Association between different attributes of physical activity and fat mass in untrained, endurance- and resistance-trained men

Abstract The objective of this cross-sectional study was to assess different attributes of physical activity and fitness and their relationship to nutritional state in endurance- and resistance-trained, compared to untrained men. The subjects were 42 men matched for age, of which 13 were untrained [UT, mean age 30.2 years, mean height 180.7 cm, mean body mass 83.6 kg, mean body mass index (BMI) 25.6 kg m⁻²], 14 were endurance-trained athletes (ET, mean age 29.6 years, mean height 178.4 cm, mean body mass 74.0 kg, mean BMI 23.2 kg m⁻²) and 15 were resistance-trained athletes (RT, mean age 28.4 years, mean height 183.4 cm, mean body mass 94.1 kg, mean BMI 27.4 kg m⁻²). Fat mass (FM), fat free mass (FFM), muscle mass (MM) and total body water (TBW) were assessed using anthropometry and bioelectrical impedance analysis. Resting energy expenditure was measured by indirect calorimetry (IC) and total energy expenditure (TEE) by a combination of IC and individually calibrated 24-h heart-rate monitoring. The activity related energy expenditure (AEE) and the physical activity level were calculated. Movements were assessed using pedometry. Aerobic fitness was determined using ergometry, muscle strength [quadriceps muscle (Fₐ₅₅ₓₜ), ischiocuralis muscle (Fₐ₅₅ₓₜ), biceps muscle (Fₐ₅₅ₓₜ), triceps muscle (Fₐ₅₅ₓₜ)] by computer tensiometry. Different time domain indexes of heart rate variability (HRV) were examined during sleep, rest and the whole day as an index of sympathetic nervous system (SNS) activity. When compared with UT and RT, ET had reduced body masses and FM, but increased percentage TBW (P<0.05 and P<0.01, respectively). FFM and MM were increased in RT, when compared with UT and ET (P<0.01). ET had higher TEE, AEE, pedometry derived activities, oxygen consumption and power during vigorous exercise than RT and UT (P<0.05 and P<0.01 respectively). Respiratory exchange ratio at moderate exercise intensities was increased in RT (P<0.05). In the 12 time domain indexes of HRV 6 and 10 were higher in ET than in RT and UT respectively (P<0.05 or P<0.01 respectively) suggesting an increased SNS activity in ET. By contrast, F₀₅₅ₓ₉₉, F₀₅₅ₓ₉₉ and F₀₅₅ₓ₉₉ were elevated in RT (P<0.01). FM was negatively associated with aerobic fitness, but not with muscle strength. We concluded that the physiological and metabolic adaptations to exercise and nutritional state differ between ET and RT subjects. Participation in RT results predominantly in changes in body composition and strength but not in energy expenditure, movements and SNS activity. The opposite was the case for ET. Aerobic fitness, physical activity, movements and activity of SNS were all increased but body mass and FM were decreased. The latter finding may support the idea that, with regard to possible health benefits, ET is more effective than RT.

Key words Physical activity · Aerobic fitness · Muscle strength · Fat mass

Introduction

At the population level physical activity has continuously decreased during the last decades (Blair et al. 1995; Prentice and Jepp 1995; Mensink et al. 1999). A sedentary lifestyle contributes substantially to being overweight and to obesity and, thus, to increased morbidity and mortality (Dietz 1996). In contrast, regular physical activity and/or exercise are associated with a reduced incidence of chronic diseases, such as coronary heart diseases, obesity, osteoporosis, hypertension, stroke and
non-insulin-dependent diabetes mellitus and probably certain cancers (Rowlands et al. 1997). It is generally assumed that physical activities and physical fitness are linked to each other. Regular physical activity as well as training have been recommended to increase fitness in order to prevent obesity and nutrition-related diseases (Rowlands et al. 1997). However, it is unclear which type of activity or training (aerobic or resistance training) is better to recommend to be part of a healthy life style.

Physical activity and physical fitness are not the same. Fitness is an attribute, whereas physical activity is a behaviour. Physical activity and exercise are words often used synonymously. However, exercise is only a subset of physical activity. Physical activity, fitness and exercise are complex phenomena and cannot be explained by one simple term. Physical activity has been defined as the number of movements per day (Rowland and Freedson 1994). During unconstrained free living it can be measured indirectly in terms of 24 h energy expenditure (TEE) relative to resting energy expenditure (REE) or directly as movements assessed using a pedometer and accelerometer. The definition of physical fitness is more difficult. It includes attributes such as muscle mass (MM), muscle strength (\(F_{\text{max}}\)) and/or aerobic fitness. It follows that physical fitness can be assessed using various methods: 1. MM by anthropometry, creatine excretion in urine and/or imaging techniques such as dual energy X-ray absorptiometry (DEXA) (Müller 1998; Illner et al. 2000) 2. Muscle strength by maximal dynamic (jump test, weight lifting) and isometric strength tests (handgrip test, tensiometry) (Glenmark et al. 1994) 3. Aerobic fitness, by ergometry and maximal as well as submaximal oxygen consumption (\(\dot{V}O_2\)). Since \(\dot{V}O_2\) is body-mass dependent, it is frequently normalised to unit body mass and/or to fat free mass (FFM). However this adjustment can lead to an underestimation of aerobic fitness in persons with high FFM. When compared to values calculated using adjusted \(\dot{V}O_2\) the respiratory exchange ratio (R) has been shown to be body mass-independent (Reybrouck et al. 1997). During exercise R greater than 1 indicates a deficiency in \(\dot{V}O_2\) and thus an increase in anaerobic metabolism, i.e. a production of lactate in skeletal muscle. Another index of physical fitness is the activity of the sympathetic and parasympathetic nervous systems, which is enhanced by regular exercise. It can be assessed by measuring heart rate variability (HRV), noradrenaline turnover, 24-h catecholamine excretion in the urine and/or by microneurography.

It is known that exercise training has effects on body composition and various physiological measurements. Regular resistance training increases muscle strength, MM and REE (Bosco et al. 1994; Ryan et al. 1995). By contrast, regular endurance training increases aerobic fitness and HRV (Kenney 1985). It has also been shown that energy expenditure is higher during aerobic than during resistance training. However, there is a lack of data on 24-h physical activity and TEE in endurance- and resistance-trained athletes during unconstrained living conditions. It is also far from clear whether resistance training also influences aerobic fitness and HRV and whether endurance training has effects on MM and strength. The association between the different attributes of fitness and body mass (FM) has also not been well described.

In the present cross-sectional study some attributes of physical activity and fitness and their associations with body composition were assessed in untrained, endurance- and resistance-trained men.

**Methods**

**Subjects**

A group of 42 age-matched healthy men (mean age 29.3 years) was examined in Kiel between July and November 1999. Of the group 13 were untrained and did not regularly participate in any sport, 14 were endurance-trained athletes (long-distance runners, triathletes). The other 15 men were resistance-trained athletes, who were recruited from fitness studios in Kiel. To take part in the study, the athletes had to be amateurs and not taking any drugs. The criterion for inclusion was that they had to have trained three times a week (at least 5 h a week) for at least 2 years. The amount of training was assessed from self-reports. Measurements of body composition and energy expenditure were made at the Institute of Human Nutrition and Food Science and the Institute of Sport and Sport Science (Department of Sport Medicine) at the Christian Albrechts Universität (CAU) in Kiel. The procedures had been explained to all subjects, who all gave their informed written consents. The Ethics Committee of the CAU had approved the study. The physical characteristics of the subjects are shown in Table 1.

**Measurement of body composition**

Body composition was measured using anthropometric methods [body mass, body height, triceps (TSF), biceps (BSF), suprailiacal (SIF), supscapular (SSF) skinfold thicknesses, waist, hip and arm circumferences] and bioelectrical impedance analysis (BIA). Body mass index (BMI) and waist to hip (w:h) ratio were calculated. All measurements were made by one investigator (AG). The measurements were made in the morning after an overnight fast of 8–12 h and after voiding. The FM and FFM were calculated from body density (D) according to Durnin and Wormersley (1974):

\[
FM = \text{body mass} \times (4.95/D) - 4.5
\]

\[
FFM = \text{body mass} - \text{FM}
\]

Body density was estimated according to age-specific formulas:

\[
20–29\text{ years: } D = 1.1631 - 0.0632 \times \log(\text{TSF + BSF + SIF + SSF})
\]

\[
30–39\text{ years: } D = 1.1422 - 0.0544 \times \log(\text{TSF + BSF + SIF + SSF})
\]

\[
40–49\text{ years: } D = 1.1620 - 0.0700 \times \log(\text{TSF + BSF + SIF + SSF})
\]

where FM and FFM and body mass are in kilograms, TSF, BSF, SIF, and SSF are in millimetres.

The MM was calculated from TSF and arm circumferences according to Heynsfield et al. (1982):

\[
MM = \text{body height} \times \{0.0264 + 0.0029[\text{arm} - \pi \times \text{TSF}]^2/4\pi - 10\}
\]