THE EFFECTIVENESS OF WRIST GUARDS FOR REDUCING WRIST AND ELBOW ACCELERATIONS FOLLOWING SIMULATED FORWARD FALLS.

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INTRODUCTION

Fractures to the wrist and forearm account for approximately 25% of reported in-line skating injuries (Scheiber et al., 1996). In-line skaters have been encouraged to utilize wrist guards with force absorbing rigid volar splints. Joint changes at the elbow have also been suggested as a method of damping the effects of impact forces (DeGoede and Ashton-Miller, 2002). While there is little agreement on the efficacy of wrist guards for preventing impact related injuries, there appears to be a clear consensus that changing elbow angles decreases ground reaction forces. However, the capacity of these interventions for reducing impact induced accelerations at the wrist and elbow has not been documented in living people. Therefore, the purpose of the current study was to determine the effectiveness of a wrist guard in attenuating the impact force effects on the upper extremity in different elbow orientations. The acceleration response at the wrist and elbow were analyzed following impacts from simulated forward falls.

METHODS AND PROCEDURES

A seated human pendulum apparatus was used to simulate the flight phase of a forward fall in a controlled fashion. Healthy university aged subjects (15 males and 13 females) were asked to arrest their forward motion with the palmar soft tissues of both hands while upper extremities were extended. Impacts of approximately 0.4-0.5 times body weight, at a velocity of approximately 1.0 m/s were targeted (Chiu and Robinovitch, 1998), and were executed with, and without an off-the-shelf wrist guard in place (Firefly Sport Line, model number: 065627). Straight arm (180^o) and natural arm (168^o) elbow angles were also studied and were measured by an electro-goniometer (Biometrics SG110 Biometrics Ltd., Gwent, UK). A skin-mounted accelerometer (MMA1213D and MMA3201D, Freescale Semiconductor, Inc, Ottawa ON, Canada) was firmly attached at the wrist and the elbow, to measure the impact response characteristics (peak acceleration (PA), acceleration slope (AS), and the time to peak acceleration (TPA)), in the axial (aligned with the long axis of the forearm) and off-axis (normal to the long axis of the forearm in the sagittal plane) directions.

RESULTS

The peak axial acceleration response at the wrist was unaffected by the wrist guard (Figure 1), however, the AS_{axial} increased by almost 60%, when the wrist guard was in place. Conversely, the off-axis acceleration responses (e.g. PA) decreased significantly by more than 50% on average, from the unguarded to the guarded condition (Figure 1). Contrary to the findings at the wrist, the magnitude of all acceleration responses in the axial and off-axis directions at the elbow decreased significantly from the unguarded to the guarded conditions. PA_{axial} and PA_{off} were decreased by 1.9g and 2g, respectively, while the AS_{axial} and AS_{off} were decreased by 537g/s and 592g/s, respectively.

At the wrist, PA_{axial} was found to increase significantly, although by only 1g, from the straight arm to natural arm conditions. PA_{off} was unaffected by any change in elbow angle. At the elbow, there were no changes in the axial parameters, however, the peak off-axis accelerations increased significantly in magnitude and experienced a change in direction on average (-1.7g to 3.7g) during natural arm impacts. AS_{off} was affected in a similar manner increasing from -421g/s to 1083g/s between straight arm and natural arm conditions, respectively.

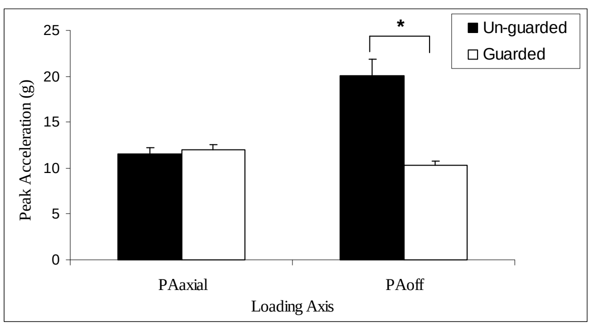

Figure 1. Mean peak axial and off-axis accelerations at the wrist in the un-guarded and guarded conditions (*$p<0.05$)

DISCUSSION

The off-axis responses at the wrist, and the full set of responses at the elbow, suggest that the volar splint tested in this study, was capable of significantly absorbing the energy produced by the impact forces. However, the axial response at the wrist supports the findings of Kim et al. (2006) that suggest that splints simply transmit the force across the wrist joint, increasing the risk of injury to susceptible structures that are more proximal.

Small changes in peak acceleration were noted in the axial direction at the wrist in the different elbow conditions. This may have been due to the fact that the difference in elbow angle between the two conditions was not large (only 12^{o}). The change in loading direction at the elbow may be a result of the localized impact of the distal humerus within the trochlear notch. When a straight arm impact occurs, the distal humerus is inline with the long axis of the radius and ulna. However, when the arm is flexed, the trochlea would have rotated in the sagittal plane within the trochlear notch, becoming more aligned with the off-axis at the elbow.

SUMMARY

The results of this study show that the wrist guard tested is beneficial in decreasing the potentially damaging off-axis forces discussed by Troy & Grabiner (2007).. Eliminating or reducing the transmission of the axial accelerations through the wrist, as a result of improved wrist guard design, and studying the effects of elbow angle when the elbow is allowed to move through a full, dynamic range of motion, is a basis for future research.

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