DETERMINANTS OF BODY FATNESS IN YOUNG ADULTS LIVING IN A DUTCH COMMUNITY

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PROEFSCHRIFT
TER VERKRIJGING VAN DE GRAAD VAN
DOCTOR IN DE LANDBOUWWETENSCHAPPEN,
OP GEZAG VAN DE RECTOR MAGNIFICUS,
DR. C.C. OOSTERLEE,
HOOGLERAAR IN DE VEETEELTWETENSCHAP,
IN HET OPENBAAR TE VERDEDIGEN
OP VRIJDAG 17 DECEMBER 1982
DES NAMIDDAGS TE VIER UUR IN DE AULA
VAN DE LANDBOUWHOGESCHOOL TE WAGENINGEN.

Het onderzoek werd mede mogelijk gemaakt door steun van het Praeventiefonds.

STELLINGEN

1. Bij de behandeling van overgewicht moet er rekening mee gehouden worden dat veel zware personen reeds minder eten dan lichtere personen terwijl ze niet minder lichamelijk actief zijn.

   Dit proefschrift.

2. Een reductie van de dagelijkse energie-opname bij jong volwassen mannen is wenselijk.

   Dit proefschrift.

3. Het argument dat men vanwege een grovere skeletbouw bij een bepaalde lengte zwaarder mag zijn, is zelden van toepassing.

   Dit proefschrift

4. De groep jong volwassen vrouwen is qua lichamelijke activiteit zo homogeen dat hierdoor verschillen in energie-opname niet kunnen worden verklaard.

   Dit proefschrift.

5. Nationale campagnes die tot doel hebben het gemiddelde lichaamsgewicht van de bevolking te verlagen zijn niet gewenst.

   Berger M, Berchtold P, Gries A & Zimmermann H. In: Björntorp P, Cairella M, Howard AN, eds. Recent advances in obesity research III. London: John Libbey, 1981:1-9.

6. Bij de bestudering van de relatie tussen voedingsvezel en de gezondheidstoestand in observationeel onderzoek dient rekening gehouden te worden met de reële mogelijkheid dat de hoeveelheid voedingsvezelopname een indicator is voor gezond gedrag in het algemeen.

7. De structuur van zowel bedrijfs- als jeugdgezondheidszorg zijn bijzonder geschikt voor het uitvoeren van epidemiologisch onderzoek.

8. Afslankthee en -enzymen maken het gesuggereerde effect niet waar.

9. Een hoge beheersdrempel is te prefereren boven een hoge verkeersdrempel.

10. Een schaatsenrijder heeft op de 500 meter deze afstand niet nodig om reglementair de eindstreep te halen.

Proefschrift J.A.H. Baecke
Determinants of body fatness in young adults living in a Dutch community
Wageningen, 17 december 1982.

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VOORWOORD

In dit proefschrift worden enkele onderzoeken beschreven naar de relatie tussen enerzijds socio-demografische kenmerken en het leefpatroon en anderzijds het lichaamsvetpercentage. Speciale aandacht is besteed aan voedselconsumptie en lichamelijke activiteit. Het onderzoek werd uitgevoerd in de gemeente Ede door medewerkers van de vakgroep Humane Voeding van de Landbouwhogeschool, financieel gesteund door het Praeventiefonds.

Van de vele mensen die mij bij dit onderzoek hebben geholpen, wil ik een aantal met name noemen. In de eerste plaats gaat mijn dank uit naar mijn promotor Prof.dr. J.G.A.J. Hautvast voor zijn talrijke adviezen bij dit onderzoek. Van bijzonder belang zijn ook geweest de vele discussies met Jan Burema, Paul Deurenberg, Jan Frijters, René Roosen en Wija van Staveren. Zij leverden allen een belangrijke bijdrage in de verschillende fasen van het onderzoek op basis van hun specifieke deskundigheid.

De administratieve en organisatorische ondersteuning was in bekwame handen van Wil Knuiman en Helmi van der Wiel, terwijl de statistische analyses op adequate wijze werden uitgevoerd door Jan Burema en Ben Scholte. Aan de samenwerking met hen heb ik prettige herinneringen.

Veel dank ben ik verschuldigd aan de diëtistes Netty van Kaathoven, Geesje Sanderink en Jeanne de Vries. Zij hebben de voedingsgegevens op nauwgezette wijze verzameld. Bij het overige veldwerk waren Klarie Baerends, Veronica van de Braak, Marjan van Item, Brigit Janssen, Mathilde Kraetzer, Helma Nijenhuis, Eveline Oosterhaven, Geesje Sanderink, Susan Vermaat en Helmi van der Wiel nauw betrokken. Hun inzet was geweldig.

De hulp van Piet Middelburg bij de financiële aspecten en de assistentie van Bert Gundlach bij de technische problemen, waren met name bij de voorbereiding van de verschillende deelonderzoeken steeds van grote waarde.

De co-auteurs van de verschillende artikelen, die in dit proefschrift zijn opgenomen, dank ik voor de vruchtbare discussies en het kritisch doorlezen van de manuscripten.

Bestuurders van de gemeente Ede ben ik dank verschuldigd voor het ter beschikking stellen van het gevraagde adressenbestand. De contacten met medewerkers van de afdeling Bevolking heb ik als plezierig ervaren. En wat zeker

niet onvermeld mag blijven is dat zonder de enthousiaste medewerking van een groot aantal inwoners van de gemeente Ede dit onderzoek niet mogelijk was geweest.

Het Engels is op zorgvuldige wijze gecorrigeerd door Helen West en het typewerk van dit proefschrift is op voortreffelijke wijze verzorgd door Riet Hoogkamer.

Veel dank ben ik verschuldigd aan mijn vrouw Miek voor haar stimulerend enthousiasme en haar inzet die het mij mogelijk maakten aan de tot stand koming van dit proefschrift te werken.

Tot slot wil ik ook aldiegenen die op een of andere wijze aan dit onderzoek hebben bijgedragen en die ik hier niet heb kunnen noemen, dank zeggen.

Wageningen, najaar 1982 Jos Baecke

1 INTRODUCTION

In 1979, the Department of Human Nutrition of the Agricultural University in Wageningen began a research project on obesity in young adults. The main objectives of this project are the investigation of aetiological aspects and health consequences of obesity. It is a prospective study being carried out in the Municipality of Ede. Other Dutch studies have shown that the prevalence of obesity appears to be much higher in the middle-aged than in children and adolescents (1,2), suggesting that the age range, 20-40 years, is a critical period for the development of obesity. Therefore, this study is being carried out in a young adult population.

This thesis describes the investigations carried out in the first part of this research project which deals with the study of the relationship between socio-demographic variables and daily life-style on the one hand and body fatness on the other. Attention has been paid to food consumption and habitual physical activity, in particular. In addition, two methodological studies concerning relative weight and habitual physical activity are reported. In this chapter, a general survey is given of current methods of measuring body fatness, and the health consequences and aetiology of obesity are also surveyed. A model for the aetiology of obesity is presented and a brief outline is given of the studies described in this thesis.

BODY FATNESS

The human body can be considered as being divided into three compartments: cell mass, extra cellular supporting tissue, and fat (3). The cell mass is the active tissue of the body. Extra cellular supporting tissue, supporting the cell mass, consists of blood plasma, lymph and fluid which bathes the cells, and minerals and protein fibres in the skeleton and other supporting tissue. Fat is the energy reserve held in adipose tissue beneath the skin and around internal organs. There are well established indirect methods for estimating the fat content of an individual. These methods are all based on the principle that the body can, in theory, be divided into two compartments; the lean body mass, and the fat mass. The lean body mass consists of the cell mass and extra cellular supporting tissue mentioned above.

Fat mass differs from lean body mass, because it contains practically no water and potassium, and has a relatively low density (approximately 900 kg/m^3). Lean body mass on the other hand, has a water content of approximately 72%, a potassium content of approximately 65 mEq/kg and a density of approximately 1100 kg/m^3 (4). Current laboratory methods of estimating the fat mass are based on these values. By measuring either total body water, total body potassium, or body density, it is possible to estimate the proportion of the body which is fat, and the proportion which is lean body mass. Lean subjects, for example, have a relatively high content of body water and potassium per kg body weight, and a relatively high body density. Since these methods of estimating body fatness are obviously time-consuming and complicated, they cannot be used in large-scale epidemiological studies. Only the plethysmometric method, in which body volume is measured by pressure changes in a closed chamber (5) may be an exception.

Relative weight, based on body weight and body height, is often used as an indicator for body fatness. Two criteria must be considered in the choice of an index of relative weight (6). Firstly, the index should be relatively independent of body height, because there is a priori no reason to believe that in the general population taller subjects are either leaner or fatter than shorter subjects. Secondly, the correlation between the index and body fatness should be as high as possible. There are two types of indices of relative weight which are independent of body height. The first is of the form body weight/body height^p (W/H^p) in which p is the exponent which makes the index independent of body height. This exponent can be calculated quite simply (7). In the second type, actual body weight is expressed as a percentage of the average body weight of a standard population of the same body height. A disadvantage of the latter type of indices of relative weight is that different standards are used thus making comparisons between studies difficult. If the exponent p of the first type of indices is restricted to an integer value, then W/H^2 which was originally described by Quetelet and referred to as the Quetelet index or body mass index (BMI), is closest to meeting the criterion of independence of body height in adults (6,8).

A general disadvantage of all indices of relative weight is that they do not differentiate between overweight caused by an excess of lean body mass, and overweight caused by an excess of fat (9). Therefore, skinfold thicknesses have often been used as a simple measure of body fat. The use of the skinfold method depends on the assumption that the subcutaneous fat constitutes a constant, or at least predictable, proportion of the total body fat. Special calipers have been designed for measuring skinfold thicknesses. Measurements taken at several sites on the body can be combined to give an index of body fatness and correlate well with the determination of the total body fat from body density measurements (10).

The average proportion of fat in the human body differs between males and females. In young adult males, about 15-18% of body weight is fat, while in females about 20-25% of body weight is fat (11). The condition in which there is an excessive amount of body fat, is referred to as obesity. However, the question remains as to when is there an 'excessive' amount of body fat. This implies that there is a certain point in body fatness above which there is an extra risk of physical and/or psychological health problems. In the next paragraph some attention is paid to these health consequences.

HEALTH CONSEQUENCES OF OBESITY

Extensive data on the relationship between body build and mortality has been collected by life insurance companies in North America from individual policy holders. The Build and Blood Pressure Study reported in 1959, was based on the records of 4.9 million people over a period of 20 years from 1935. This study has had an enormous impact on the attitudes to obesity of both the medical community and the general public (12). It was calculated that there is, in fact, a consistent gradient (linear) advance in mortality with increasing degree of overweight. However, a critical re-evaluation of these data by Seltzer (13) in 1966 showed the existence of a U-shape relationship (Fig. 1). There does not appear to be a significant increase in mortality until a BMI of about 30 kg/m^2 is reached at which point the rise in the mortality ratio becomes considerable.

This critical interpretation which has been largely neglected in the past is in accordance with prospective scientific studies on the relationship between relative weight and mortality. At present data of these studies are becoming increasingly available. In several studies, a quadratic relationship between mortality from all causes and relative weight has been observed (14-16), which suggests that mortality is lowest in those of average weight and is increased in people weighing more or less than average. Keys concluded that risk increases substantially only at the extremes of under- and overweight (17).

FIG. 1. The relationship between mortality ratio and body mass index adapted from data from the Build and Blood Pressure Study of 1959 (13). Average mortality is 100.

It should be stated, however, that these studies were carried out mainly in middle-aged populations. There is some evidence from prospective studies, which also included younger age categories, that excess mortality risk is particularly apparent in obesity occurring before the age of 45 years (15,18,19). Life insurance data also support these findings in younger populations (13,20).

Coronary heart disease appears to be the major factor in the higher mortality of those who are overweight (15). This can be explained by the fact that relative weight is positively related to risk factors of cardiovascular diseases such as blood pressure and serum cholesterol (17,21,22). Weight gain can also lead to rise in atherogenic traits and weight loss to a decline (21,23). It has been shown that the effect of relative weight on the incidence of cardiovascular disease is mediated to a large extent by blood pressure, impaired glucose tolerance and serum cholesterol (24). Thus, obesity is probably not an important independent coronary risk factor, but, in any case, grossly obese people can be considered at coronary risk due to high prevalence of primary risk factors.

Other diseases which are less prevalent than cardiovascular disease have also been observed to be related to obesity. Diabetes mellitus is a well--recognized complication of obesity and gallstones also appear to be closely related to obesity (25). Other related physical health problems are musculoskeletal disorders particularly those involving the weight-bearing joints, ventilation disorders, and surgical and anaesthetical risks (26). The definition of obesity should also include degrees of overweight which are known to increase the morbidity of those diseases mentioned above. As at present insufficient quantitative information is available with respect to the relationship between body fatness and morbidity (12), a definition of obesity can be based only on the relationship between body fatness and mortality.

In fact, an operational definition of obesity should also be based on data available on the psychosocial consequences of obesity, but in regard to this there are again only few studies from which conclusions can be drawn (26). The most salient psychosocial consequence of obesity known at present is the effect on the individual's self-concept and emotional well-being (27). If psychopathology is related to obesity, it may arise from society's reaction to body fatness (27). There is some evidence to suggest that there is a negative attitude to obesity in western society (27,28). This may be based on the presumption that obese people are responsible for their physical deviance (28).

It can be concluded from the studies on the relationship between mortality and relative weight that it is desirable to consider an excess in body weight of about 20 to 25% above the present average weight standards as a pathological disorder which requires intervention (12). This parallels a BMI of about 30.0 kg/m^2, which has generally been accepted as the cut-off point for severe obesity (11,29). A BMI of 30.0 kg/m^2 corresponds to a percentage of body fat of about 28 in males and 37 in females (8). On the basis of this definition, 5-10% of the western adult population would be considered to be obese (29-31). There is little evidence that a BMI of between 25.0 and 29.9 kg/m^2, which can be considered to be moderately obese, carries significant health hazards. This may not be the case in younger people as already mentioned. Therefore, it seems justified that some action should be taken regarding moderate obesity in younger people. It is clear that treatment of moderate obesity is also indicated if health problems are present which can be improved by weight reduction such as hypertension (12,32).

AETIOLOGY OF OBESITY

Obesity occurs only when the intake of food is in excess of physiological needs during a certain period of time. The physiological needs, which parallel the energy output and energy for growth, depend directly on metabolic rate and the amount of physical activity. In research on obesity, not only energy intake and output but also their determinants should be studied. Only by understanding the aetiology of obesity in detail will it be possible to develop successful methods for its prevention and treatment.

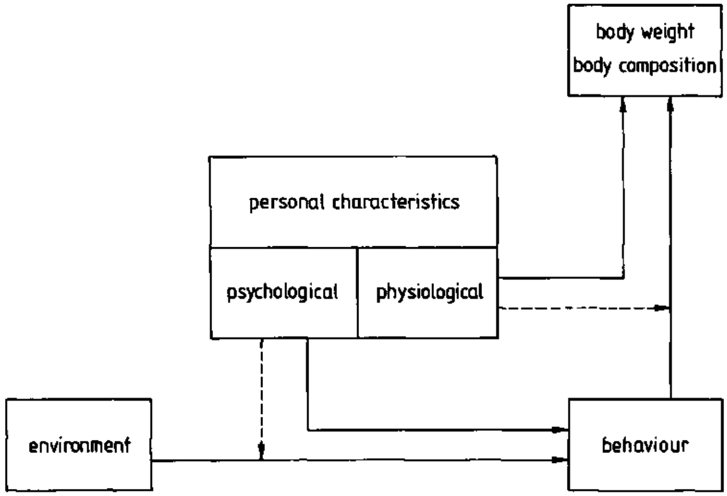
Obesity is clearly multiple determined and it derives from the contribution and interaction of genetic, biological, psychological and environmental factors. It often runs in families, which suggests that genetic factors are important determinants of obesity; however, it is difficult to separate genetic from environmental factors. In the Tecumseh Community Health Survey, evidence was found for long-term synchrony of body fatness change in husbands and wives (33). They are genetically unrelated subjects living together under very similar circumstances. In a study using data from families with biologically unrelated children, and from families with biologically related children, the effects of family environment and heredity were distinguished (34). It appeared that family environment was more important in determining obesity in children than heredity. If genetic factors partially determine the development of obesity their influence will act through the central nervous system. Genes may also have a direct effect on the metabolic rate and on the proliferation of fat tissue (35).

In general, biological factors such as metabolic rate and morphology of fat tissue, have received more attention in research on obesity than the genetic factors. While there appear to be several factors which affect metabolic rate (36), research on the aetiology of obesity is mainly focused on the effect of food intake on metabolic rate. A decrease in metabolic rate has been observed in people on a restricted diet (37,38). This phenomenon is in accordance with the frequently observed smaller weight loss than expected in people who are slimming. A similar trend has been observed in cases of overeating; weight gain often appears to be smaller than expected from the positive energy balance. Possible explanations of this observation have been summarized (39). One of the most feasible seems to be an increase in metabolic rate. Another is change in body composition, so that more energy is stored than is apparent from the change in body weight. An increased form of heat production, which is referred to as "luxusconsumption" or dietary induced thermogenesis, has been postulated to operate as a homeostatic mechanism for energy balance during overeating. The last explanation is supported by findings in several studies (40,41), and it appears to be a phenomenon independent of the thermic effect of meals (40). There is evidence that obese people have a smaller thermogenic response to food than those who are lean. However, it is not clear at present, whether this is of quantitative importance in causing and maintaining obesity in human subjects (42).

From the point of view of the morphology of adipose tissue, two general types of obesity can be distinguished: hyperplastic obesity, characterized by an excess number of fat cells; and hypertrophic obesity, characterized by large fat cells. These represent the two extremes by which adipose tissue can increase. In the dynamic phase of obesity, triglycerides can be stored either by multiplication or by enlargement of fat cells. For a long time it was thought that hyperplastic obesity began at an early age, especially in infancy and that adult-onset obesity is mostly hypertrophic (43). This was known as the fat cell hypothesis. Prognosis for the treatment of the hyperplastic type of obesity is poor (43), perhaps because fat cells are conditioned to a certain filling rate. It has been proposed that fat cell expansion plays a role in the regulation of the energy balance (43). This has been an important reason for emphasis on the prevention of obesity during childhood and in particular in infancy. If the fat cell hypothesis is correct, there should then be a relationship between obesity in childhood and in adulthood. This relationship may be explained also by environmental factors. Nevertheless the trend in the studies reviewed (36) and in two recently reported studies (44,45) is that body fatness in adults cannot be accurately predicted from measurements made when they were children. In addition, data from recent studies also suggest that fat cells can increase in number in adults (46,47). Thus it seems that multiplication of fat cells in childhood is not a very important determinant of obesity in adulthood.

Following this survey of aspects of the aetiology of obesity, factors affecting food intake and physical activity are to be considered. In general, it can be stated that food intake is affected by physiological, psychological and environmental factors. In the physiological control of feeding especially, certain regions of the central nervous system and the gastro-intestinal tract are of great importance. Certain hormones and internal sensory systems such as distension of the gastro-intestinal tract, have been shown to affect food intake (29,48,49). In addition, nutrient composition, taste and other sensory aspects of the ingested food modulate food intake (29,28,49), but all these aspects are outside the scope of this thesis. Food intake is also affected by psychological and environmental factors which also affect physical activity. The influence of psychological and environmental factors on food habits, habitual physical activity and the development of obesity are being studied in detail in the research project on obesity in young adults of which the studies described in this thesis constitute the first part.

The model used in this project for the aetiology of obesity, is given in Scheme 1. The elements included in the model are: environment; behaviour; personal characteristics; and body weight and body composition. These elements were identified by examining the possible causes and underlying factors contributing to obesity. There are similarities to the elements proposed by investigators in other areas of research on health (50-53). In general, the environment includes all factors external to the human body. In the aetiology of obesity, the social environment and the changes in this environment (life events) may be especially important because of their influence on behaviour.



SCHEME 1. Model for the aetiology of obesity in adults (⟶ direct effect; ---> effect modification).

It can be assumed that the physical environment is less important in the aetiology of obesity. Food habits and habitual physical activity are the most important factors in the element behaviour. However, other aspects of daily life-style, which are also related to health, such as smoking habits, cannot be completely ignored. In order to put food habits and habitual physical activity in the general context of health behaviour it is advisable to consider also other aspects of life style. The element, personal characteristics, in the model includes both psychological and physiological characteristics which are developed within the human body as a consequence of genetic and environmental factors and the interactions between these factors. Psychological characteristics such as personality traits (54,55), and knowledge and attitudes about health and nutrition (54) can have a direct effect on behaviour. Nevertheless it is also possible that these characteristics act as modifiers of the effect of environment and changes in environment on behaviour. Not everyone will respond in the same way to a particular environment; individual response will depend on psychological characteristics. Similarly, the physiological characteristics of the individual may modify the effect of behaviour on body weight and body composition. It may well be that certain individuals have a better system for compensating for increased food intake, as mentioned above. In these individuals weight gain may be limited, while in others having an impaired compensatory system, a considerable weight gain may be observed. The physiological characteristics of an individual may also directly affect metabolic rate and consequently affect body weight and body composition. This will occur, for example, if an endocrine abnormality is the cause of obesity. However, the question remains whether endocrine abnormalities are important causes of obesity in the general population. In addition, it has been shown that many hormonal changes are secondary to the subjects' increased body weight (3,8).

OUTLINE OF THIS THESIS

In the studies described in Chapter 2 and 3, about 3900 subjects participated, while a subsample of about 300 subjects from this initial population participated in the studies described in the Chapters 4-6. Chapter 2 deals with a descriptive study, in which the relationship between socio-demographic variables and BMI was studied. The socio-demographic variables represent various personal and environmental characteristics. This study indicates the categories of the population which should be given special attention in treatment and prevention of obesity, and, in addition, it provides some insight on the potential primary causes of obesity.

Chapter 3 deals with the study of the relationship between aspects of daily life-style and BMI. In the literature, several aspects of daily life-style are shown to be related to obesity. It is not clear whether all these aspects are independently related to obesity, or whether they represent only a limited number of indicators of causal determinants. The aim of this study was to investigate whether general types of behaviour could be distinguished within various aspects of daily life-style which were related to BMI. From this study, hypotheses can be formulated which can be tested in the prospective study.

Two methodological studies are described in Chapter 4 and 5. Previously, two criteria have been considered in the choice of an index of relative weight derived from body weight and body height: firstly, the index should be relatively independent of body height; and secondly, the correlation between the index and body fatness should be as high as possible. Chapter 4 is concerned with the desirability of adding a third criterion, that the index should be relatively independent of frame size. The results of this study have been applied in Chapter 2 and 3. A short questionnaire has been developed for the measurement of habitual physical activity, the results of which are presented in Chapter 5. This questionnaire was developed in particular for the prospective study but has also been used in the food consumption study described in Chapter 6.

The food consumption study was carried out firstly, to study the intake of energy and macronutrients in comparison with recommended intakes and secondly, to investigate the relationships between body fatness and both food consumption and habitual physical activity. An adequate measurement of energy intake had to be established because there are no recent data available on the energy intake of young Dutch adults on a community basis. For the management of obesity it is essential to know whether the actual energy intake of the population deviates from the recommended intake. This would indicate whether it may be expected that energy intake is relatively high or that physical activity is relatively low. In this context, data on food consumption and physical activity of both obese and non-obese people are also essential. A general discussion of the studies presented in this thesis is given in Chapter 7.

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2 OBESITY IN YOUNG DUTCH ADULTS: I, SOCIO-DEMOGRAPHIC VARIABLES AND BODY MASS INDEX

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SUMMARY

The simultaneous contribution of various socio-demographic variables to body mass index (BMI; weight/height^2) was studied in young adults in three age groups (19-21, 24-26 and 29-31 years) in a Dutch population. Medians of the BMI of males (n = 1765) and females (n = 2092) were 23.1 and 21.8 kg/m^2, respectively. The prevalence of severe obesity (BMI $\geqslant$ 30.0 kg/m^2) was 2% in both sexes. There was a positive relationship between age and BMI, while level of education and level of father's occupation were inversely related to BMI in both sexes. Married females who had given birth to two or more children weighed more than those with one or no children. The mean BMI of the males in the rural area was higher than that of the males in the urban area. Both the Lutheran males and females weighed more than the non-Lutherans. The mean BMI was lower in males attending church more frequentely than once a month. There were no independent relationships between BMI and the other socio-demographic variables (marital status, main daily occupation, size of family of origin and birth order) in either sex. In conclusion, it can be stated that age and socio-economic status were the most important socio-demographic determinants of BMI. Socio-economic status can be useful in directed prevention of obesity.

INTRODUCTION

Some health disorders are believed to be related to obesity. From the point of view of public health, the most important disorders to which obesity may contribute include: cardiovascular disease, diabetes mellitus, gallbladder disease, psychosocial disability and musculoskeletal disorders (33). The relationship between relative weight, coronary heart disease and mortality has been recently reviewed by Keys (14). Risk appears to be substantial only at the extremes of underweight and overweight in middle-aged males and females. Few data are available on younger men and women, but there is some evidence to suggest that obesity occurring before the age of 45 has more health consequences than obesity occurring after this age (11,29,30).

For planning and developing of programmes aimed at the prevention of obesity, knowledge of the prevalence of obesity in various categories of the population is required. Relationships between several socio-demographic variables and obesity have been reported, but only a few studies have been carried out in young adults and in most studies only a few socio-demographic variables have been included. This has the disadvantage that the observed relationship may be confounded by other socio-demographic variables.

Cross-sectional studies suggest that, in both sexes, relative weight increases during adulthood, is maintained in middle age, and decreases in old age (16,23,34), but cohort differences may influence these observations. Longitudinal studies, however, have also shown a similar trend (6,10,13).

In males no relationship has been found between marital status and obesity (18), while in females such a relationship has been shown (25,28), but it is important to study this relationship after adjustments for age and parity have been made. Both variables are related to marital status, and in addition to age, parity has also been shown to be related to obesity in females. Obesity tends to be more common in women who have borne more children (3,4,9,25).

Even though in affluent countries obesity is generally more common in people of lower socio-economic status (8,12,25,26,32), some investigations in males have not shown this relationship (17,23) and the opposite trend has even been observed (7,20,21,28). These discrepancies may have arisen because of differences in the definition of obesity, the socio-economic indices used, differences in the study population and various cultural factors. The prevalence of obesity in both males and females appears to be higher in rural areas than in urban areas (24,27), but the opposite has also been reported for males (28). In a study in 19-year-old males, obesity was found to be related to small families and especially to the one-child families, while no clear relationship between obesity and birth order was observed (31).

The purpose of the present study in young adults living in an urban-rural Dutch community is to investigate the simultaneous contribution of various socio-demographic variables to relative weight. By this approach each relationship is an adjusted relationship for the other socio-demographic variables in the model.

METHODS

Population. Between March and May in 1980, a population of young adults was studied in the Municipality of Ede in The Netherlands. The municipality, situated in the centre of the country, consists of three districts in an urban area with a total population of about 72,000 inhabitants, and four villages in a rural area with a total population of about 10,000 inhabitants. Each district in the urban area has more than 10,000 inhabitants, and each village in the rural area has less than 3,000 inhabitants.

All inhabitants in three age groups (19-21, 24-26 and 29-31 years as at 1 January 1980) were invited by mail to participate in the study. Their addresses were obtained from the Civil Registration Office in Ede. Complete information was obtained of 3,936 subjects representing 33% of all invited subjects. Women, pregnant for three months or longer (n = 79), were excluded from further analysis.

Procedure. All participants were requested to complete a questionnaire at home and to visit a mobile research unit which was stationed in each section of the municipality for a period of two weeks. At the mobile research unit the questionnaire was checked for completeness and body weight and body height without shoes and jacket were measured to the nearest 0.1 kg and 0.1 cm, respectively. The body mass index (BMI; weight/height^2) was calculated as an index of relative weight.

Socio-demographic variables. By means of the questionnaire, information was collected on specific socio-demographic, behavioural and medical aspects. In this paper attention is paid only to the socio-demographic factors as related to the BMI. The socio-demographic variables considered were: age, marital status, parity, level of education, main daily occupation, urbanization, religion, church attendance, father's occupation, size of family of origin, and birth order in the family (Table 1). In the final analysis some categories were combined, as indicated by brackets in Table 1, because there were only a limited number of observations and because mean BMIs of categories were similar in both sexes.

Three levels of education were distinguished: low level comprising the primary school and some occupational training; middle level comprising the secondary school; and high level comprising the university and other tertiary institutions. Students were coded according to the level of education of the course of study to be completed.

The participants were categorized according to religious affiliation as follows: Protestant, Roman Catholic, other religions and no religion. Protestants were further subdivided into two groups, Lutheran and Calvinist. There may be a relationship between life style and religion, however it may be expected that this relationship is weak, if people do not attend church regularly. Therefore, frequency of church attendance more or less than once a month, was taken into account.

The occupations of the fathers of the participants were divided into four categories which were derived from a Dutch classification (35). The first category included blue-collar workers, that is wage-earners such as plumbers and carpenters, and unskilled manual workers such as factory workers. The second category included self-employed tradesmen, small businessmen and farmers. White-collar workers formed the third category and included occupations such as office work and laboratory work. The fourth category consisted of professional workers including teachers, business executives, doctors and all other occupations with a university education.

Non-participants study. As a result of the low rate of response, a non--participants study was carried out in which efforts were made to visit all non-participants in two sections of the Municipality of Ede. The rate of response of those subjects who were at home on the first or second visit (n = 472) was 92% (including five women more than three months pregnant). Subjects were asked for their reasons for not responding to the mail invitation and to state their education. Body weight and height without shoes and jacket were measured at home to the nearest 0.5 kg and 1.0 cm, respectively.

Statistical methods. The differences between participants and non-participants were tested using Student's t-test, and analysis of variance was used to test the age and level of education adjusted BMI-difference. Product-moment correlation-coefficients were calculated in order to study the mutual relationships between the socio-demographic variables. Multiple regression analysis with dummy variables (19) was used to study the relationship between

Table 1.

SOCIO-DEMOGRAPHIC CHARACTERISTICS OF THE STUDY POPULATION

Variables[1]	Males (n=1765)	Females (n=2092)	Variables[1]	Males (n=1765)	Females (n=2092)
	%	%		%	%
Age (years):			Religion:		
19 - 21	36.7	34.8	Protestant: - Lutheran	36.8	38.3
24 - 26	31.7	31.2	- Calvinist }	21.1	22.1
29 - 31	31.6	33.9	Roman Catholic }	14.3	14.8
			Other religions }	3.3	3.6
Marital status:			No religion }	24.5	21.2
Single }	49.1	38.1			
Divorced/Widowed }	1.0	1.6	Church attendance:		
Married	50.0	60.3	Less than once a month	54.1	51.1
			More than once a month	45.9	48.9
Parity:					
0 }	68.3	54.8	Father's occupation:		
1 }	11.7	13.2	Blue-collar workers	28.0	31.0
2 }	16.4	24.1	Self-employed	16.6	17.7
≥ 3 }	3.6	7.8	White-collar workers	21.5	22.2
			Professional workers	33.9	29.1
Level of education:					
Low	17.1	25.5	Size of family of origin:		
Middle	51.5	59.0	1 child }	3.3	3.2
High	31.4	15.5	2 children }	19.2	17.5
			3 children }	23.4	22.7
Main daily occupation:			≥ 4 children }	54.1	56.7
Wage-earners }	75.5	50.2			
Self-employed }	3.2	1.4	Birth order:		
Unemployed }	2.5	1.5	1	36.1	33.1
Students	18.8	11.1	2	27.3	27.4
Housewives	-	35.7	≥ 3	36.6	39.5
Urbanization:					
Rural	7.1	7.3			
Urban	92.9	92.7			

[1] Brackets indicate that the categories were combined for the analyses.

BMI and the various socio-demographic variables, because most independent variables were nominal or ordinal variables. For each independent variable of interest with k categories, k-1 dummy variables were introduced in the analysis. With this approach, the intercept can be interpreted as the mean BMI of a well-defined reference group, this is the group of subjects with zero scores for each dummy variable in the equation. Each regression coefficient represents the mean BMI-difference between the subjects in a certain category and the reference group. It is easy to calculate the mean BMI for each specific group, because the model is additive. Only P-values < 0.05 are reported.

RESULTS

In the non-participants study, no differences between the participants and non-participants were observed with respect to age and BMI (Table 2) in either sex, but the non-participants had lower levels of education.

Table 2.
COMPARISON OF AGE, LEVEL OF EDUCATION AND BMI (kg/m^2) OF PARTICIPANTS AND NON-PARTICIPANTS IN TWO SECTIONS OF THE MUNICIPALITY

Sex	Variable	Participants		Non-participants		P-value
		mean	SEM	mean	SEM	
Males		(n=239)		(n=227)		
	Age[1]	1.7	0.1	1.8	0.1	
	Level of education[2]	2.1	0.1	1.6	0.0	< 0.001
	Unadjusted BMI	23.2	0.2	23.2	0.2	
	Adjusted BMI[3]	23.4		23.0		
Females		(n=256)		(n=201)		
	Age[1]	1.9	0.1	1.8	0.1	
	Level of education[2]	1.9	0.0	1.7	0.1	< 0.001
	Unadjusted BMI	22.5	0.2	22.3	0.2	
	Adjusted BMI[3]	22.5		22.3		

[1] The three age groups 19-21, 24-26 and 29-31 years were coded as 1, 2 and 3, respectively. [2] The low, middle and high level of education were coded as 1, 2, and 3, respectively. [3] Adjusted for age and level of education.

The median BMIs of the total male and female study population were 23.1 and 21.8 kg/m^2, respectively. The older subjects had higher percentiles (Fig. 1).

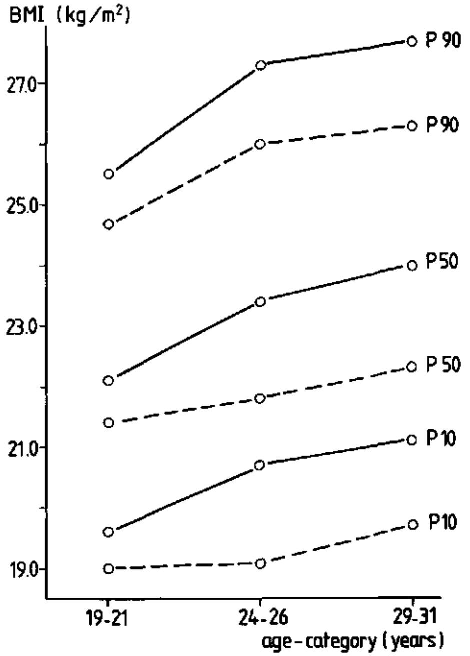

Fig. 1. The relationship between BMI and age in males (n=1765; ——) and females (n=2092; ---)

The difference between medians of the 19-21 and 29-31 year old males and females were 1.9 and 0.9 kg/m^2, respectively. The percentiles of the BMI in the three age categories show that the distributions were slightly skewed to the right. The prevalence of severe obesity (BMI $\geq$ 30.0 kg/m^2) was 2% in both sexes and the prevalence of moderate obesity (BMI between 25.0 and 29.9 kg/m^2) was about 22% in males and 12% in females.

The mutual relationships between the various socio-demographic variables are presented in Table 3. The most important relationships were between age, marital status, parity and main daily occupation, and secondly between level of education, main daily occupation, urbanization, and father's occupation.

Table 4 shows the relationship between BMI and all socio-demographic factors not concerned with the family of origin in one multivariate model.

Table 3.

CORRELATION COEFFICIENTS[1] BETWEEN THE SOCIO-DEMOGRAPHIC VARIABLES OF MALES (n=1765; BELOW DIAGONAL) AND FEMALES (n=2092; ABOVE DIAGONAL)

Variable[2]	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Age	—	.58	.58	-.14	-.19	.44			-.10			
(2) Marital status	.69	—	.53	-.26	-.14	.57			-.10	-.14		
(3) Parity	.52	.49	—	-.22		.57				-.12		
(4) Level of education				—	.39	-.22	.11	.12	.10	.30		-.13
(5) Main daily occupation A[3]	-.46	-.43	-.23	.31	—					.20		
(6) Main daily occupation B[3]						—						
(7) Urbanization				.10			—	.14	-.10	.11		
(8) Religion				.10			.19	—	-.14	.17		
(9) Church attendance				.12				-.18	—		.10	
(10) Father's occupation[4]		-.10		.26	.25		.10	.13		—		
(11) Size of family of origin									.12		—	.40
(12) Birth order				-.12						-.12	.40	—

1 Correlation coefficients ≥ .10.

2 The categories of the variables were coded in sequence as presented in Table 1.

3 Main daily occupation was divided in two separate dichotomous variables: employed/unemployed and students (A) and employed/unemployed and housewives (B).

4 Blue-collar workers and self-employed were coded together.

Table 4.

MULTIPLE REGRESSION ANALYSIS WITH BMI (kg/m^2) AS DEPENDENT VARIABLE AND SOCIO-DEMOGRAPHIC FACTORS NOT CONCERNED WITH THE FAMILY OF ORIGIN AS INDEPENDENT VARIABLES

Independent variables	Males (n=1765)		Females (n=2092)	
	B	SE	B	SE
Intercept	23.2		22.2	
Age (years):				
24-26 versus 19-21	1.1^{xxx}	0.2	0.4^{x}	0.2
29-31 versus 19-21	1.4^{xxx}	0.2	0.6^{xx}	0.2
Marital status:				
Married versus not married	0.3	0.2	-0.1	0.2
Parity:				
⩾ 2 versus < 2 children	0.2	0.2	0.5^{xx}	0.2
Level of education:				
Middle versus low	-0.7^{xxx}	0.2	-0.6^{xxx}	0.1
High versus low	-1.4^{xxx}	0.2	-1.0^{xxx}	0.2
Main daily occupation:				
Students versus employed/unemployed	-0.1	0.2	-0.4	0.2
Housewives versus employed/unemployed	-	-	-0.1	0.2
Urbanization:				
Rural versus urban	0.6^{x}	0.2	0.2	0.2
Religion:				
Lutheran versus non-Lutheran	0.5^{xxx}	0.1	0.4^{xx}	0.1
Church attendance:				
More versus less than once a month	-0.3^{xx}	0.1	0.1	0.1
Explained variation (R^2)	0.14		0.05	

^{x} P < 0.05, ^{xx} P < 0.01, ^{xxx} P < 0.001.

Age was significantly related to BMI in both sexes. The mean BMI of the 29-31 year old males was 1.4 kg/m^2 higher than of the 19-21 year old males, but in females this difference was only 0.6 kg/m^2. The difference between the 24-26 and 29-31 year old groups was small in both sexes.

No significant relationship between marital status and BMI was found in either sex. Married females who had given birth to two or more children were significantly heavier than those who had one child, or no children. The difference was 0.5 kg/m^2. Such a relationship did not exist in males.

Differences in BMI as related to level of education were significant and the trends were similar in both sexes; the higher the level of education was the lower the mean BMI. Mean BMIs in males and females with a high level of education differed by 1.4 and 1.0 kg/m^2 respectively from those of the low level of education. The middle level of education about half-way in between.

There appeared to be no significant differences in BMI between the categories of main daily occupation, although the female students tended to be lighter than the employed/unemployed group and housewives.

The mean BMI of males living in the rural area was 0.6 kg/m^2 higher than the mean BMI of those in the urban area, but this difference was only weakly significant ($P < 0.05$). No relationship between urbanization and BMI was observed in females.

The mean BMIs of both the Lutheran males and females were higher than of the non-Lutheran males and females, 0.5 and 0.4 kg/m^2, respectively. Males attending church more frequently than once a month, regardless of their religion, had a slightly, although significantly, lower mean BMI than others, 0.3 kg/m^2.

In an additional analysis, a possible age-dependent effect of level of education was investigated. Interaction terms of age by level of education were introduced in the analysis, but did not prove to be statistically significant.

Table 5 shows the relationship between BMI and the socio-demographic factors concerned with family of origin. The relationship between father's occupation and BMI was inverse as was the relationship between the own level of education and BMI, although daughters of professional workers did not differ from daughters of white-collar workers. The mean BMI of sons and daughters of the self-employed and the blue-collar workers did not differ.

A relationship between BMI and size of family of origin, and birth order was not observed in either sex.

Table 5.

MULTIPLE REGRESSION ANALYSIS WITH BMI (kg/m^2) AS DEPENDENT VARIABLE AND SOCIO-DEMOGRAPHIC FACTORS CONCERNED WITH THE FAMILY OF ORIGIN AS INDEPENDENT VARIABLES

Independent variables	Males (n=1765)		Females (n=2092)	
	B	SE	B	SE
Intercept	23.9		22.6	
Father's occupation:				
Self-employed versus blue-collar	-0.1	0.2	-0.2	0.2
White-collar versus blue-collar	-0.5[xx]	0.2	-0.8[xxx]	0.2
Professional versus blue-collar	-0.9[xxx]	0.2	-0.7[xxx]	0.2
Size of family of origin:				
≤ 2 versus > 2 children	0.2	0.2	0.1	0.2
Birth order:				
1 versus ≥ 3	-0.1	0.2	0.1	0.2
2 versus ≥ 3	-0.1	0.2	0.0	0.2
Explained variation (R^2)	0.02		0.02	

[xx] $P < 0.01$, [xxx] $P < 0.001$.

DISCUSSION

An adequate index of relative weight derived from measures of body weight and height should have a high correlation with body fatness, and a low correlation with height (15). In a separate study these correlations were checked for the BMI in a subsample of 139 males and 167 females of the present population. The correlation between BMI and percentage of body fat as derived from the sum of four skinfolds (5), was 0.81 in males and 0.79 in females. The correlations with height were only -0.08 and -0.11, respectively (1). These results showed that in the present population, the BMI is a suitable index of relative weight.

The common indicators of socio-economic status are level of education, level of occupation, level of father's occupation, income and monthly rent. For various reasons, many young adults are unemployed and therefore level of occupation and income are inadequate indicators of socio-economic status in this population. The same is also true for monthly rent, because some young adults live with their parents, and others live independently. As many young adults do not have a job, the main daily occupation was introduced as a socio-demographic parameter. It seems a reasonable approach to code the level of education of students according to the course of study to be completed, as otherwise the older subjects tend to have higher levels of education.

It is thought that the most important reasons for the low rate of response in this study was that the subjects were invited by mail to participate, because the home visits in the non-participants study resulted in a high response (92%). The non-participants study showed that no bias was introduced to BMI, even after adjustments for age and level of education no differences between participants and non-participants were observed with respect to BMI. The rate of response was dependent on level of education which has the consequence that the mean BMI of the total young adult population is slightly biased because level of education is related to BMI. Selection by level of education, however, does not hinder the investigation of the BMI-differences between various categories of the population. It can be stated that for such an analysis, as for the study of the aetiology of a disease in general, a representative population is not necessary.

The choice of 30.0 kg/m^2 as a cut-off point for separating severe obese from moderate obese subjects is arbitrary. However. it has been shown that above this point health problems increase considerably (11,14), whereas there is little evidence for an increased risk in the range 25.0-29.9 kg/m^2. The BMI levels in these young Dutch adults are similar to those reported in other studies, such as the Manitoba follow-up study, in which the mean BMI ranges from about 22.3 to 23.9 kg/m^2 in the 17-34 year old males (10). The results of a study in London in which the mean BMI was 22.6 and 21.6 kg/m^2 in 15-29 year old males and females, respectively are also in accordance with the present study (22).

The relationship between age and BMI, as shown by multiple regression analysis, was stronger in males than in females. This suggests a greater increase in body weight in young adult males, if it is assumed that no cohort effect is present.

Unlike other studies (25,28), no relationship between marital status and BMI was shown in this study, because adjustments were made for age and parity. The positive relationship between parity and BMI in females has also been shown by others (3,4,9,25). This finding may be explained by: changes in endocrine functions during pregnancy; changes in food habits and physical activity during pregnancy which remain after delivery and after breast feeding; or by the fact that the increased size of the family influences living conditions in such a way that behaviour is changed.

The negative relationship between BMI and level of education in females is in accordance with findings of other studies (7,8,12,20-22,25,26,28). An inverse relationship has also been observed in males by others (8,12,18). The negative relationship between father's occupation and BMI suggests that socio-economic status is a causal determinant of overweight, because it may be assumed that the socio-economic status of the family of origin is not influenced by body weight of the children (8).

Main daily occupation showed no independent relationship with BMI. Other variables related to the main daily occupation, such as age, parity and level of education, appear to be more important determinants of obesity than the occupation itself.

In earlier studies, a higher prevalence of obesity was observed in rural areas than in urban areas in both sexes (24,27). In the present study, a weak relationship was observed in males only. This discrepancy may be partly explained by the adjustments for level of education. The average level of education in the rural population was lower than in the urban population studied.

The higher BMI in the Lutheran males and females, and the lower BMI in those males attending church regularly, suggest that the general attitude to life may have an influence on food habits and pattern of physical activity.

Mean BMI of sons and daughters of small families was not higher than that of sons and daughters of larger families, as observed in studies in children and in 19-year-old males (31). It may be suggested that such differences disappear with aging. As in the study of Ravelli and Belmont (31), no independent effect of birth order was found for either sex.

In conclusion, it can be stated that certain socio-demographic variables show a distinct relationship with BMI. However, it must be recognized that both in males and females, only a small proportion of the variation in BMI is explained by these socio-demographic factors. This indicates that other factors may be more important in the aetiology of obesity, such as physiological factors which influence energy metabolism, and psychological factors which effect eating behaviour, choice of food, and pattern of physical activity.

The most important socio-demographic determinants of BMI found in this study were age and socio-economic status as measured by level of education and father's occupation. Socio-economic status can be useful in directed prevention of obesity, but it is also necessary to know which types of behaviour are important in the aetiology of obesity, and to know the differences between the various socio-economic classes with respect to this behaviour. Therefore, the relationships between daily life-style and age, level of education, and BMI have also been studied in the present population (2).

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3 OBESITY IN YOUNG DUTCH ADULTS: II, DAILY LIFE-STYLE AND BODY MASS INDEX

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SUMMARY

The relationships between aspects of daily life-style and age, level of education, and body mass index (BMI; weight/height^2) were studied in young adult males (n=1765) and females (n=2092) in three age groups (19-21, 24-26 and 29-31 years) in a Dutch population. By means of principal-components analysis five conceptually meaningful factors could be distinguished within the aspects of daily life-style which were considered. These factors were interpreted as constructs of: 1, slimming behaviour; 2, behaviour characterized by the consumption of coffee and alcohol, smoking habits and the number of hours sleep per night (CASS behaviour); 3, eating sweet and savoury snacks between meals; 4, health-conscious behaviour; and 5, physical activity. After adjustments were made for age and level of education, multiple regression analysis showed that slimming behaviour was positively related to BMI in both sexes, CASS behaviour was positively related to BMI in males, and health-conscious behaviour was inversely related to BMI in both sexes. An observed positive relationship between BMI and occupational physical activity in males could be explained by a confounding effect of socio-economic status. The observed weak positive relationship between number of hours active sport per month and BMI in males is possibly due to a difference in lean body mass. The consumption of sweet and savoury snacks was not related to BMI in either sex. These findings suggest that the daily life-style variables should be interpreted as indicators of more general types of behaviour, some of which may be important determinants of obesity.

INTRODUCTION

In order to successfully prevent and treat obesity, it is essential to understand the aetiology of obesity. Hence it is important to investigate the relationships between aspects of daily life-style and obesity, as a number of these aspects may be relevant to the description of the obese population, and the population which is most prone to become obese. Although various aspects of daily life-style and obesity have already been considered in a number of studies, most of these studies were only concerned with isolated variables. It is not clear whether the observed relationships between these variables and obesity were direct relationships or, whether in fact, these variables should be interpreted only as indicators of more general types of behaviour.

It has been shown in several studies that cigarette smokers weigh less than non-smokers (5,15,17,22,31), but in general heavy smokers weigh more than light or moderate smokers. A U-shape relationship has often been observed between smoking categories and relative weight (5,17,31). The average weight gain in people who have stopped smoking has generally been found to be higher than in smokers and those who have never smoked (5,6,31), but individual weight losses have also been observed (6). Up until now there have been three hypotheses to explain this observed relationship (6): firstly, smoking acts as an appetite suppressant; secondly, smoking stimulates the resting metabolic rate; and thirdly, after giving up the habit of smoking, the amount of food eaten is increased as a substitute for smoking.

Relationships between smoking and other aspects of daily life-style have also been observed. Positive relationships have been observed between smoking and the consumption of alcohol (4,9,10,12,15,35), and coffee (4,9). The three aspects of daily life-style mentioned above, together with the number of hours sleep per night have been found to be related to type-A behaviour (4,18,25). Hence it may be that these aspects of daily life-style are only indicators of a more general type of behaviour.

Observational studies have shown no clear agreement on the contribution of physical inactivity at work to obesity. In some studies, an inverse relationship has been observed between physical activity at work and obesity (20,29). In the Seven-countries study, this influence was found to be much smaller after adjustments had been made for socio-economic differences (20). In other studies, no relationship was observed (14,23), or the prevalence of obesity was found to be lower only in those whose physical activity at work was high and who were also physically active in leisure time (16). This result may also have been confounded by socio-economic differences. An inverse relationship between physical activity during leisure time and risk indicators of coronary heart disease, including relative weight, has been observed (14). It was suggested that physical activity itself was not responsible for the lower levels of risk indicators, because in the same study no such relationship was observed between physical activity at work and the levels of risk indicators. It is possible that those subjects who were physically active during leisure time also differed with respect to other habits.

Studies have shown that the number of meals per day is inversely related to obesity (13,27,28); especially omitting breakfast is a habit which is more common in obese people than in others (3,7). In a recent experiment, Garrow *et al.* found that the number of meals per day had no effect on the rate of fat loss (11). Therefore, omitting meals may be an effect of obesity rather than a cause; people who are obese may omit meals more often than others in their efforts to reduce total energy intake. If this is so, omitting meals should be related to typical slimming behaviour, such as frequent weight measurement, restricting the intake of sweet foods, and adding less sugar to beverages. An inverse relationship between sugar intake and relative weight has already been observed (33).

The purpose of the present study is: firstly, to investigate the relationship between aspects of daily life-style and to construct conceptually meaningful behaviour indices; and secondly, to investigate the relationships between these indices and age, level of education, and relative weight in young adults living in an urban-rural Dutch community.

METHODS

Population. In 1980 a population of young adults living in the Municipality of Ede in The Netherlands was studied. The addresses of people were obtained from the Civil Registration Office in Ede and complete information was obtained from 3,936 people in three age groups (19-21, 24-26 and 29-31 years as at 1 January 1980). Women, pregnant for three months or longer (n=79), were excluded from further analysis. Details of the municipality, the study population and the procedure followed have already been described elsewhere (2).

Variables. As an index of relative weight, the body mass index (BMI; weight/height^2) was calculated. By means of a questionnaire information was collected on specific socio-demographic, behavioural and medical aspects. In this paper, the relationships between aspects of daily life-style and age, level of education, and BMI are considered. The present subdivision of education into three levels has been described elsewhere (2).

The aspects of daily life-style which were studied are summarized in Table 1. Three levels of occupational physical activity as derived from a Dutch classification (36) were distinguished; the low level including occupations such as clerical work, driving, shop keeping, teaching, studying, housework, medical practice, and all other occupations with a university education; the middle level including occupations such as factory work, plumbing, carpentry and farming; and the high level including occupations such as dock work, removals and construction work.

Statistical methods. Principal-components analysis with quartimax rotation (30) was used to study the relationship between the aspects of daily life-style, and to find meaningful underlying concepts of these aspects. Only factors with Eigenvalues greater than 1.0 were retained for the final rotated solution. For several underlying concepts, behaviour indices were constructed as a linear combination of the variables with high loadings (> 0.40) on the factor in question; standardized factor scores of separate one-factor solutions of the appropriate set of variables were used as scores of the various indices. Differences between males and females with respect to the constructed behaviour indices were tested using Student's t-test. The relationships between behaviour indices and age, and level of education were studied by calculating partial correlation coefficients. Multiple regression analysis was used to study the relationships between BMI and smoking habits, and behaviour indices. Four dummy variables were introduced in the analysis for smoking habits (24). Adjustments for age and socio-economic status were made by adding dummy variables simultaneously in the analyses, because in earlier analyses the relationships between these variables and BMI appeared to be non-linear (2). Only P-values < 0.05 are reported.

RESULTS

In Table 1, males and females are compared with respect to the daily life-style variables. Females tended to weigh themselves more frequently, to slim more often, to add sugar to beverages less frequently, and to eat butter on bread less frequently than males. While on the other hand, males reported a higher consumption of coffee and alcoholic drinks and to sleep fewer hours per

Table 1.

FREQUENCY DISTRIBUTION OF DAILY LIFE-STYLE VARIABLES IN MALES AND FEMALES

VARIABLES	MALES (n=1765)	FEMALES (n=2092)
	%	%
FREQUENCY OF WEIGHT MEASUREMENT:		
less than once a month	39.5	18.0
one a month	36.9	38.2
once a week	20.3	35.2
once a day	3.2	8.6
SLIMMING DURING PREVIOUS 12 MONTHS:		
no	90.2	70.4
yes	9.8	29.6
SUGAR IN COFFEE/TEA[1]:		
seldom	13.3	38.3
sometimes	3.5	4.6
often	17.6	17.1
most of the time	65.6	40.0
EATING BUTTER ON BREAD[2]:		
seldom	5.0	8.8
sometimes	2.7	4.6
regularly	6.0	8.3
most of the time	86.3	78.3
COFFEE CONSUMED PER DAY:		
< 1 cup	7.3	11.0
1 - 3 cups	30.4	41.1
4 - 6 cups	47.1	40.2
≥ 7 cups	15.2	7.7
ALCOHOLIC DRINKS CONSUMED PER WEEK[3]:		
none	23.1	48.8
1 - 8 glasses	14.8	23.0
9 - 16 glasses	19.5	16.0
≥ 17 glasses	42.5	12.2
SMOKING HABITS[4]:		
ex-smokers	18.4	16.3
never smoked	34.6	34.7
light smokers (1 - 5 cigarettes per day)	13.1	15.8
moderate smokers (6 - 15 cigarettes per day)	20.9	19.4
heavy smokers (≥ 16 cigarettes per day)	13.0	12.8
HOURS OF SLEEP PER NIGHT:		
< 7 hours	15.1	7.0
7 - 8 hours	68.5	67.1
8 - 9 hours	15.1	24.2
> 9 hours	1.3	1.6

VARIABLES	MALES (n=1765)	FEMALES (n=2092)
	%	%
EATING SWEET SNACKS[5]:		
seldom	23.2	16.7
sometimes	36.1	37.3
regularly	30.4	34.9
most of the time	10.3	11.1
EATING SWEET AND SAVOURY SNACKS[6]:		
seldom	22.9	20.7
sometimes	50.2	55.7
regularly	22.8	20.9
most of the time	4.1	2.7
TYPE OF BREAD EATEN:		
white only	16.7	10.4
brown, and possibly white	36.8	35.4
wholemeal, and possibly white/brown	46.6	54.2
FRUIT CONSUMED PER DAY:		
< 1 piece	29.3	17.6
1 - 2 pieces	56.8	64.6
≥ 3 pieces	13.9	17.7
OMITTING BREAKFAST:		
seldom	61.7	63.8
1 - 2 times a week	19.7	17.3
≥ 3 times a week	18.6	18.9
WALKING/CYCLING (most days):		
no	33.6	23.9
yes	66.4	76.1
OCCUPATIONAL PHYSICAL ACTIVITY:		
low	56.2	52.6
medium	41.9	46.8
high	1.9	0.6
HOURS OF ACTIVE SPORT PER MONTH:		
none	32.5	49.4
< 5 hours	15.5	24.4
5 - 10 hours	21.4	16.5
> 10 hours	30.6	9.6

1 This variable was derived from two separate questions concerning the use of sugar in coffee and tea.

2 Margarine is also included.

3 This variable was derived from three separate questions concerning the consumption of beer, wine and spirits.

4 There were only a few people who smoked cigars and/or a pipe.

5 Sweet snacks with coffee/tea between meals.

6 Sweet and savoury snacks with soft and/or alcoholic drinks.

night than females. Differences between males and females in reported smoking habits were quite small. Females reported to eat sweet snacks with coffee and tea between meals slightly more frequently than males, but the reported frequency of eating sweet and savoury snacks with soft and alcoholic drinks differed very little between males and females. Females reported eating more bread containing more dietary fibre and eating more fruit per day than males. Omitting breakfast was as common in males as in females. Females tended to walk and cycle more often, but to spend fewer hours per month participating in sport than males. The number of males and females with a high level of occupational physical activity was small, females were more often classified as having a medium level of occupational physical activity than males.

Table 2.

MULTIPLE REGRESSION ANALYSIS WITH BMI (kg/m^2) AS DEPENDENT VARIABLE AND INDICATORS OF CATEGORIES OF SMOKING HABITS AS INDEPENDENT VARIABLES

Smoking categories	Males (n=1765)		Females (n=2092)	
	unadjusted	adjusted[1]	unadjusted	adjusted[1]
	B	B	B	B
Ex- versus never	0.87[xxx]	0.31	0.47[x]	0.29
Light versus never	0.19	-0.04	0.02	-0.04
Moderate versus never	0.47[xx]	0.04	0.06	-0.12
Heavy versus never	1.43[xxx]	0.71[xxx]	0.39[x]	0.19
Explained variation (R^2)	0.03	0.13	0.00	0.05

[1] Adjusted for age and level of education.

[x] $P < 0.05$, [xx] $P < 0.01$, [xxx] $P < 0.001$.

A U-shape relationship between smoking habits and BMI was observed in males (Table 2), but after adjustments for age and level of education, it appeared that only the mean BMI of the heavy smokers was significantly higher (0.7 kg/m^2) than the mean BMI of those who had never smoked. In females only the ex-smokers and heavy smokers were slightly heavier than those who had never smoked, while there were no significant differences after adjustments had been made for age and level of education. Interaction terms were introduced in an additional analysis, but did not appear to be statistically significant.

Table 3 gives the factor-loading matrix of the variables concerned with the aspects of daily life-style. Data on males and females were pooled because the sex-specific matrices showed a similar pattern. The reported frequency of weight measurement, slimming during previous 12 months, adding sugar to coffee and tea, and eating butter on bread had high loadings on the first factor.

Table 3.

FACTOR-LOADING MATRIX OF THE DAILY LIFE-STYLE VARIABLES; COMBINED RESULTS OF MALES (n=1765) AND FEMALES (n=2092).

Variables	Factor				
	1	2	3	4	5
Frequency of weight measurement	*.64*	-.02	.12	.02	-.03
Slimming during previous 12 months	*.72*	.02	.01	-.07	-.08
Sugar in coffee/tea	*-.69*	-.02	.10	-.19	.13
Eating butter on bread	*-.50*	.12	.17	.09	-.24
Quantity of coffee	.01	*.68*	.01	-.08	-.14
Quantity of alcoholic drinks	-.10	*.67*	-.05	-.13	.27
Smoking habits[1]	-.03	*.47*	-.20	-.40	-.19
Hours of sleep per night	-.01	*-.59*	-.05	-.07	.03
Sweet snacks with coffee/tea	-.10	-.25	*.71*	.17	-.07
Snacks with soft/alcoholic drinks	.01	.16	*.81*	-.13	.08
Type of bread	.21	.12	-.09	*.58*	.22
Fruit consumption	.31	-.15	.02	*.43*	.09
Omitting breakfast	.15	.06	-.06	*-.63*	.12
Walking/cycling (most days)	-.04	-.05	-.02	*.52*	-.01
Occupational physical activity	.01	.16	-.01	-.02	*-.66*
Active sport	-.06	.11	.02	.09	*.73*
Percentage of explained variation[2]	11.5	10.5	7.9	9.3	7.9

[1] Ex-smokers and never smoked were classified as non-smokers for this analysis.

[2] After rotation.

As these variables are aspects of slimming, the first factor may be interpreted as a construct of slimming behaviour. The reported consumption of coffee and alcoholic drinks, the number of cigarettes smoked per day, and the hours sleep per night had high loadings on the second factor. This factor is also conceptually meaningful and has been referred to as CASS behaviour (coffee, alcohol, smoking and sleep). Both eating sweet snacks with coffee and tea between meals, and eating sweet and savoury snacks with soft and alcoholic drinks had high loadings on the third factor. This factor may be indicative of eating sweet and savoury snacks between meals. Choice of type of bread with respect to the amount of dietary fibre it contains, eating fruit, omitting breakfast, and walking and cycling were interrelated and had high loadings on the fourth factor. This factor may be indicative of health-conscious behaviour. Occupational physical activity and hours active sport per month had high loadings on the fifth factor, and it appeared that these variables were inversely related to each other.

Behaviour indices were constructed from the first four factors (Table 3) for further analysis. Occupational physical activity and the number of hours active sport per month were dealt with separately, because their inverse relationship would have made it difficult to interpret the relationship between BMI and an index combining these two variables. The mean scores of the indices of slimming behaviour, eating sweet and savoury snacks, and health-conscious behaviour were significantly higher in females than in males (Table 4), while the mean score of the CASS behaviour-index and the number of hours active sport per month were higher in males.

Table 4.
COMPARISON OF SCORES OF THE BEHAVIOUR INDICES OF MALES AND FEMALES

Behaviour index	Males (n=1765)		Females (n=2092)		P-valu
	mean	SD	mean	SD	
Slimming behaviour	-0.39	0.76	0.33	1.06	< 0.001
CASS behaviour[1]	0.29	1.00	-0.24	0.93	< 0.001
Eating sweet/savoury snacks	-0.04	1.02	0.03	0.98	< 0.05
Health-conscious behaviour	-0.16	1.03	0.14	0.96	< 0.001
Occupational physical activity	1.46	0.54	1.48	0.51	
Active sport	2.50	1.23	1.86	1.01	< 0.001

[1] CASS behaviour-index was derived from coffee and alcohol consumption, smoking habits and hours of sleep per night.

Table 5.

PARTIAL CORRELATION COEFFICIENTS BETWEEN BEHAVIOUR INDICES AND AGE[1], AND LEVEL OF EDUCATION[2] IN MALES AND FEMALES

Behaviour index	Males (n=1765)		Females (n=2092)	
	Age	Level of education	Age	Level of education
Slimming behaviour	-.01	.09^x	-.06	.09^x
CASS behaviour[3]	.20^x	-.11^x	.11^x	-.05
Eating sweet/savoury snacks	-.02	.06	-.02	-.07
Health-conscious behaviour	.01	.21^x	.07	.22^x
Occupational physical activity	.00	-.47^x	-.05	-.29^x
Active sport	-.17^x	.12^x	-.07^x	.16^x

[1] Adjusted for BMI and level of education.

[2] Adjusted for BMI and age.

[3] CASS behaviour-index was derived from coffee and alcohol consumption, smoking habits and hours of sleep per night.

^{x} $P < 0.001$.

Table 5 shows the relationships between the behaviour indices and age, and level of education. There was a weak positive relationship between slimming behaviour and level of education in both sexes. A positive relationship was found between CASS behaviour and age, particularly in males. A weak inverse relationship between CASS behaviour and level of education was also found in males. Eating sweet and savoury snacks was not related to age or level of education. Health-conscious behaviour was positively related to level of education in males and females, while occupational physical activity was inversely related to the level of education in both sexes. The number of hours active sport per month was inversely related to age, especially in males, but positively related to the level of education in both sexes.

The independent relationships between BMI and behaviour indices, before and after adjustments for age and level of education, are presented in Table 6. Slimming behaviour was positively related to BMI, the regression coefficient being similar in both sexes. The CASS behaviour-index was positively related to BMI only in males, eating snacks was not related to BMI in either sex and health-conscious behaviour appeared to be negatively related to BMI in both sexes. Occupational physical activity was positively related to BMI in males. The regression coefficient, however, became much smaller after adjustment, and was no longer significant in the employed males (n=1386) after adjustments had been made, not only for age and level of education, but also for level of occupation. After adjustment for age and level of education, there was a weak positive relationship between the number of hours active sport per month and BMI in males. Interaction terms were introduced in an additional analysis, but did not appear to be statistically significant.

Table 6.

MULTIPLE REGRESSION ANALYSIS WITH BMI (kg/m^2) AS DEPENDENT VARIABLE AND BEHAVIOUR INDICES AS INDEPENDENT VARIABLES

Behaviour index	Males (n=1765)		Females (n=2092)	
	unadjusted	adjusted[1]	unadjusted	adjusted[1]
	B	B	B	B
Slimming behaviour	1.11[xxx]	1.04[xxx]	1.06[xxx]	1.06[xxx]
CASS behaviour[2]	0.39[xxx]	0.21[xx]	0.06	0.00
Eating sweet/savoury snacks	-0.07	-0.05	0.03	0.01
Health-conscious behaviour	-0.19[xx]	-0.17[xx]	-0.18[xx]	-0.15[x]
Occupational physical activity	0.70[xxx]	0.35[xx]	0.23[x]	0.07
Active sport	0.00	0.11[x]	-0.12[x]	-0.04
Explained variation (R^2)	0.15	0.22	0.16	0.20

[1] Adjusted for age and level of education.

[2] CASS behaviour-index was derived from coffee and alcohol consumption, smoking habits and hours of sleep per night.

[x] $P < 0.05$, [xx] $P < 0.01$, [xxx] $P < 0.001$.

DISCUSSION

By means of principal-components analysis, five meaningful factors could be distinguished within the aspects of daily life-style which were considered. The first factor consisted of four typical aspects of slimming behaviour. The amount of fruit consumed also had a loading on this factor, indicating that this is also an aspect of slimming behaviour, but it had a higher loading on the fourth factor. The strong positive relationship between BMI and the constructed slimming behaviour-index may be partly responsible for the finding of several cross-sectional studies, that the obese population does not eat more food than the non-obese population (32,34).

An inverse relationship between BMI and level of education had been observed in the present population (2). As the relationship between the slimming behaviour-index and level of education was weak, it does not seem likely that greater weight-consciousness anu social pressure to be thin in higher socio-economic classes are largely responsible for the earlier observed inverse relationship.

The second factor showed that the amount of coffee and alcohol consumed and the number of cigarettes smoked were related. This is in concordance with the findings of other studies (4,9,10,12,15,35). The number of hours sleep per night was inversely related to these variables, which are all aspects of daily life-style which tend to be related to type-A behaviour (4,18,25). The relationship between age and the constructed CASS behaviour-index showed that there was an increase of this type of behaviour with age, especially in males. It may be hypothesized from the observed relationship with BMI, that this type of behaviour is a determinant for the development of obesity in young adult males.

In the present study, the generally observed U-shape relationship between smoking and body weight (5,17,31) disappeared after adjustments were made for age and level of education. Only the male heavy smokers had a significantly higher mean BMI than those who had never smoked. The differences between the categories of smoking habits may become greater with increase in age, because in other studies, differences in body weight between the different categories also tended to be smaller in young adults than in older people (15,17).
The finding that the mean BMI of male heavy-smokers was higher than the BMI of other categories is not in agreement with the hypotheses, that smoking acts as an appetite suppressant, or that smoking stimulates the resting metabolic rate. The trend, that ex-smokers are heavier than those who have never smoked, may well be explained by the above hypotheses, or by the hypothesis, that after stopping smoking the amount of food eaten is increased as a substitute for smoking. In addition to a loading on the second factor, smoking had a considerable loading on the fourth factor, indicating that the interpretation of this variable is not simple. Smoking is concerned with more than one theoretical dimension, and therefore it is not possible to explain an observed relationship between smoking and body weight adequately without taking into

consideration other aspects of behaviour.

Eating fewer sweet snacks with coffee and tea between meals, and eating fewer sweet and savoury snacks with soft and alcoholic drinks did not appear to be typical aspects of slimming behaviour as these variables did not have high negative loadings on the first factor. They formed a separate factor, and the derived behaviour index was not related to age, level of education, and BMI in either sex.

It was also shown in principal-components analysis that omitting breakfast was not a typical aspect of slimming behaviour, because the loading on the first factor was low. Thus, there is no reason to suppose that omitting breakfast is characteristic of people who are trying to loose body weight by reducing their total energy intake. Omitting breakfast had a negative loading on the fourth factor, and this factor may be indicative of health-conscious behaviour. There was an inverse relationship between the constructed health-conscious behaviour--index and BMI in both sexes. Therefore it may be hypothesized that the findings in other studies that frequency of food intake is inversely related to obesity (13,27,28) and that omitting breakfast is more common in obese people (3,7), can be explained by a less health-conscious type of behaviour among obese people, and that frequency of food intake or omitting breakfast are indicators of this type of behaviour.

The positive relationship observed between BMI and occupational physical activity in males could be explained by a confounding effect of socio-economic status. After adjustment for level of education the regression coefficient was smaller, and was no longer significant in the employed males after adjustment for level of occupation. Keys *et al.* also observed such a confounding effect of socio-economic status (20). The finding, that there is no inverse relationship between occupational physical activity and relative weight, has also been observed in other studies (14,23). This may be due to small differences in the intensity of physical activity between the low and medium levels of occupational physical activity, and the small number of people with a high level of occupational physical activity. The positive relationship between lean body mass and physical activity at work, which was observed in a subsample of males in the present population (1) and by others (19,21,26) may also be partly responsible for the absence of an inverse relationship.

The number of hours active sport per month, which was positively related to level of education in both sexes and negatively related to age, especially in males, was not independently related to BMI in females after adjustments for age and level of education, but had a weak positive relationship in males. In the present study, the subjects were asked to state the number of hours active sport per month but not the type of sport, and thus the intensity of physical activity was not taken into account. It may well be that heavier people tend to choose sports which require less physical activity, but it is also possible that they are less active while playing sport than lighter people (8). A more obvious explanation may be the observed positive relationship between the amount of active sport and lean body mass found in the subsample (1).

In summary, it can be concluded that there is a clear pattern within the daily life-style variables considered, which suggests that the daily life-style variables can be interpreted as indicators of more general types of behaviour, some of which may be important determinants of obesity. It is necessary to describe these types of behaviour in more detail and to study whether these types of behaviour are causally related to obesity. This will be investigated in a subsample of the present population in a prospective study, which will also be concerned with personality traits, attitudes and knowledge about health and nutrition, and more specific questions about eating behaviour, choice of food and pattern of physical activity.

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4 BODY FATNESS, RELATIVE WEIGHT AND FRAME SIZE IN YOUNG ADULTS

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SUMMARY

1. Body weight, body height, knee width, wrist width and skinfold measurements were made on males (n=139) and females (n=167) in three age groups (20-22, 25-27 and 30-32 years). Percentage of body fat was calculated from skinfold thicknesses using regression equations according to Durnin & Womersley (1974). Three indices of relative weight were calculated, namely W/H^2, W/H^p and $W/\hat{W}$, where W is body weight, H is body height, p is the exponent that made the index of relative weight independent of height, and $\hat{W}$ is the weight estimated from body height and frame size.

2. The standard error of the estimate of body weight was only reduced by 5% in males and by 13% in females, when in addition to body height knee width was taken into account. The addition of wrist width did not improve the accuracy of estimation of body weight in either sex. Therefore in further analyses $\hat{W}$ was estimated from body height and knee width. In the present population the exponent p was 1.7 in males and 1.6 in females.

3. The correlations between the percentage of body fat and the indices, W/H^2, W/H^p, and $W/\hat{W}$, were all very similar, being approximately 0.8 in both sexes.

4. A positive relationship was observed between percentage of body fat and knee width in females, which may be explained by an artifact of measurement.

5. In conclusion it can be stated that the accuracy of estimation of percentage of body fat was not improved when the index of relative weight was adjusted for knee width or wrist width in the present population. The W/H^2 was the most preferable of the three indices which were calculated.

INTRODUCTION

In epidemiological studies, several indices of relative weight have been used as indicators of obesity. Previously, in the choice of an accurate index of relative weight derived from measures of body weight and body height, two criteria have been considered: first, the index should be relatively independent of body height, and secondly, the correlation between the index and body fatness should be as high as possible (Billewicz *et al.*, 1962; Keys *et al.*, 1972). In several studies the body mass index (weight/height^2; W/H^2) appeared to meet both criteria for adult males (Florey, 1970; Keys *et al.*, 1972; Womersley & Durnin, 1977; Watson *et al.*, 1979). In other studies in which no information about body fatness was available, W/H^2 appeared to be almost independent of body height in males (Khosla & Lowe, 1967; Goldbourt & Medalie, 1974). W/H^2 has also been shown to be the most accurate index of relative weight in adult females (Womersley & Durnin, 1977), but in other studies weight/height has been preferred (Florey, 1970; Watson *et al.*, 1979). Another method often used to obtain an index of relative weight independent of height is to express the actual body weight as a percentage of average weight of a reference population of the same body height and sex.

The disadvantage of the indices of relative weight mentioned previously is that they are confounded by body-build type; muscularity and skeletal robustness are not taken into account (Seltzer *et al.*, 1970). In the weight standards established by the Metropolitan Life Insurance Company (1959), weights are categorized in terms of sex, body height and frame size, but no objective definition of frame size is given. There are several bone diameters which are related to skeletal frame size (Jackson & Pollock, 1976; Harrison *et al.*, 1977), but in epidemiological studies it may be easiest to measure knee width and wrist width. Furthermore, it was observed that the accuracy of estimating body weight in young adults was not improved, when in addition to body height and knee width, other bone diameters were included in multiple regression analysis (Wijn & Zaat, 1968).

The purpose of the present study in young adults was first, to construct an index of relative weight adjusted for body height and frame size, and secondly, to investigate the relationship of this index and also of two weight-height indices to body fatness derived from the sum of four skinfold thicknesses.

METHODS

Population. In the first part of 1980 a study was carried out in the Municipality of Ede in The Netherlands in which all inhabitants in three age groups (19-21, 24-26 and 29-31 years as at 1 January 1980) were invited to participate (Baecke *et al.*, 1981). Their addresses were obtained from the Civil Registration Office in Ede. All the participants from three sections of the municipality, with a distribution of sex, age and level of education comparable with the total study population, were invited again in November 1980 to participate in the present study. Complete information was obtained from 309 subjects, representing 70% of all invited subjects. Women, pregnant for three months or longer (n=3), were excluded from further analyses.

Procedure. All subjects were invited by mail to visit a mobile research unit which was stationed in each section for seven days. The anthropometric measurements were made at the mobile research unit. Non-participants were visited at home in order to invite them once again to participate.

Measurements. Body weight and body height without shoes and jacket were measured to the nearest 0.1 kg and 0.1 cm, respectively. Knee width and wrist width were measured on both sides of the body to the nearest 0.1 cm, according to Weiner & Lourie (1969), using a GPM anthropometer. If the difference between the left and right side measurements was greater than five percent, the width measurements were repeated. The sum of left and right measurements were used in further analyses. Biceps, triceps, suprailiac and subscapular skinfold thicknesses were measured, according to Durnin & Rahaman (1967), twice on the left side of the body to the nearest 0.2 mm using a Holtain skinfold caliper. Body fat was calculated as a percentage of total body weight from the average sum of the four skinfold thicknesses, using linear regression equations for 20-29 years old males and females (Durnin & Womersley, 1974). All measurements were made by one observer for each sex, but it was not necessary to make adjustment for observer bias, because the analyses for males and females were done separately.

Three indices of relative weight were calculated, *i.e.* W/H^2, W/H^p, and $W/\hat{W}$ where W is body weight, H is body height, p is the exponent which made the index of relative weight independent of body height (calculated according to Benn, 1971), and $\hat{W}$ is the body weight estimated from body height and frame size.

Statistical Methods. Stepwise multiple regression analysis was done with body weight as a dependent variable and body height, knee width, and wrist width as independent variables. Product-moment correlation-coefficients were calculated in order to study the relationship between the indices of relative weight and percentage of body fat, body height, and knee width.

RESULTS

Table 1 shows the distribution of age in the study population. The three age groups appeared to be reasonably well represented in both sexes.

Table 1.
DISTRIBUTION OF AGE OF THE STUDY POPULATION

Age (years)	Males (n=139)	Females (n=167)
	%	%
20 - 22	38.1	35.9
25 - 27	35.3	31.1
30 - 32	26.6	32.9

Table 2 shows mean values with their standard errors for the anthropometric measurements. The distributions of the percentage of body fat in males and body weight in females were slightly skewed to the right, but all other measurements had an approximately normal distribution.

The estimation of body weight from body height, knee width and wrist width in multiple regression analysis is shown in Table 3. It was observed, that the accuracy of estimation of body weight from body height was slightly improved in both sexes, when knee width was also taken into account. The addition of wrist width in the third step did not improve the accuracy of estimation. Even when knee width was excluded, the contribution of wrist width in addition to body height was not significant in either sex. In an additional analysis, the interaction term of body height and knee width was introduced, but did not appear to be statistically significant. As the accuracy of estimation of body weight was not improved after logarithmic transformations of all measurements, the simpler equations without transformation were used to calculate $\hat{W}$.

Table 2

MEAN BODY WEIGHT, BODY HEIGHT, KNEE WIDTH, WRIST WIDTH AND PERCENTAGE OF BODY FAT IN MALES AND FEMALES

Measurement	Males (n=139)		Females (n=167)	
	mean	SE	mean	SE
Body weight (kg)	76.9	0.9	62.5	0.6
Body height (cm)	180.5	0.6	167.3	0.4
Knee width (cm)	19.2	0.1	17.2	0.1
Wrist width (cm)	11.5	0.1	10.0	0.0
Body fat (%)	17.0	0.4	27.3	0.4

Table 3.

REGRESSION COEFFICIENTS OF STEPWISE MULTIPLE REGRESSION ANALYSIS WITH BODY WEIGHT (kg) AS DEPENDENT VARIABLE AND BONE MEASUREMENTS (cm) AS INDEPENDENT VARIABLES IN MALES AND FEMALES

Independent variables	Males (n=139)			Females (n=167)		
	step 1	step 2	step 3	step 1	step 2	step 3
Intercept	-58.18	-89.24	-85.74	-40.39	-85.34	-84.93
Body height	0.75[x]	0.49[x]	0.51[x]	0.62[x]	0.33[x]	0.34[x]
Knee width	-	4.01[x]	4.42[x]	-	5.42[x]	5.49[x]
Wrist width	-	-	-1.30	-	-	-0.32
R^2	0.29	0.36	0.37	0.17	0.38	0.39
SEE[1]	8.55	8.11	8.11	7.53	6.52	6.54

[1] SEE, square root of residual variance.

[x] $P < 0.001$.

The relationships of W/H^2, W/H^p, and $W/\hat{W}$ with percentage of body fat, body height, and knee width are shown in Table 4. In the present study the exponent p in W/H^p, which rendered an index of relative weight almost completely independent of body height, was 1.7 in males and 1.6 in females. The correlations of the percentage of body fat with the three indices were all equal in males (0.81). In females, the correlations of the percentage of body fat with the three indices were similar, although the correlation with $W/\hat{W}$ was slightly lower (0.76). This finding may have been due to an artifact of measurement, because the correlation between the percentage of body fat and knee width was 0.26 ($P < 0.001$) in females. As a consequence of the latter, the index adjusted for knee width ($W/\hat{W}$) was inevitably adjusted to some extent for body fatness. All three indices were independent of body height, but W/H^2 and W/H^p correlated with knee width in both sexes.

Table 4.

PRODUCT-MOMENT CORRELATION-COEFFICIENTS OF W/H^2, W/H^p AND $W/\hat{W}$[1] WITH PERCENTAGE OF BODY FAT, BODY HEIGHT AND KNEE WIDTH IN MALES AND FEMALES

Sex	Index	Percentage of body fat	Body height	Knee width
Males (n=139)	W/H^2	0.81^{xxx}	−0.08	0.24^{xx}
	$W/H^{1.7}$	0.81^{xxx}	0.03	0.30^{xxx}
	$W/\hat{W}$	0.81^{xxx}	0.01	0.00
Females (n=167)	W/H^2	0.79^{xxx}	−0.11	0.42^{xxx}
	$W/H^{1.6}$	0.80^{xxx}	0.00	0.47^{xxx}
	$W/\hat{W}$	0.76^{xxx}	−0.01	−0.02

[1] W/H^2, weight/height^2; W/H^p, weight/height^p (p is 1.7 in males and 1.6 in females); $W/\hat{W}$, weight/predicted weight (weight is predicted from the multiple regression equation with height and knee width).

^{xx} $P < 0.01$, ^{xxx} $P < 0.001$.

DISCUSSION

The densitometric method has often been considered to be the most accurate method of determining body fatness in vivo, but Womersley & Durnin (1977) estimated that the accuracy of the densitometric method and the skinfold method in the prediction of percentage of body fat are probably of the same order of magnitude. Thus, it seems reasonable to assume that the skinfold method is an adequate reference for body fatness in the present study.

The standard error of the estimate of body weight was only reduced by approximately 5% in males and by approximately 13% in females, when in addition to body height, knee width was taken into account. The regression coefficients of knee width suggested that knee width had a great influence on body weight in both sexes. However, it should be noted that the regression coefficient of body height decreased considerably, when knee width was added as an independent variable, because of a relationship between body height and knee width. Wrist width did not improve the accuracy of estimation of body weight. Similarly, it was shown in a study in young adults that the additional contribution of shoulder, chest and pelvic width was also small (Wijn & Zaat, 1968). Explanations for these findings may well be: first, that only a small proportion of body weight consists of bone tissue (approximately 14%; Passmore & Robson, 1973); secondly, that bone mass can be predicted mainly from body height; and thirdly, that there is a weak relationship between bone diameters and muscle mass (Harrison *et al.*, 1977). Brozek (1956) suggested that the lateral size of the bony frame of the trunk is closely related to the size of the skeletal musculature and viscera. Thus, it may be implied that the bone diameters of the trunk are more important in the prediction of body weight than diameters of limb bones, but this is not in accordance with the findings of Wijn & Zaat (1968).

The correlation of the percentage of body fat with $W/\hat{W}$ was not higher than the correlation of the percentage of body fat with W/H^2, and with W/H^p. This finding is in agreement with the small improvement in the accuracy of estimation of body weight from knee width. In females, the correlation of the percentage of body fat with $W/\hat{W}$ was even smaller than the correlation of the percentage of body fat with W/H^2, and with W/H^p. This finding may well be the result of an artifact of measurement, because some subcutaneous fat may be unavoidably included in the anthropometric measurement of knee width (Harrison *et al.*, 1977). The relationship between the percentage of body fat and knee width was only significant in females. Keys *et al.* (1967) observed a positive relationship between the laterality-linearity index (sum of the bi-acromial and bi-cristal diameter : total body height) and skinfold thickness in adult males, which was not considered to be the result of an artifact of measurement. The suggested artifact may only occur in the measurement of knee width. This is supported by another study in adults, in which it was shown by factor analysis, that the anthropometric measurement of knee width was related to fat measurements, but this relationship was not observed for the bi-acromial and bi-cristal diameter measurements (Harrison *et al.*, 1977).

No difference was found between the correlation of the percentage of body fat with W/H^2, and with W/H^p in males, and the difference in females was negligible. This can be explained by the fact that W/H^2 is almost independent of body height in this population. The correlation of W/H^2 with the percentage of body fat was of the same order of magnitude as was found in adult males by Keys *et al.* (1972).

In conclusion, it can be stated that the relationship between the percentage of body fat and the index of relative weight was not improved after the index had been adjusted, not only for body height, but also for knee width or wrist width. Adjustment of the index of relative weight for other bone diameters is also unlikely to improve the accuracy of prediction of body fatness, because of the small improvement in the accuracy of estimation of body weight, when in addition to body height and knee width, other bone diameters are taken into account (Wijn & Zaat, 1968). This would have the practical consequence that in general adjustment of body weight for skeletal frame size does not improve the accuracy of prediction of body fatness. The W/H^2 often referred to as the body mass index, is the most preferable of the three indices which were calculated. This index appeared to be the most accurate index of relative weight for adults in several studies, and hence has been used regularly, with the additional advantage of making comparisons between studies easier.

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5 A SHORT QUESTIONNAIRE FOR THE MEASUREMENT OF HABITUAL PHYSICAL ACTIVITY IN EPIDEMIOLOGICAL STUDIES

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ABSTRACT

The construct validity and the test-retest reliability of a self-administered questionnaire about habitual physical activity were investigated in young males (n=139) and females (n=167) in three age groups (20-22, 25-27 and 30-32 years) in a Dutch population. By principal-components analysis three conceptually meaningful factors were distinguished. They were interpreted as: 1, physical activity at work; 2, sport during leisure time; and 3, physical activity during leisure time excluding sport. Test-retest showed that the reliability of the three indices constructed from these factors was adequate. Further, it was found that level of education was inversely related to the work index, and positively related to the leisure-time index in both sexes. The subjective experience of work load was not related to the work index, but was inversely related to the sport index, and the leisure-time index in both sexes. The lean body mass was positively related to the work index, and the sport index in males, but was not related to the leisure-time index in either sex. These differences in the relationships support the subdivision of habitual physical activity into the three components mentioned above.

INTRODUCTION

Measurement of physical activity is often found to be important in research about health, especially in the area of cardiovascular disease and obesity. The accuracy in assessing energy expenditure by both direct and indirect calorimetry techniques is good, but these laboratory techniques are not applicable to large scale epidemiological studies.

There are various methods for measuring physical activity in larger scale epidemiological studies. Body movement can be measured with pedometers, but this method has limitations as it only measures certain types of movement (1). Two further techniques are monitoring heart rate with a portable heart rate recorder (1,2) and the use of an activity diary in which the subjects record their activities (1). With all three methods, information is only collected about a relatively short period of time and the long-term pattern of habitual physical activity of the individual is not measured. In studying the relationship between physical activity and health, it is necessary to consider not only the total energy expenditure during a certain day or week, but also to consider the pattern of habitual physical activity over a longer period.

Questionnaires developed to measure habitual physical activity at work and during leisure time have been used in observational studies, such as the Framingham Study (3) and the Tecumseh Community Health Study (4). A questionnai was also developed to assess habitual physical activity only during leisure tim by Taylor *et al.* (5). The three questionnaires, which were not designed to be self-administered, measured habitual physical activity in terms of the usual time spent in various types of activity. This was then multiplied by the energy expenditure per unit of time of the activity. The values for the intensity of the activities were derived from data in the literature. In the Health Insuranc Plan Study, a self-administered questionnaire containing ten items about occupational and leisure time physical activity, was used (6). The scores were calculated without the use of intensities for the different types of activities

To the authors' knowledge, the reliability of the questionnaires mentioned above has not been tested. Criterion-oriented validation (concurrent validation is not possible because a valid reference method which measures habitual physical activity independently, does not exist. Therefore, some investigators have studied the relationship between the assessed habitual physical activity and another parameter which is assumed to be related to habitual physical activity, *e.g.* physical work capacity (5). It is of interest to study the construct validity of the questionnaire (7), especially when a completely valid criterion is not available. This implies that an adequate investigation encompasses the study of subdivision of physical activity into more specific groupings of activities. Up until now two dimensions of habitual physical activity have been distinguished namely, occupational and leisure time physical activity. However, it may be possible to distinguish more or other dimensions, which are important to the description of the pattern of habitual physical activity.

The purpose of the present study in young adults is firstly, to investigate the construct validity of a self-administered questionnaire about habitual physical activity and to establish meaningful indices of physical activity, secondly, to estimate the test-retest reliability of the questionnaire, and thirdly, to investigate the relationship between the indices of physical activity and age, level of education, subjective experience of work load, and lean body mass.

METHODS

Population. In the first part of 1980 a study was carried out in the Municipality of Ede in The Netherlands in which all the inhabitants in three age groups (19-21, 24-26 and 29-31 years as at 1 January 1980) were invited to participate (8). Their addresses were obtained from the Civil Registration Office in Ede. All the participants from three sections of the municipality, with a distribution of sex, age and level of education comparable with the total study population, were invited again in November 1980 to participate in the present study. Complete information was obtained from 309 subjects, representing 70% of all invited subjects. Women, pregnant for three months or longer (n=3), were excluded from further analyses.

Procedure. All subjects were invited by mail to complete the questionnaire at home and then to visit a mobile research unit which was stationed in each section of the municipality for seven days. The questionnaire was checked for completeness and the anthropometric measurements were made at the mobile research unit. Body weight and body height without shoes and jacket were measured to the nearest 0.1 kg and 0.1 cm, respectively. Biceps, triceps, suprailiac and subscapular skinfold thicknesses were measured, according to Durnin and Rahaman (9), twice on the left side of the body to the nearest 0.2 mm using a Holtain skinfold caliper. Body fat was calculated as a percentage of total body weight (BF%) from the average sum of the four skinfold thicknesses, using linear regression equations for 20-29 year old males and females (10). Lean body mass (LBM) was calculated from total body weight (W) and BF% (LBM = W (100 - BF%)/100).

About three months after this examination, the participants were visited at home and requested again to complete the questionnaire on habitual physical activity so that the test-retest reliability could be studied. The visit was part of a food consumption study in which 90% (n=277) of all subjects participated.

Questionnaire. Using a questionnaire, information was collected on the level of education, subjective experience of work load and habitual physical activity. The present subdivision of education into three levels has been described elsewhere (8). Subjective experience of work load was measured by means of an existing Dutch questionnaire (SEWL) devised by Josten (11). This questionnaire consists of 53 items referring to daily activities. It contains a dichotomous response format; a subject experiences a certain activity either as physically strenuous or not. This response scale is different from the Borg's perceived exertion rating scale (12), however it may be assumed that both scales are related to the identical concept.

The original questionnaire on habitual physical activity consisted of 29 items concerning the following five components: occupation, movement, sport, leisure time activities excluding sport, and sleeping habits. All responses were precoded on five-point scales with the exception of the questions on the name of main occupation and the types of sport played. Three levels of occupational physical activity were defined according to The Netherlands Nutrition Council (13): the low level for occupations as, clerical work, driving, shopkeeping, teaching, studying, housework, medical practice, and all other occupations with a university education; the middle level for occupations such as, factory work, plumbing, carpentry and farming; and the high level for occupations such as, dock work, construction work, and sport.

Sports were subdivided into three levels of physical activity according to Durnin and Passmore (14); the low level for sports such as, billiards, sailing, bowling and golf (average energy expenditure 0.76 MJ/h); the middle level for sports such as, badminton, cycling, dancing, swimming and tennis (average energy expenditure 1.26 MJ/h); and the high level for sports such as, boxing, basket ball, football, rugby and rowing (average energy expenditure 1.76 MJ/h). A sport score was calculated from a combination of the intensity of the sport which was played, the amount of time per week playing that sport, and the proportion of the year in which the sport was played regularly (see Appendix).

Statistical methods. Principal-components analysis with quartimax rotation (15) was used to find meaningful underlying dimensions of habitual physical activity Only factors with Eigenvalues greater than 1.0 were retained for the final rotated solution. Indices of physical activity were constructed from the underlying concepts by combining the variables with high loadings (≥ 0.50) on the factor in question as described in the Appendix. With a second method, factor scores of separate one-factor solutions of the appropriate set of variables were calculated. Finally the first method was chosen because it was the simplest and the correlation between the two methods was high for all indices ($r > 0.95$).

Product-moment correlation-coefficients were calculated in order to study the test-retest reliability, and for the determination of the relationships between the indices of physical activity and age, level of education, and SEWL. Multiple regression analysis was used to study the relationship between LBM and the indices of physical activity, with adjustments for body height and percentage of body fat being made by adding these variables simultaneously in the analysis.

RESULTS

Table 1 shows the frequency distribution of age and level of education in the present study population. There were a reasonable number of subjects in each age group and each level of education in both sexes. Table 2 shows the mean and standard deviation of body weight, body height and percentage of body fat. The distribution of the percentage of body fat in males and body weight in females were significantly skewed to the right, but other measurements were approximately normally distributed.

Thirteen of the original 29 items about habitual physical activity were excluded, because of a bimodal distribution of responses, or because the items did not have a high loading on one specific factor. Table 3 contains the factor loading matrix of the 16 remaining items. Data on males and females were pooled because the sex-specific matrices showed a similar pattern. Items 1-8 had high loadings on the first factor. Since these items were concerned with occupational physical activity, the first factor may be interpreted as a dimension of physical activity at work. The second factor is indicative of sport during leisure time, because Items 9 and 12 which were concerned with sport had high loadings on this factor. It appeared that Item 10 about the self-perception of the degree of physical activity during leisure time and Item 11 about the frequency of sweating during leisure time, were related to the same concept as the items about sport. Items 13-16 about watching television, cycling and walking during leisure time, and the time spent walking and/or cycling per day to and from work, school, and shopping had high loadings on the third factor. This third factor may be interpreted as a dimension of habitual physical activity during leisure time excluding sport.

Table 1

FREQUENCY DISTRIBUTION OF AGE AND LEVEL OF EDUCATION IN MALES AND FEMALES

Variable	Males (n=139)	Females (n=167)
	%	%
Age (years):		
20 - 22	38.1	35.9
25 - 27	35.3	31.1
30 - 32	26.6	32.9
Level of education:		
low	18.0	25.7
middle	48.2	52.1
high	33.8	22.2

Table 2

MEAN BODY WEIGHT, BODY HEIGHT AND PERCENTAGE OF BODY FAT IN MALES AND FEMALES

Measurement	Males (n=139)		Females (n=167)	
	mean	SD	mean	SD
Body weight (kg)	76.9	10.1	62.5	8.3
Body height (cm)	180.5	7.2	167.3	5.6
Body fat (%)	17.0	4.5	27.3	5.0

For further analysis, indices of physical activity were established for the three factors mentioned above. The mean scores of the indices of work and leisure time were significantly higher in females than in males (Table 4), while the mean score of the sport index was significantly higher in males. The test-retest reliability of the work index, sport index and leisure-time index were 0.88, 0.81 and 0.74, respectively.

Table 3

FACTOR-LOADING MATRIX OF THE ITEMS ABOUT PHYSICAL ACTIVITY[1]; COMBINED RESULTS OF MALES (n=139) AND FEMALES (n=167)

Item	Factor 1	Factor 2	Factor 3
1	*0.74*	-0.08	-0.08
2	*-0.85*	0.05	-0.01
3	*0.80*	-0.02	0.01
4	*0.81*	-0.06	-0.02
5	*0.83*	0.02	-0.01
6	*0.59*	-0.23	0.10
7	*0.57*	0.04	-0.09
8	*0.71*	0.04	-0.05
9	-0.09	*0.86*	-0.09
10	0.04	*0.78*	0.23
11	-0.13	*0.59*	0.18
12	-0.12	*0.87*	-0.06
13	0.15	-0.10	*-0.52*
14	-0.02	-0.09	*0.72*
15	-0.03	0.15	*0.79*
16	0.03	0.04	*0.50*
Explained variation (%)[2]	28.0	16.0	11.1

[1] See appendix for the items. [2] After rotation.

Table 4

MEAN SCORES OF THE INDICES OF PHYSICAL ACTIVITY IN MALES AND FEMALES

Index	Males (n=139)		Females (n=167)		P-value
	mean	SEM	mean	SEM	
Work	2.6	0.1	2.9	0.0	< 0.001
Sport	2.8	0.1	2.4	0.1	< 0.001
Leisure-time	2.8	0.1	3.1	0.0	< 0.01

Table 5 shows the relationship between the indices of physical activity and age, level of education, and SEWL. Age was related to the work index only in females, the index was higher in the older females. The level of education was inversely related to the work index, and positively related to the leisure-time index in both sexes, while in females there was also a weak positive relationship between the level of education and the sport index. SEWL was inversely related to the sport index, and the leisure-time index in both sexes.

Multiple regression analysis showed a positive relationship between LBM and the work index, and the sport index in males (Table 6). Body height and the percentage of body fat were also positively related to the LBM in males as well as in females. Interaction terms were introduced in an additional analysis, but did not appear to be statistically significant.

Table 5

PRODUCT-MOMENT CORRELATION-COEFFICIENTS OF THE INDICES OF PHYSICAL ACTIVITY WITH AGE, LEVEL OF EDUCATION AND SEWL[1], IN MALES AND FEMALES

Sex	Index	Age	Level of education	SEWL
Males (n=139)	Work	-0.15	-0.56^{xxx}	0.11
	Sport	0.04	0.13	-0.20^{x}
	Leisure-time	0.05	0.38^{xxx}	-0.29^{xxx}
Females (n=167)	Work	0.19^{x}	-0.25^{xxx}	0.09
	Sport	0.00	0.17^{x}	-0.24^{xx}
	Leisure-time	-0.01	0.34^{xxx}	-0.18^{x}

[1] Subjective Experience of Work Load.

^{x} P < 0.05, ^{xx} P < 0.01, ^{xxx} P < 0.001.

Table 6

MULTIPLE REGRESSION ANALYSIS WITH LBM (kg) AS DEPENDENT VARIABLE AND THE INDICES OF PHYSICAL ACTIVITY, BODY HEIGHT (cm) AND BODY FAT (%) AS INDEPENDENT VARIABLES IN MALES AND FEMALES

Independent variables	Males (n=139)		Females (n=167)	
	B	SE	B	SE
Intercept	-66.66		-40.51	
Work index	1.36[x]	0.42	0.48	0.41
Sport index	1.23[x]	0.43	0.23	0.36
Leisure-time index	0.15	0.49	-0.27	0.42
Body height	0.64[xx]	0.05	0.47[xx]	0.04
Body fat	0.47[xx]	0.07	0.25[xx]	0.05
R^2	0.65		0.46	

[x] $P < 0.01$, [xx] $P < 0.001$.

DISCUSSION

In the present study population, there were a reasonable number of subjects from each level of education. This has the advantage that the questionnaire which has been developed can be used for the various socio-economic classes in the general population. The average anthropometric measures also showed that the study population was similar to the general population with respect to body composition.

By means of principal-components analysis, three meaningful factors could be distinguished within the aspects of habitual physical activity which were studied. The first factor consisted of aspects of occupational physical activity (Items 1-8). As all occupations have been precoded according to three levels of physical activity, Item 1 gives an objective measure of physical activity at work. However, this measure has the disadvantage, that a particular occupation is always classified in the same way and therefore inter-individual variability in physical activity within a certain occupation is not taken into account. The measurement of physical activity at work can be improved with the addition of

Items 2-8 concerning self-assessment of physical activity. It has been shown that self-assessment of physical activity parallels the scores of actual physical activity reasonably well (16).

The second factor can be interpreted as sport during leisure time. Items 10 and 11 about habitual physical activity during leisure time in general were related to sport. This finding suggests that people connect physical activity during leisure time mainly with playing sport. Bullen *et al.* (17), who measured physical activity by observation, showed that there is inter-individual variability in the energy expenditure within certain types of sport. It can be suggested that this inter-individual variability is partly taken into account by Items 10 and 11. In addition to sport in leisure time, another dimension of physical activity in leisure time could be distinguished. This relates to watching television, walking and cycling during leisure time in general, and the time spent walking and/or cycling per day to and from work, school and shopping, in particular.

The test-retest reliability of the indices of physical activity, measured with an interval of three months, being between 0.80 and 0.90 for the work index and sport index, and 0.74 for the leisure-time index, makes the questionnaire useful.

The finding, that the level of education was inversely related to the work index, and positively related to the leisure-time index, is in accordance with the results of the Oslo Study (18). The sport index also tended to be positively related to the level of education, but this was only significant in females. The inverse relationship observed between SEWL and the sport index, and leisure-time index, while SEWL was not related to the work index, may be explained by the fact that there is more freedom of choice in the selection of activities during leisure time than at work. People who have a high SEWL tend to choose more sedentary activities during leisure time than people with a low SEWL.

LBM was chosen as a parameter of body composition because there is supposed to be a relationship between LBM and physical activity. However, in analysing the relationship between LBM and the indices of physical activity, adjustments for body height and the percentage of body fat should be made. The effects of the percentage of body fat may be especially confusing since the relationship of body fat to LBM is assumed to be positive (19,20), whereas that of body fat to physical activity may be negative. The adjusted positive relationship between LBM and the work index, and the sport index in males is in accordance with the positive relationship between LBM and physical activity observed by others (21,22,23). The leisure-time index was not related to LBM, which may indicate that the intensities of the activities during leisure time are too low to affect LBM. The independence of physical activity and LBM observed in females may also be explained in the same way.

In summary, it was concluded that habitual physical activity encompassed three distinct dimensions. These were physical activity at work, sport during leisure time, and other physical activity during leisure time. The indices of physical activity derived from these dimensions were reliable. The differences in the relationships between the three indices of physical activity on one side and level of education, SEWL and LBM on the other, emphasize the need to distinguish the three dimensions. Therefore, the present study suggests that habitual physical activity can be determined when these three factors are measured and included in the assessment.

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Appendix

Questionnaire, codes and method of calculation of scores on habitual physical activity.

1) What is your main occupation?			
....			1 - 3 - 5
2) At work I sit			
never/seldom/sometimes/often/always			1 - 2 - 3 - 4 - 5
3) At work I stand			
never/seldom/sometimes/often/always			1 - 2 - 3 - 4 - 5
4) At work I walk			
never/seldom/sometimes/often/always			1 - 2 - 3 - 4 - 5
5) At work I lift heavy loads			
never/seldom/sometimes/often/very often			1 - 2 - 3 - 4 - 5
6) After working I am tired			
very often/often/sometimes/seldom/never			5 - 4 - 3 - 2 - 1
7) At work I sweat			
very often/often/sometimes/seldom/never			5 - 4 - 3 - 2 - 1
8) In comparison with others of my own age I think my work is physically			
much heavier/heavier/as heavy/lighter/much lighter			5 - 4 - 3 - 2 - 1
9) Do you play sport?			
yes/no			
If yes:			
- which sport do you play most frequently?	....	Intensity	0.76 - 1.26 - 1.76
- how many hours a week?	<1/1-2/2-3/3-4/>4	Time	0.5 - 1.5 - 2.5 - 3.5 - 4.5
- how many months a year?	<1/1-3/4-6/7-9/>9	Proportion	0.04 - 0.17 - 0.42 - 0.67 - 0.92
If you play a second sport:			
- which sport is it?	....	Intensity	0.76 - 1.26 - 1.76
- how many hours a week?	<1/1-2/2-3/3-4/>4	Time	0.5 - 1.5 - 2.5 - 3.5 - 4.5
- how many months a year?	<1/1-3/4-6/7-9/>9	Proportion	0.04 - 0.17 - 0.42 - 0.67 - 0.92
10) In comparison with others of my own age I think my physical activity during leisure time is			
much more/more/the same/less/much less			5 - 4 - 3 - 2 - 1
11) During leisure time I sweat			
very often/often/sometimes/seldom/never			5 - 4 - 3 - 2 - 1
12) During leisure time I play sport			
never/seldom/sometimes/often/very often			1 - 2 - 3 - 4 - 5
13) During leisure time I watch television			
never/seldom/sometimes/often/very often			1 - 2 - 3 - 4 - 5
14) During leisure time I walk			
never/seldom/sometimes/often/very often			1 - 2 - 3 - 4 - 5
15) During leisure time I cycle			
never/seldom/sometimes/often/very often			1 - 2 - 3 - 4 - 5
16) How many minutes do you walk and/or cycle per day to and from work, school and shopping?			
<5/5-15/15-30/30-45/>45			1 - 2 - 3 - 4 - 5

Calculation of the simple sport-score (I_9):
(a score of zero is given to people who do not play sport)

$$I_9 = \sum_{i=1}^{2} (\text{Intensity} \times \text{Time} \times \text{Proportion})$$

= 0/0.01-<4/4-<8/8-<12/≥12   1 - 2 - 3 - 4 - 5

Calculation of scores of the indices of physical activity:

WORK INDEX $= \{ I_1 + (6-I_2) + I_3 + I_4 + I_5 + I_6 + I_7 + I_8 \}/8$

SPORT INDEX $= \{ I_9 + I_{10} + I_{11} + I_{12} \}/4$

LEISURE-TIME INDEX $= \{ (6-I_{13}) + I_{14} + I_{15} + I_{16} \}/4$

6 FOOD CONSUMPTION, HABITUAL PHYSICAL ACTIVITY AND BODY FATNESS IN YOUNG DUTCH ADULTS

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ABSTRACT

The relationship between body fatness and both food consumption and habitual physical activity, were studied in young adult males (n=122) and females (n=140) in three age groups (20-22, 25-27 and 30-32 years) in a Dutch population. In males the average daily energy intake was rather high (about 3000 kcal) and average body weight increased by 1.2 kg in the preceding year. Both findings suggest the existence of a positive energy balance. In females the average daily energy intake was normal (2170 kcal) and average body weight remained constant. Physical activity at work and sport were not related to the percentage of body fat (BF%) in either sex, but physical activity, such as walking and cycling during leisure time, was slightly lower in fatter males. The fatter subjects tended to eat less than the leaner subjects but this was only significant in females. However, after adjusting for lean body mass and physical activity in a multiple regression model, energy intake was inversely related to BF% in both sexes. Change in body weight in the period of four months preceding the food consumption study seemed to reflect energy balance at the time of the food consumption study in only leaner and fatter females. After adjusting also for change in body weight in these females energy intake of fatter females remained lower, suggesting a reduced need for energy among many fatter females.

INTRODUCTION

In several studies in adult populations an inverse relationship between relative weight or body fatness and energy intake has been observed (1-3), while others have observed non-significant trends, both negative (4,5) and positive (6,7). Physical activity, however, should be taken into consideration as a possible confounder of the relationship between body fatness and energy intake. In the Framingham study, it appeared that the fatter subjects not only had a lower energy intake per unit of body weight, but they also had a lower score for physical activity (8). A similar trend was also observed by Hutson *et al.* (9). Other studies have shown no differences between obese and control groups with respect to energy intake and physical activity (10-12).

In general, studies do not support the hypothesis that obese people eat more, or are less physically active than non-obese people. Three aspects may be important in order to explain these findings; the accuracy of the methods used, the time of measurement and physiological confounders.

It may be that the field methods used to measure energy intake and expenditure are inadequate to detect an energy imbalance (13). It is also possible that obese people systematically under-report the quantity of food they eat, as has been shown by some investigators (14-16). Keen *et al.* (1), however, observed an inverse relationship between energy intake and the body mass index across the whole range of the index, and this trend was not only restricted to the manifestly obese subjects versus controls. They suggested that under-reporting of energy intake occurs especially in clinically obese patients as a behavioural response to obesity. It also is important to mention that if obese people tend to under-report their weights, this also is a potential confounding factor unless measured weights are used.

The time of measurement can be important in two ways. Firstly, subjects may have had a positive energy balance in an earlier period of their lives (7,17). It may be assumed that the dynamic phase of obesity is a relatively short period, and as a consequence in cross-sectional studies most obese people will be in energy balance. Secondly, it is possible that a number of obese people have reduced their food intake in an attempt to reduce body weight. Thus in both cases, it is desirable to be aware of the changes in body weight of the subjects. This may provide an opportunity to distinguish three categories: those who are in positive energy balance, the dynamic phase of obesity; those who are in energy balance, the static phase of obesity; and those who are in negative energy balance.

The potential physiological confounders are resting metabolic rate and thermogenesis. In general, the resting metabolic rate is about 22 kcal/kg lean body mass/day (18,19). This can be taken into account in epidemiological studies but it should be noted that the resting metabolic rate may decrease when food consumption is restricted (20,21). In addition, obese people may have an impaired thermogenic mechanism (22), which may be an important compensatory system for a high energy intake. For practical reasons these physiological confounders can only be studied in detail in laboratory experiments.

The present study was part of a larger prospective study concerning the aetiology of obesity in young Dutch adults for whom few data on food intake were available. This study has been undertaken: firstly, to study the intake of energy and macronutrients in comparison with recommended intakes; and secondly, to investigate the relationships between body fatness and both food consumption and habitual physical activity. Change in body weight has been taken into account as a possible indicator of the energy balance.

METHODS

Population. In the first part of 1980, a study was carried out in the Municipality of Ede in The Netherlands in which all the inhabitants in three age groups (19-21, 24-26 and 29-31 years as at 1 January 1980) were invited to participate (23). The addresses were obtained from the Civil Registration Office in Ede. All participants from three of the nineteen sections of the municipality (n=439) were again invited in November 1980 to participate in the present study. All socio-economic classes were represented in these three sections of the municipality. In November 1980, 309 subjects participated in the study and 277 of these subjects also participated in the second part of this study between February and April 1981. Women, pregnant for three months or longer during the study (n=15), were excluded from further analyses.

Procedure. Body weight was measured three times over a period of approximately one year. It was first measured between March and May 1980, without shoes and jacket to the nearest 0.1 kg. Body height was also measured without shoes to the nearest 0.1 cm.

In November 1980, body weight was again measured. In addition, biceps, triceps, suprailiac and subscapular skinfold thicknesses were measured, according to Durnin and Rahaman (24), twice on the left side of the body to the nearest 0.2 mm using a Holtain skinfold caliper. Body fat was calculated as a percentage of total body weight (BF%) from the average sum of the four skinfold thicknesses using linear regression equations for 20-29 year old males and females (25). All measurements were made by one observer for each sex, but it was not necessary to make adjustments for observer bias, because the analyses for males and females were done separately. Lean body mass (LBM) was calculated from total body weight (W) and BF% (LBM = W (100-BF%)/100).

On the first two occasions, body weight of the participants was measured during visits to the mobil research unit which was stationed in each of the three sections of the municipality for several days. On the third occasion, body weight was measured during home visits between February and April 1981. At the same time, information was collected on food intake and habitual physical activity. At home, body weight was measured to the nearest 0.5 kg without shoes and jacket. The balances used in this study were calibrated regularly.

Physical activity pattern and food consumption. A self-administered questionnaire was used to measure habitual physical activity of which the construct validity and test-retest reliability had been investigated (26). It appeared to be meaningful to distinguish three dimensions within the pattern of habitual physical activity: physical activity at work; sport during leisure time; and other physical activities during leisure time. The participants were coded on a scale ranging from one (low) to five (high) for each dimension of habitual physical activity. The test-retest reliability of the work index, sport index and leisure-time index were 0.88, 0.81 and 0.74, respectively.

Information about food intake was collected by using a two-day record method. Food intake was noted in household measures in diaries, and recipes were requested for all mixed dishes. The subjects were visited on two occasions by one of three trained dietitians. On the first visit, the dietitian gave instructions on how to complete the diary. On the second visit, the dietitian checked the diary for completeness and the household measures and portions of foods used regularly were also checked. The intake of energy and nutrients was calculated by multiplying the weights of foods consumed with the appropriate values from a computerized food consumption table (27).

The subjects recorded their food intake on two consecutive days. The average daily intakes of energy and nutrients of each subject were used in further analyses. The possible combinations of two consecutive days were randomly assigned to the subjects. The ratio of recording days during the weekend (Saturday and Sunday) to recording days during the working week (Monday to Friday) was about 2 : 5 in both sexes. This had the advantage that the average for all record days could be interpreted as a weighted average for the whole week. Each subject was given a code for the combination of days on which food intake was recorded. Two workdays, one workday and one day of the weekend, and two days of the weekend were coded as zero, one and two, respectively. This code made it possible to adjust for the combination of recording days in the analyses. The subjects were adequately randomized over the three combinations of recording days, because the groups were comparable with regard to age, level of education (the three levels of education have been described elsewhere (23)), BF%, LBM and indices of habitual physical activity. No evidence of an observer effect was found between the three dietitians.

Statistical methods. Student's t-test was used to test differences between groups of subjects. Regression coefficients of energy intake of specific food groups and meals on BF% were calculated, while energy intake was adjusted for the combination of recording days. Multiple regression analysis was also used to study simultaneously the relationship between energy intake and both body composition and habitual physical activity. The mean energy intake in categories according to body fatness and change in body weight, taking confounders into account, was studied in an analysis of covariance. Unless otherwise indicated, two-sided P-values smaller than 0.05 are reported.

RESULTS

Table 1 shows the frequency distribution of age and level of education in the present study population. There was a reasonable number of subjects from each age group and each level of education in both sexes. Table 2 shows the mean and standard deviation of body weight during the three periods of measurement, body height, BF% and LBM. During the year before the food consumption study, mean body weight increased by 1.2 kg ($P < 0.001$) in males, but the change in mean body weight in females was negligible.

Mean daily intake of total energy was about 830 kcal higher in males than in females (Table 3). The proportion of energy intake as animal protein and the relative intake of dietary fibre were slightly higher in females, but the proportion of energy intake as alcohol and the intake of dietary cholesterol was higher in males. No differences were observed between males and females with respect to the proportion of energy intake as vegetable protein, fatty acids, sugars and polysaccharides.

Table 4 shows the proportional energy intake of food groups and meals to total energy intake and the regression coefficients of the absolute energy intake of food groups and meals on BF%. Sugar and sugar-rich products appeared

Table 1

FREQUENCY DISTRIBUTION OF AGE AND LEVEL OF EDUCATION IN MALES AND FEMALES

Variables	Males (n=122)	Females (n=140)
	%	%
Age (years):		
20 - 22	38.5	36.4
25 - 27	34.4	29.3
30 - 32	27.0	34.3
Level of education:		
low	15.6	24.3
middle	50.0	52.9
high	34.4	22.9

Table 2

MEAN BODY WEIGHT, BODY HEIGHT, BODY FATNESS AND LBM IN MALES AND FEMALES

Measurement	Period[1]	Males (n=122)		Females (n=140)	
		mean	SD	mean	SD
Body weight (kg)	1	75.7	9.6	62.2	8.1
	2	76.4	9.5	62.4	7.8
	3	76.9	9.9	62.3	7.8
Body height (cm)	1	180.6	7.2	167.4	5.6
BF%	2	16.8	4.5	27.2	4.9
LBM (kg)	2	63.7	6.5	45.1	4.2

[1] Period 1, March-May 1980; Period 2, November 1980; Period 3, February-April 1981.

to contribute most to the total energy intake in both sexes, followed by dairy products and cereal products. About 55% of total energy intake was consumed at lunch and dinner, while about 35% was consumed as snacks. A negative relationship was observed between BF% and the amount of fruits and vegetables consumed by males, and between BF% and food groups containing products such as margarine, fats, sugar and sugar-rich products in females. In both males and females, a negative relationship was observed between the amount of food eaten at breakfast and BF%. A negative relationship was also observed in females between the amount of food eaten at lunch and BF%, and between the amount of food eaten in the evening and BF% in males.

Table 3

MEAN DAILY INTAKE OF ENERGY, MACRONUTRIENTS, DIETARY CHOLESTEROL AND DIETARY FIBRE IN MALES AND FEMALES

Variables	Males (n=122)		Females (n=140)		P-value
	mean	SEM	mean	SEM	
Energy (kcal)	3005	66	2173	40	< 0.001
(MJ)	12.6	0.3	9.1	0.2	< 0.001
Total protein (energy %)	12.6	0.2	13.6	0.2	< 0.001
animal protein	8.2	0.2	9.0	0.2	< 0.01
vegetable protein	4.4	0.1	4.5	0.1	
Total fat (energy %)	37.7	0.6	38.3	0.5	
saturated	16.9	0.3	17.4	0.3	
mono-unsaturated	14.0	0.3	14.4	0.3	
poly-unsaturated	5.8	0.2	5.5	0.2	
Total carbohydrates (energy %)	44.4	0.6	45.3	0.5	
sugars	22.5	0.5	23.7	0.5	
polysaccharides	22.0	0.4	21.6	0.4	
Alcohol (energy %)	5.3	0.5	2.7	0.4	< 0.001
Dietary cholesterol (mg)	396	17	317	12	< 0.001
Dietary fibre (g/1000 kcal)	9.7	0.3	10.6	0.3	< 0.05

Table 4

CONTRIBUTION OF FOOD GROUPS AND MEALS TO TOTAL ENERGY INTAKE AND THE REGRESSION COEFFICIENTS[1] OF DAILY ENERGY INTAKE ON BF% IN MALES AND FEMALES

Variables	Males (n=122)		Females (n=140)	
	mean	B	mean	B
	Energy%	Kcal/BF%	Energy%	Kcal/BF%
Food groups[2]:				
cereal products	15.4	-6.0	14.3	-3.5
potatoes, rice, etc.	8.2	-4.1	7.8	1.1
margarine, fats and oils	12.5	1.3	10.3	-5.4[xx]
meat, meat products, fish	12.3	6.6	12.7	-1.6
dairy products and eggs	15.3	-0.8	16.8	-4.1
fruits and vegetables	4.8	-4.1[x]	6.1	-1.1
sugar, sugar-rich products	16.2	-7.1	17.6	-10.6[xx]
soft drinks	3.3	-0.7	4.1	1.4
alcoholic drinks	6.9	-5.5	3.4	3.1
savoury snacks	2.8	-0.3	4.0	-1.8
Meals:				
breakfast	11.6	-9.2[x]	11.3	-4.6[x]
lunch	23.1	5.4	20.8	-8.6[xx]
dinner	31.7	3.9	33.0	-0.0
morning and afternoon snack	15.5	-8.2	17.5	-5.3
evening snack	18.1	-13.9[x]	17.5	-3.0

[1] Adjusted for combination of recording days.

[2] Miscellaneous group ($<$ 70 kcal) is omitted.

[x] One-sided $P < 0.05$, [xx] One-sided $P < 0.01$.

Table 5

DAILY ENERGY INTAKE, INDICES OF HABITUAL PHYSICAL ACTIVITY AND LBM PER CATEGORY OF BODY FATNESS IN MALES AND FEMALES

Sex	Variables	Category of body fatness[1]						P-value[2]
		leaner		middle		fatter		
		mean	SEM	mean	SEM	mean	SEM	
Males		(n=47)		(n=48)		(n=27)		
	Energy intake (kcal)	3070	105	2953	97	2983	167	
	Work index	2.5	0.1	2.4	0.1	2.7	0.1	
	Sport index	2.8	0.1	2.8	0.1	2.7	0.1	
	Leisure-time index	2.8	0.1	2.8	0.1	2.3	0.1	<0.05
	LBM (kg)	61.5	0.8	64.8	0.9	65.6	1.4	<0.05
Females		(n=50)		(n=45)		(n=45)		
	Energy intake (kcal)	2280	65	2184	73	2045	64	<0.05
	Work index	2.9	0.1	2.7	0.1	2.8	0.1	
	Sport index	2.4	0.1	2.5	0.1	2.3	0.1	
	Leisure-time index	3.1	0.1	3.0	0.1	3.0	0.1	
	LBM (kg)	44.1	0.6	45.2	0.5	46.1	0.7	<0.05

[1] The leaner, middle and fatter categories comprise of males with BF% of < 15.0, 15.0 - 19.9, and ≥ 20.0, respectively and females with BF% of < 25.0, 25.0 - 29.9, and ≥ 30.0, respectively.

[2] The differences between the fatter and leaner category is tested.

The daily energy intake of fatter males tended to be slightly lower than of leaner males but this was not significant (Table 5). On the other hand, the daily energy intake of fatter females was about 235 kcal less than of the leaner females. No differences in indices of habitual physical activity were observed between the categories of body fatness in either sex, except for the mean score of the leisure-time index, which was lower for the fatter group of males than for the other males. For both males and females, the LBM was higher in the fatter group than for the leaner group.

Table 6 shows the relationships between energy intake and body composition, and habitual physical activity in a multiple regression model. Energy intake of males appeared to be negatively related to BF% and positively related to LBM and to the work index. The sport index tended to be positively related to energy intake, but this was not statistically significant. The type of recording days, introduced in the analysis in order to make an adjustment for the combination of days of the week the subjects recorded their food intake, was positively related to energy intake of males. It appeared that on each day of the weekend, daily energy intake was 207 kcal higher than on workdays.

Table 6

MULTIPLE REGRESSION ANALYSIS OF TOTAL ENERGY INTAKE (kcal/day) ON BF%, LBM (kg) AND INDICES OF HABITUAL PHYSICAL ACTIVITY IN MALES AND FEMALES[1]

Independent variables	Males (n=122)		Females (n=140)	
	B	SE	B	SE
Intercept	232		2252	
BF%	-37^{xx}	14	-27^{xxx}	8
LBM	35^{xxx}	9	24^{x}	9
Work index	307^{xxx}	82	-34	64
Sport index	125	80	-16	59
Leisure-time index	-26	83	-109	67
Type of recording days	207^{x}	81	66	51
R^2	0.29		0.13	

[1] Adjusted for combination of recording days.

^{x} P < 0.05, ^{xx} P < 0.01, ^{xxx} P < 0.001.

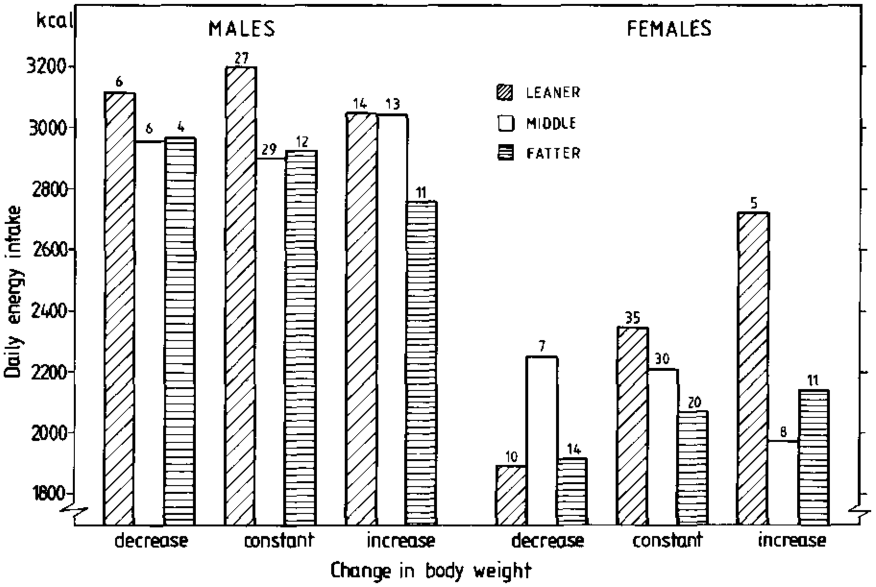

FIG. 1. The relationship between daily energy intake and body fatness within categories of change in body weight in males and females. Daily energy intake is adjusted for LBM, work index and the combination of recording days. The leaner, middle and fatter categories comprise of males with BF% of <15.0, 15.0-19.9, and ≥20.0, respectively and females with BF% of <25.0, 25.0-29.9, and ≥30.0, respectively. Change in body weight during four months preceding the food consumption study was subdivided into three categories: ≤ -1.5, -1.4 to +1.4 and ≥+1.5 kg. The number of subjects is indicated above the bars.

The energy intake of females was also negatively related to BF% and positively related to LBM, but was not significantly related to any index of habitual physical activity, although the leisure-time index tended to be negatively related to energy intake. Interaction terms were introduced in an additional analysis, but did not appear to be statistically significant.

The daily energy intake of fatter males and females also tended to be lower within the categories of change in body weight than of leaner males and females (Fig. 1). It should be noted however, that in males no clear evidence was found of a positive relationship between daily energy intake and change in body weight during the four months before the recording days. In females, a positive relationship between energy intake and change in body weight was observed in the leaner and the fatter groups but not in the middle group.

DISCUSSION

In comparison with a prudent diet (28,29), the proportional intake of fat is slightly higher and the intake of sugar is rather high in the present study population. The contribution of poly-unsaturated fatty acids to total fat intake is lower than recommended. In addition, the intake of dietary cholesterol is rather high especially in males, and the proportional intake from total protein is slightly higher than recommended, especially in females.

The average daily energy intake of about 3000 kcal in males seems to be rather high for the present population of sedentary to moderately active subjects. Generally, a daily energy intake between 2500 and 2900 kcal is recommended (29-31) for such a population. This observation parallels the gradual increase of mean body weight in males which was 1.2 kg during the year before the food consumption study. Both findings suggest the existence of a positive energy balance for the male population. The stability of mean body weight in females seems to be in concordance with the average daily energy intake of about 2170 kcal which is closer to the recommended daily energy intake for females (29-31).

The finding, that differences in physical activity between categories of body fatness were negligible in both sexes, is in accordance with some other studies (10-12). The observation that fatter males tended to eat slightly less than leaner males has also been shown by others (4,5,10). This is also the case for the more pronounced inverse relationship between body fatness and energy intake in females (1,3). An explanation for this inverse relationship may be that the fatter females in particular restrict their food intake in an attempt to lose body weight. This interpretation is supported by the finding that BF% in females was inversely related to the intakes of foods such as margarine, fats, oils, sugars and sugar-rich products (Table 4); limitation of intakes of these products with a high energy density is generally found desirable when slimming (13,32). Other investigators have also found an inverse relationship between obesity and the intakes of sugar (1,33) and fat (1). Further, it has been shown that obese people systematically under-report their intake (14-16), and this may also explain the inverse relationship. However, this is not likely to occur across the whole range of body fatness, as has been stated by Keen *et al.* (1). The inverse relationship already exists between the leaner and middle category of body fatness (Table 5). The relationship between meal pattern and body fatness (Table 4) also suggests that under-reporting is not an appropriate explanation for the inverse relationship between energy intake and body fatness.

It may be assumed that, if people under-report food intake, they will especially under-report the food between meals, when a dietary record method is used (14). While the inverse relationship was found to be most pronounced in females (Table 5), there was no clear evidence in the present study to support the suggestion that obese females under-report the amount of food eaten between meals. The fatter females restricted their food intake mainly at breakfast and lunch.

An adjustment for energy expenditure should be made in order to study the relationship between body fatness and energy intake in detail. Therefore, multiple regression analysis was used to explain energy intake by BF%, LBM and habitual physical activity. It is assumed that LBM is an adequate parameter for the assessment of resting metabolic rate (18,19,34). After making the adjustment, a clear inverse relationship between BF% and energy intake was also observed in males. The reason for this relationship being poor before adjustment for energy expenditure may well be that fatter people have on average a higher resting metabolic rate as has been shown by James *et al.* (35).

The work index was the only index of habitual physical activity which was related to energy intake in males (Table 6). A positive relationship between energy intake and expenditure in army recruits over a longer period has been shown by Edholm *et al.* (36). Lincoln (10) also observed a positive relationship between energy intake and physical activity at work in males. A similar relationship in females was not observed by McCarthy (12) and this is also in concordance with the present study.

The positive trend between the sport index and energy intake in males was not significant, perhaps because food intake was measured on two randomly selected days, whereas the sport index is related to the habitual sport, which is often played on particular days of the week. The finding that energy intake was related to the work index and tended to be related to the sport index only in males, parallels the earlier observed positive relationship in the same population between LBM and work index, and sport index in males (26). In addition, LBM was not related to leisure-time index in males, and was not related to any of the three indices of physical activity in females (26). This suggests that different scores on these indices reflect too small differences in energy expenditure to observe an effect on the amount of LBM and energy intake. The present female population, which is a normal young adult population, seems to be sufficiently homogeneous with regard to physical activity to allow variation in energy intake to be influenced only by body composition and other personal and environmental factors. Whereas in males, physical activity at work also affects variation in the amount of energy intake.

The period of about four months immediately before the recording days of the food consumption study was used to classify the subjects according to the changes in their body weight. Acheson *et al.* (37) stated that changes in body energy may be seen as changes in weight, but because of day-to-day fluctuations, changes in the body weight do not necessarily reflect changes in energy balance or energy stores. If the cut-off point for change in body weight is, however, greater than these fluctuations, only a few people will be incorrectly classified. The cut-off point of 1.5 kg used seems to be adequate according to other studies (38,39). It was observed, however, that the adjusted daily energy intake tended to be lower among those with a decrease in body weight and to be higher among those with an increase in body weight only in the leaner and fatter group of females (Fig. 1). Therefore it is assumed that the change in body weight reflects an energy balance at the time of the food consumption study only in the leaner and fatter group of females. An explanation for the absence of this relationship in other females and in males may be that relevant changes in body weight often occur in relatively short periods or abruptly. This will have the consequence that change in body weight over a period of four months, as in the present study, does not always reflect energy balance at the end of this period.

For the reason mentioned above, it may be supposed only in females that the trend of a lower daily energy intake of fatter subjects cannot be explained by a negative energy balance or successful slimming at the time of the study. The fatter females seem to have a reduced need for energy, but it is not clear whether this is a causal factor of obesity or an effect of prolonged slimming. The latter is supported by the observation in other studies that resting metabolic rate decreases when energy intake is restricted (20,21). There may be one exception to this, that is the group of fatter females who were successful in reducing body weight, because they ate the same amount of food as the leaner females who also lost body weight.

The authors consider that in studies on the relationship between energy intake and body fatness it is desirable to take the phase of obesity into account. However, the present findings with respect to this should be interpreted with caution for two reasons. Firstly, the subdivision of the study population according to body fatness and change in body weight has led to unavoidably small numbers of subjects in each category. Secondly, an adjustment for energy expenditure was made by taking LBM and habitual physical activity into account. It may have been better to have used an activity diary technique in which measurements of energy expenditure for specific activities (13) were made, because it must be recognized that only a small proportion of the variation in energy intake is explained by LBM and habitual physical activity (Table 6). However, for practical reasons the diary technique is not useful in large-scale studies.

In summary, the average energy intake in males was higher than the recommended intake, which was not found to be the case in females. This observation is supported by a mean increase in body weight in males during the preceding year, while mean body weight of females during the same period remained constant. In both sexes, the fatter groups were not less physically active than the leaner groups, apart from the fatter males who had a slightly lower score on the leisure-time index. The fatter groups tended to eat less than the leaner groups, but this was only significant in females. In a multiple regression model, it appeared that energy intake was determined by BF% and LBM in both sexes, and the work index was related to energy intake only in males. These findings suggest that females are so homogeneous with regard to physical activity that physical activity has little influence on differences in energy intake between individuals. In addition, it is supposed that many of the fatter females have a reduced need for energy. Nevertheless, mean body weight remained constant for about one year in females, while body weight of males increased. It may be that social pressure to be thin is greater for females, which makes females more conscious of body weight than males.

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7 GENERAL DISCUSSION

BODY FATNESS

It has been shown in Chapter 4 that the body mass index (BMI; weight/height^2) is a reasonable indicator of body fatness, as has also been observed in other studies (1,2). It is noteworthy that an index of relative weight, based not only on body weight and body height, but also on knee width and/or wrist width did not improve the prediction of body fatness in either sex. Even in females accuracy in prediction of body fatness was slightly less when knee width was taken into account, perhaps because of an artifact of measurement. It would appear to be unavoidable that some subcutaneous fat is included in the anthropometric measurement of knee width (3).

A general disadvantage of all indices of relative weight is that they do not differentiate between overweight caused by an excess of lean body mass (LBM), and overweight caused by an excess of body fat. An increased LBM per unit of body height may be the result of increased physical activity in particular. However, in the present study no relationship between LBM and physical activity was observed in females (Chapter 5). Therefore also from this point of view BMI appears to be an adequate indicator of body fatness in females. On the other hand in males, it was shown that physical activity at work and the amount of sport undertaken were positively related to LBM (Chapter 5). It can be assessed from the regression coefficients that the males with the highest physical activity at work (score 5) have on average an LBM of 5.4 kg more than those with the lowest physical activity at work (score 1). This may result in a BMI-difference of approximately 1.7 kg/m^2 with the average body height of 1.80 m. This difference is 4.9 kg or approximately 1.5 kg/m^2 for males with extreme scores on the sport index. Both differences can be added in order to assess the maximum overall effect of physical activity on LBM, but in general it seldom occurs that males are both extremely physically active at work and extremely active sportsmen, because physical activity at work is inversely related to the amount of sport undertaken (Chapter 3).

FOOD CONSUMPTION AND PHYSICAL ACTIVITY

The average daily energy intake of about 3000 kcal in the present population of young adult males appears to be rather high, while the average energy intake of about 2170 kcal in females is quite normal (Chapter 6). In The Netherlands no comparable food consumption studies in young adults have been carried out on a community basis. However, a study recently carried out in 17 and 18 year old Dutch boys showed an even slightly higher daily energy intake (4), while in studies including older age categories, a lower daily energy intake was observed (5,6). This suggests that the energy intake decreases with age, perhaps because of a reduced need of energy for growth and physical activity. The reduction in energy intake may occur too slowly in males, because in the present study average body weight increased in males (Chapter 6) which indicates the existence of a positive energy balance.

In respect of the proportional intake of both macronutrients and food groups, and the distribution of energy intake over the various meals, differences between males and females were generally small, the most salient being the higher consumption of alcoholic drinks by males. It is clear from the present food consumption study that a large part of energy intake is derived from food groups with a high energy density and/or with a low dietary fibre content (Chapter 6). In both sexes approximately 28% of energy intake only is derived from cereal products, potatoes, fruit and vegetables. It has also been suggested by de Wijn that this is a negative characteristic of the food consumption pattern of the Dutch (6). It indicates that little food is consumed which has a high satiety because of its slow digestibility and/or the intensive mastication required.

It is noteworthy that approximately 35% of total daily energy intake is derived from food and drinks consumed between meals (Chapter 6), whereas it is generally believed that the typical daily food consumption pattern of the Dutch consists of three main meals; breakfast, lunch and dinner. In another Dutch study including older age categories, only about 20% of energy intake was obtained from food eaten in addition to the three main meals (5). The observation in the present study may be typical of the eating pattern of young adults, but such a pattern may be undesirable because it may lead to a high total energy intake, and because the food consumption between meals consists mainly of foods of low nutritive value. In the present study, it appeared that between meals more foods were consumed of lower protein content and higher alcohol, and mono- and disaccharides contents than at the main meals (7).

The average daily energy intake by males was about 200 kcal higher during the weekend than on workdays, while the difference between weekend and workdays in females was negligible (Chapter 6). Further analysis showed that the higher energy intake during the weekend by males could be explained especially by a higher consumption of alcoholic drinks of about 100 kcal per day (7). There was no significant difference during the weekend and on workdays in the energy intake derived from foods in the other nine groups distinguished. This means that the extra alcohol consumption during the weekend is not compensated by a reduction in consumption of food from the other groups.

The results of the development of a short questionnaire for the measurement of habitual physical activity are reported in Chapter 5. It was concluded that habitual physical activity encompassed at least three distinct dimensions: physical activity at work; sport during leisure time; and other physical activity during leisure time. Physical activity at work and sport during leisure time were both positively related to LBM (Chapter 5) and to daily energy intake (Chapter 6) in males, but not in females. In addition, energy expenditure through physical activities such as walking and cycling during leisure time was not related to LBM (Chapter 5) or to daily energy intake (Chapter 6) in both sexes. These observations suggest that the present female population is so homogeneous in respect of physical activity, that the latter cannot be responsible for differences in daily energy intake.

DETERMINANTS OF BODY FATNESS

In the literature, several aspects of daily life-style are shown to be related to obesity, but it is not clear whether all these aspects are independently related to obesity, or whether they are only indicators of more general types of behaviour. Structuring the various aspects of daily life-style is important because this will make it easier to interpret its relationship to body fatness. Indeed, in the present study it appeared that a number of aspects of daily life-style could be interpreted as indicators of general types of behaviour (Chapter 3). Five types could be distinguished within the 16 aspects of daily life-style considered. These were: slimming behaviour, CASS behaviour (characterized by coffee and alcohol consumption, smoking habits and hours of sleep per night), eating sweet and savoury snacks, health-conscious behaviour, and physical activity.

Slimming behaviour was positively related to BMI in both sexes. This parallels the findings in Chapter 6 that fatter people eat less food than leaner people. Similar findings have also been observed in several other cross-sectional studies (8,9). This illustrates the importance of studying the aetiology of obesity in prospective studies instead of cross-sectional studies, because changes in food consumption may occur after the development of obesity. In addition, other aspects of behaviour and psychological characteristics may also change as a consequence of increased body weight.

CASS behaviour was positively related to BMI in males and health-conscious behaviour was inversely related to BMI in both sexes. It may be hypothesized that CASS behaviour is influenced especially by a certain personality structure, whilst health-conscious behaviour is influenced, in particular, by knowledge and attitudes about health and nutrition. This view is supported by the findings in other studies that items concerning CASS behaviour are related to a type A personality (Chapter 3). Separating these two types of behaviour may be important for health education programmes, which are aimed at changing behaviour by increasing knowledge, changing attitudes and/or influencing norms and values (10). If CASS behaviour is primarily dependent on certain personality traits, the effect of a health programme to reduce this type of behaviour may be less than the effect of a programme to stimulate health-conscious behaviour.

Assuming that no cohort effect is present, then the wide difference between the average BMI of the 19-21 and 29-31 year age groups (Chapter 2) suggests that this age range is a critical period for the development of obesity. There seems to be a large increase in body weight in this period, especially in males. In general, this period of life is characterized by a number of changes in the social environment; a number of life events take place during this period. Stressful life events may temporarily affect food habits and physical activity to the extent that body weight is increased (11). In addition to the effect of life events on behaviour, also new living conditions themselves may be related to other food habits and habitual physical activity.

The observations, that those who have a lower level of education and whose fathers have a lower level of occupation, have on average a higher BMI (Chapter 2) is in accordance with the relationship as generally observed in the literature (12). This relationship may be explained in two ways. Firstly, characteristics such as level of education and level of occupation are indicators of the type of social environment of the subjects. These characteristics reflect certain aspects of the living conditions. If, therefore level of education and occupation are related to BMI, then different values, norms and attitudes about health and nutrition in various social environments will be important underlying causal determinants of obesity. Secondly, a certain level of education will be concomitant with a certain level of knowledge in relation to health and health-related behaviour. This knowledge about health and health-related behaviour is also a potential causal determinant of obesity. This view is supported by the observed positive relationship between level of education and both health-conscious behaviour (Chapter 3), and the amount of physical activity during leisure time (Chapter 5). The weaker positive relationship between level of education and slimming behaviour (Chapter 3), indicating a slightly higher level of weight-consciousness among people with a higher level of education, also supports this view.

The relationships between BMI and the other socio-demographic variables were less important than those between BMI and both age and level of education. However, a relationship such as between BMI and religion, and church attendance (Chapter 2) illustrates the possible influence of attitudes, and in this case the general attitude to life, on food habits and/or habitual physical activity. The finding that females who had given birth to two or more children were heavier than other females may be explained by physiological changes during pregnancy. However, it is also possible that because of the increased size of the family, living conditions are influenced to the extent that behaviour is changed.

The mechanisms described above may partly explain the observed relationships between socio-demographic variables and BMI. These mechanisms link up with the model for the aetiology of obesity presented in Chapter 1, and will be studied further in the prospective study also mentioned. In addition, it is necessary to describe in more detail the specified types of behaviour within the aspects of daily life-style (Chapter 3), and to study them in relation to characteristics such as personality traits and attitudes. Furthermore, the relationships between these types of behaviour and change in body weight should be studied in order to determine whether they are causal determinants of obesity.

The study described in Chapter 6 showed that the daily energy intake of fatter people was lower than of others, whereas physical activity at work and the amount of sport undertaken were not related to body fatness in either sex. Only physical activities such as walking and cycling during leisure time were slightly less in fatter males, but it has been suggested already that this may be accompanied by only a minor difference in energy expenditure. The trend that fatter people eat less than others, may be explained by a restriction of food intake by the fatter people in an attempt to lose body weight and, as already mentioned, is in concordance with the observed relationship between slimming behaviour and BMI (Chapter 3). However, there is also some evidence to suggest that apart from slimming behaviour, fatter people have a reduced need for energy. It appeared that within the categories of change in body weight: decrease, constant, and increase (Chapter 6) fatter people also tend to eat less than leaner people. For reasons mentioned in Chapter 6, this could only be concluded from the results in females. It is not clear from the present study whether the suggested reduction in the fatter subjects is a potential causal factor of obesity or an effect of prolonged slimming. The latter is supported by the observation in other studies that resting metabolic rate decreases when energy intake is restricted (13,14).

The contribution of the various food groups to total daily energy intake differed only slightly between categories of body fatness (Chapter 6). Nevertheless it is noteworthy that the fatter females tended to restrict consumption of products such as margarine, fats, sugar and sugar-rich products especially. This suggests that the diet of fatter females is more in accordance with a prudent diet (15,16) than that of other females. It may well be that this trend is secondary to the increased body weight of the subjects and should be interpreted as a reflection of slimming behaviour; limitation of intake of foods which have a high energy density is generally found to be desirable when slimming (17,18). The contribution of various meals to total daily energy intake in relation to body fatness has received much attention in the past (19-22). In general, it has been found that obese people omit more meals than others, in particular breakfast. In Chapter 3 it is suggested that omitting meals is an effect of obesity rather than a cause; people who are obese may omit meals more often than others in their efforts to reduce total energy intake. This is supported by the inverse relationship found between the amount of food eaten at breakfast and body fatness (Chapter 6). However in the study described in Chapter 3, it appeared that omitting breakfast was not related to slimming behaviour, but inversely related to health-conscious behaviour. This suggests that omitting breakfast should be interpreted as an indicator of health-conscious behaviour which may be causally related to obesity.

MANAGEMENT OF OBESITY

A general survey of the health consequences of obesity is given in Chapter

1. It is concluded that a definition of obesity can only be based on the relationship between body fatness and mortality. At present insufficient quantitative data on the relationship between body fatness and both morbidity and psychological problems are available in order to include these aspects in an operational definition of obesity. In the present study the prevalence of severe obesity (BMI $\geq$ 30.0 kg/m^2) was 2% in both sexes (Chapter 2). In other studies in adult western populations the prevalence of severe obesity has been found to be between 5 and 10% (23-25). It should be noted however, that the present study population consisted only of young adults and that, in general, body weight increases during adulthood (26-28). The prevalence of moderate obesity (BMI between 25.0 and 29.9 kg/m^2) was about 22% in males and 12% in females (Chapter 2). Similar cut-off points for males and females are often chosen for simplicity (24) but it may be that the higher prevalence of moderate obesity in males can be explained partly by a larger LBM in males than in females as shown in Chapter 6. Therefore, different cut-off points for males and females as proposed by de Wijn (29) have also been used in the present study. Ten percent of males had a BMI of at least 27.0 kg/m^2 and 9.6% of females had a BMI of at least 26.0 kg/m^2 (30). These prevalence rates of obesity were similar to the rates in young adults in a study carried out with a representative sample of the Dutch adult population (31).

It is generally accepted that both individual and group treatment programmes to reduce body weight are useful for the severely obese and also for the moderately obese, if obesity-induced health consequences are present which can be improved by weight reduction such as hypertension. However, there is less agreement as to whether it is desirable to develop programmes for moderately obese people without health problems related to obesity.

Since the number of people who are moderately obese is considerable, it is not practical to administer individual weight reduction programmes. If necessary, these programmes should be based on the group or community. Such programmes may influence people who are not yet obese and those who are already obese. However, Berger has stated that public campaigns in order to enforce a reduction of the populations' average body weight do not appear to be justified for several reasons of which the absence of valid evidence to support the slogan 'the slimmer the healthier' is the most important (32). But as mentioned in Chapter 1, the effect of obesity on health seems to be greater in younger people than in middle-aged and older people. For this reason the management of obesity should be focused more on younger people than on the population as a whole. Young adults in particular may be an important target group because the age range between 20 and 30 years seems to be a critical period for the development of obesity, as discussed above. In addition, level of education and/or level of occupation can be useful in directed prevention and treatment of obesity, because there is a considerable difference between the mean BMIs of those with lower levels of education and occupation and those with higher levels of education and occupation. It seems to be justified to give more attention to the management of obesity at primary school and schools for occupational training.

Severe and moderate obesity are often the concomitant of a number of psychosocial problems such as inability to cope with the environment; social, economic or other types of discrimination; impairment of self-image; and deviation from the prevailing aesthetic view of attractive appearance (33). Females, especially, seem to experience the most problems with respect to this, which is supported by the findings that slimming behaviour is more prevalent in females than in males (Chapter 3), and that anorexia nervosa developes more often in females (34). However, many obesity related psychosocial problems do not seem to be a direct consequence of the development of obesity but rather a consequence of the seemingly negative attitude towards the obese in western societies (35,36). Therefore, in fact these problems are no reason to start a weight reduction programme. Health programmes may be successful in changing the negative attitude towards the obese by educating people that obesity is a complicated disorder, and that it is a naive theory that overeating and lack of exercise are the sole causes of obesity (35). It should be recognized and emphasized that the primary causes of obesity in individuals are often derived from their living conditions and personal characteristics (see Chapter 1), which cannot be influenced by people themselves. In addition, publication of normal ranges of body weight requires more attention in these programmes. It is concluded that people often perceive their own body weight as too heavy while from the medical point of view there are no justifications for this opinion (30,31), which may lead to unnecessary efforts to reduce body weight.

While some of the findings which are summarized and discussed in this chapter, can be useful for the management of obesity, it must be emphasized that several aspects have yet to be studied in further detail before definite conclusions can be drawn. This is being done in the research project of which the present studies form the first part.

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SUMMARY

In 1979, the Department of Human Nutrition of the Agricultural University at Wageningen began a research project on obesity in young adults. The main objectives of this project are the investigation of aetiological aspects and health consequences of obesity. It is a prospective study and is being carried out in a young adult population of three age groups (19-21, 24-26 and 29-31 years as at 1 January 1980) in the Municipality of Ede. The present thesis deals with the investigations into determinants of body fatness and two methodological studies concerning relative weight and habitual physical activity which form the first part of the research project mentioned above.

In the Introduction, a general survey is given of the methods of measuring body fatness. Health consequences and aetiology of obesity are also surveyed. Approximately 3900 subjects participated in the studies described in Chapter 2 and 3, and a subsample of approximately 300 subjects from the initial population participated in the studies described in Chapters 4-6.

The relationship between various socio-demographic variables and body mass index (BMI; weight/height^2) is dealt with in Chapter 2. The prevalence of severe obesity (BMI $\geq$ 30.0 kg/m^2) was 2% in both sexes. The most salient socio-demographic determinants of BMI were age and level of education. Older subjects were heavier, and subjects who had a higher level of education were lighter. Other socio-demographic determinants of BMI were: level of father's occupation and religion in both sexes; parity in females; and urbanization and church attendance in males.

The relationship between aspects of daily life-style and BMI are described in Chapter 3. Five conceptually meaningful factors could be distinguished within the aspects of daily life-style considered. These factors were interpreted as constructs of: 1, slimming behaviour; 2, behaviour characterized by the consumption of coffee and alcohol, smoking habits and number of hours of sleep per night (CASS behaviour); 3, eating sweet and savoury snacks; 4, health-conscious behaviour; and 5, physical activity. Heavier subjects had higher ratings for slimming behaviour and lower ratings for health-conscious behaviour. In addition heavier males had higher ratings for CASS behaviour.

Possible improvement in the prediction of body fatness when an index of relative weight is based not only on body weight and body height, but also on

frame size, is considered in Chapter 4. The prediction of body fatness was not improved when frame size, as assessed by knee width and wrist width, was taken into account. BMI was the most preferable of the indices considered.

The development of a short questionnaire for the measurement of habitual physical activity is discussed in Chapter 5. Three dimensions could be distinguished within the pattern of habitual physical activity. They are interpreted as: 1, physical activity at work; 2, sport during leisure time; and 3, physical activity during leisure time excluding sport. Level of education was inversely related to physical activity at work, and positively related to physical activity during leisure time excluding sport. Subjective experience of work load was inversely related to both sport and other physical activities during leisure time. Lean body mass was positively related to both physical activity at work and sport, in males only.

The relationship between body fatness and both food consumption and habitual physical activity are dealt with in Chapter 6. The average daily energy intake in males was rather high (about 3000 kcal) and average body weight increased by 1.2 kg in the preceding year. Both findings suggest the existence of a positive energy balance. In females the average daily energy intake of about 2170 kcal was closer to the recommended intake and average body weight remained constant. There were no important differences in the pattern of habitual physical activity between the categories of body fatness defined. However the daily energy intake of fatter subjects was lower than that of leaner subjects. This finding may be explained by a reduction of food intake in fatter subjects in an attempt to reduce body weight. There is also some evidence to suggest that many fatter subjects have a reduced need for energy, but it is not clear whether this is a causal factor of obesity or an effect of prolonged slimming.

Finally, a general discussion of the results is given in Chapter 7. While some of the findings can be useful for the management of obesity, it must be emphasized, that several aspects have yet to be studied in detail in the research project of which this thesis forms the first part.

SAMENVATTING

In 1979 is de vakgroep Humane Voeding van de Landbouwhogeschool te Wageningen gestart met een onderzoeksproject op het gebied van obesitas bij jonge volwassenen. De belangrijkste doelstellingen van dit project hebben betrekking op de etiologie en op gezondheidsconsequenties van obesitas. Het betreft een prospectief onderzoek dat in de gemeente Ede wordt uitgevoerd bij jonge volwassenen in drie leeftijdsgroepen (19-21, 24-26 en 29-31 jaar op 1 januari 1980). Dit proefschrift handelt over onderzoeken naar determinanten van het lichaamsvetpercentage en twee methodologische onderzoeken met betrekking tot relatief gewicht en het gewoonlijke lichamelijke activiteitenpatroon die zijn uitgevoerd in het eerste deel van het bovengenoemde onderzoeksproject.

In de Inleiding wordt een algemeen overzicht gegeven van gangbare methoden om het lichaamsvetpercentage te meten. Gezondheidsconsequenties en de etiologie van obesitas worden hierin ook besproken. De onderzoeken die in Hoofdstuk 2 en 3 worden gerapporteerd hebben betrekking op ongeveer 3900 personen, terwijl een steekproef van ongeveer 300 personen hieruit deelnam aan de onderzoeken die in de Hoofdstukken 4-6 worden beschreven.

Hoofdstuk 2 heeft betrekking op de relatie tussen verschillende socio--demografische variabelen en de body mass index (BMI; gewicht/lengte^2). De prevalentie van ernstige obesitas (BMI $\geqslant$ 30.0 kg/m^2) was zowel bij mannen als vrouwen 2%. De meest uitgesproken socio-demografische determinanten van BMI waren leeftijd en opleidingsniveau. De oudere personen waren zwaarder dan de jongere personen en diegenen met een hoger opleidingsniveau waren lichter dan diegenen met een lager opleidingsniveau. Andere socio-demografische determinanten van BMI waren: het beroepsniveau van de vader en religie zowel bij mannen als vrouwen; pariteit bij vrouwen; en de urbanisatiegraad en kerkbezoek bij mannen.

In Hoofdstuk 3 wordt de gevonden relatie tussen het leefpatroon en BMI beschreven. Vijf goed interpreteerbare factoren konden worden onderscheiden binnen de aspecten van het leefpatroon die bij het onderzoek waren opgenomen. Deze factoren werden geïnterpreteerd als indicatoren voor: 1, aan de lijn doen; 2, gedrag dat gekarakteriseerd wordt door de consumptie van koffie en alcohol, rookgewoonten en het aantal uren slaap per nacht (CASS-gedrag); 3, snack--gebruik; 4, gezond-gedrag; en 5, lichamelijke activiteit. De zwaardere personen hadden een hogere score voor aan de lijn doen en een lagere score voor gezond-gedrag. Zwaardere mannen hadden ook een hogere score voor CASS-gedrag.

Hoofdstuk 4 heeft betrekking op de mogelijke verbetering van de schatting van het lichaamsvetpercentage wanneer het relatief gewicht niet alleen is gebaseerd op gewicht en lengte maar ook op skeletbouw. De schatting van het lichaamsvetpercentage bleek echter niet verbeterd te kunnen worden wanneer ook rekening werd gehouden met maten voor skeletbouw, zoals kniebreedte en polsbreedte. Van de berekende gewicht-lengte indices bleek BMI de meest geschikte index te zijn.

In Hoofdstuk 5 worden de resultaten gepresenteerd van een vragenlijst die ontwikkeld is voor de meting van het gewoonlijke lichamelijke activiteitenpatroon. Drie dimensies werden onderscheiden binnen dit patroon, namelijk: 1, lichamelijke activiteit bij het werk; 2, sport; en 3, lichamelijke activiteit in de vrije tijd exclusief sport. Het opleidingsniveau was negatief gerelateerd met de lichamelijke activiteit bij het werk, en positief met de lichamelijke activiteit in de vrije tijd exclusief sport. Subjectieve belasting bij lichamelijke inspanning was zowel negatief gerelateerd met de hoeveelheid sport die men beoefende als met de overige lichamelijke activiteit in de vrije tijd. Bij mannen was ook de lean body mass positief gerelateerd met lichamelijke activiteit bij het werk en met de hoeveelheid sport die men beoefende.

Hoofdstuk 6 heeft betrekking op de relaties tussen enerzijds het lichaamsvetpercentage en anderzijds voedselconsumptie en het lichamelijke activiteitenpatroon. De gemiddelde energie-opname bij mannen was tamelijk hoog (ongeveer 3000 kcal); hetgeen een verklaring kan zijn voor de gemiddelde gewichtstoename van 1,2 kg in het jaar voorafgaande aan het voedselconsumptieonderzoek. De gemiddelde energie-opname bij vrouwen was ongeveer 2170 kcal, hetgeen in overeenstemming is met de aanbevolen hoeveelheid terwijl het gemiddelde lichaamsgewicht constant bleef. Er waren geen grote verschillen tussen categorieën naar lichaamsvetpercentage wat betreft het lichamelijke activiteitenpatroon. Maar de energie-opname bij zwaardere personen was wel lager dan bij lichtere personen. Deze bevinding is wellicht te verklaren door een bewuste vermindering van de voedselconsumptie bij zwaardere personen die proberen af te vallen. Er is ook een aanwijzing dat veel zwaardere personen een verlaagde energiebehoefte hebben, maar het is niet duidelijk of dit een oorzaak is geweest van het ontstaan van hun overgewicht, of juist een gevolg van langdurig aan de lijn doen.

Dit proefschrift wordt besloten met een algemene discussie in Hoofdstuk 7. Enkele van de bevindingen kunnen nuttig zijn voor de preventie en behandeling van obesitas. Wel moet worden benadrukt dat verschillende onderdelen nog nader bestudeerd moeten worden in het onderzoeksproject waarvan dit proefschrift het eerste resultaat is.

CURRICULUM VITAE

De auteur werd geboren op 10 november 1949 te Nieuw-Namen (gemeente Clinge). Na het behalen van het diploma aan de Hogere Landbouwtechnologische School te 's-Hertogenbosch in 1971 en het vervullen van de militaire dienstplicht begon hij in september 1972 met zijn studie aan de Landbouwhogeschool te Wageningen. In 1979 slaagde hij voor het doctoraal examen met Voedingsleer en Gezondheidsleer als hoofdvakken en Inspanningsfysiologie als extra bijvak. Van april 1979 tot september 1982 verrichtte hij met financiële steun van het Praeventiefonds het in dit proefschrift beschreven onderzoek bij de vakgroep Humane Voeding van de Landbouwhogeschool. Vanaf januari 1982 is hij tevens werkzaam bij het Instituut voor Sociale Geneeskunde van de Katholieke Universiteit Nijmegen.