行政院國家科學委員會專題研究計畫　成果報告

地板體操選手前手翻與後手翻之上肢動力學分析

計畫類別：個別型計畫
計畫編號：NSC93-2213-E-039-002-
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執行單位：中國醫藥大學運動醫學系

計畫主持人：許弘昌
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行政院國家科學委員會補助專題研究計畫 ■ **成果報告** □**期中進度報告**

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執行單位：中國醫藥大學運動醫學系

中　華　民　國　94　年　10　月　31　日

中文摘要

在過去 30 年來，體操在國際性競技運動比賽呈現倍數成長，而其相對應的骨骼肌肉系統之運動傷害亦隨之增加，其中身軀佔 20%，四肢佔 80%，而四肢中，下肢佔 50%，上肢佔 20%。大約 50%到 65%為急性傷害，35%到 50%為慢性傷害。一般而言，體操選手之高受傷率與體操動作之關節呈重與負荷有密切關係。對於地板動作而言，上肢原本非呈重關節，此時卻轉變為呈重關節，此種上肢功能性的改變，可能為上肢體操運動傷害原因之一，尤其是腕關節之受傷最為常見。然而，過去文獻關於體操上肢關節負荷之研究並不多見，同時，地板體操選手受傷率是佔所有體操項目當中最高的，因此，本研究針對體操運動地板項目前手翻及後手翻動作，上肢著地承重時，探討體操選手上肢關節三維力量及力矩，以增進對上肢關節負荷及可能受傷機轉的進一步了解。本實驗共有男性及女性大專體操地板校隊選手 9 位，利用 VICON 動作分析系統，以收集每位受試者的上肢運動學及動力學資料，並由自行研發之上肢運動分析模式及自行撰寫的 MATLAB 程式，分析體操地板選手在前手翻及後手翻之上肢關節力量及力矩。研究結果顯示，前手翻及後手翻動作時，主要的動作是肩關節 elevation, plane, rotation。肩、肘、腕各關節承受的力量主要是 compression force，其可達到 4 倍體重之大小。在腕關節，posterior force 亦達到 3 倍體重之大小，同時伸展角度亦到達 100 度的極限值，顯示地板體操選手腕關節腕隧道症候群發生率相當高。此外，外展肌肉肌群是前手翻及後手翻動作的主要作用肌群，主要是維持身體的平衡。而前翻及後翻主要是靠軀幹之屈曲及伸展的動力來轉換達成。臨床上，建議地板體操選手應加強外展肌肉肌群的肌力及軀幹之柔軟度的訓練，以避免運動傷害。

Abstracts

Gymnastic as a sport has seen an exponential rise in the number of national participants over the past three decades. The relative injury rate for the musculoskeletal system is approximately 20% for the axial skeleton and 80% for the appendicular skeleton (50% lower extremity and 30% upper extremity). Injury mechanism reports vary from 50% to 65% acute and 35% to 50% chronic. It is believed that the high injury rate of gymnasts is highly correlated to the high impact in the weight bearing joint when performing the specific gymnastic activities. For the gymnastic floor, the upper extremity, whose function is usually not weight bearing, is transferring to be a weight bearing limb. This functional change from carrying load to weight bearing might be one of the possible causes to explain why there is high incidence of gymnastic injury occurrence in upper extremity, especially in wrist. Based on the survey of literatures, there was so high incidence of sports injury in upper extremity for gymnasts. However, there was little researches regarding to the three-dimensional kinetic analysis of upper extremity during gymnastic performance, which might be quite closely relevant to gymnastic injury. Because the highest injury rate in all competitive items of gymnastics is the floor, the purposes of this study are to investigate the joint loads in upper extremity when performing handstands forward and backward. Nine floor gymnasts in college was asked to perform the handstands forward and backward in the laboratory. VICON motion analysis system was used to collect the subjects' kinematic and kinetic data. Self-developed MATLAB program and upper extremity model was established and used to calculate the joint forces and moments in upper extremity during the handstands forward and backward in the floor.

The results show that the major joint movements of shoulder plane, elevation, and rotation, elbow flexion, wrist joint extension both for forward and backward rolls. The range of wrist flexion/extension reach 100 degrees, the gymnastics has the greater risk of to suffer from carpal tunnel syndromes. The results also show that the maximal forces of three joints are compression forces and reach about 4 times of body weight. Besides, the wrist joint force in the posterior direction reaches 3 times of body weight during forward and backward rolls. In clinical, it would be suggested that the flexibility of trunk, and strength training of the abductors of in upper extremity are important for the floor gymnastics.

Introduction

In the past 12 years, gymnastics has grown rapidly in the world, and the recognition of its problems has grown accordingly. Problems with gymnasts' wrists have been particularly difficult. There is still a significant amount of confusion and difference of opinion among treating physicians. The exact pathomechanics of problems in the wrists of gymnasts are yet to be defined. Problems are so common that Arone (1985) has stated that wrist pain is perceived as a "normal and direct result of the sport."

Gymnastic as a sport has seen an exponential rise in the number of national participants over the past three decades. Increased involvement in the United States is demonstrated in the success in the summer Olympics. Participation in gymnastics is represented by a triangle with the Olympic and international gymnast at the apex, attaining a degree of skill pursued by tens or hundreds of athletes for every gymnast at the highest level. This achievement results form dedication to and an intense curriculum that is accompanied by practice and competition involvement for as many as 30 to 50 hours per week. Although the elite gymnast may be involved at this level of training, the most common gymnast is the younger child in a class such as tumbling or a similar activity, with an attendant lower level of potential for injury. Within these extremes, more than 4 million athletes take part in events that range in difficulty from the most benign to those with a slim margin for error. The cumulative effect of participation for each of these athletes and their specific characteristics result in an injury prevalence as high as other sports (Gabel, 1998).

The injury profile for each of these groups is distinct and dependent on the amount of time spent involved in the sport. For the elite gymnast, the time is extensive, with entry into organized training occurring as early as 4 or 5 years of age with peak involvement in the early to mid teens and retirement from competition in the sport at age 20 years or soon thereafter. During this 10- to 15-year-long career, the athlete generally reaches a practice and competition apex of 50 hours per week. The injury characteristics of this person include acute injuries such as fractures and ligamentous tears, which should be qualified as accidents, and chronic injuries, such as distal radius physis "stress fractures" and dorsal impingement, which owing to their frequency and mechanism, are more appropriately termed consequences of this level of participation. Unlike the elite gymnast with chronic injuries, the tumbler has an injury profile akin to any age-comparative group, with distal radial, supracondylar humerus, and forearm fractures representing most of the acute injuries. Chronic injuries, by definition, are not seen in this group.

The management of each of these types of athletes is different: that of the casual participant may be similar to that of the nonathlete without the short- and long-term consequences that management will have on the return to competition. Formal gymnasts, however, owing to the narrow window of opportunity for progression to the elite level, require the method of management that will return them to competition as quickly as possible with the lowest probability of injury, even though that management may not be conventional. It is this deviation from expectation and treatment that poses the greatest challenge for the physician, that is, how to return gymnasts to train and compete even though they are still injured and will in many instances continue to be symptomatic throughout their career.

There was so high incidence of sports injury for gymnasts. However, there was little research regarding to the kinetic analysis of upper extremity during gymnastic performance, which might be quite relevant to gymnastic injury. Therefore, the purposes of this study are to investigate the joint kinetics of upper extremity for gymnasts during forward and backward rolls. It will be valuable to understand the relationship between the joint force distribution and the injury mechanism.

Purpose

It is believed that the high injury rate of gymnasts is highly correlated to the high impact in the weight bearing joint when performing the specific gymnastic activities. For the gymnastic floor, the upper extremity, whose function is usually not weight bearing, is transferring to be a weight bearing limb. This functional change from carrying load to weight bearing might be one of the possible causes to explain why there is high incidence of gymnastic injury occurrence in upper extremity, especially in wrist. However, there were little studies investigating the joint impact in upper extremity during floor performance. Therefore, the joint loadings of upper extremity for the gymnasts was evaluated in this study when performing the forward and backward rolls in the floor.

Reviews

About the biomechanical Study of Upper Extremity in Gymnasts, Koh (1992) studied the ground reaction forces at the hand that produced compression forces and varus/valgus moments at the elbow joint during the double-arm support phase of the back handspring. The relationship of technique, namely elbow joint flexion, to these forces were also studied. Compression forces and forces producing valgus moments have been implicated in overuse injuries to the elbow joint. Video and force plate analysis of six young female gymnasts showed that 1) the elbow joint flexed during the double-arm support phase, and 2) the reaction forces at the hand produced large compression forces (an average of 2.37 times body weight) and sizable valgus moments at the elbow (an average of 0.03 times body weight times body height). The combination of these forces may contribute to the occurrence of lateral compression injuries of the elbow joint (e.g., osteochondritis dissecans of the capitellum). Correlations of measures of elbow angle and measures of reaction force showed that large elbow flexions may protect the elbow from large valgus moments.

In the rings event in men's gymnastics, marks are deducted if the rings and gymnast are swinging during a held handstand position. The unwanted swing can be reduced in the next handstand position if the gymnast is able to properly time the start of the connecting giant circle. Sprigings (1998) searched for the optimal time to commence a backward giant circle in order to attenuate swing in the succeeding handstand. Computer simulations, using a four-segment and a three-segment model which employed two-pulse muscular control strategies, were used to search for the optimal timing solution. Qualitative validation tests between the performance of a world class gymnast and the simulation models indicated that a three-segment model comprising a cables-rings segment, an arms segment with a shoulder torque generator, and a head-torso-legs segment, produced similar results to that of a four-segment model which separated the legs segment from the torso and employed an additional torque generator at the hip joint. The results from the simulation indicated that a gymnast should be advised to initiate a backward giant circle when his swinging handstand has reached the bottom of its swing-arc. For a handstand with an original swing-amplitude of 10 degrees, the simulation results indicate that a properly timed backward giant circle can reduce this amplitude to a negligible 1.5 degrees of swing.

Kerwin (2001) determined the contributions made by wrist, shoulder, and hip joint torques in maintaining a handstand. Handstand balances (N = 6) executed on a force plate and recorded with two genlocked video cameras were subjected to inverse dynamics analysis to determine anterior-posterior joint torques at the wrists, shoulders, and hips. Multiple regression analyses were conducted to investigate which of the joint torques were influential in accounting for anterior-posterior whole-body mass center (CM) movement. Results demonstrated that, in general, all calculated joint torques contributed to CM movement. In a number of trials, wrist torque played a dominant role in accounting for CM variance. Ostensibly, superior handstand balances are characterized by important contributions from wrist torques and shoulder torques with little influence from hip torques. In contrast, hip torques were found to be increasingly influential in less successful balances. It is concluded that multiple joints are utilized in maintaining a handstand balance in the anterior-posterior direction, and there appears to be two joint involvement strategies, which supports similar findings from postural research on normal upright stance.

Methods

Nine gymnasts were recruited to perform the forward and backward rolls in the floor at the motion laboratory. A set of fourteen reflective markers are placed on selected anatomic landmarks. The selected anatomic landmarks are as follows: processus xiphoideus, sternal notch, spinous process of the 7th cervical vertebra and bilateral acromion process, medial and lateral epicondyles of the elbow, radial and ulnar styloid processes, 3rd metacarpal, knuckle II and knuckle V. In addition, a triangular frame with three-markers is placed on the upper arm in order to calibrate the trajectories of the markers in the acromion process, medial and lateral epicondyles of the elbow. The VICON 612 system was used to collect the trajectories of the reflective markers during movements and neutral postures at the sampling rate 250Hz. Two AMTI force plate were used to collect ground reaction forces and moments when the hands were placed on the force plates at sampling rate 1000Hz. The inverse dynamic method was used to calculate the joint forces and moments for the wrist, elbow, and shoulder joints.

Results and Discussion

The results in the Figure 1 are the joint range of motion (ROM) for shoulder, elbow, wrist, trunk, and forearm during forward and backward rolls. The results show that the major joint movements of shoulder plane, elevation, and rotation both for forward and backward rolls. The range of motion of these three movements are more than 120 degrees. The major joint movements of elbow are flexion. For the wrist joint flexion/extension movements, the range of motion reaches 100 degrees. It implies that the gymnastics has the greater risk of to suffer from carpal tunnel syndromes. In clinical, the most of gymnastics complain of the wrist pain. The movements of trunk and forearm are in the range of motion of daily activity.

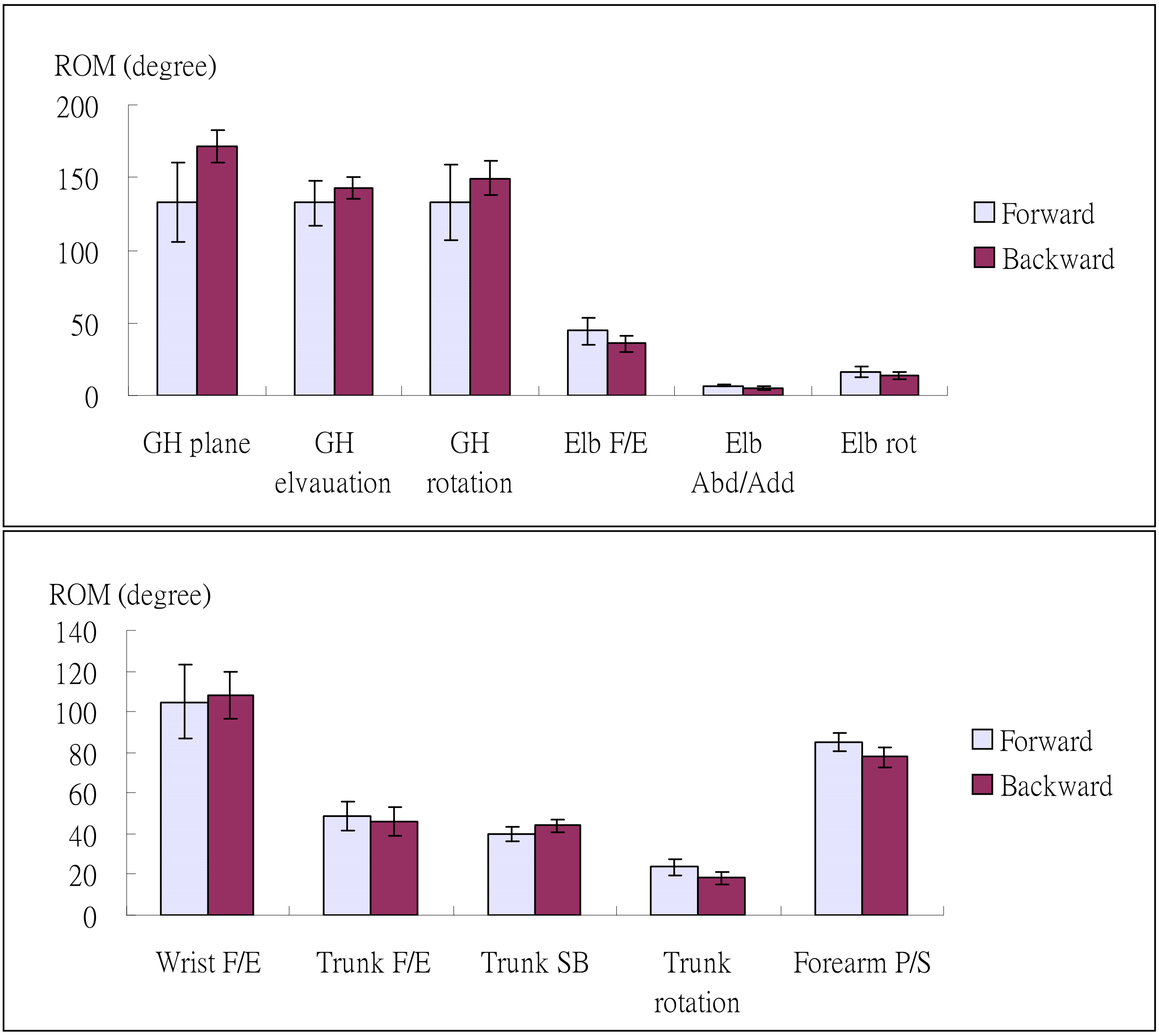

Figure 1: The joint range of motion (ROM) for shoulder, elbow, wrist, trunk, and forearm during forward and backward rolls. GH: shoulder joint; Elb: elbow joint; F/E: flexion/extension, Abd/Add: abduction/adduction; rot: rotation.

The results in Figures 2 and Figure 3 are the maximal joint forces and joint moments of shoulder, elbow and wrist joints during forward and backward rolls. The results show that the maximal forces of three joints are compression forces and reach about 4 times of body weight. Besides, the wrist joint force in the posterior direction reaches 3 times of body weight during forward and backward rolls. It implies that the pressure of compression in carpal tunnel was very high when the subject placed his/her hand on the ground to perform forward and backward rolls. The major joint moments of three joints are abductor moments. It implies that the major power for forward and backward rolls is transfer from the impulse of trunk flexion/extension movement, not from the work done by flexors. The results also showed that the abductors of three joints in upper extremity are very important for balance to maintain the handstand posture during forward and backward rolls. In clinical, it would be suggested that the flexibility of trunk, and strength training of the abductors of in upper extremity are important for the floor gymnastics.

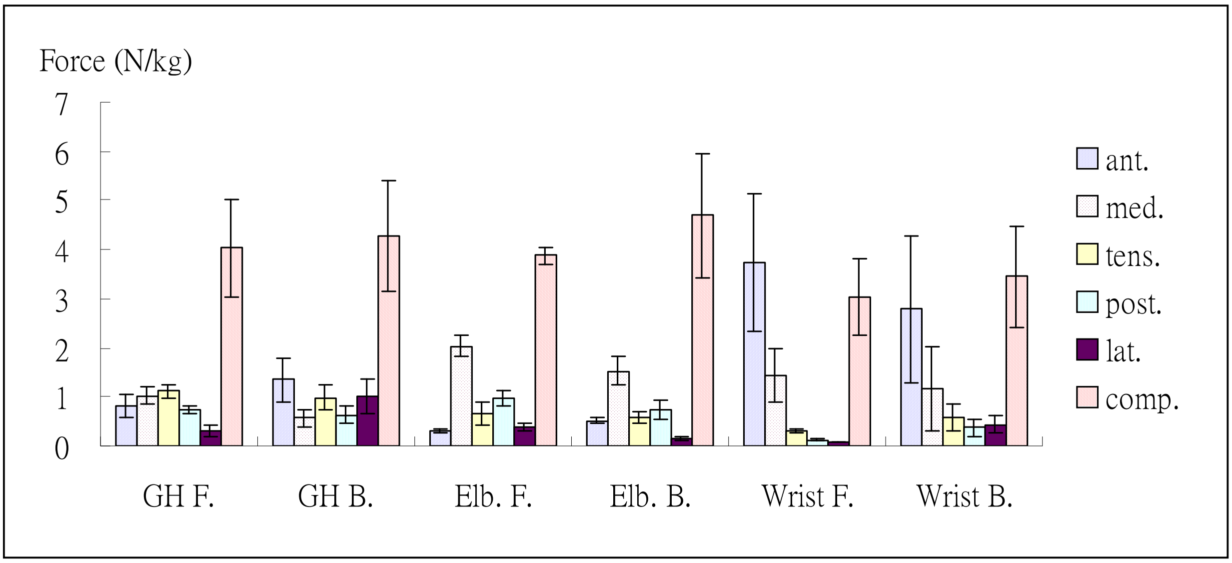

Figure 2: The maximal joint forces for shoulder, elbow, wrist, trunk, and forearm during forward and backward rolls. GH: shoulder joint; Elb: elbow joint; ant: anterior; med: medial; tens: tensile; post: posterior; lat: lateral; comp: compression.

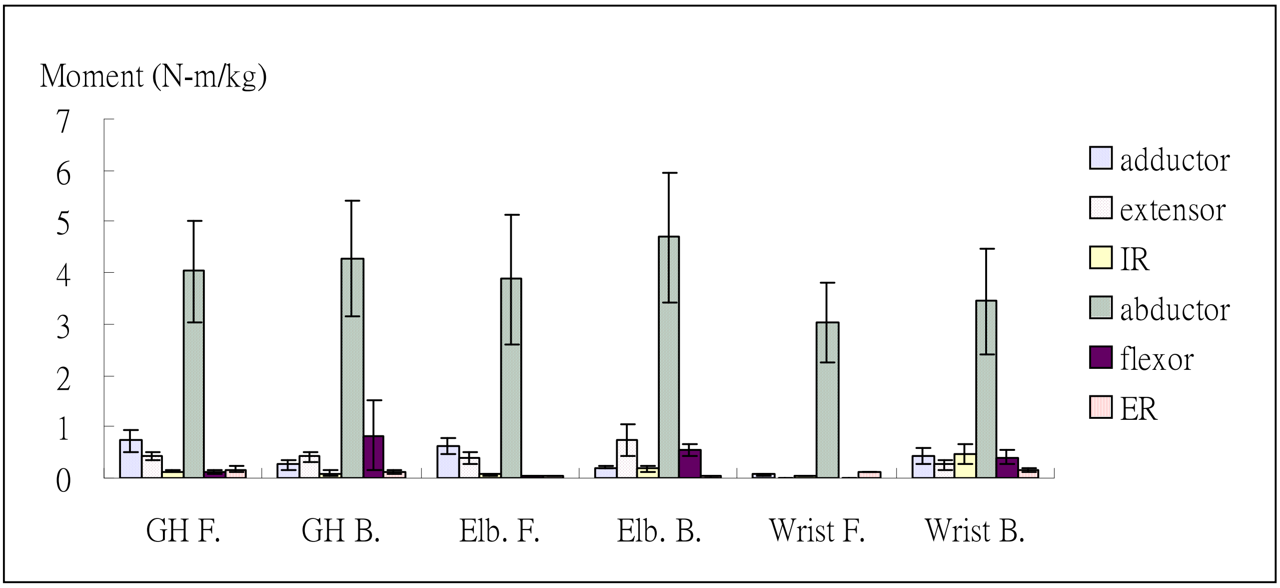

Figure 3: The maximal joint moments for shoulder, elbow, wrist, trunk, and forearm during forward and backward rolls. GH: shoulder joint; Elb: elbow joint; IR: internal rotator; ER: external rotator.

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