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Factors affecting energy and macronutrient requirements in elderly people

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Abstract

Objectives: (i) to describe energy and macronutrient requirements in healthy and diseased elderly patients from knowledge acquired about the age-related changes in energy balance (ii) to describe changes in body composition and the consequences of physical activity and exercise programs.

Results: Aging in individuals considered healthy is associated with a reduction in muscle mass and strength (with consequences on autonomy), and an increase in fat mass mainly in the central area, the latter might increase the risk of cardiovascular disease. Body composition changes can be seen as a positive energy (fat) balance. The reduced fat-free mass is responsible for a low resting metabolic rate. Therefore, energy requirements are reduced all the more since physical activity is decreased. A simple means for calculating individuals' energy requirements from estimated resting metabolic rate and physical activity is not yet available in a validated form and is much required. Protein requirements are still debated.

Exercise programs can be implemented for increasing muscle mass and strength (resistance training) or for improving aerobic fitness and reducing fat mass (endurance exercise). It is not yet clear whether structured exercise programs or spontaneous physical activity have similar advantages. It is not known in which cases resistance, endurance, or a combination of both exercises should be recommended. The consequences of physical activity and exercise programs on energy and macronutrient requirements is not clear.

Diseased elderly persons are prone to malnutrition which impairs clinical and functional outcome. Malnutrition is the result of an energy intake inadequate to match energy requirements. Literature is very short of data on energy requirements in diseased elderly persons, who are under the complex influences of stress (increasing resting energy requirements), reduced body mass and physical activity (reducing energy requirements), plus potential effects of drugs. Almost nothing is known about macronutrient requirements.

Conclusions: Further studies are required to enable calculations of energy and macronutrient requirements of individuals, especially diseased. More work has to be done to understand the energy imbalance in the elderly (healthy and diseased). Careful evaluations of physical activity and exercise programs are necessary.

Keywords
Energy
Protein
Carbohydrate
Fat
Elderly

Introduction

The elderly population is growing in number. This is a specific feature of the 20th century. While at the turn of the century life expectancy was close to 50 yrs for women, it is now well over 70 yrs in developed countries. This phenomenon is however heterogeneous. It is the 80 yr. old group that is likely to double in number by 2005, with the 60–75 yr. old group being foreseen as stable. This demographic trend raises new nutritional issues since:

1. There is very little data about dietary recommendations above 80 yrs.
2. Although a significant part of the elderly population remains healthy, old age is associated with an increased prevalence of disease. There is even less data about the nutritional requirements of elderly diseased patients.
3. Aging is associated with decreased physical activity. On the one hand, physical activity is not always taken into account in the recommendations. On the other hand, physical activity is strongly encouraged but little is known about the specific nutritional requirements associated with specific exercise programs.
4. Scientists, health officers, and governments are gradually changing their minds about nutritional,

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therapeutical, or behavioural interventions in elderly people. Twenty years ago, the elderly population was considered a minority, whose nutritional needs were extrapolated from those derived in younger groups. Strategies for treatment would consider the balance between patient benefits and side effects in the context of a short life expectancy. The general belief was that one should not use aggressive treatments at the end of life. Recently, concern is growing about the potential benefits of interventions aimed at reducing a specific risk (cardiovascular, cancer…). The literature is as yet short of intervention studies specifically designed for the elderly. It is however obvious that prevention (nutritional) strategies implemented even at the age of 60 yrs can pay off since a lot of citizens will still be alive 20 years later. Whether prevention strategies are of worth after the age of 80 is probably true in the case of muscle mass and function, but remains unknown for cardiovascular diseases and cancer.

The present paper deals with nutritional requirements in elderly subjects, and is focussed on changes in body composition, physical activity and the prevalence of diseases. The first section describes changes in body composition because:

1. Body composition changes can be related to health and social hazards. For example, the decrease in muscle mass and function impairs autonomy and reversing this change can be the target for nutritional interventions.
2. Similarly, the maintenance of muscle mass and function may be done so by the promotion of physical activity and/or exercise training which in turn might influence nutritional needs.
3. Body composition changes in elderly subjects (gain in fat mass during healthy aging, loss of body mass in malnourished institutionalized elderly patients) can be viewed as an energy (and macronutrient) imbalance. The energy balance concept is valid at all ages. Energy balance is achieved when metabolizable energy (energy available after food is digested) equals total energy expenditure (TEE), then body composition and weight are constant. TEE is the sum of the resting energy expenditure (REE, the energy necessary for the basic functioning of the body), the energy expended on physical activity, diet induced thermogenesis (the energy expended in relation to processing food into macronutrient stores) and, the energy expended for tissue repair and healing, synthesis of specific proteins (inflammatory for example), and adaptation to the cold. Any imbalance between intake and expenditure affects body composition: excess energy is stored (mostly as fat) while the missing energy (from intake) is derived from fat and/or lean tissues.
4. Body size and composition influence energy requirements since REE and TEE are positively related to fat-free mass. Factors released by adipose tissue (such as leptin) see their influence on energy metabolism progressively clarified.

Therefore, the energy needs in elderly people are likely to be affected by various factors. Although some recommendations can be made for an average population, the ultimate objective is to design recommendations for an individual taking into account his/her specific characteristics of age, body composition, physical activity, and health. No such possibility exists.

Body composition changes

It is well known that aging is associated with major quantitative body composition changes. This is known from both longitudinal and cross-sectional studies[1,2].

Body mass tends to increase from adulthood to 70–75 yrs and thereafter decreases. Height tends to be reduced with age, and the classical body mass index (weight/height^2) increases by roughly one unit value every 10 years after 40 yrs of age.

More importantly, fat mass and fatness (fat mass/weight) increase. Age-related increase in fatness is probably different from obesity, which is defined as a body mass index over 30 kg/m^2. The mean value for populations between 60 and 70 years is around 26 kg/m^2. Furthermore, obese young adults display an increased fat mass and an increased fat-free mass (FFM). The latter declines with aging (see below). An important feature of the increase in fat mass is a rapid accumulation of intraabdominal fat[3]. There is now increasing evidence that an accumulation of intraabdominal fat plays a major role in age-related metabolic changes, particularly insulin resistance which is a key factor in type 2 diabetes, and has been related to cardiovascular diseases[4]. There is a clear cut difference between genders, with women remaining fatter than men.

Fat-free mass is decreased mainly as a result of the loss of muscle mass (termed sarcopenia) while the remaining part of fat-free mass (organs) is conserved. To some extent, as for fat mass, there is a redistribution of FFM. The consequences of sarcopenia are well recognized. There is a decrease in physical performance (potentiated by the decline in aerobic fitness) and in muscle strength. The decline in muscle mass is the main determinant of the decline in muscle strength[5]. This affects performance of both the lower and upper extremities, and extension and flexion to the same extent. Muscle strength remains similar up to 45 yrs and decreases by 50% between 50 and 80 yrs. In the mean time muscle mass declines by 30%[6]. The autonomy of elderly people is therefore impaired since muscle strength is a critical component of walking ability, and of the high prevalence of falls in institutionalized patients[5]. Data from the Framingham study (cited in[5]) show that 40% of women between 55 and 64 yrs, 45% between 65 and 74 yrs, and 65% between 75 and 84 yrs cannot lift a 4.5 kg weight. With respect to the activities of daily living, the Euronut-Seneca[7,8] studies have clearly shown that: (i) Only 54% of the men and 37% of the women could do all mobility and self care items of daily living (aged 70–75 yrs); five years later these percentages dropped to 40 and 20 respectively, (ii) There was a large variety in physical activity between individuals living in different towns in those European countries. One consequence is that a significant proportion of the aged subjects spend their remaining years bed-, room-, or house-bound[9] or are dependent on others (30 to 46% for people above 65 yrs[5]). Muscle mass also plays a key role in maintaining bone density, insulin sensitivity and aerobic capacity[5]. Muscle is also a vast amino-acid store that can be used for the synthesis of specific proteins (inflammation, healing…).

Total body water decreases with aging[10]. Early studies[11] reported a relative expansion of extracellular fluid whereas more recent ones suggest that in the healthy elderly, intracellular and extracellular water are reduced proportionally[10,12].

These quantitative changes in body composition can be viewed either as the consequence of aging per se, aged-related behavioral changes (reduced physical activity) or metabolic changes (changes in hormone sensitivity). However, these changes either affect the energy balance (for example, the reduced FFM reduces energy requirements) or are the result of an energy imbalance (an increase in fat mass and a decrease in FFM in such quantitative terms that body weight is slightly increased corresponding to a positive energy balance).

Energy, macronutrient, and water requirements

Energy requirement can be defined as the amount of energy that needs to be taken in (energy intake) to maintain a constant body weight, a desirable level of physical activity and long-standing good health[13]. It is now widely accepted that for a healthy subject, as well as for a diseased patient, energy requirement is best estimated by total energy expenditure.

Healthy subjects

Energy requirements

Expressed in absolute values (MJ/d) resting energy expenditure decreases with age at a rate of about 2–4% per decade between 30 and 80 yrs [data acquired from both cross-sectional and longitudinal studies]. The decline starts at 30 yrs, accelerates from 40 yrs onward in men and from 50 yrs onward in women. This decline is mainly attributed to the loss of fat-free mass. Whether there is a genuine age-related metabolic defect, which is independent of changes in body composition, is still unclear[14]. After differences in body composition are taken into account, women expend about 11% less energy than men[15].

Diet induced thermogenesis is the amount of energy expended during the processing of food into nutrient stores. There is no clear evidence that diet induced thermogenesis is altered with age. This discrepancy relates to the variety of the techniques used for this measurement. In any case, DIT represents a small proportion of TEE (5–10%), and any age-related change in DIT is unlikely to modify significantly the energy requirements[16–21].

It is widely accepted that there is an age-related reduction in physical activity, and of the energy expended for physical activity[22–24]. It appears that the energy expended for a specific movement is hardly affected by age except for walking[15,25]. Therefore, the reduction in EE is the result of a reduction of the time spent in physical activity. However, as for young subjects, there is considerable variety between subjects in their degree of physical activity, with some people remaining active til a very old age[7], and others reducing their physical activity dramatically, sometimes as a consequence of various disabilities.

Physical activity level (PAL), which is the ratio of TEE over REE is an indirect marker of physical activity, and is useful in recommending energy intakes based on a measured or estimated REE and a degree of physical activity. Black *et al.*[26] have shown that for women PAL is 1.62 between 65 and 74 yrs and 1.48 beyond 75 yrs. For men PAL is 1.61 between 65 and 74 yrs and 1.54 beyond 75 yrs. The study by Black *et al.* has considerable interest since TEE was measured in free living conditions by the state of the art technique (doubly labelled water). In another doubly labelled water study on 100 people aged 56 to 90 years, Starling and Poehlman[27] found similar values for women (PAL 1.61) but higher values for men (PAL 1.75). Clearly, these values are higher than those recommended by FAO/WHO/UNU[13] in 1985 (PAL 1.51). A recent report from an IDECG working group[28] recommends the use of a PAL value of 1.65, and that more research should be performed in subjects older than 85 yrs. However, these PAL values are only mean values that do not account for between subject variability in physical activity. Some national councils propose the use of tables that allow calculations of PAL from timed recorded activities and conversions to energy expenditure. These tables have not been validated with a satisfactory procedure: between countries, on a long enough period taking weight stability as an end-point.

Total energy expenditure therefore declines with age[26,29–31]. A little less than 50% of the reduction is attributed to reduced REE, while the rest is associated with reduced physical activity. However, it is impossible to provide numerical values since TEE depends on body mass, FFM and physical activity. The PAL ratio would be a

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Table 1 Physical activity levels

Life style and level of activity	PAL
Bed-bound or chair-bound[34]	1.2
Bed-bound[70]	1.22
Bed-bound[71]	1.41
Seated work, no option of moving around[34]	1.4–1.5
Seated work with requirements to move around[34]	1.6–1.7
Standing work[34]	1.8–1.9
Sports and strenuous leisure activity (30–60 min, 4–5 times a week)	+0.3
Strenuous work or highly active leisure	2.0–2.4

simple procedure to recommend energy requirements for populations. It would require:

1. An estimation of resting energy expenditure with simple equations depending on weight, sex and age. The classical Harris-Benedict[32] equations overestimate REE by only 2%[3]. The WHO equations have a specific component for people older than 60 yrs. Fredrix *et al.*[33] specifically designed equations for elderly people. Unfortunately, none of these equations sets were validated beyond 80 yrs of age.
2. A valid estimate of PAL. Shetty *et al.*[34] have proposed PAL values corresponding to various degrees of physical activity in normal life circumstances (Table 1). Since PAL is the ratio of TEE/REE, it is valid regardless of the age of the persons. PAL is however imprecise, varying for both methodological and biological reasons when measured. Shetty *et al.*[34] have estimated that the PAL has 95% confidence limits of ± 0.3 PAL unit. Therefore, energy recommendations based on estimates of REE and on PAL ratios are likely to be invalid for individuals, and further work is required to define energy requirements better at the individual level.

Recommendations for macronutrient intake

Protein requirements in healthy elderly subjects is a matter of vivid debate between specialists[35,36]. The FAO/WHO/UNU[13] 1985 recommendation is 0.6 g protein/kg body weight (average value) and 0.75 g/kg (safe allowance), and is the same for young and elderly healthy subjects. Based on nitrogen balance studies (which is uniformly recognized as not being an entirely satisfactory tool) Campbell and Evans[35] concluded that protein requirements might be higher than 0.8 g/kg (i.e. a safe allowance ≥1g/kg). Millward *et al.*[36] considering nitrogen balance studies and more sophisticated tracer studies, recommend an intake of 0.69 g/kg. These levels of protein intake are easily met for most of the healthy elderly subjects living in developed countries. However, the need for a desirable upper level of protein intake is pointed out[35] because of a potential connection between excessive protein intake and accelerated decline of the kidney function in the elderly. No such desirable upper level is yet validated. There is not enough data available to conclude about the presence of a gender difference. There is no available data on the requirement of essential amino acids in elderly subjects. There is no specific data about protein requirements above 80 years of age.

There is no data supporting the recommendation of a specific distribution of the sources of energy between fat and carbohydrate in the elderly. However, the accumulation of fat mass can be the result of a positive fat balance, i.e. a situation where fat intake is greater than fat disposal. Fat intake (mainly triglycerides) tends either to be decreased or unchanged with age[7,8,37]; therefore the positive fat balance is the result of a reduced fat disposal. Triglycerides are mainly used for energy production, and fat losses through faeces are not altered with age. Fat is oxidised essentially in post-absorptive and fasting conditions and during low intensity exercise. Most studies show that when compared to young people elderly subjects oxidise less fat in the resting state[38–42]. During exercise, elderly subjects rely more on glucose than on fat for energy production[40]. There is no published study about 24 hour fat oxidation. However, data acquired in room calorimeters (Ritz, unpublished) show that in absolute values (grams per day) elderly subjects oxidise less fat than their younger counterparts, and women oxidise less fat than men. Fat-free mass is a major determinant of fat oxidation[43] When differences in body composition are taken into account fat oxidation is not affected by age per se[38,40]. These elements (reduced fat oxidation and increased fat mass) suggest that a reduction of energy or fat intake could be beneficial; that remains to be studied.

At least 10% of energy intake should be from unsaturated fat to provide an adequate amount of fat soluble vitamins and essential fatty acids[44].

Carbohydrate intake is recommended to be 50 to 60% of energy intake in adults. This proportion should be reconsidered to make 100% of energy when protein requirements are met and when a desirable proportion of fat is set. It is important to encourage the consumption of complex carbohydrates especially since they contain fibers. The beneficial effects of fibers on constipation and intestine function, blood lipids and glucose tolerance are well established[44].

Age-related alterations in the regulation of thirst, in the taste for water, and in the opioid drive to drink tend to reduce fluid intake in elderly persons[45]. Together with the reduced body fluid volumes, this exposes elderly people to an increased risk of dehydration. Dehydration is indeed a threat to the diseased elderly, being responsible for a significant number of hospital stays and subsequent health care expenditures[46]. Very few recommendations exist with regard to water intake in the elderly[47]. An intake of 1 ml per kcal of energy consumed or 30 ml per kg body weight with a minimum of 1500 ml appear to compensate for body fluid losses. Water intake should be increased in all circumstances favouring dehydration[47].

Healthy subjects and physical exercise

Considerable efforts are made to promote physical exercise and increase physical activity in elderly subjects. There is a double objective:

1. To restore muscle mass and strength so as to avoid the loss of autonomy. Resistance training (RT) is very effective in maintaining skeletal muscle mass, increasing aerobic fitness, and increasing spontaneous activity[5,6]. RT has to be intense and validated protocols are described in Evans[5]. RT is defined as training where the resistance against a muscle generates force and progressively increases over time, generally from 60 to 100% of 1 repetition maximum (RM). Evans[5] suggests 80% of 1 RM, three sets of 8 repetitions per muscle group, for 3 days per week. Nutritional supplements alone cannot restore muscle mass, but a combination of nutritional supplements with RT is more beneficial on muscle mass than exercise alone[5]. RT should be started around 50 yrs in sedentary people. Benefits can be obtained even in the older old frail subject[5].
2. To improve aerobic fitness (i.e. VO_{2max}). The rationale is that the higher the VO_{2max}, the less relatively intense is a given physical exercise or task. Working at relatively low intensities reduces the degree of the hormonal response (mainly catecholamines) and the cardiovascular stress, hence limits the fatigue associated with the exercise. Endurance or aerobic training decreases both mortality and morbidity and improves the quality of life by resisting the cascade of disabilities*. It also has metabolic advantages in terms of macronutrient utilization. The cross-over concept describes fuels oxidized to produce the energy required during exercise[48]. For low intensity activities muscle uses mainly fatty acids as fuel, while for intense exercise (including those performed in the anaerobic range) glucose is the unique fuel. It is estimated that for young adults the mixture of fatty acid-glucose is 50:50 at 50–60% VO_{2max}.

Energy requirements

It would sound logical that TEE would increase for elderly subjects taking exercise, owing to the potential increase in muscle mass and/or to the energy expended during exercise. This is not always true. The available data is too sparse to draw conclusions and this is a domain that would require thorough investigation, especially because of the promotion of physical activity.

As far as resistance training is concerned (for the promotion of muscle mass) it is agreed that TEE increases as a consequence of the increased REE and energy expended during exercise[49,50]. Energy requirements may be increased by up to 15% to maintain body weight. Another effect of resistance training is that it increases spontaneous energy intake.

Controversy exists concerning endurance training. In the very short term (4 weeks) REE is increased[51]. In the short term (8 weeks) two studies[51,52] have shown that TEE is not increased. Goran *et al.*[52] suggested that it is the consequence of a reduction in habitual physical activity because of the burden of the exercise. Morio *et al.*[51] have shown that during the period of training, time spent by the subjects on quiet activities was increased while time spent on more intense activities was decreased. On the other hand, Bunyard *et al.*[53] have shown that medium term (6 months) endurance training at low to moderate intensities increased energy requirements by 5 to 8%. [this was obtained in the context of a decreased fat mass and improved VO_2max]. This suggests that efforts have to be made to define the best training protocols. This is even more important if we consider the necessity of very long term exercise programs since beneficial effects of physical training are lost within 12 weeks of deconditioning[5,53,54].

Recommendations for macronutrient intake

The effect of training on protein requirements is not clear. They appear to be decreased by 10–15% by resistance training[5] but increased by endurance training. There is however no sufficient data to support a specific recommendation.

In longitudinal trials, resting fat oxidation is reduced by bed-rest[55] and increased by short term endurance and resistance training (8 weeks[50,56,57]). It appears than in the very few studies done with longer term training (14 weeks) fat oxidation is not increased[57,58]. This may be in connection with the failure to increase energy expenditure in those conditions.

Therefore, an increase in energy intake might be recommended for a period of resistance training, the aim being to avoid too great a weight loss (see paragraph about diseased elderly people). Energy intake should not be increased during endurance training until further proof is obtained that energy requirements are or not increased by specific training protocols. Further studies are also necessary to assess fat requirements associated with exercise training in the elderly.

Diseased elderly subjects

Aging is associated with an increased prevalence of diseases. In the Euronut-Seneca Study[8] 68% of the men and 78% of the women had at least one chronic disease, with a huge variation existing between countries (40% for Spanish men and 100% in Portuguese women). It would be important to evaluate whether special nutritional requirements prevail in these states, especially for patients above 85 yrs. The current literature is very short of data in the diseased elderly. Disease might affect energy balance in various ways:

*See article by I Vuori in this issue.

1. Disease is often associated with weight loss, i.e. a state of negative energy balance. This is illustrated by the high prevalence of malnutrition in institutions and hospitals. The prevalence of malnutrition is lower than 5% in elderly subjects living at home, but zooms up to 40 to 60% as soon as the subject is ill and enters hospital. The consequences of malnutrition on mortality and morbidity are well known[59].
2. It is well established that metabolic stress, fever, and modified substrate cycles are able to increase resting energy expenditure. It is also possible that metabolic derangments, such as inflammatory syndromes, increase REE[60].
3. It is well established that disease is associated with reduced physical activity[9]. Chronic disabilities affect 55% of subjects above 65 yrs and 65% above 75 yrs. This reduces activity in daily life confining patients to bed or the home. This physical inactivity reduces energy expenditure. Bed-rest studies in young healthy individuals show clearly that REE and TEE are reduced[9].
4. Drugs can modify energy requirements. Again the effect is complex. Theophylline for example is shown to increase REE, but its effect on TEE is unknown[61]. Corticoids increase REE but not TEE[62].
5. Therefore, the effect of disease on TEE is likely to be complex. Three examples illustrate this complexity. In Alzheimer disease[63,64] both REE and TEE are reduced as a consequence of the reduced body mass, but are independent of the level of physical activity. In Parkinson disease[65] there is no change in REE, but a reduction in TEE related to the reduced physical activity. In cardiac failure[66] REE is increased but TEE is not.
6. Beyond recommendations for energy requirements one has to consider whether a corresponding energy intake is possible. Disease is associated with anorexia[37]. Bed-rest and physical inactivity might reduce spontaneous energy intake[9]. Elderly people do not appropriately adjust their energy intake to brief periods of underfeeding[67]. There is conflicting evidence about the effect of food supplements to fight malnutrition. Some authors consider that the extra energy is taken at the expense of a roughly equivalent reduction in spontaneous intake. Some others consider that food supplements increase total energy intake. This is a very critical issue since to avoid or counteract malnutrition, there is little scope to reduce energy expenditure. Hence, the stress in on promoting energy intake. The satiety effect of foods high in calories and/or in proteins should be investigated as well as that effect of less energy dense foods.

In conclusion, energy requirements of diseased elderly people are subjected to a triangular influence illustrated in

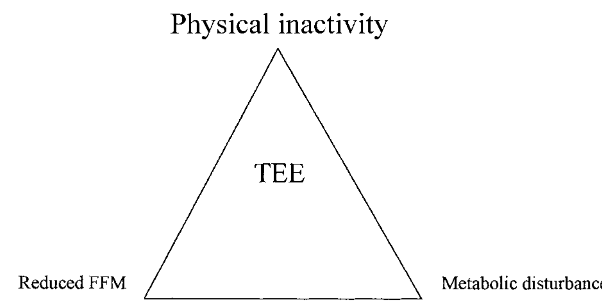

Fig. 1

Fig. 1. At one summit of the triangle, TEE is determined by FFM which is reduced by aging and further reduced by malnutrition. At the second summit, TEE is influenced by the reduction in physical activity. At the third summit, REE can be increased by disease, or drugs. This points at the necessity of the prescription of energy requirement at the individual level, as is stressed in conclusion 3 of this paper.

Almost nothing is known about the protein and macronutrient needs and of the unhealthy elderly[35,36]. However, the prevalence of inflammatory processes might create specific amino acid requirements.

Conclusion 1

Initiative should be taken to derive simple tables that would:

1. Enable the calculation of REE from FFM (± fat mass). This is likely to be more accurate than calculations based on body weight since body weight means different body compositions. This is not currently available in a validated form.
2. Enable the conversion of activities of daily living into a category or a PAL equivalent. This is a critical issue considering the large variety of criteria used to define physical activity, and the lack of a validated continuous score to assess the degree of physical activity.
3. Enable the taking of disease into account, especially above 80 years of age.

Such tables would permit a simple recommendation of energy intake for each individual, even in diseased subjects.

Conclusion 2

All together, the current levels of energy intake are probably too high in healthy individuals. Regardless of the mechanisms that lead to the accumulation of fat, fat stores increase with age. This accumulation corresponds to a positive energy balance, despite the tendency of a decrease in energy intake observed in the elderly. This mismatch between energy intake and energy expenditure predisposes to comorbidities associated with positive

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energy balance and reduced physical activity[68,69]. This is probably more important in women than in men since women are fatter and have a reduced metabolic rate, and fat oxidation. Furthermore, because of the reduction in fat oxidation, studies are necessary to determine whether a fat intake lower than 30–35% of calorie intake is beneficial. However, in some individuals too rigid a restriction may contribute to energy deficit, which is a threat to diseased elderly persons.

Conclusion 3

If strategies for the preservation of muscle mass with advancing age and for increasing muscle mass and strength in the previously sedentary elderly are implemented this will affect energy and macronutrient requirements. Since this might be an important way to increase functional independence and decrease the prevalence of many age associated chronic diseases, strategies and requirements should be carefully evaluated.

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