Abstract  The purpose of this study was to comparatively investigate the energy expenditure of jumping on sand and on a firm surface. Eight male university volleyball players were recruited in this study and performed 3 sets of 10 repetitive jumps on sand (the S condition), and also on a force platform (the F condition). The subjects jumped every two seconds during a set, and the interval between sets was 20 seconds. The subjects performed each jump on sand with maximal exertion while in the F condition they jumped as high as they did on sand. The oxygen requirement for jumping was defined as the total oxygen uptake consecutively measured between the first set of jumps and the point that oxygen uptake recovers to the resting value, and the energy expenditure was calculated. The jump height in the S condition was equivalent to 64.0±4.4% of the height in the maximal jump on the firm surface. The oxygen requirement was 7.39±0.33 liters in S condition and 6.24±0.69 liters in the F condition, and the energy expenditure was 37.0±1.64 kcal and 31.2±3.46 kcal respectively. The differences in the two counter values were both statistically significant (p<0.01). The energy expenditure of jumping in the S condition was equivalent to 119.4±10.1% of the one in the F condition, which ratio was less than in walking and close to in running. J Physiol Anthropol 25(1): 59–61, 2006 http://www.jstage.jst.go.jp/browse/jpa2 [DOI: 10.2114/jpa2.25.59]

Keywords: energy expenditure, jump, sand

Introduction

In walking, running, or jumping on sand, people obviously have a feeling that they need more exertion than in doing the same activity on firm ground. It has been reported that walking on sand requires about 1.2–1.6 times more energy expenditure than running on a hard surface (Zamparo et al., 1992; Lejeune et al., 1998). Regarding jumping, maximal jumping height on sand is less than on a firm surface (Bishop et al., 2003; Giatsis et al., 2004); however, no study has examined the energy expenditure of jumping on sand and on firm ground comparatively.

Jumping on sand is often done in beach volleyball, where attacking and blocking are often performed with maximal effort. The purpose of this study was to investigate the energy expenditure of jumping with maximal effort on sand compared with the energy expenditure in jumping on a firm surface as high as jumping on sand so that the difference in energy expenditure between the two jumping conditions could be revealed.

Methods

Subjects

Eight male university volleyball players participated in this study. Their mean age, height, weight, and maximal oxygen uptake were 21.4±0.7 years, 179.3±6.0 cm, 72.6±5.2 kg, and 49.5±8.3 ml/min/kg, respectively. The subjects were informed of the purpose of this study and all the test procedures, and their written consent was obtained before the experiment.

Exercise

Thirty repetitive jumps were assigned in the present study, similar to the frequency of jumps in a beach volleyball match (Giatsis, 2001). The subjects performed 3 sets of 10 counter movement jumps in two different conditions, on sand designed for the present study (the S condition) and on the plywood surface of a force platform (the F condition). For the S condition, the 1-m-long, 1-m-wide, 0.5-m-deep frame was attached to the force platform, and 0.2 m³ of dry sand (Tochu Corp., Aichi, Japan; 99.8 percent of dry SiO₂, grain sizes:
35.7% of 300 μm, 31.7% of 212 μm, 12.8% of 425 μm, and 10.8% of 150 μm) was used to cover the surface area. The depth of the sand was 0.2 m. Each jump was done every 2 seconds and the resting time between sets was 20 seconds. In the S condition, the subjects were required to perform each jump with maximal exertion. In the F condition, the subjects were directed to jump as high as they jumped on the sand. To jump to their targeted height, the subjects practiced in advance with monitoring.

**Measurement**

Data from the force platform were collected during consecutive jumps by use of the Power Lab system (AD Instruments, Castle Hill, Australia) and analyzed on a computer (Macintosh G4, Apple Inc., Cupertino, CA) connected to the force platform (TR61750-103; Sogokeiso) via a strain amp (AS2102; NEC San-ei, Tokyo, Japan). The jump height was calculated as a rise in the center of gravity of the body based on flight time that was calculated as the period between takeoff and subsequent landing (Newton et al., 2001). Measuring oxygen uptake was conducted from three minutes before the first exercise set, continuing to the point that oxygen uptake returned to the resting value after the third set, using a gas monitor system (AE300S; MINATO Medical Science, Tokyo, Japan). The oxygen requirement for the jumping was defined as the total oxygen uptake during the consecutive period of 3 sets and of recovery, and the energy expenditure was calculated using an equation in which 1 liter of oxygen uptake is equivalent to 5 kcal (Bosco et al., 1982).

**Statistical analyses**

The results were expressed as the mean±SD. The t-test (a paired t-test) was applied to examine the statistical difference in oxygen requirement between the S condition and the F condition. The statistical significance was set at p<0.05.

**Results**

The jump heights collected in the S condition and the F condition are shown in Fig. 1. The differences in jump heights in each set between the two conditions were 0.008, 0.01, and 0.015 m, which were not statistically significant, and therefore these results allow a comparison of their energy expenditure as the same performance in different conditions. The jump heights performed on the firm surface in 3 sets were, in mean value, 64.0±1.1% as high as the maximal jump heights on the firm surface measured in advance.

The changing oxygen uptake during the sequential period of resting, jumping, and recovery is shown in Fig. 2. The oxygen uptake in the S condition was greater than that in the F condition from the endpoint of the first exercise set to the end of the measurement.

The oxygen requirement and the energy expenditure both in the S condition and in the F condition are shown in Fig. 3. The oxygen requirement was 7.39±0.33 liters in the S condition and 6.24±0.69 liters in F condition. The energy expenditure was 37.0±1.64 kcal in the S condition and 31.2±3.46 kcal in the F condition. The differences between the S condition and the F condition were both statistically significant (p<0.01). The energy expenditure of the total sets of jumps in the S condition was 119.4±10.1% as much as in the F condition.
Discussion

Lejeune et al. (1998) reported that walking on sand requires 2.1–2.7 times more energy expenditure than walking on a hard surface at the same speed, while running on sand requires 1.6 times more energy expenditure than running on a hard surface. Zamparo et al. (1992) reported that walking on sand at a given speed requires 1.8 times more energy expenditure than on a firm surface, and running requires 1.2 times as well. Pinnington and Dawson (2001) reported that running on sand requires 1.5–1.6 times more energy expenditure than on a firm grass surface. Our findings in the present study were that jumping on sand requires 1.2 times more energy expenditure than jumping on a firm surface when comparing maximal jumping on sand and jumping on a firm surface to the same height. The ratio of the energy expenditure is rather close to the case of running previously reported.

Morgan and Proske (1997) suggest that an increase in foot contact time when running on sand may result in a degradation of elastic energy potentiation and reduce the muscle-tendon complex efficiency. Zamparo et al. (1992) reported a reduction in the re-utilization of elastic energy as well as energy loss due to a backward slip of the foot during the stride push phase. These biomechanical and physiological conditions have been considered the causes for spending more energy on sand than on firm surfaces in running.

Jumping is similar to running in that the elastic energy of lower leg extensor muscles is re-utilized to enhance the efficiency of the movement (Bosco et al., 1987). Therefore, even on jumps, a degradation of elastic energy potentiation one of the causes for the greater energy expenditure on sand than on a firm surface. However, it has been reported there were no significant differences in ground contact time and in knee joint angular velocity between jumping on sand and on a firm floor (Giatsis et al., 2004). This fact suggests that, even when comparing sand and firm ground, there might be no difference in the prestretch potentiation of the knee joint extensor muscles that have such an important influence on the performance of the counter movement jump.

On the other hand, in soft sand, the ankle has a larger range of motion and larger angular velocity with smaller resistance (Giatsis et al., 2004), which directly leads to a reduction of the force or energy of the ankle to push along the vertical axis of the body. The phenomenon happens on sand when both jumping and running as both movements suffer energy loss as the ankle joint extends, where the only difference lies in the force directions. The contribution of the plantar flexion to jumping on firm ground was evaluated as 22% (Luhtanen and Komi, 1978). The contribution on sand might be less than that. It is therefore inferred that the lower contribution of the plantar flexion may be a main cause of the greater energy expenditure on sand.

Furthermore, the increased work to maintain balance on an unstable surface and the decreased exercise efficiency in coordinating the different body segments to jump might be considered as factors for increasing the energy expenditure on sand. More research on these aspects needs to be carried out.

References


