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Evaluating lumbar spine impact loads using IMUs during Women's Artistic Gymnastics training

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1. Introduction

Women's artistic gymnastics (WAG) is the 2nd most injury-prone sport after men's American football (Campbell et al. 2019). Among these injuries, low back pain (LBP) is particularly common, although it is relatively under-recognized.

The prevalence of LBP is thought to be related to the repetitive nature of jumps and landings during training and competition. The application of repetitive high impact loads to the lumbar region has been identified as a risk factor for LBP (Makovitch & Eng. 2020).

Furthermore, the fatigue caused by the intensive training and repetition of these jumps could increase the load on the lumbar spine, further increasing the risk of LBP, as already noted by Glassbrook et al. 2022. Given the potential risks associated with high impact loads, it is important to monitor these loads directly during training to prevent the risk of injury.

The aim of this study was to explore the effects of acute training on the evolution of lumbar impact load during the landing of a back somersault. To this end, we used Inertial Measurement Units (IMU) placed on the athletes to estimate the impact load. We assumed that the load would increase significantly during training.

2. Methods

2.1 Participants

17 female artistic gymnasts, aged 21.8 years (± 3.8), were approached by their respective gymnastics clubs to take part in this study. The present study excluded gymnasts who had sustained injuries within the

previous six weeks that necessitated their cessation in training.

2.2 Procedure

The protocol was carried out during the gymnasts' training sessions at their respective clubs, lasting two hours. The gymnasts performed a jumping protocol at three distinct points: pre-, mid-, and post-training. The jump protocol involved a series of round-off back somersaults on the gymnastic floor, and a landing was considered valid if the gymnast achieved a stuck landing without taking extra steps. For each measurement, the three best landings out of a maximum of five were selected.

2.3 Data collection

The gymnast was equipped with three Delsys Trigno® inertial units (16g, 370 Hz). The sensors were placed on the sacrum, on the lateral part of the right thigh (approximately one-third on the way along the total length of the thigh) and on the right leg (beneath the medial condyle of the tibia). To minimize the saturation of the sensors, those positioned on the shin and thigh were placed obliquely from the longitudinal axes.

2.4 Data analyses

Back somersault recording was isolated and filtered using a 4th order Butterworth low-pass filter with a cut-off frequency of 85 Hz across all trials (Campbell et al. 2020). The resulting acceleration was calculated, and the maximum value was extracted. The trials in which the acceleration signal saturated were identified, in order to integrate this factor into subsequent analyses.

To ascertain whether there were any significant differences in the resulting peak accelerations between the measurement times (pre-, mid-, post-training), a non-parametric Friedman test was performed, followed by a post-hoc Conover test and Bonferroni correction.

3. Results and discussion

Significant differences in peak acceleration at the sacrum were observed between measurement times ($p=0.013$, $W=0.111$). Significant increases in acceleration were observed between the pre-training and the mid-training ($p_{\text{bonf}}=0.024$, $r_{\text{rb}}=-0.674$) and between the pre-training and the post-training ($p_{\text{bonf}}=0.033$, $r_{\text{rb}}=-0.585$) (Figure 1). No difference was found between the mid-training and the post-training. The resulting acceleration at the thigh did not change between the measurement times.

Some IMU data was saturated during landing, especially after training, and probably underestimated values due to the 16g sensor limit per axis.

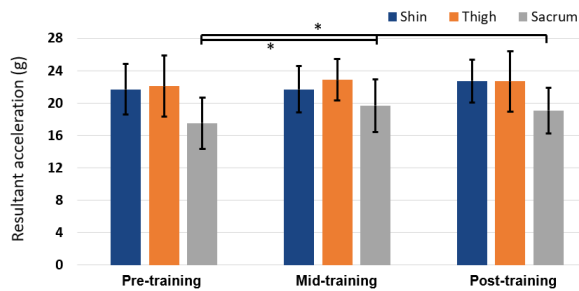


Figure 1. Resultant acceleration at back somersault landing. Representation of significant differences between measurement times. $*:p<0.05$.

These results highlight a significant increase in resultant acceleration during WAG training, particularly at the sacrum.

This increase may indicate a reduced ability of the lower limb musculoskeletal system to absorb shocks effectively during training (Coventry et al. 2006). A lot of studies have shown that in a fatigued state, the active involvement of the knees in load absorption is reduced, leading to an increased transfer of load to the upper structures.

However, this increase in load may also reflect an increase in task demands, such as jump height. While we cannot clearly identify the causes of the increased sacrum acceleration, this study nonetheless demonstrates an increase in stress applied to the lumbar region during training, as well as the potential of IMUs for athlete monitoring.

This study has limitations, particularly regarding the measurement range of the IMU sensors. The saturation of the IMUs placed on the tibias and thighs means that we cannot fully examine the effects of fatigue. Sensors with a larger measurement range would allow for a better assessment of the origin of the increase in sacral acceleration.

4. Conclusions

A significant increase in the resulting acceleration of the sacrum region during training reflected an increase in mechanical stress. The combination of repeated jumping and the increase in training-related stress represents a significant risk of damage to the lumbar region. The use of IMU during training would facilitate more effective monitoring of athletes and help to prevent injuries that can result from fatigue.

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Conflict of Interest Statement

The authors declare that they have no competing interests.

Contributor Roles

RC: Conceptualization, Methodology, Investigation, Writing original draft; SP: Investigation; RB: Investigation; MM: Writing- review & editing, Supervision, Validation, Investigation; DH: Writing- review & editing, Supervision, Validation, Investigation; CP: Writing- review & editing, Funding acquisition, Supervision, Validation.

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