

## Sport Science: Biomechanics

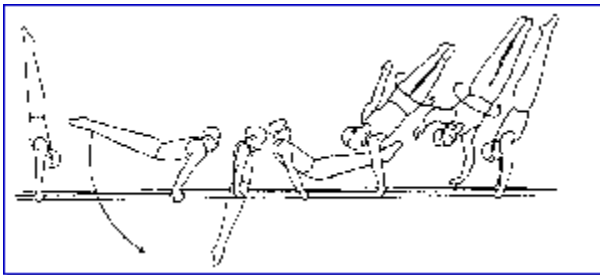
# Handstand to Stutzkehre

## The Relationship between the Anatomical and Mechanical



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Understanding and utilizing biomechanical principles is an important means by which the gymnastics community can procure effective performances. This can be implemented by being acutely aware of how body segments are effectively manipulated during a performance. It is essential to provide a means by which the gymnast can be more competent while performing on the apparatus. As the coach and athlete collectively deal with this matter by sharing ideas, they come face to face with the need to understand relationships between anatomical and mechanical concerns. Discerning how an artistic performance occurs depends a great deal on a biomechanical perspective. We simply must grasp the relationship between a gymnast and his environment and how these act as mechanisms of motion.



*Figure 1*

There is an interrelationship between those aspects that are internal and external to the human system. Figure 1 provides a means by which a discussion can take place concerning the anatomical and mechanical aspects of human motion. The handstand to a stutzkehre combination depicts both static and dynamic skills and serves to illustrate anatomical and mechanical inseparability.

## Biomechanical Analysis

### Static equilibrium

The combination begins with a handstand position and serves to illustrate the vertical alignment of body segments over the base of support at the hands (frame 1). Static equilibrium exists when the line of gravity is within the base of support. This is secured only when the gymnast's center of gravity is over the base of support.

Static equilibrium is improved when major joints are stabilized by recruiting specific muscle fiber types in particular muscle groups. Stabilizing joints at the elbow, shoulder complex, back, and pelvis are particularly important. The elbow joint is best stabilized when fully extended. This prepares the gymnast for controlling forward swing in frames 2-5. The shoulder girdle (scapula and clavicle) is elevated, and related articulations stabilized, in order to facilitate a hollow chest position. Pelvic alignment is secured by adequate strength in the abdominal and hamstring muscles because these muscle groups reduce anterior pelvic tilt and lumbar hyperextension. This is augmented by proper levels of flexibility in hip flexor and erector spinae muscle groups. Consequently, securing a straight handstand in equilibrium is highly dependent on a strength balance between agonist and antagonist

muscle groups, along with related connective tissue flexibility.

### **Body segments and the tap**

A beat or tap action at the bottom of the swing (frames 3-4) creates a reaction force from the bars that acts as an upward motive force. The effects of the tap action can accentuate the angular momentum phenomenon when preparatory body segment position occurs. A hollow chest position out of the handstand assists in setting up the tap action. The following are necessary sequential anatomical adjustments when moving into the tap: a) chest leading and legs trailing in order to position the body prior to the bottom of the swing, b) lowering the total center of gravity by relaxing the shoulder girdle into the bottom point of the swing, and c) pulling backward on the bar and quickly moving the legs forward out of the swing bottom. Tapping technique follows the point where the chest passes the bottom of the swing. The purpose of the tap is to maximize the relationship between movements of the gymnast's shoulder girdle, bar reaction force, and resulting increased angular velocity of the lower body at the hip joints. The effects of the resistive force of gravity during the forward swing (following frame 3) are reduced when the tap action is well timed. Such relationships are important in implementing sufficient angular momentum for a dynamic stutzkehre forward.

### **Elbow joint locking mechanism**

Parallel bar swing in straight arm support requires that there be anatomical adjustments at the proximal radioulnar and glenohumeral joints. Particular adjustments at these joints provide a locking mechanism for maintenance of full elbow extension. The elbow joint is uniaxial and only allows flexion and extension. This hinge joint does not permit motion around the longitudinal axis; therefore, necessary anatomical adjustments are made at associated articulations. Effective swing technique is reliant on anatomical adjustment. Necessary preparation occurs through supination of the lower arm at the radioulnar joint and slight outward rotation of the humerus at the shoulder joint. These movements are around the longitudinal axis in the transverse plane. The result is to limit elbow joint flexion created from a buckling action at the bottom point in the swing. This can be problematic when an explosive maneuver is required. The pull of gravity is difficult to control unless the anterior elbow is facing forward immediately prior to and at the bottom of the swing (frame 3). The locking mechanism is particularly relevant when coupled with the effects of high levels of centrifugal force created in angular motion. The gymnast flies away from the axis of rotation when support is lost due to the bucking effect. Consequently, the gymnast's anatomical structure serves to maintain control, at this critical point in the swing, and positions the body segments to receive the inwardly directed centripetal force from the bars in order to counteract centrifugal force.

### **Maximizing forward angular displacement**

Angular displacement on the forward swing (frames 1-5) can be maximized by releasing one bar (frame 5). The result is increased range of motion and a continued ability to control angular momentum (product of the moment of inertia and angular velocity). On the other hand, the anatomical limitation connected with hyperextension occurs at the shoulder joints when holding on too long with both hands. Value in the technique of releasing with one hand, prior to the point of anatomical limitation, cannot be overstated. The effectiveness of a one hand release can be further reinforced by slightly flexing the head at the cervical vertebra (frames 3-5). Neck flexion reduces the tendency to move the shoulder backward

beyond the vertical line that passes through the base of support at the hands (Watanabe, 1995). The single hand base of support allows the forward swing to continue longer and permits the application of a backwardly directed action force on the bar. Hand contact with the bar can result in a forwardly directed external reaction force that is crucial to controlling the shoulder position and provides a mechanism for increasing angular momentum. It is more likely that a handstand position can be attained in frame 6 with the release of one hand prior to the position shown in frame 5, rather than simultaneous release of both hands.

### **Multiaxial rotation**

Rotation of the gymnast's body during the stutzkehre is around both the primary mediolateral axis (frames 2-7) and the secondary longitudinal axis (frames 5-7). Maximizing angular momentum about the primary axis is essential if there is to be an acceptable position at the completion of the stutzkehre (frame 7). There must be sufficient transfer of angular momentum from the primary axis to the secondary axis, yet enough continued angular momentum about the primary axis throughout the stutzkehre.

The generated angular momentum shown in frames 2-5 is directly related to the magnitude of that which is produced while in bar support (Kreighbaum and Barthels, 1990). Angular momentum produced in the first part of the combination around the mediolateral axis (frames 1-5) is dependent on torques external to the gymnast. Utilizing the gravity torque by elongating the body from frame 1 to a point just shy of frame 3, use of the bar relation torque generated from a tap action beginning just prior to frame 3, and reaction torque from pulling on the bars (frames 3-5), are effective mechanisms for producing angular momentum. There must be sufficient angular momentum entering the second phase of the combination (frames 3-7) for rotating effectively around both axes. These techniques should be fully exploited during support because additional angular momentum is not possible once free of support (frame 6).

Rotating the human system during performance of the stutzkehre embodies conservation of angular momentum. This mechanical principle is relevant while in bar support as well as free of support. From the point of releasing one hand, through the point at which both hands recontact the parallel bars, provides an important opportunity for having a positive effect on the rate at which the elongated body rotates around the secondary axis (frames 5-7). While maintaining an extended support arm and torso, the free or unsupported arm can act to reduce the moment of inertia (rotational inertia) by bending at the elbow joint in frame 5. The moment of inertia can be further decreased while free of support by decreasing the length of both arms in frame 6. This results in greater angular velocity and assists in completing the 180 degree turn in preparation for subsequent gymnastics skills.

Angular momentum is the primary principle related to rotating the body and conservation of this vector quantity is essential if insufficient angular momentum exists around the longitudinal axis when free of support. External torque must be present to increase or decrease angular momentum; therefore, conservation of angular momentum occurs in frame 6. Furthermore, the stutzkehre forward will not reach a handstand position (frame 7) unless there is sufficient angular momentum present around the mediolateral axis in the sagittal plane at release (frame 5). Transfer of angular momentum from the mediolateral axis to the longitudinal axis can take place in both support or free of support. However, overall angular momentum cannot be changed while free of support unless there is the presence of external torque. In this case, gravity acts only to reduce angular momentum in frame 6 when the gymnast is dissociated from the bar.

## Summary

The interrelationships between anatomical and mechanical aspects of human motion permeate gymnastics activity. One affects the other. The athlete and coach should strive to open lines of communication and continue to study movement and its scientific principles. Effective gymnastics performance and progressive change can otherwise be elusive.

## References and Acknowledgements

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2. Watanabe, M. (September 9, 1995). Parallel bar swing. Gymnastics Association of Texas Annual Meeting. Austin, Texas.

Figure 1 was based on drawings by H. Mizoguchi in the USA Gymnastics Junior Olympic Age Group Compulsories.

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