KINEMATIC CHARACTERISTICS OF IMPACT ABSORPTION DURING LANDINGS OF MULTI-REVOLUTION JUMPS IN FIGURE SKATING

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Competitive success in the sport of figure skating has been largely attributed to the skater's ability to execute multi-revolution jumps, landing backwards, on a single leg, in a prescribed configuration. On-ice training regimes employed by these athletes are characterized by repetitive impact or mechanical load-type activities. The primary concern arising as a consequence of the impulsive nature of on-ice jumping has been the potential for impact related injuries. Although this aspect of research has been uninvestigated in the sport of figure skating, previous investigations conducted on both animal models (Radin et *al*., 1973) and in humans (Robbins & Gouw, 1990) have associated this type of loading with injury and specifically, the degeneration of tissue structures of the body. **A** number of authors in similar impact related sports with an inherent landing component, have also suggested that landings account for the highest incidence of injury to the lower extremities and warrants further investigation (McNitt-Gray, 1991; Dufek & Bates, 1991).

A preliminary study was undertaken to quantify the impact forces upon landing single, double, and triple revolution jumps to evaluate if a potential injury situation exists as a result of on-ice jump training (Lockwood & Gervais, 1995). Landing impact was quantified using the Mikro EMED System (novel gmbh, Munich, Germany). Results revealed that the magnitude of impact significantly increased with additional revolutions ranging from three to nine times the skater's respective body weight. In addition, two distinctly different landing techniques were identified; soft landings producing less force for a longer period of time and hard landings characteristic of a collision type of contact. Decreasing the time to properly dissipate the force may suggest that the impact propagated through the lower extremity musculo-skeletal system was of greater magnitude and intensity introducing greater potential for injury.

Shock moderating behaviours or the desirable reduction of forces are commonly adopted as protective mechanisms of the human body in reducing peak forces during landings. These strategies are a result of complex interactions between the links or segments of the body (Lees, 1981). Therefore, the aim of the present study was to compare and contrast the kinematic profiles of landing positions of single and multi-revolution jumps. **A** three dimensional kinematic analysis was performed to examine the influence of impact on kinematic variables and the possible parameters responsible for the effectiveness of the individual to dissipate impact forces. From both biomechanical and technical aspects, the present research investigated how the body segments interact with each other, the restraints imposed by the skate, and the technique utilized by these athletes in producing soft verses hard landings.

Methodology

Subjects: Three national calibre male figure skaters volunteered to perform single, double, and triple revolution jumps for the purpose of this investigation. Subjects ranged from 16-26 years of age, from 48.5-89.5 kilograms in body weight and from 160-188 centimeters in height.

Experimental Procedures: Upon completion of a standardized warm-up, the skaters were instructed to execute single and multi-revolution jumps to the best of their ability and complete the landings in their typical form. Skaters were video taped performing three trials of each jump by four panasonic cameras, placed at 90° to each other. A light placed in the field of view was manually activated during the airborne phase of the jump to allow for synchronization of video records. Four views of each jump trial were then manually digitized using the Ariel Performance Analysis System. Three dimensional coordinates for 15 segment endpoints were calculated using direct linear transformation and data was subsequently smoothed using a quintic spline.

The complexity of the skill of landing demanded the isolation of component variables which were evaluated as to their contribution to the attenuation of impact. For the purpose of this analysis, ankle, knee, and hip flexion were selected for comparison. The magnitude of joint segment angles as well as the time-sequencing or kinematic time-history displayed at the point of impact and maximal flexion prior to stabilization of the landing phase were determined. Due to the limited number of subjects in this analysis, only basic descriptive statistics were performed. This analytical approach also eliminated the possibility of individual subject trends from being masked by group mean data.

Results & Discussion

Individual data illustrated that comparable performance strategies in shock absorbing mechanisms were utilized by all of the skaters examined. Maximum knee and hip flexion increased with the complexity of the jump, whereas ankle flexion decreased (Fig. 1.). The shock wave pattern of flexion from distal to proximal joints which normally occurs as a result of landing, was demonstrated in single revolution jumps. However, this was not evident in multi-revolution on-ice landings. Maximal ankle flexion was preceded by flexion at both the knee and hip joints in jumps of higher impacts.

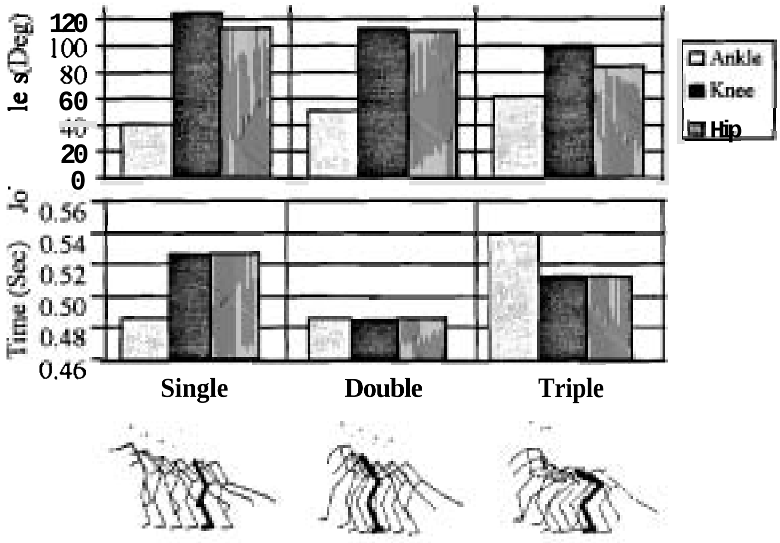

Fig. 1. (a) Peak Joint Angles, (b) Time Sequencing of Peak Joint Flexion, and (c) Stick Figures, representing the entire landing phase.

Previous research has identified that high frequency impact forces (shock) are influenced by several factors including; kinematic positions, equipment (eg., skate structure), and landing surface (Dufek et al., 1993). Trends in these data seem to confirm that all the aforementioned factors may influence the performance strategies employed by these athletes in an attempt to attenuate impact upon landing. Positional data demonstrated that the body increases the degree of flexion of the lower extremities when exposed to greater impacts with the exception of ankle flexion. The stability of the boot appeared to provided a mechanical block to increased ankle flexion. Although thought to provide support, the boot may be introducing a barrier allowing only minimal attenuation of impact to occur at this location and furthermore interrupting the normal sequencing of shock absorbtion.

Soft landings as demonstrated in single revolution jumps are defined by Ozguven & Berme (1988) as phased segmental deceleration and muscular activity anticipating the impact. In contrast, the multi-revolution jumps appeared to be representative of harder landing, demonstrating a unique flexion time-history sequence. Peak flexion of the hip and knee occurred simultaneously, followed by ankle flexion. As observed in other investigations conducted on hard surfaces, during on-ice landings there was a marked increase in joint flexion and an appreciable amount of give in the upper body (Dufek & Bates, 1993).

Conclusions

Landing imposes forces on the body that must be absorbed primarily by the musculo-skeletal components of the lower extremities (Dufek & Bates, 1991). The present research attempted to include lower extremity joint kinematics and landing technique to better understand the mechanisms used to accommodate the forces applied to the body during the landing of on-ice jumps of single and multi-revolutions. The data presented revealed that parameters altered as a result of greater impact forces upon landing include both the degree of joint flexion and the sequencing of joint flexion. Although the natural landing styles of single, double, and triple revolution jumps are technically similar, the body's reaction or attempt to absorb the shock of greater impacts altered the landing position and performance strategy. It may be recommended that coaching guidelines include a learning progression of specific prerequisite skills inherent in impact absorption techniques. These should be mastered by the athlete prior to the training the execution of multi-revolution jumps. A larger sample population would allow us to address the question of whether, the observed landing kinematics of the study are a result of a strategies learned in training or a mere consequence of impact loading.

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