

Pattern and intensity of physical activity

Keeping moderately active is the best way to boost total daily energy expenditure.

A low level of physical activity is a pervasive feature of our modern lifestyle. Attempts to counteract the negative effects of sedentary living include introducing bouts of high-intensity exercise, but I show here that it can be more effective to increase the amount of time spent on activities of moderate intensity while reducing periods of inactivity during waking hours.

Physical inactivity may be associated not only with being overweight but also with disorders such as coronary heart disease or type-2 diabetes¹, which may be prevented by exercising regularly². Consequently, sedentary people often include spells of vigorous exercise in an otherwise inactive and unhealthy lifestyle. I have tested whether this is the most effective way to enhance people's total daily activity levels by determining how these are influenced by exercise duration and intensity.

Healthy, non-obese adults (14 women and 16 men; 27 ± 5 yr; 24.1 ± 2.3 kg m⁻²) participated in the study³. Total energy expenditure was measured by monitoring their metabolism with doubly labelled water over a two-week period, the optimal observation interval for the biological half-lives of the isotopes. The physical activity level (PAL) is defined as the factor by which total energy expenditure exceeds resting energy expenditure, measured during an overnight stay in a respiration chamber.

To determine the amount of body movement over 1-min intervals, I recorded movements over the first of the two weeks with a 'Tracmor' portable motion sensor. This consists of a body-fixed triaxial accelerometer and a data unit for on-line registration, processing and storage of acceleration signals. The triaxial accelerometer ($50 \times 30 \times 8$ mm; 16 g) consists of three uniaxial piezoresistive accelerometers and registers accelerations in three orthogonal directions as the body moves. Acceleration signals are processed to obtain the sum of the rectified and integrated acceleration curves from all three measurement directions. The integration time is set at 1 min and the final output is expressed as counts per minute (c.p.m.)⁴.

Using data from Tracmor recordings in combination with activity details recorded in diaries, three activity categories were defined: low intensity (lying, sitting and standing; Tracmor output under 1,000 c.p.m.), moderate intensity (walking and cycling; output 1,000–3,000 c.p.m.); and high intensity (housework, gymnastics and sport; output greater than 3,000 c.p.m.).

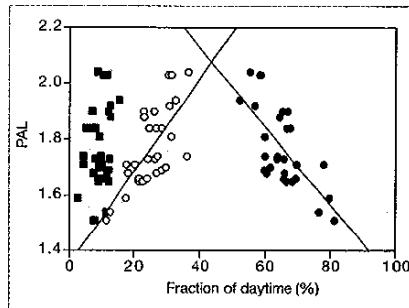


Figure 1 Physical activity levels (PAL) as a function of the fraction of daytime hours spent by 30 healthy subjects (with body-mass indices within the normal range) on activities of low (filled circles), moderate (circles) and high (squares) exercise intensity. Linear regressions are shown for low- and moderate-intensity activities: subjects spending more time on moderate-intensity exercise and less on low-intensity activity can improve their PAL values. Time spent on high-intensity exercise does not appear to influence total energy expenditure.

Calculated PAL values fell in the range 1.51–2.04 for all subjects, apart from one woman whose PAL value was 2.57; her data were excluded as an outlier. Three subjects reported not wearing the Tracmor while performing intensive sports activities, so the time spent on high-intensity activity by these subjects was corrected accordingly.

In a multiple regression analysis with the fraction of time spent on activities of moderate and high intensity, only moderate-intensity activity came out as a significant predictor of PAL ($r^2 = 0.51$, $P < 0.0001$). Subjects spending relatively more time on moderate-intensity activity and therefore less on low-intensity activity had a higher PAL value (Fig. 1). There was, however, no relation between PAL value and the time spent on just high-intensity activity, presumably because this was limited by its nature to being relatively short.

In the general population, PAL ranges between 1.2 and 2.2–2.5. At PAL values of about 2.5, subjects have problems main-

taining energy balance and may lose weight; PAL is about 1.5 or 2.1 for sedentary or very active people, respectively⁵. My results indicating that short periods of vigorous activity do not have much impact on PAL in the normal population are borne out by studies on obese patients: adding exercise to an energy-restricted diet does not further increase weight loss^{6,7} because the costs of the extra activity are compensated by a reduction of energy spent on physical activity outside the training sessions⁸.

My results show, however, that the proportion of time distributed between activities of low and moderate intensity is what influences the total energy expenditure and so determines the value of PAL. Subjects wanting to increase their metabolic rate should exchange low-intensity activities such as sitting in front of a screen for moderate-intensity activities such as walking or cycling. Moderate-intensity activities are better tolerated than high-intensity activities, especially by the middle-aged or obese. An improvement in overall activity levels should bring important health benefits as subjects expend more energy and reduce their risk of running into positive energy balance and gaining weight.

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Forensic palaeontology

The *Archaeoraptor* forgery

The *Archaeoraptor* fossil was announced as a 'missing link' and purported to be possibly the best evidence since *Archaeopteryx* that birds did, in fact, evolve from certain types of carnivorous dinosaur¹. It reportedly came from Early Cretaceous beds of China that have produced other spectacular fossils transitional

between birds and extinct non-avian dinosaurs^{2,3}. But *Archaeoraptor* was revealed to be a forgery in which bones of a primitive bird and a non-flying dromaeosaurid dinosaur had been combined^{4,5}. Here we use high-resolution X-ray computed tomography (CT)⁷ to determine the nature and extent of the forgery, as well as how it was built, by imaging the fracture pattern and distribution of materials through the entire specimen.

The *Archaeoraptor* specimen, which was reportedly collected from the Early Creta-