Effect of Upper Extremity Impact Strategy on Energy Distribution Between Elbow Joint and Shoulder Joint in Forward Falls

Paul Pei-Hsi Chou1,2,3  Hsin-Chieh Chen4  Hsiu-Hao Hsu5  Yen-Po Huang5
Tun-Chin Wu6  You-Li Chou6,*

1Faculty of Sport Medicine, College of Medicine, Kaohsiung Medical University, Kaohsiung 804, Taiwan, ROC  
2Department of Orthopedic Surgery, Central Taiwan University of Science and Technology, Taichung 406, Taiwan, ROC  
3Department of Orthopedic Surgery, Kaohsiung Municipal Hsiao-Kang Hospital, Kaohsiung 804, Taiwan, ROC  
4Department of Biomedical Engineering, Huangku University, Taichung 404, Taiwan, ROC  
5Department of Engineering Science, National Cheng Kung University, Tainan 701, Taiwan, ROC  
6Institute of Biomedical Engineering, National Cheng Kung University, Tainan 701, Taiwan, ROC

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Abstract

In a forward fall, the majority of the impact energy is absorbed by the elbow joint and shoulder joint. This study examines the effect of the impact strategy on the energy absorption distribution between the two joints during the impact phase of a forward fall. Twenty healthy young male subjects with an average age of 24 years participated in a series of forward fall experiments. The kinematics and kinetics of the upper extremity and the impact forces at the elbow joint and shoulder joint are investigated for three impact strategies, namely elbow dominant, intermediate, and shoulder dominant. The energy absorption ratio and pain score of the elbow dominant group are significantly lower (Energy absorption ratio: p = 0.011, pain score: p = 0.012) than the corresponding values of the intermediate and shoulder dominant groups. The low energy absorption ratio of the elbow dominant group indicates a more uniform distribution of the impact energy between the elbow joint and the shoulder joint. This implies that elbow flexion provides a beneficial damping effect during impact, and therefore reduces the energy absorbed at the shoulder joint. Overall, the results suggest that the elbow dominant impact strategy is optimal for forward falls. The results can aid the development of an effective impact strategy for minimizing the risk of upper extremity injuries due to forward falls.

Keywords: Forward fall, Energy absorption ratio, Elbow joint, Shoulder joint, Upper extremity

1. Introduction

Outstretching the hand to arrest a fall is an instinctive reaction to prevent impact to sensitive parts of the body, such as the head, cervical spine, and hips. As a result, falls onto an outstretched hand are the leading cause of upper extremity injuries. Fall-related elbow injuries include distal radius, humeral neck, and supracondylar fractures [1-4]. Fall-related shoulder injuries include acromio-clavicular joint dislocation, gleno-humeral joint dislocation, proximal humerus fracture, clavicle fracture, scapular fracture, rotator cuff tear, and superior labrum anterior to posterior lesion [5-7].

Chou et al. [8] compared the elbow loads induced in forward falls performed with elbow flexion and elbow full extension models, respectively. The results showed that the elbow valgus-varus shear force was 68% lower (p = 0.002) in the elbow flexion model. In addition, it was shown that elbow flexion not only reduces the intensity of the initial peak impact force, but also delays the occurrence of the second maximum peak. Therefore, the authors suggested that elbow flexion provides an effective damping mechanism in forward falls, and consequently minimizes the risk of upper extremity injuries. The effect of various forearm rotation postures on the elbow load and elbow flexion angle in a forward fall was investigated in another study [9]. It was shown that falls with the forearm internally rotated resulted in both a greater elbow flexion angle (i.e., 40.3°) and a lower valgus-varus shear force (i.e., 4.3% of body weight) than those of falls with the forearm externally rotated. These results show that the energy dissipation resulting from elbow flexion increases with increasing elbow flexion angle. Thus, elbow flexion plays an important role in