation, I don't intend to deal with all of the nutritional requirements of the normal state of health that we would like our patients and our healthy population to have. So it has to be a very restricted presentation and I really only want to deal with energy, for two particular reasons. First of all, I think, in most diets, if you provide enough energy in the diet then for a very large percentage of people they're going to get enough of almost every other nutrient that they require. And secondly, I think the most common alteration we find in patients relates to changes in their energy balance – they're either getting too little energy in their food or they're getting too much energy and this causes changes in their body composition. So in this very short account I really want to concentrate on some aspects of energy requirements and of the changes that occur in body composition and how we can measure these.

Now I think it's really quite important for many medical practitioners to be able to make some measurements of the composition of the human body. We can really only do this in a very simple way because it's always surprised me how little we know about the composition of the body. Now I keep thinking about all these millions of dissections that anatomists have made throughout the years and we're really quite restricted in what we know about the composition of the body.

<**Durnin narrates over a diagram of a body shape**>

And in this first, very rough diagram that I'm going to show you, this is meant to represent the subdivisions of the body so that, for instance, we have here the subcutaneous fat. Fat is distributed in two main areas of the body, in the subcutaneous tissues and in these internal tissues which are situated in the thoracic and abdominal cavities. Fat constitutes quite a large percentage of the body which is variable, as you know. The rest of the body is made up of the fat free mass and we can get rid of the fat in this diagram so that we're left with only the fat free mass which is, first of all, muscle. These big hunks of muscle that we've got in the limbs represent roughly about 50% of the fat free mass. That's a very rough estimate and it's probably very variable and we don't know how variable it is, it's one of the things the anatomists haven't told us. The other big proportion of the fat free mass is the skeleton so that we've got the skull and the vertebral column and the ribs and the limb bones and so on. These constitute about 20% of the total fat free mass but the common impression that doctors and lay people have about people being either big-boned or heavy-boned may be quite accurate but we really don't know, there's no way that we can measure accurately skeleton. And then there's a whole lot of other components in the body which comprise small percentages – the skin making up about 8%, the liver about 3% of the fat free mass, the lungs another 3%, brain and nerve constituting another 3% or so and there are a lot of miscellaneous things left over. So this would be roughly the anatomical composition of the body and in the next diagram just very roughly we can show what the chemical composition of the body is.

<**Durnin narrates over chart showing body composition**>

We take the standard sized male and the standard sized female because the proportions vary very considerably with size. But if we take a 65 kg man, then he's got about 11 kg protein, a very small amount of carbohydrate, only about ½ kg. The average man who doesn't look fat, in this country, has probably about 10 kg of fat. Minerals constitute about 4 kg and the large proportion of the body is water, about 40 litres or 40 kg of water. And you can see that in the female, these quantities are quite different. Protein and fat being less than the male for protein, a good lot more than the male for fat and minerals a bit less, water a bit less. But if you take the fat free mass of the body, that is, if we exclude the fat, the proportions of protein, minerals and water in the male and female bodies are almost exactly the same. So proportionally there's not too much difference if we exclude the fat.

Now, for many conditions which we may have to deal with in treating patients or giving advice to patients, it may be quite important to measure the fat and the fat free mass in an individual.

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<**Durnin to camera**>

There are many reasons for this, if we're dealing with where the fat free composition of the body has altered, for instance in obesity or in anorexia nervosa or in any chronic wasting disease, then it would be quite useful to be able to measure the amount of fat in the body and see how little fat is left. Or if it's an obese patient, how much fat?

<**Table**>

Body compartments: measurement

Fat **by densitometry**
by skinfolds

Fat free mass ('lean body mass')

by total body water

by total body potassium

<**Durnin narrates over table**>

And we can measure fat by two techniques. By measuring the density of the body and by measuring the skin-fold thickness, which tells us about the fat under the skin. We can also measure the fat free mass by various techniques and this may be a very important indication of what's happening to the body quite apart from fat. In patients who have a chronic disease or if they're recovering from a serious injury or if they've had a major operation or if they've had severe burns or many other disorders. They may have considerable alterations in their fat free mass, nothing to do with the fat content but the fat free mass, the muscle and the skeleton and so on. So there are ways by which we can measure both of these.

<**Table** >

Measuring fat and ffm

Densitometry

Fat has density of 900 kg/m^3

Ffm has density of 1100 kg/m^3

<**Durnin narrates over above table**>

This next diagram will tell us some of the basic reasons that allow us to make the measurement of fat and fat free mass, for instance, density. If we measure the density of the human body which we can do by Archimedes Principle and weigh somebody in air and weigh them completely immersed in water we can work out how much fat and how much fat free mass is present in that individual. Because the density of fat and fat free mass are very different these two have been measured, the density of fat has been taken from various sites in the body and from many different types of individuals and we know, fairly exactly, that the density of fat is about 900 kg per metre cubed, this is in SI units and 010 units about .9 of a gram per cc. The density of the fat free mass we know from the measurements of many animals and we can calculate approximately what we think it should be in a human being and again it's very consistent, it seems to be about 1100 kg per metre cubed and about 1.1 g per cc. So if we can measure the density, depending on what the density turns out to be in a patient, we can say the patient has about 10% or 20% of his body weight as fat.

<**Durnin to camera**>

And this is a technique that's been used in many thousands of individuals in laboratories throughout the world. Now another technique of measuring body composition, one which is used fairly commonly for other purposes in clinical departments is to measure the total body water.

<**Table**>

Total body water

Fat has no water

Ffm has 72% water

<**Durnin narrates over above table**>

And in this next diagram we can see that we can extrapolate from the measurement of the total body water the amount of fat free mass in the body because again we find that as with body density fat and fat free mass are very different as far as the water is concerned. There is no water in fat. And when I talk about fat I'm meaning it in the chemical term, that is I'm talking about lipid, chemical fat inside the fat cell and I'm not talking about adipose tissue. Adipose tissue is made up of the fat inside the cell plus the membranes plus connective tissue and a bit of water in between the interstitial tissues, so that adipose tissue contains fat plus fat free mass and when we discriminate from the amount of water present in the fat free mass by fat we're meaning only lipid. The lipid has no water and all the water in the body is present in the fat free mass and in a constant proportion so that about 72%, and that seems to be a fairly exact figure, in a normal individual, is present as water. And if we therefore measure the total water content, we can derive from that the fat free mass. For instance if we had a very big, fat man, weighing about 150 kg and we measured his total body water by one of the standard techniques we might find it came out as 72 litres. And 72 litres of water weighs about 72 kg and since this makes up about 72% of the fat free mass we know that this man has got about 100 kg of fat free mass in his very big body. And the other 50 kg is fat. Anyhow, measuring total body water gives us a fairly accurate estimate of the fat free mass and therefore of the fat content.

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Another technique which is used on a rather limited scale because the equipment is so expensive is to count the potassium content of the body and from that we can derive, again, the fat free mass because, like water, potassium is present only in the fat free mass. And we can measure this by putting our patient into a counter, a specially constructed counter, and this allows us to be able to measure exactly the total potassium. So again we can derive the fat free mass and therefore the fat from this measurement.

<**Durnin to camera**>

Now, measurement of fat and fat free mass by density, by total body water and by total body potassium are techniques that are really only applicable in a very expensively and rather elaborately equipped laboratory. They're not much use as methods for measuring routinely patients coming into a surgery in general practice or patients in hospital. But there is a technique we can use on these sort of patients which is really very simple and I'm always surprised that it hasn't been used much more widely.

<**TAble**>

Measuring body fat from skinfolds

biceps

triceps
sub-scapular
supra-iliac

total

<**Durnin narrates over above table**>

And that's to measure the skinfold thickness. By measuring the skinfold thickness what we're doing is to measure the thickness of the subcutaneous fat. The fat that is present in the body is distributed between the subcutaneous layers and these internal depots in the abdominal and thoracic cavities. Now within any given group of individuals, there's a fairly consistent distribution of fat between these two sets of depots. That is between the subcutaneous and the internal layers. Although this differs between men and women and it changes with age, for any given group of individuals it's a pretty consistent ratio. And it's been found also that if we measure the skinfold thickness at only four sites in the body, these are the ones that are depicted in this diagram, that is the biceps, triceps, sub-scapular and supra-iliac regions, this gives us a very good idea of the distribution of fat throughout the whole of the subcutaneous tissue.

<**Durnin narrates while demonstrating callipers**>

Now, if we do these measurements of skinfold tissue and it's very simple, we can use the callipers – there are very many versions of callipers on the market, this is the standard British model, rather an old-fashioned version of it, and you can see that it's an instrument in which the jaws of the callipers can open to different dimensions and the width of this distance between the jaws which you can read off on the dial, gives you the thickness of the skin fold. And the fatter the person, of course, the bigger the skinfold.

<**Durnin to camera**>

Now when we measure skinfold thickness at these sites, we find that the totals correlate very highly with the measurement of the total fat content of the body by any of the laboratory techniques. That is, using total body potassium or density or total body water.

<**Durnin narrates over diagrammatic chart**>

And therefore it's quite feasible to construct a table which will tell you how much fat is present in an individual's body at different thicknesses of skinfolds. And this table shows you that for these three depicted quantities of skinfolds, let's say a total of 30 mm, one of 60 mm, one of 90 mm, we can read off, depending on the sort of individual we're measuring, what this represents in the way of a fat content. Now I said that there were differences between men and women and you can see this – for the same skinfold thickness of 30 mm, if it's a young man you've measured he's got 13% of his body weight as fat. If it's a young woman that means she's got 20% and if it's an elderly man over 55, then 30 mm means a total fat content of 19%, an elderly woman 27%. And so on, with this rather high skinfold thickness which would be equivalent to a modest amount of obesity, these are the fat percentages that you'd find in a particular type of individual.

Now, tables are available which allow us to read off very easily and with reasonable accuracy, just what total particular skinfold means in relation to the amount of fat in the body. And this is a technique that I think could quite easily be used as part of a routine medical examination.

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<**Durnin to camera**>

Now what is much more difficult, and I really don't intend to deal with this at all because we know so little about it, is the actual meaning and significance that we can deduce from these measurements of total fat and fat free mass, especially the total fat content. For instance, you know that if you take a group of young, healthy men in this country and they all look apparently slim, you've excluded all the fat ones, then they would have about 15% of their total body weight as fat. If you took an equivalent group of young, healthy women, none of whom looked fat, they would have about 25% of their body weight as fat on average. Whether these are desirable amounts or not I just don't know and I don't think anyone knows at the present time. But it seems to me that it would be very helpful if we could start measuring the fat content in the human body in our various patients and try and see how this relates to all the medical diseases and disorders and disabilities that are supposed to be associated with varying quantities of fat. When it comes to the bit, I think we're very unsure about the medical significance of obesity, especially if it's only moderate obesity and I think it probably varies between men and women but at least if we started measuring the amount of fat in our patients, we might eventually get a better idea of how medically significant these quantities were.

Now, if we've been able to do this measurement of body fat and fat free mass, we get some idea of the state of our patient and if the energy balance of that patient alters then of course he's going to alter his body composition. The amount of energy that we take in in our food will represent a quantity which will keep us in balance but which is going to be very variable depending on what sort of an individual we are and what sort of a job we do. It seems, as far as we can tell, it's occupation for most individuals, it's occupation which is the big variable in effecting the amount of energy we need to keep us in balance.

<**Durnin narrates over animated table**>

And this next diagram shows some of the values that are accepted at this present day in this country and for most international tables giving the amounts of energy for people in different occupations. This table represents these quantities for men with different types of jobs. I think an idea of these values is quite useful in general medical practice because it allows us to give some better advice to patients either who are able to carry on with their job, or if they're patients in hospital we get a better idea of what they should need in the way of an adequate diet in hospital.

Now, the values are given in megajoules and calories and we really ought to be thinking in terms of megajoules now because these are the standard units and we soon won't see calories mentioned in text books or medical journals. At this time I think people are still thinking in terms of calories so I'll deal primarily with them. But for an average sized man, that means somebody weighing 65 or 70 kg, his total energy to keep him in balance is supposed to be about 2700 calories. And you can see if you split this up throughout the 8 hours spent in these different types of activity during the day, bed requires about 500 calories, 8 hours in bed; 8 hours of non-work / leisure needs about the same amount of energy we use up at work. If we are in a job where the activity is only light, and that would include most professional people and most people working in offices and similar types of occupation.

If we look at the levels now for men in a moderate activity / occupation, it doesn't seem to be so much higher – the total has gone up to about 3000 calories and you can see this is balanced by an increase in the amount of energy required by work. We assume from all the information that we've got available that the time spent in bed and therefore the total energy that we use up and the total energy used up in leisure doesn't offer very much irrespective of occupation. Even up to this heavy occupation where a relatively small proportion of people in this country are expending these much higher amounts of energy – these would be men working at, say, the coal face in a mine or doing forestry work or some kind of farmers or military recruits. A relatively tiny proportion of the working population are up at these levels. Again you can see it's the working energy that increases the total quantity. Now if we've got an idea of these relative quantities, especially this one because that encompasses a very large proportion of the population, this gives us an idea of what an average patient is likely to need if he's a hospital patient in bed. It's highly improbable that patients will need any more than that quantity and very often, less.

<**Durnin to camera**>

Now, if it's a patient not staying in hospital for too long, it really doesn't matter if we give them a bit more than these requirements so we can up it a little, we can increase the quantity a little if we feel that it is desirable, I don't think that it makes a great deal of difference and probably about 2500 calories a day for an average sized man is a figure that would fit most patients. There are exceptions to that figure which would really apply to patients who'd had serious injuries or serious burns. But even in these cases it seems to me to be very unlikely that the value of energy they will need will be more than about 3000 calories.

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<**Durnin narrates over animated table** >

Now the equivalent for women, and again we take a sort of average sized woman weighing about 55-58 kg, you see her values are quite different to the equivalent male. They are much slower at about 2000 calories per day or 8.4 megajoules. And her distribution of energy between her 8 hours in bed and her 8 hours at leisure and work comes to these different sorts of figures. And again, with the extra values attached to the second activity level, the moderate activity, where a fairly small proportion of women are engaged in these jobs, the increase in energy is pretty small. Light activity, unfortunately I think, from an emotional point of view, includes housewives. It would be nice to think that housewives require very large amounts of energy because of the mentally and exhaustive nature of their work, but it's not a physical exhausting labour – as far as all the measurements done on housewives have been concerned, they're at this fairly low level of energy which I think probably explains why it's very easy for a housewife to become slightly obese. Increase value is really not very much for women working in occupations that involve a bit more physical activity.

<**Durnin to camera**>

Now these figures then are the sorts of values that apply to men and women of average size. But the amount of energy that they use up will vary quite considerably if you're quite different in size, which really means in body weight, from this 65-70 kg for a man and about 55-58 kg for a woman.

<**Table**>

Effects of weight on energy

Wt. (kg) MJ	**light activity MJ**	**moderate activity MJ**	**heavy activity MJ**
60	**10.5**	**11.5**	**13.6**
70	**12.3**	**13.5**	**15.8**
80	**14.1**	**15.4**	**18.1**

<**Durnin narrates over above table**>

And the next diagram will show you how we think this variation reflects the differences in weight. And for men, and for women both, the differences are supposed to be more or less different to proportions in weight. So that if you're a man in a light activity doing work in most offices, professional work, then the total amount of energy that you use up if you weigh 60 kg is quite different to the amount of energy that you require if you weigh 80 kg. There's a great deal of doubt in practice about whether these differences are valid. You see, if you add them up, as far as the differences are concerned and relate them to body weight, they're really proportional and there's a great deal of doubt in real terms if this is valid or not. We don't have a great deal of information about this so we assume that if you've got a patient that weighs 100kg, he's going to need twice as much energy as a patient weighing 50 kg, assuming they're both the same sex.

<**Table**>

Effects of weight on energy

Wt. (kg) MJ	**light activity MJ**	**moderate activity MJ**	**heavy activity MJ**

45	**6.8**	**7.5**
55	**8.4**	**9.2**
65	**9.8**	**10.9**

<**Durnin narrates over above table**>

And the next diagram simply shows these same values for women, with again similar differences occurring relating to body weight. A woman who weighs 10 kg less than the standard average one of 55, is going to need proportionately that much less energy and the same if she's a bit heavier, she needs that much more energy. The assumptions are that the routines of life of these women is roughly similar so that if you're heavier because you're much fatter and this means you're less active, of course these differences will not be absolutely valid. But for most people, in general, we assume that weight has an effect on the total amount of energy required.

<**Durnin to camera**>

Now these different amounts of energy relate only to adults and of course for many of our many subjects and patients in practice, children are a much more difficult group to deal with.

<**Table**>

age yrs	**MJ**	**kcal**
1	**4.9**	**1180**
5	**7.8**	**1870**
10	**10.5**	**2500**
15	**12.6**	**3000**

<**Durnin narrates over above table**>

And the amount of energy required by quite young children, as you can see from this diagram, is often fairly high. So that a 10-year-old may require almost as much energy as an adult man in sedentary occupation. And these differences with the age of children are really quite difficult to relate in terms of what many people think of as the importance of growth. I'm sure that many doctors and almost any lay person feels that the fact that children are growing is the main reason why an individual child may need quite a lot of extra energy. And this factor of growth is one which, if you look at it in a properly integrated, scientific fashion, that is using the few bits of data that we've got, mostly obtained from animal studies but with a bit of calculation on humans, the amount of energy required for growth seems to be very considerably less than we used to think.

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<**Table**>

Energy for growth (per day)

age	**growth**		**total**	
	MJ	**kcal**	**MJ**	**kcal**
<3 mnths	**0.54**	**130**	**2.3**	**550**
2-3 yrs	**0.13**	**30**	**5.7**	**1350**
9-10 yrs	**0.13**	**30**	**10.3**	**2400**
14-15 yrs	**0.25**	**60**	**12.6**	**3000**

<**Durnin narrates over above table**>

The period of maximum growth is one where the infant is less than 3 months of age and you can see from this diagram that under 3 months, the amount of energy required for growth alone is 130 calories per day out of a total energy requirement for that infant of 550. So it's a very big proportion of the total amount of energy. But by the time the infant grows even at this fairly early age of 2-3 years, out of the total amount of energy required for the infant of just over 1300 calories per day, growth only needs about 30 calories, quite an insignificant proportion. At an age where, again, many of us would think that children are growing very rapidly, 9-10 years, a total energy requirement to keep the child within balance of 2400 calories per day involves only 30 calories for the growth component. And in early adolescence, at 14-

15 years or possibly even a bit younger, the fairly considerable total amount of energy involves a growth component which is very small. And this leads us into quite a considerable dilemma it seems to me, because the factor of growth itself, alone, seems to mean that very little extra energy is required because of this.

<**Durnin to camera**>

And the total amount of energy required by children, if it is high, relates to the total amount of physical activity that they have and has very little to do with the fact that they're at this growing stage. So perhaps it may be advice that it might be important to give to a parent that if the child isn't active, then there may be very little reason for trying to induce it to eat a bit more because it's growing, because this is not a necessary amount of extra food to get into this growing child.

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Another area where we think that there may be very considerable differences in the amount of energy required in a physiological state is when women become pregnant, or when they're lactating.

<**Table**>

Energy for pregnancy and lactation
(Theoretical requirements)

Pregnancy

1.5 MJ (350 kcal) per day <u>extra</u> in last 6 months
(allows 4 kg fat deposition for lactation)

Lactation

2.8 MJ (550 kcal) per day

<**Durnin narrates over above table**>

And we know that if we have exactly comparable women, one of whom is non-pregnant and the other is pregnant and they're carrying on an exactly similar routine of life, then the pregnancy will require quite a considerable amount of extra energy. Now this has been calculated to be of the order of 350 calories per day over the last 6 months of pregnancy. An extra 350 calories per day over this last 6 months. Now that 350 calories includes quite a significant quantity which is supposed to be laid down as extra fat in the body of the pregnant woman and which she can use up when she lactates, if she breastfeeds her infant. Of course if she doesn't intend to breastfeed her infant, she won't need that equivalent amount of energy and the extra will be quite considerably reduced. And the fact is, when we actually make measurements of the amount of food eaten by women who are pregnant, we find that very often it's not very different from the non-pregnant state. And this is because most pregnant women will reduce the amount of physical activity that they have in their normal daily life to allow some compensation to allow for the fact that they actually are pregnant and therefore their actual energy requirement may be virtually little above the non-pregnant state. And if we encourage the pregnant woman to eat more for her pregnancy, then we may well be inducing her to lay down extra fat and to start off the whole process of obesity as she may have recurrent pregnancies. Many women blame their pregnancies, probably quite rightly, for producing obesity and it may sometimes be due to the wrong sort of medical advice.

Lactation is, again, something which we know requires very considerable amounts of extra energy and if a woman's breastfeeding her child and producing an adequate quantity of milk, then she's going to need about 550 extra calories per day for this lactation. Now, the assumption is that this will be extra if the woman is carrying on a way of life exactly comparable to the non-pregnant, non-lactating state. And most women who are breastfeeding are not doing this. Because they are breastfeeding they have to sit with the babies for quite considerable times during the day and their total amount of physical activity will also be very much reduced over the non-pregnant state. So that in real terms, most women who are breastfeeding their infants are eating much less extra energy than this theoretical requirement. So in practical terms, as far as advice to a breastfeeding mother is concerned, she will certainly need extra food to cater for the milk being fed to the baby but a careful look should be kept on her weight balance to make sure that she's not getting too much energy and becoming slightly obese.

<**Durnin to camera**>

Now these are various aspects of the amount of energy which may be required by different types of individuals and which can vary quite considerably and where alterations occur in the energy balance, changes result in the body composition. I think the whole subject of energy at all levels is a very important one and especially for the human body and therefore it seems to me that we could well look quite carefully at the amount of energy used up by our patients with different types of medical conditions. We might try making much more careful assessments of the sorts of diet which should be given to various hospital patients to keep in a proper balanced state of energy and I think we should also begin to make many more measurements of changes in body composition which result from changes either in the energy balance of patients or the medical state of these patients.

<**End credits**>