LOADS ON THE LUMBAR SPINE DURING BUNGEE JUMPING

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INTRODUCTION: Simultaneously with the increasing popularity of bungee jumping the number of case reports of various injuries (Vanderford & Meyers 1995; Omololu & Travlos 1995) – also referring to the spine – caused by this sport has risen. However, opinions on the potential risks of bungee jumping are quite varied: According to Mees (1994) it is possible to suffer minor whiplash injury, according to Loew et al. (1993) the loads on the joints during bungee jumping are, e.g., lower than when trampolining. Nor are opinions concerning the extent of acceleration consistent: For bungee jumping – analogous to parachuting – vertical accelerations of 10 g are predicted by Simons and Krol (1995). By contrast, according to Loew et al. (1993) these acceleration values vary from 2 to 2.5 g. Because of this clear uncertainty about the accelerations occurring during bungee jumping and because of the lack of studies of this activity, acceleration measurements are necessary.
Such acceleration measurements were carried out in this study. The purpose was to quantify the load placed on the lumbar spine during bungee jumping and to compare these results with loads that occur during vertical jumps and trampolining.

METHODS: For each of ten bungee jumpers representing two weight classes (class A: 50 – 80 kg; class B: 80 – 110 kg), three-dimensional acceleration measurements were recorded by an accelerometer attached to the skin on the crista iliaca. Similarly, two-dimensional (vertical and sagittal) acceleration measurements were recorded for trampoline and vertical jumps. In trampolining, due to the different jumping heights at different performance levels, a distinction was made between a lower level (students who had practiced on the trampoline for only half a year) and a higher level (competitors who had practiced on the trampoline for more than 5 years). In vertical jumps a distinction was made between different heights (0.5 m, 0.7 m, 0.9 m, 1.1 m, 1.3 m, . . . 1.5 m) and landing performances (soft and hard landings).
The following loading parameters were analyzed: maximum vertical acceleration; maximum sagittal acceleration; maximum transversal acceleration (only for bungee jumping); calculated vertical forces on the lumbar vertebral bodies in relation to the tensile strength of vertebral bodies for bungee jumping and in relation to the compressive strength of vertebral bodies for trampoline and vertical jumps (called relative vertical forces on the vertebral bodies); calculated vertical forces on the lumbar intervertebral discs in relation to the tensile strength for bungee jumping and in relation to the compressive strength for trampoline and vertical jumps (called relative vertical forces on the intervertebral discs); Head Injury Criterion (HIC) concerning the vertical acceleration (in this criterion the course of the vertical acceleration and the period of time are considered). In addition, for bungee jumping the influence of body weight on acceleration was examined.

RESULTS:

1. During bungee jumping, in both groups the correlation between body weight and vertical acceleration maximum is negative; in the lower weight class there is a high correlation ($r = -0.995$; $p < 0.01$) and in the higher weight class there is a low correlation ($r = - 0.075$; $p > 0.05$) between these parameters. In both weight classes there are neither significant correlations between body weight and the sagittal accelerations nor between body weight and the transversal accelerations.
2. The mean of the vertical acceleration (Figure) maxima for bungee jumping (2.7 g) is lower than the corresponding means for the trampoline[1] (students: 5.8 g; competitors: 8.7 g), the soft vertical jump landings[2] from 0.7 m to 1.5 m (3.3-7.3 g) and the hard vertical jump landings (3.7-11.1 g).

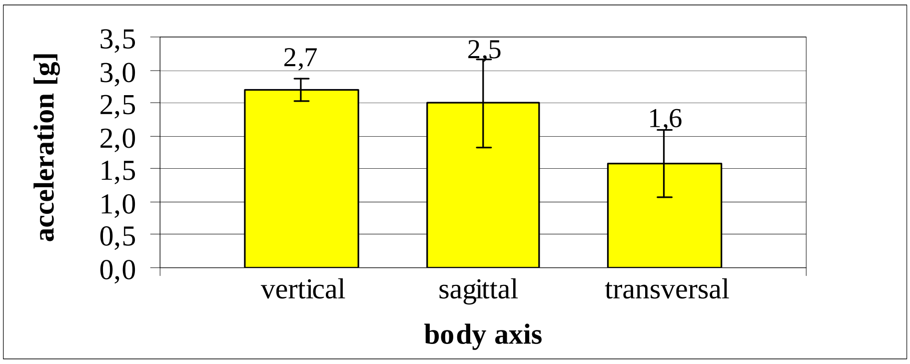

Figure – Means of acceleration during bungee jumping

3. The mean of the maximum sagittal acceleration (Figure) for bungee jumping (2.5 g) is higher than for the student group on the trampoline (1.5 g), the soft landings from a heights of 0.5 m to 1.1 m (1-2.2 g) and the hard landings from heights of 0.5 m to 0.7 m (1.1-1.9 g).
4. For bungee jumping the mean of the maximum transversal accelerations is 1.6 g (Figure). There are no corresponding values for trampoline and vertical jumps.
5. The mean of the relative vertical forces on the lumbar vertebral bodies for bungee jumping (30.3 %) is lower than when trampolining (students: 38.3 %; competitors: 59.2 %), in the hard vertical jump landings from 0.7 m to 1.5 m (34.5-67.3 %) and in the soft vertical jump landings from 1.1 m to 1.5 m (33.2-44.4 %).
6. The mean of the relative vertical forces on the lumbar intervertebral discs during bungee jumping (34 %) is higher than the corresponding means for trampoline (students: 17.1 %; competitors: 27.0 %), and hard (10.0-29.9 %) and soft (6.5-19.6 %) vertical jump landings.

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[1] These vertical and sagittal acceleration maxima during trampolining are comparable with the results of Riehle's study (1979).

[2] These vertical acceleration maxima occurring during soft and hard vertical jump landings are comparable with the results of Nigg and Spirig (1976); in particular, the different heights of the mats in the two studies must be considered.

7. For bungee jumping, the mean of the HIC (19.4) is higher than for the student trampoline group (11.3) and all soft (1.5-4.7) and hard (2.2-11.2) vertical jump landings.

DISCUSSION: For bungee jumping, the higher the body weight, the lower the vertical acceleration maximum (see above); possible reasons for this relation are the greater stretching of the elastic bungee rope and the longer stopping distance. Thus body weight influences the maximum vertical acceleration. However, there must be other influences, because the negative correlation between body weight and maximum vertical acceleration in the higher weight class is only low ($r = -0.075$) and not significant ($p > 0.05$). Such further influences may be the way in which a jumper jumps off, the trajectory of the jump and different properties of the elastic rope (e.g., influenced by the sun, temperature, etc.).

The maximum vertical accelerations during bungee jumping with a mean of 2.7 g and maximum values of 3.0 g are lower than estimated by authors such as Simons and Krol (1995), who expected vertical accelerations of 10 g. The assumptions of Loew et al. (1993), expecting vertical accelerations of 2 g to 2.5 g, are nearly identical to the results of this study. However, it has to be mentioned that information about the parts of the body where those accelerations are expected by the authors, is missing; thus the comparison of their estimated values with the results of studies such as this is difficult.

Due to the relatively low mean of the maximum vertical accelerations during bungee jumping in comparison with the corresponding means of trampoline and vertical jumps, one might assume that there is no critical load during bungee jumping. However, the relative vertical forces on lumbar vertebral bodies and especially the relative vertical forces on lumbar intervertebral discs during bungee jumping are higher than most of the corresponding values of trampoline and vertical jumps (see above); so the loads occurring during bungee jumping seem to be more critical than one would conclude after looking only at the maximum vertical accelerations. On the other hand, it is important to note that the activity of the trunk musculature, that is able to reduce the tensile strength, has not been considered in this study. So it is possible that the actual load on the lumbar spine occurring during bungee jumping is lower than these results indicate.

In comparison with trampoline and vertical jumps the mean of the maximum sagittal accelerations during bungee jumping is in a middle band (see above). Further more, the maximum transversal accelerations during bungee jumping are lower than the maximum sagittal accelerations. On the one hand, these relatively low acceleration values do not indicate any potential risk of injuries for the lumbar spine, but on the other hand, there is a high standard deviation of the maximum sagittal and transversal accelerations compared with the vertical accelerations. So in a few cases the values of maximum sagittal and transversal accelerations can be much higher than the corresponding means indicate. Moreover, the torsional strength of the lumbar vertebral body is lower than the tensile strength (Sonoda 1962), which indicates that torsional loads are more dangerous for the lumbar vertebral bodies than purely tensile loads.

During bungee jumping the mean of the HIC values are relatively high compared to the corresponding means in vertical jumps and trampolining; they are only lower than the HIC-values of the competitor trampoline group. So one could assume a quite high load is placed on the lumbar spine by bungee jumping. However, it is

important to consider that the main reason for these high HIC values during bungee jumping is the much longer period of time, which is 10 to 28 times longer for bungee jumping (mean: 4.8 sec) than for trampolining (means: 0.42-0.45 sec) and vertical jumps (means of soft vertical jump landings: 0.47-0.5 sec; means of hard vertical jump landings: 0.17-0.21 sec). A further critical aspect is that the HIC has been developed only for jolting loads on the head and therefore, in the context of this study, can only be used in a very limited way. It will perhaps be necessary to modify this criterion, if it is used for sport disciplines where loads occur over a long period of time. Because of these limitations the relatively high HIC values for bungee jumping compared to those for trampoline and vertical jumps are not of great importance.
Generally it has to be considered that the results of this study are transferable only with great reservation to other bungee jumping facilities, because there are great differences with respect to such things as the elasticity and the length of the bungee cords.

CONCLUSIONS: This study gives insight into the loads on the spine that can occur during bungee jumping. For more detailed results – especially concerning the influencing factors of the maximum accelerations and when dividing into subgroups – more extensive studies are necessary.
Because the activity of the trunk musculature has not been considered in this study, the resulting values for the tensile loads occurring during bungee jumping are too high. For more specific results further studies using electromyography are necessary.
The acceleration measures and calculations of this study refer to the lumbar spine; therefore no statements about loads on other parts of the spine are possible. For such statements further measures of accelerations would be necessary. Those studies could also give some information about the dampening property (reduction of the tensile load) of the spine.

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