Human Power Production and Energy-harvesting

Subjects: Nursing | Transportation

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The maximal mechanical power produced by man, especially by large groups of people practicing sport or intense physical activity, has been proposed to be used for charge small electronic device or to partially sustain the power requirement of a gym. This practice can help to reduce carbon emissions.

human power production human energy energy harvesting sustainable gyms

1. History

The need to reduce carbon emission worldwide, is one of the biggest challenges' science face today and in the years to come. The "green transition" and the increased public awareness about environmental problems, pushed the search for alternative sources of energy. One source of energy is the human body. Energy harvesting from human body is a rapid developing field of research. The interest in harvesting energy from the human body is not new, ad it is just embedded in some everyday devices, such as automatic watches, which use the energy from movement to feed themselves. In this case, arm oscillation (pendulum) during walking, feed the watch mechanism, which can also store energy. It is intuitive that, large movements with much higher force production, are capable of generating higher energy, which can be used to sustain the functioning of various devices (e.g. cell phones) and, partially or totally, the energy requirements of a gym or of a sport facility, if harvested at the same time from many people. The mechanical efficiency of the human body is in the range 15–30%, it means that 70%, most of the energy provided by food, is dissipated into heat [1].

2. Concept

The human body contains enormous quantities of energy, the average adult has as much energy stored in fat as a one-ton battery [2] and has been calculated that the monthly energy capacity of a person taking 7500 steps/day is equivalent to a 0.40 mAh battery rated at 1.2V [3]. A human can generate at least as much power as a 1 m^2 solar PV panel on a sunny day and as much as 10m^2 of solar PV panels on a heavy overcast day [4]. Robert Obrest, an athlete competing in the "strong man" is told eat 15.000 to 20.000 calories per day, thus producing probably much more energy [5].

Body heat can be a continuous source of energy because the core body temperature is maintained at 37 °C. Has been calculated that the whole human body dissipate 60–180W depending on the type of activity performed [6]. Thermoelectric devices has been proposed to harvest this energy and has been calculated that, if this device has a conversion efficiency of ∼1%, the generated power would have been ∼0.6–1.8 W, which is enough to power many wearable sensors [4]. This energy is generated from energy dense sources (fat). Motion energy is particularly interesting as source of energy because it has a power density as high as 200 ?W/cm^2 and is available on demand [4], depending on fatigue. An average person's energy expenditure, (energy used by the body), is 1.07*107 J per day [6], an amount equivalent to approximately 800 AA (2500 mAh) batteries, whose total weight is about 20 kg. In comparison to batteries, this amount of energy can be produced from 0.2 kg of body fat [7].

Shapiro et al. [6], proposed the following table about energy production in various activities:

Energy source	Production rate (w)
Olympic 50m sprinter	2,000 w
Sprinting	1,500 w
Professional cyclist	400 w
In shape cyclist	200 w
Laborer (over 8 h)	75 w
Hand crank power	30 w
One footstep	2-5 w

Top level track cyclists can sustain 600-700 Watts for 1 minute, the amount of energy necessary to roast a toast. They can peak for a few seconds 2500 watts [8] during a sprint, while during a competition lasting one hour a professional cyclist can sustain 400 W while an amateur cyclist, 200 W. Of course, power that can be produced by upper limbs is much lower, and is equal to 30W for arm cranking over 30 minutes, in top athletes [6]. Power lifters can achieve values for the jerk drive from 2140 watts in the 56 kg class to 4786 watts in a 110 kg lifter [9] in fractions of a second.

In sprint running, value of 2392 ±271 and 1494 ±186 W and 30.3±2.5 and 24.5 ±4.2 W·kg-1 (males and females) after one second were recorded [9] . Vertical jump with run up is probably the human task who shows the maximal power production, which can reach 5600 W [10][11]. Arm power averaged over 10 maximal strokes, in 24 elite Spanish rowers (body mass 84 ± 5 Kg) was 630 ± 45 W, or 7.5 W·kg-1 [12]. In cross country skiing, the propulsive phase is likely well above 1000 W (>15 W·Kg^{-1}) [13] and the instantaneous power as high or higher (i.e., 1350 W) using the classical style in a 1500 m sprint race [14].

3. Evolution

Recently, some researchers hypothesized to harvest the energy produced by human body, to feed or small wearable or portable devices (such as smart phones) or to produce energy for facilities such as gyms. Among wearable, sensors and probes embedded in cloches for health monitoring such as EEG, can be feed by thermo-electric generators (TEG) which use body heat (evaporation, convection and radiation) to produce energy [15].

Treadmills and bikes able to harvest human energy [16] are commercially available, albeit economically can be sustained by the end users only in presence of public incentives, or in the long run has been demonstrated not to be economic for the high cost of the devices [17].

The jaw joint has been proposed as a source of energy through mastication [18] albeit knee joint is still the main energy producer by motion in the human body [19]. With the advent of powered exoskeletons, the energy harvesting in knee joint can power orthosis able to help walking disabled people [18]. For this purpose, piezoelectric converters has been proposed as harvester from the knee joint during walking and stair climbing [18]. Walking and running energy [20] can be harvested with embedding into the shoe's sole various kind of transducers (piezoelectric, strain, pressure, capacitive, triboelectric) [21][22][23]. To harvest energy from motion, other technologies has been proposed, ranging from small harvester, such as sliding backpacks to recharge smart phones [24], to large harvester, such as oscillating bridges or instrumented walkways, able to store energy from vibration [22][25].

Interesting, the amount of energy harvested, can be used as an indicator of energy expenditure, and thus useful for physiological studies as well for obtaining information about a population mobility behavior [26].

4. Conclusion

The need to reduce pollution and carbon dioxide emission worldwide, can be obtained only with the summation of many sources of energy, producing low power in comparison to traditional energy sources. In specific situations, such as in sport, there is a voluntary production of energy that usually gets lost. Operating a large-scale change in sport facilities and sport gears design, can help the harvesting of some of this dissipated energy, using several different available technologies. Sport is in some ways an energy dissipator itself, trough the increase in food consumption. Developing energy harvester can thus be beneficial non only for health, but also for the environment, and can help the sustainability of power usage.

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