Introduction
Observations of landings in handball and volleyball show a very large variability. The landing can be executed with different flexion in the joints. These and further parameters influence joint forces (DeVita/Skelly 1992, McNitt-Gray 1993). No investigations of joint forces of the lower extremities during landings in handball and volleyball are published. The aims of this study are to determine the peak joint forces after sport specific landings and the influence of different landing techniques on these forces.

Methods
32 subjects participated in the study which play handball or volleyball actively. Landings after a jump shot or a spike jump were investigated by recording kinematic and dynamic data synchronously with a frequency of 625 Hz.

A 3-D inverse dynamic model was used to calculate joint forces of the segments: foot, shank, thigh, rest of the body. Muscle activities were not considered in this model. Different landing movements were classified by the following criteria: Landing stiffness, fore foot or flat foot landing, one or two-legged landings, jump height, whereby the landing stiffness is defined by the minimum knee angle during landing. Peak forces and maximum rate of net joint forces were selected to determine internal load. The significant differences between the groups were determined with the t test on a 5% (*) or 1% (**) level.

Results and Discussion
Peak forces and maximum rate of net joint forces are listed in table 1:

<table>
<thead>
<tr>
<th>Joint</th>
<th>Peak joint forces mean</th>
<th>SD</th>
<th>Maximum rate mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle</td>
<td>4.4</td>
<td>1.2</td>
<td>378</td>
<td>173</td>
</tr>
<tr>
<td>Knee</td>
<td>3.9</td>
<td>1.1</td>
<td>356</td>
<td>161</td>
</tr>
<tr>
<td>Hip</td>
<td>3.0</td>
<td>0.9</td>
<td>304</td>
<td>134</td>
</tr>
</tbody>
</table>

Table 1: Average net joint forces (bw) and maximum rate (bw/s) of two legged landings

The calculated peak joint forces decrease from proximal to distal. However, the calculated forces amounts several times bw even in the more proximal joints. The highest peak joint forces range from 7.2 bw (hip) to 9.2 bw (ankle).

The influence of different landing techniques is to be represented in detail:
- one versus two-legged landings:
  peak joint forces are significantly (p<0.01) higher during one-legged landing. Differences apply to all parameters and in every joint (Figure 1).

![Figure 1: Comparison of one-legged and two-legged landings](image-url)
• landing stiffness:
  A great range of landing stiffness can be determined during landing. Minimal knee angle under 90° and more than 120° are measured. Correlations between landing stiffness and internal load parameters are significant ($r^2>0.30; p<0.05$): peak joint forces increase with greater minimum knee angle (i.e. with harder landings)

• fore foot versus flat foot landings:
  the earlier the heel strikes the more largely the joint forces. Flat foot landings produce higher joint forces compared to fore foot landings.

![Comparison of fore foot and flat foot landings](image)

**Figure 2: Comparison of fore foot and flat foot landings**

• jump height:
  The middle jump height is 59 cm. Clear interpersonal differences of maximum 40 cm appear. On the other hand, the jump height varies relatively little within the subjects. Average standard deviations of the mean jump height of every subject is 2.6 cm. The correlation of the jump height and internal load parameters shows: peak joint forces increase with increasing jump height, but this correlation is very small and not significant ($r^2<0.10; p>0.60$).

The clear difference of peak joint forces comparing one legged and two legged landings could be expected because at one-legged landings the complete landing impulse is caught of only one leg. The great peak joint forces in the area of approximate 10 bw which have to be stated at one-legged landings particularly have closed on great loads at the landing.

In order to reduce the internal load at the landing two possibilities are given primarily: landings with a greater knee flexion and fore foot landings. These parameters have a bigger influence on the load parameters than the jump height. For the jump height only a small correlation with internal load parameters can be stated.

**Conclusion**

The loads in the joints of the dominant leg during landings are relatively high. Consequently, they can be identified as one possible factor for overuse injuries. Therefore, the athlete should control his landing movements. So one foot landings should be avoided. The athlete should initiate the landing movements on the fore foot and end landing with a greater knee flexion. Hereby, the internal load can be reduced clearly.

**References**
