VERTICAL SURFACE REACTION FORCES DURING LANDING MOVEMENTS ON HARD AND ELASTIC GYMNASIUM SURFACES

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INTRODUCTION: Usually forces acting on the human body during sports movements are investigated with the help of a force platform. The force platform is placed on a rigid, level surface, although many sports disciplines are performed on an elastic surface in a gymnasium. Most of these surfaces have area-elastic characteristics, which means that the area of deformation is much larger than the loaded area. The studies investigating surface-related injuries dealt with the influence of horizontal friction (Vaillant et al., 1986; Yeadon & Nigg, 1988) and vertical deformation (Cavanagh & Lafortune, 1980; Yeadon & Nigg, 1988; Nigg et al., 1987; de Koning et al, 1997). Nigg et al. (1987) measured the deformation of different surfaces during a controlled jumping movement performed by national volleyball players and recreational athletes, respectively. They pointed out that the deformation during landing does not depend on the surface's construction alone, but also on the athlete's landing technique. The difference between the surface with the lowest and the surface with the highest maximum deformation is 10 times greater for the national volleyball players. Furthermore, the deformation of each surface is lower for the recreational athletes. Yeadon & Nigg (1988) reported the same tendency. It is suggested that a greater deformation of an area-elastic surface results in lower vertical forces acting on the athlete. Nevertheless, there is a lack of force measurements directly on the surface due to technical problems. Nigg (1990) estimated that the accelerated mass of an area-elastic surface is about 10 kg, the maximum vertical acceleration during a hard landing performance is about 300 m/s². So the contribution of inertia equals values of 3000 N, which cannot be neglected. The purpose of the present study is to compare parameters of the vertical surface reaction force during landing after a jump shot in handball on a hard surface and on an elastic surface in a gymnasium and to obtain some information concerning the influence of the force platform on the measured acceleration.

METHODS AND PROCEDURES: Eight experienced handball players were involved in this study. Each performed about 15 trials on both a hard and an elastic surface in a gymnasium. Forces acting during landing were measured by a Kistler force platform, which was fixed directly on the floor. 3-dimensional kinematic data were obtained with the Hentschel System. The measuring systems were synchronized, the measuring frequency was 750 Hz. For a few further trials the force platform was removed and the vertical acceleration was measured by an 1-dimensional accelerometer fixed directly on the floor.

In the present study four forces measured on the two different surfaces were statistically compared using two-tailed unpaired t-tests: passive and active peaks, average and maximum loading rate.

Results and **Discussion:** Figure 1 shows typical vertical force curves measured during landing movements with one foot on hard and elastic surfaces.

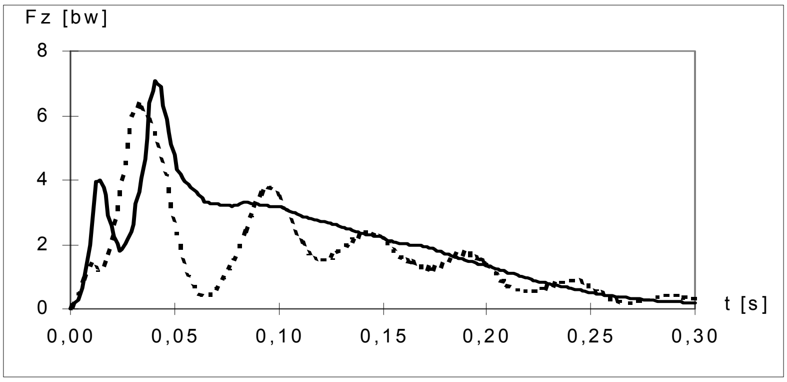

Fig. 1: Vertical force (Fz) on a hard (dashed line) and elastic (dotted line) surface

The shape of the curves shows large differences. On the hard surface the vertical force has one (simultaneous landing of forefoot and rearfoot) or two (non-simultaneous landing of forefoot and rearfoot) maximums, both occurring during the first 50 ms. So these maximums can be identified as passive peaks. After 50 ms the curve shows one further maximum, the active peak. On the elastic surface there are several local maximums after 50 ms, which will be discussed later. Table 1 shows the range of the analyzed four parameters on both surfaces normalized to body weight (bw).

Parameter	hard surface	elastic surface
passive peak[bw]	4,6 - 8,3	3,3 - 6,8
active peak [bw]	1,4 - 3,0	1,5 - 3,3
average loading rate [bw/s]	100 - 388	94 - 251
maximum loading rate [bw/s]	542 - 978	245 - 860

Tab. 1: Comparison of the four parameters between the investigated surfaces (normalized to bw)

On the hard surface there is a passive peak of 4,6-8,3 bw, followed by an active peak of 1,4-3,0 bw. The values of the average loading rate vary from 100-338 bw/s, the maximum loading from 542-978 bw/s. On the elastic surface, the passive peak varies between 3,3-6,8 bw. In contrast to the hard surface, the passive peak is followed by more than one active peak. There are 3-4 further local maximums, and the loading rate to these local maximums (up to 100 bw/s) equals values of the loading rate to the passive peak during jogging (Natrup, 1997). The maximum active peaks range from 1,5-3,3 bw. The average loading rate varies from 94-251 bw/s, and the maximum loading rate from 245-860 bw/s, respectively. For all subjects but one the passive peak on the elastic surface was significantly lower ($p < 0,05$) compared to the hard surface. Also, for all subjects the average and the maximum loading rates to the passive peak are lower on the elastic surface. Most of these differences are significant. Surprisingly, for all subjects the active maximum is higher on the elastic surface, and this difference is usually significant. Usually local maximums of the ground reaction force after 50 ms are called active peaks, because this part of the force curve is composed of low frequencies and is influenced by muscular tension (Nigg, 1980). The above-mentioned high loading rates to these local maximums after 50 ms during landing on an elastic surface indicate that this part of the force curve is composed of high frequencies. It can be suggested that these maximums are not influenced by muscular tension so that they have the characteristics of a passive peak. Nevertheless, this hypothesis should be investigated by EMG measurements. By discussing the results of this study it should be considered that the subjects did not perform the trials directly on the elastic surface, but on the force plate fixed to this ground. The force plate not only influences the accelerated mass, but also the loaded and accelerated area.

Figure 2 shows the acceleration of the area-elastic surface during landing performance.

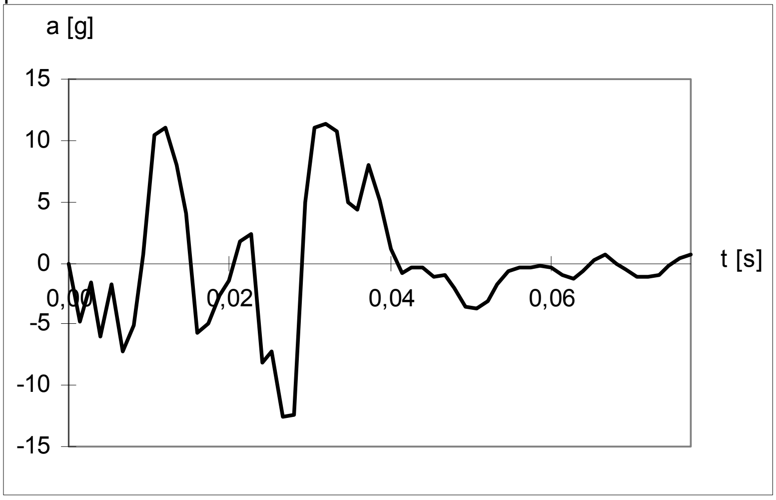

Fig. 2: Acceleration (a) of an area-elastic surface during landing

The curve is similar to the acceleration measurements of Nigg (1990), who published maximum acceleration ranging from 2 g (soft landing) to 30 g (hard landing). Figure 2 shows that the period of acceleration is much shorter than the period of force in Figure 1 (dotted line). Consequently, the period of force acting on the athlete during landing performance on an area-elastic surface is much shorter compared to the landing performance on a force platform fixed on an area-elastic surface. If it is assumed that the momentum, which is decelerated during landing performance, is the same in both cases, the shorter time period must be compensated for by higher maximum forces and/or higher loading rates and/or transformation of mechanical energy to other form(s) of energy.

CONCLUSIONS: The study shows that under load aspects the elastic surface produces lower passive peaks, average and maximum loading rates during landing movements in sports but higher and more local maximums with characteristics of passive maximums after the first 50 ms. It is speculated that this tendency is the same when the force platform is removed. In this case the described effects may occur in a shorter time period. For the classification of the investigated surfaces, a load function with, e.g., active and passive peaks, average and maximum loading rates should be developed as independent variables. A further aim of this study is the development of a transfer function to determine the influence of the force platform.

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