BACK SALTO BIOMECHANICS FOR COACHES

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Professional gymnastics coaches often have to teach backwards flipping saltos, called “back tucks”. With more insight into the gymnast’s movements, the forces exchanged, and timing, we can teach this skill better. Moreover, a deeper understanding provides context to the different drills out there. First, I present the forces that create a back salto and then explain differences between standing and tumbling back saltos. Then I compare two groups of advanced saltos. Finally, there are practical recommendations for coaching back saltos, based on the biomechanics.

Looking at a backwards salto by itself, the two most important aspects are **how high** the gymnast jumps, the height of the salto, and **how fast** the gymnast’s body is turning around itself, flipping. What separates a good from a poor backward, or double backward, salto is **maximum height** and **sufficient angular momentum** for the required rotation, 360° or 720°, to go feet-to-feet. The height of the salto is relatively easy to see; how fast the gymnast is flipping is the gymnast’s angular momentum, an underlying quantity that cannot be directly seen. I describe m**aximum height** and **sufficient angular momentum** next.

To understand salto height and angular momentum, we look at the take-off because the take-off causes much of what happens once the gymnast is airborne, even though the airborne phase is more spectacular. The take-off is what the gymnast does while hers or his feet are touching the floor, just before becoming airborne and saltoing. The goal of the take-off is to create conditions for performance of as many saltos as possible during the airborne phase (Brüggemann, 1989). We begin by looking at one result of the take-off phase, the salto height.

Salto Height

The height above the floor is an obvious but important feature of any backwards flipping salto. We see obvious, significant differences in height, but not rotation, in backwards saltos that are landed on the feet (Brüggemann, 1983). The important difference is H2 in Fig. 1, the actual height changed. The difference between the height of the center of mass of the gymnast, which represents the gymnast’s entire body, at the instant the feet leave the floor (H1), and the height of the gymnast’s center of mass at the highest point of the salto (H in Fig. 1.). The gymnast’s center of mass is the dot at the top of the H1 and H2 lines. A gymnast’s **center**

of mass is used to represent her or his entire body. The center of mass is the simplest, most convenient model of a body, reducing a body to a single point in space. This model has proven to be very useful for over 400 years, for everything from moon landings to biomechanics.

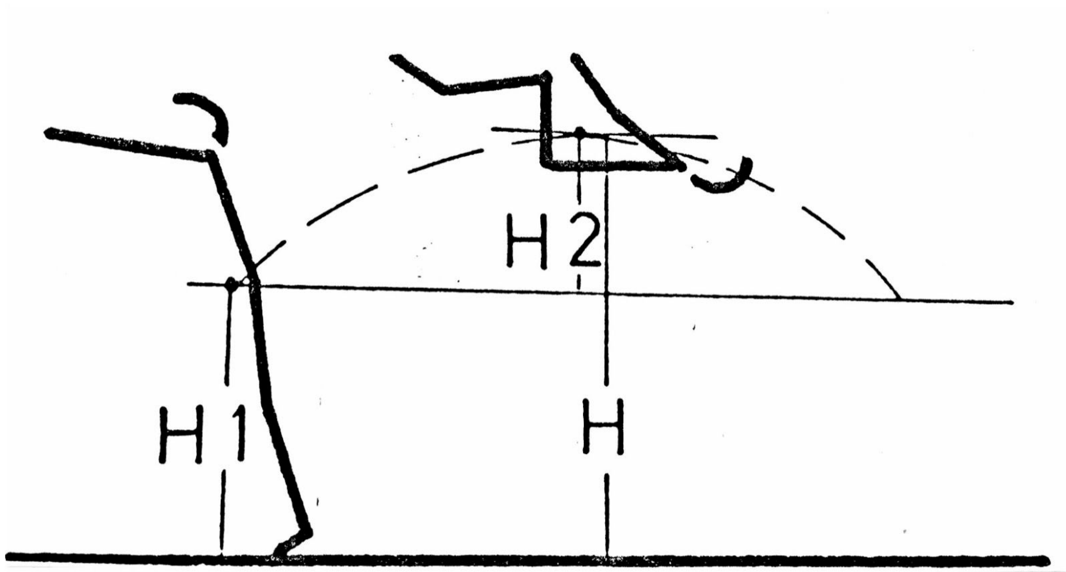


Fig. 1. Height of the gymnasts center of mass at the take-off instant (H1) and height of the gymnast's center of mass at the highest point of the salto (H). The difference between H and H1 is H2, the height of the salto. The dot at the end of the H1 and H2 shows the location of the gymnast's center of mass. H2 is therefore the amount the body of the gymnast has risen. The gymnasts center of mass is a model for the gymnast's body. Time runs from left to right. From Brüggemann, 1983.

A mental trick that makes complicated skills easier to understand imagines a force that moves a gymnast as made up of parts of that force, acting together, but in different directions. These "parts of forces" are forces acting in the up-down or vertical direction, the forwards-backwards direction of the tumbling pass, and the left-right direction. Together, these partial forces make up the resultant force acting on the gymnast's center of mass. This biomechanical technique has proved its value for centuries. In the case of our backwards flipping salto, the forces in the up-down, or vertical direction, and the horizontal, forwards-backwards direction of the tumbling pass are the interesting ones. When we want to twist a back salto, forces in the right-left direction also become interesting.

The velocity of the body in the straight upwards direction, vertically, at the instant the gymnast becomes airborne (H1) determines the height of the body at the highest point of the back salto (H). The take-off **vertical velocity** is how fast the gymnast is rising. This vertical velocity is created by the **vertical impulse** exerted during contact with the floor. An impulse is a force multiplied by how long the force was acting. The vertical impulse is this impulse acting straight up or down only. The vertical impulse is graphed by the total area under the force-time curve of the take-off in Fig. 2., representing how much and how long force is acting vertically. The total vertical impulse is the area under the curve between **t0** and **t4** in Fig. 2. The instant the feet leave the floor, the gymnast is no longer accelerating upwards. The gymnast can only accelerate upwards when a force is acting on hers or his body, and this is only when there is contact with the floor. The mass of the gymnast as well as the vertical velocity before the take-off also influence the vertical take-off velocity, and with the vertical impulse, create the height of the salto (Brüggemann, 1983).

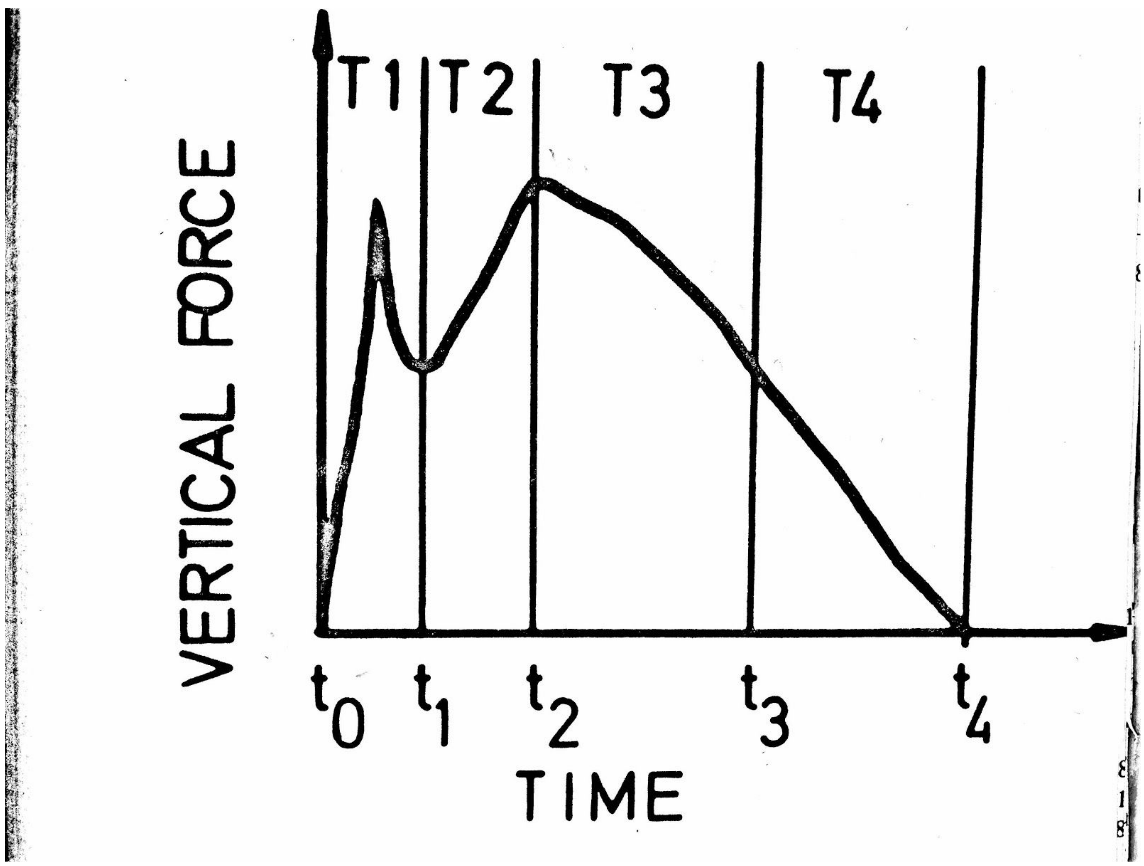


Fig. 2. Vertical force-time curve during the floor contact time between a round-off or back-handspring touch-down (**t0**) and the take-off when the feet leave the floor (**t4**) into a back salto. This curve is a record of the force in the vertical direction immediately before what we saw in Fig. 1. The amount of force increases in the upwards direction and time runs from left to right. The area under the curve between **t0** and **t4** represents the total vertical impulse. This impulse shows the typical two peak shape of a tumbling take-off to a backwards flipping salto. From Brüggemann, 1983.

With a given vertical impulse, the heavier the gymnast, the lower the salto height. Conversely, with the same gymnast, the greater the impulse, the higher the salto. In his 1983 research, Brüggemann found no significant differences between the 40 gymnasts he tested in height at take-off (H1), even though the higher H1 is, the higher H2 can be. This implies that there was little difference between the size of the gymnasts or their take-off technique. However, the height of the gymnasts body (center of mass) at the top of the salto (H2) varied significantly between gymnasts. This means that they were taking off at different velocities, so the impulses were different. There were different amounts of force making up the total impulse because in practice, in gymnastics, there is little difference in duration of the impulse, how long time the gymnast was pushing against the floor. The significant difference is the **peak force**. This fact, the importance of the force peak, is important for gymnastics conditioning, as well as technique.

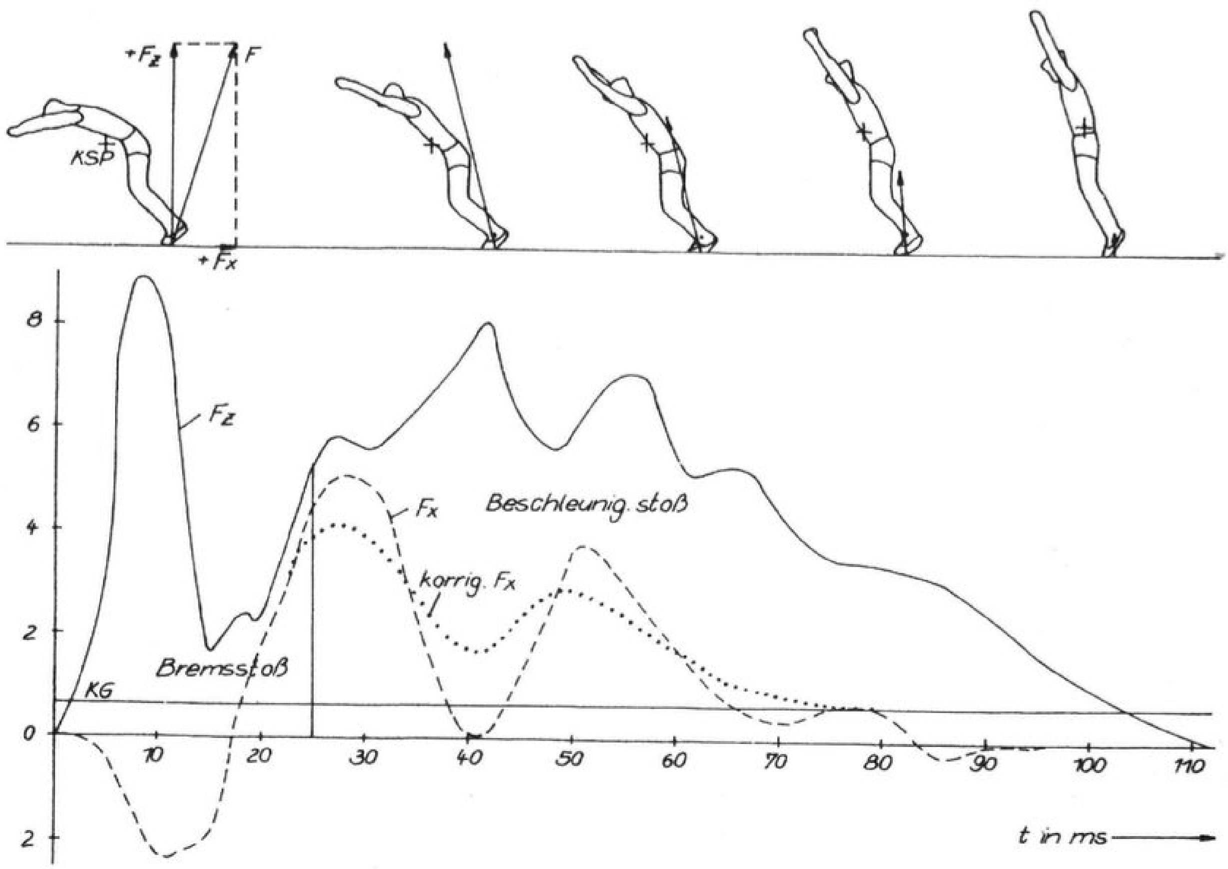


Fig. 3. Synchronized film and force recording of a take-off to a tucked double back salto following a back handspring. The drawings of the gymnast were made by tracing high-speed film. Time runs from left to right in 1/1000 seconds (ms). The tracing of a gymnast at the top left shows the gymnast approximately 10/1000 seconds <u>after</u> touching down at the end of a back handspring. On this tracing, the cross marked KSP is the location of the gymnast's center of mass, Fz is the part of the force in the vertical direction, Fx is the part of the force in the horizontal direction of the tumbling pass, and F is the total, resultant force. The length and direction of the arrow (F) in each tracing shows the direction and amount of force acting to flip the gymnast and lift him up. In the force-time curve below the tracings of the gymnast, the solid

line is the vertical force (Fz) and the dashed line is the horizontal force in the direction of the tumbling pass (Fx). The solid line, the vertical force Fz, is a more detailed example of the curve in Fig. 2. In Fig. 3. the amount of vertical force in thousands of Newtons is the vertical line on the left side <u>above</u> 0. The amount of horizontal force in thousands of Newtons in the direction of the tumbling pass is the vertical line on the left side <u>below</u> 0. The horizontal line marked “KG” is the gymnast’s body weight in Newtons standing still. A Newton is a unit of force equal to a 1 kilogram weight (2.2 lbs.) accelerated at 1 meter/second^2 (about 3 ft./second squared). From time 0 to approximately 25/1000 seconds is the counter- or blocking-impulse, in German “Bremstoß”. From approximately 25/1000 seconds to 110/1000 seconds is the vertical acceleration impulse, in German “Beschleunigungsstoß”. This double back salto attained a peak height of 7.68 ft. above the floor. The force data are from a plate dynamometer attached to a 1978 era foam block competition floor. Today’s gymnasts, tumbling on modern spring floors, would probably not bend their knees as much as we see here. From Knoll & Zocher, 1979.

The impulse is related to changes in the gymnasts salto in a way described by Newton’s second law of motion. We coaches should think about force in terms of the changes in acceleration that a force acting over time (impulse) causes, which is **Newton’s second law**. This law says that a force is the same as a change in velocity divided by a change in time, times a mass, or in other words, a mass times the acceleration of that mass. A force applied to a body causes an acceleration, which is a change in velocity. The same idea is that if a body is accelerating, there is a force acting on it.

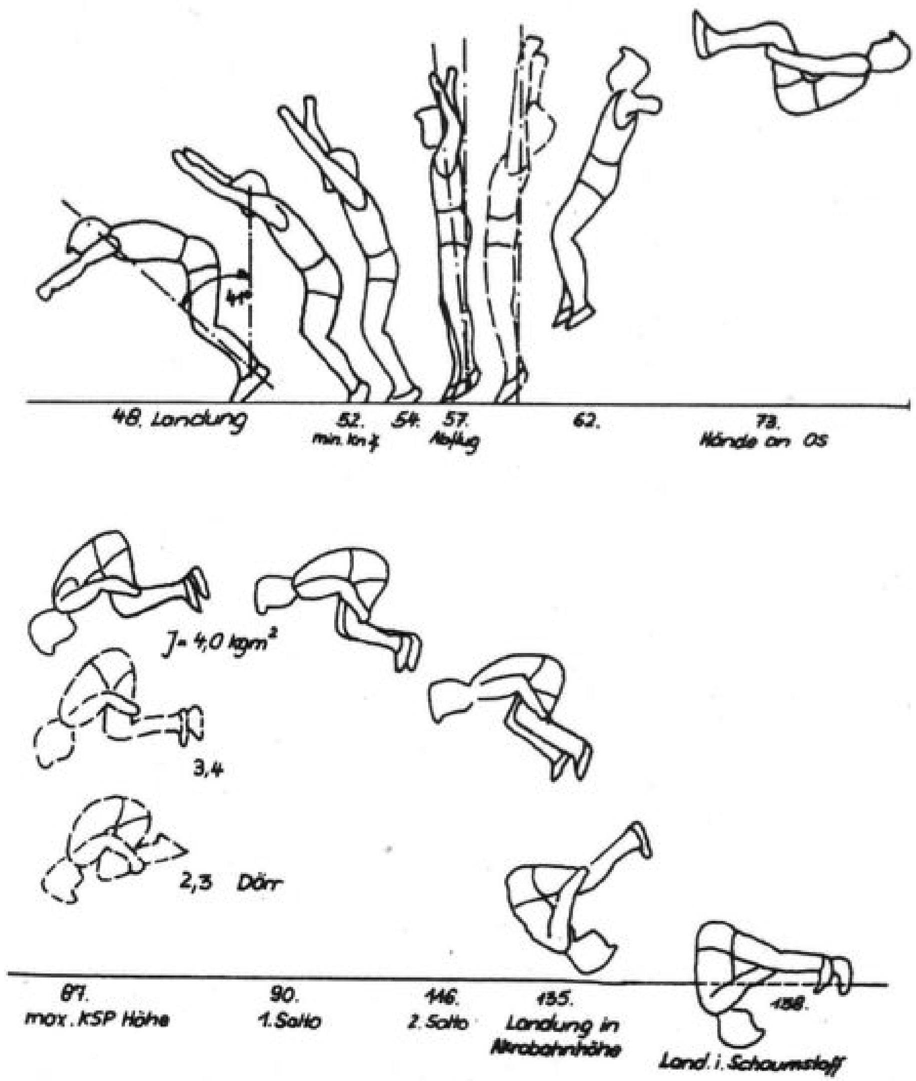
Force-time curves like Fig. 2. or 3. are distinctly different from other athletic take-offs. The landing from the preceding skill, for example the feet hitting the floor at the end of a round-off or back handspring and then jumping off the floor again, is particular among athletic take-offs. The impulse typically has two force peaks. The typical first vertical force peak immediately after impact is markedly lower than track-and-field take-offs for example. However, the second peak is as high or higher than in the high or long jump, at least vertically. This second peak is typically many times the body weight of the gymnast (Brüggemann, 1989). These two peaks are separated by a low point; only when the feet actually leave the floor is the force less. In data from 40 male gymnasts, Brüggemann (1983) found that the first peak between **t0** and **t1** is the gymnast absorbing the landing and the second peak between **t2** and **t4** is the force that actually creates the salto flight. In Fig. 2., the time interval **T1** is the landing from the preceding skill, round-off or back-handspring. During **T2**, the gymnast slows and stops the landing and reverses direction. The force peak at **t2** is largely produced by an extension of the hips, using lower back, seat, and hamstring muscles. Then there follows an addition from the knees extending, and finally at **T4** by the ankles straightening (plantar flexion).

I think that Brüggemann (1989) found gymnastics force-time curves to be distinctly different from other athletic take-offs because gymnastics equipment is bouncy, not just padded. For example, the floor is mounted on steel springs. The time course of the resulting body vertical velocity is particular. After the impact, the resulting velocity is at first slowed, and then speeds up again in the second phase of the take-off (Brüggemann, 1989). This would be consistent with the spring floor first pushed down and then recoiling upwards.

Salto Speed

How fast the gymnast flips through the air is the visible sign of the gymnast's angular momentum. **Angular momentum** is the amount of flip that a body has at any instant in time. Angular momentum is the product of a body's rotational **inertia** multiplied by the **rotational velocity** around an axis. Inertia is the resistance to change in a body's movement. Rotational inertia is the resistance to turning a body around itself. In other words, angular momentum is how much force is required to rotate a body, multiplied by how fast the body is rotating. In our case, the axis is an imaginary line passing roughly between the hips (see Fig. 1.). When a gymnast rotates around this axis, she or he does a salto. The gymnast's angular momentum is determined by the **angular impulse**. An angular impulse is a torque multiplied by how long that torque acts. A **torque** is a force that turns a body. When the impulse acts in a direction beside the center of mass of the gymnast, a torque is created that turns the body. In this case, we call it an angular impulse. In other words, the bigger the angular impulse, the faster the angular velocity, or the greater the inertial mass, or both. The inertial mass describes how much force is necessary to make that body turn and depends on the weight of the body parts and the body shape, for example tuck or layout. After take-off, the gymnast's angular momentum essentially remains the same until landing because in practice only gravity is acting on the gymnast until landing. An impulse is a force times how long the force acts. So a gymnast can increase her impulse by either pushing harder, or longer, or both. In gymnastics, a longer push is rarely effective, and can cause a deduction, for example vaulting a handspring if the gymnast is too long in support. To make a bigger impulse, a gymnast usually needs to push harder, with more force, not longer.

A reason Brüggemann (1983) didn't find significant differences in saltoing speed in successful backwards saltos, landed on the feet, is that the shape of the gymnast's body while flipping has a huge effect on how fast the gymnast flips. Once the gymnast leaves the floor, the angular momentum remains the same until landing. However, if the gymnast opens their tuck, their inertial mass increases, and the salto speed decreases. If the gymnast makes a tighter tuck, their inertial mass decreases, and the salto speed increases. This is much the same as a figure skater spinning faster as they pull their arms in. Pulling the arms in decreases the skater’s inertial mass, so the speed of spinning increases, the angular momentum remaining



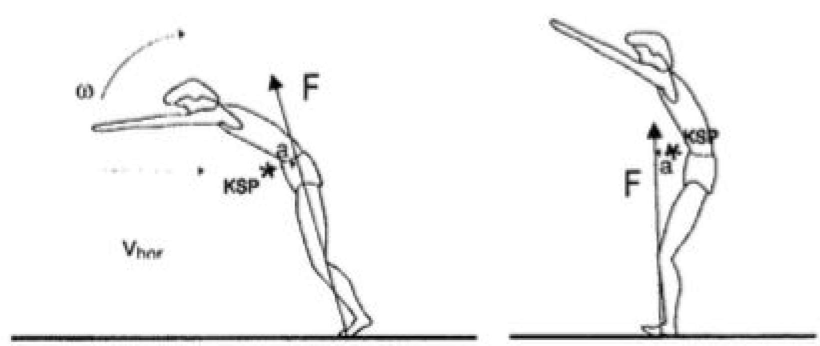
constant.

Fig. 4. A triple back attempt into a foam pit. These drawings were made by tracing high-speed film of an elite gymnast. In this series, picture 48 is the landing after a back handspring, showing a lean of the body through the center of mass of 41° before the vertical. Picture 52 shows the instant of minimum knee angle. Picture 57 is the instant of take-off. By picture 83, the gymnast grabs the back of his thighs. Picture 87 shows the instant of maximum height of the center of mass above the floor, 90 is the first salto, 116 the second, 135 the gymnast at the height of the tumbling strip, and 138 landing in the foam pit. Above picture 87 we see a tighter tuck, and then an even tighter tuck holding the shins, with the corresponding mass moment of inertia values. From Knoll, 1981.

The force required to flip a body in a layout is four times greater than in a tight tuck, holding the shins (Hochmuth, 1981). Calculations have shown that the triple back salto attempt in Fig. 4. that went head first into the foam pit could have been landed on the feet if the gymnast had just been in a tight tuck like a diver, instead of an open tuck, holding the back of the thighs. The open tuck, holding the back of the thighs had a rotational inertia (**J)** almost twice that of the tight tuck (**J** = 4 kgm^2 compared to **J** = 2.3 kgm^2; Knoll, 1981). So the tight tuck flips much faster for the same amount of force. Because even the slightest change in the shape of the gymnast while flipping causes such a big change in the speed of the flip, the gymnast can relatively easily control hers or his angular momentum to consistently land on their feet. In practice, increasing the height of the salto is much more difficult.

Standing and Tumbling Back saltos

Based on the biomechanics, we should always think about standing back saltos differently from backwards flipping saltos performed after some tumbling skill(s). During a standing back salto, the angular moment (**M** in Fig. 5.) acts <u>in</u> the direction of travel, backwards. During a salto take-off after a round-off, back handspring, the angular moment acts <u>against</u> the salto direction. Dr. Knoll believes some coaches think that angular momentum is increased during a tumbling take-off and that this error is due to confusion with what happens in a standing back salto (Knoll, 2004). Angular momentum is <u>always</u> reduced during a tumbling take-off, but increases until the take-off of a standing backwards salto. In floor tumbling, angular momentum is reduced a lot during the take-off to a tucked triple back, but much less during the take-off to a double layout. But angular momentum is reduced during the take-off in both cases. However, the tuck shape flips much easier than a layout shape, requiring much less force to flip, making height more important than retaining flipping force. For great tumbling, the important question is how much.



Take-off after a round-off — **M** acts <u>against</u> the direction of rotation

Standing take-off — **M** acts backwards <u>in</u> the direction of rotation

Angular moment **M** = Fa
F = force
a = lever arm
* KSP = center of mass of the gymnast

ω = flipping speed (angular velocity)

Fig. 5. The floor reaction force (F) and angular moment (**M**) during back salto take-offs, from a tumbling series (left) and from standing (right). From Knoll, 2004.

When tumbling back salto(s), the purpose of the skill(s) preceding the salto(s) is to create as much kinetic energy as possible. On floor, or the Yurchenko vault for that matter, the gymnast has a horizontal speed in the direction of the tumbling pass at the end of the preceding acrobatic skill like a round-off and/or back handspring. In addition to this horizontal speed, there is also a lot of flip (fast rotation around the transverse axis of the body) (Brüggemann, 1983). The decrease in angular momentum and rotation speed around the transverse axis of the body, and the associated optimization of the vertical impulse, in other words salto height, depends on how much flip is necessary for the salto and on the gymnast's body (size, shape, strength, flexibility). Some of this energy will be lost to the counter angular impulse of the take-off, but enough must be left to make salto height as well as complete the salto(s). Salto angular impulse is always smaller after the take-off than before. In other words, a take-off always reduces the force that makes the salto turn over (Knoll, 2004). The important coaching issue is how much.

Tumbling Back Saltos

The biomechanics of tumbling back saltos are very different than say, a standing back tuck on the beam. Watching expert tumblers, we might imagine that the gymnast, who is trying so hard and moving so fast, is increasing flipping force and speed during the take-off. But this is not correct. After careful investigations, gymnastics specialists have known for over 30 years that angular momentum is always decreased during a tumbling take-off to a back salto (Knoll & Zocher, 1979; Knoll, 1981; Brüggemann, 1983). Brüggemann (1989) found that when tumbling, the reaction force of the floor acts behind the center of mass, reducing saltoing force. For example, Brüggemann (1983) found that there was a large angular momentum at the end of the flick-flack, which was then reduced by approximately 50% during the take-off to the back salto(s)! Knoll (2004) found that this also happens when blocking off the vault table or releasing the uneven or high bar, for both release skills and dismounts. Retaining angular momentum during a take-off, blocking, or releasing the bar is in this sense a technical principle (Knoll, 2004).

Some coaches believe that the angular momentum of the gymnast is increased during take-off by lifting the arms up (shoulder flexion). Brüggemann (1989) found no evidence that this is the case. If you look at Fig. 7., you can see that the shoulders are already open when the gymnasts lands after the round-off or back-handspring. This is typical. The lifting of the arms has taken place a long time before take-off and therefore cannot be increasing angular momentum. What any eventual role of the arms during the take-off is unknown. Some muscle physiologists have suggested on the basis of computer simulations that the lifting of the arms may slow the shortening of the leg muscles during take-off so these muscles can produce more force. Brüggemann (1983) did find that during the T4 interval in Fig. 2., just before the feet leave the floor, the force of the arms was negative, not positive, and had a big influence on the acceleration of the entire body upwards.

When coaching tumbling, our attention should be focused on the execution of each preceding skill because these have such an important influence on the backwards salto that follows. In practice, the gymnast's linear velocity, horizontal, parallel to the floor, and in the direction of the tumbling pass, as well as the angular momentum before take-off, have big effects on the backward salto. Therefore, it is important that the gymnast perform the round-off and/or back handspring very well (Brüggemann, 1983). The fact of an angular momentum decrease during the take-off requires a highest possible velocity at the end of the preparatory skills. When there is a high velocity and/or high angular momentum at the start of the take-off, then after the decrease there is still a correspondingly greater remainder that can be used for the airborne skill. Performing a salto with virtuoso execution, which above all means maximal height, also requires a high initial velocity. Then the necessary, more powerful angular impulse reduction can be made by changing body and touch-down angles. The necessary strength is assumed, but not by any means a given (Knoll, 2004).

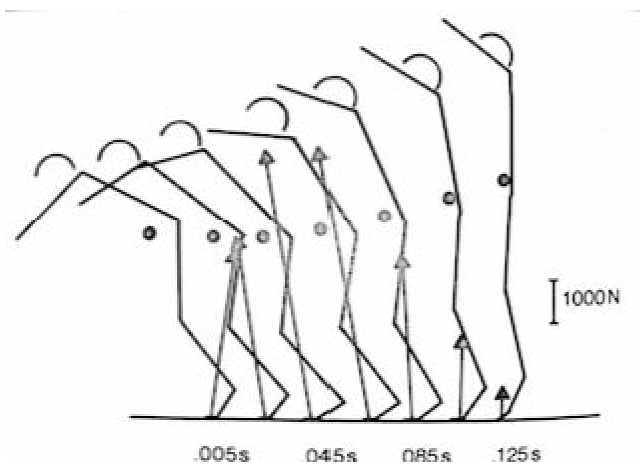


Fig. 6. A typical take-off to a tumbling back salto showing the location of the gymnast's center of mass as a dot near the gymnasts waist, and arrows showing at each instant the size and direction of the resulting floor reaction force. Shown are the 0.12 seconds the feet are on the floor, from 0.005 seconds after touch-down to 0.125 seconds later, the take-off instant. "N" refers to Newtons, a unit of force equal to 1 kilogram of weight (about two lbs.) accelerated at 1 meter per second squared (about 3 feet per second squared). The length of the vertical bar at the utmost right symbolizes 1000 Newtons of force. The peak vertical force at second 0.045 is between 5.5 and 6 thousand Newtons. From Brüggemann, 1989.

When tumbling, the amount of time the gymnast's feet are on the floor is very short, only between 10/100 to 15/100 seconds, depending among others on how stiff the floor is. After the preceding round-off or back handspring, the gymnast rotates around hers or his feet during the short time their feet are on the floor. In Fig. 6., the gymnast rotates through more than 40° while both the tumbling speed in the direction of the tumbling series and the angular momentum is reduced, in some cases a lot. At the initial contact, the velocity of the gymnast's center of mass is at first slowed, before increasing until the feet leave the floor. However, the gymnast (center of mass) rises continuously throughout the entire time the feet are in contact with the floor (Brüggemann, 1989). In the upper example in Fig. 7., the gymnast rotates through 43°, taking off straight up (vertically). In the lower example in Fig. 7., the gymnast strikes the floor at a sharp 32° angle and then rotates over his feet just 9° to take-off at 21° before the vertical (Knoll, 2004). This global rotation of the gymnast over hers or his feet is a sign of the angular momentum the gymnast has during the take-off, but created during the preceding skill.

The biomechanical problem of the backward flipping salto lies in the solution of an optimization problem: how to create or retain the biggest possible vertical impulse, in order to get great height, while at the same time reducing as little as possible the angular impulse so that the salto flips fast. This technique requires high speed at the end of any preceding skills, for example a back handspring. Knoll and Zocher (1979) found that elite male gymnasts had a horizontal velocity in the direction of the tumbling pass during the "snap-down" phase before a half-in, half-out full twisting double back salto of between 14.76 and 17.06 ft./second, with a snap-down rotation of 630° to 745°/second. Not at the level of elite track-and-field, but still fast. The amount of time the feet were on the foam block floor between the end of the snap-down and the salto take-off was 100 to 130/1000 of a second. Vertical impulse during take-off is similar to that of elite track-and-field long jumpers, even though horizontal velocity is much slower in gymnastics. This similarity between tumbling take-off and long-jump is explained by the high speed of rotation of the body at the end of a snap-down. This is a very important fact because this means that the gymnast's angular momentum immediately prior to take-off is decisive for the height of the salto. The blocking action of the round-off or back handspring landing then produces very brief, but very great forces (in Fig. 3. 10/1000 of a second after touch-down). Ten thousandths of a second after touch-down, there are peak forces up to 14 times body weight. During the part of the vertical impulse that produces the acceleration of the gymnast upwards, the force is 10 to 13 times body weight. The horizontal force of the blocking action (counter angular impulse) can be 7 times body weight (Knoll & Zocher, 1979).

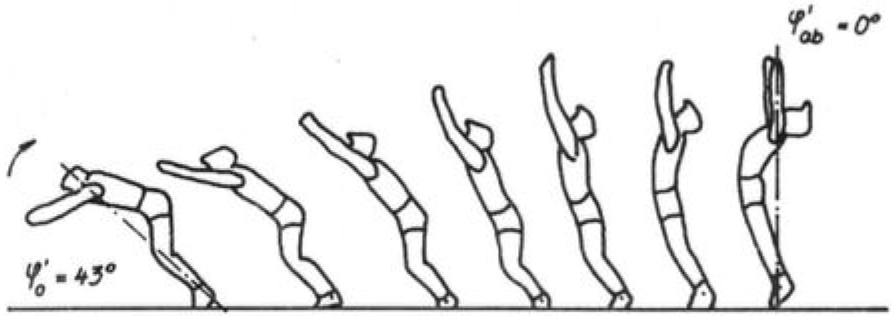
Tumbling Take-offs with Larger and Smaller Angular Impulses

Backwards tumbling saltos can be divided into two distinct groups based on their biomechanics: 1.) a group with take-offs with a bigger angular impulse, and 2.) a group with take-offs with a smaller angular impulse. Fig. 6. shows an example from each group. In both groups, there is a counter-impulse that reduces the angular momentum present at the end of the round-off or back handspring, but by very different amounts. The reduction of the angular impulse, and the closely associated optimization of the vertical impulse, in other words the salto height, depends on the angular impulse necessary for the salto, for example tuck or layout, and on the anatomical characteristics of the gymnast (Knoll, 2004).

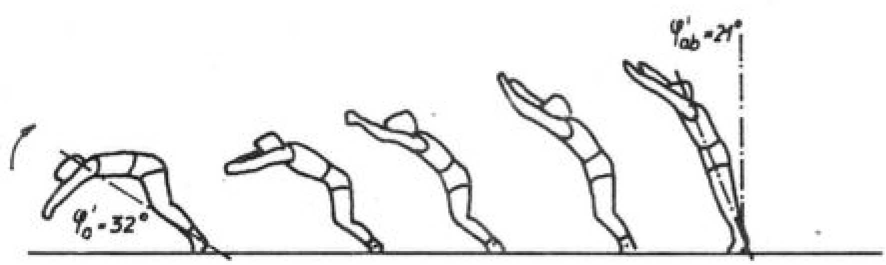
These two groups of skills by angular impulse have another difference: the height of the salto. Assuming equivalent initial flipping force, speed, as well as strength abilities, saltos in the "smaller angular impulse group" can be performed with greater height. Correspondingly, saltos in the "greater impulse group" can only be performed with lower salto height. For example, Dr. Knoll found that the blocking action (counter angular impulse) during the take-off to a tucked double back off the floor produced an average maximum height of 5.64 ft., while the take-off to the layout double back, which retains more of the initial angular impulse, had an average maximum height of only around 4.43 ft., all other things being equal (Knoll, 2004). However, expect the layout double back salto to travel farther backwards over the floor than the tucked double back because the smaller counter-angular impulse reduces the gymnast's horizontal velocity less than the bigger counter-angular impulse used to make the higher, and shorter, tucked double back.

Fig. 7. Examples of take-offs after a back handspring with smaller and bigger counter angular impulses. These drawings were made by tracing high-speed film of elite gymnasts. From Knoll, 1981.

Small Counter Angular Impulse (layout double back salto)



Big Counter Angular Impulse (tucked or layout back salto)



PRACTICAL RECOMMENDATIONS

- Coach standing and tumbling back saltos differently because their mechanics are different. The effort required for a standing back tuck and tumbling back tuck is also very different. To perform a good standing back tuck, a very fast stretch-shortening, plyometric, action is required from the legs, hip flexors, abdominals, and even shoulder (hyper-) extensors. To perform a good back tuck after a round-off and/or back handspring, the muscle action is much more static, resisting the enormous forces of the touch-down, then resisting and extending against the recoil of the spring floor to the take-off. For this reason, when tumbling, the gymnasts maximal strength and explosive strength become almost the same ability.

- Pay attention to the distance between the take-off and the landing. Any back salto is an optimization problem: not too much, not too little, but just right. There needs to be an optimal balance between height of the salto, flip, and travel backwards. If the gymnast is traveling far backwards, suggest that they place their feet farther behind them at the end of the round-off or back handspring. If the gymnast is getting good height but lacking flip, suggest that they take-off with their feet more underneath them, giving up a little height for faster flipping.
- Remember that even small changes in body shape while airborne can have a big effect on how fast the gymnast is flipping. An open tuck, holding the back of the thighs is an inefficient shape of limited use; might as well try a pike. Teach instead a tight tuck holding the shins. For future development, also teach an open tuck without grabbing the legs, but maximum flexion in the knees, for twisting, tucked saltos.
- When coaching tumbling, pay particular attention to the preceding skill, for example the round-off and/or back handspring. Changes in the preceding skill will often have big effects on the following backwards salto(s). Remember when coaching tumbling, that all of the gymnast's flip is there <u>before</u> she or he takes-off. During the last floor contact before taking off to the salto, the amount of flip is <u>reduced.</u> Consequently, the gymnast must be turning over fast <u>before</u> the take-off. If you see an error or problem, suggest a change in the <u>preceding</u> skill.
- Tumble fast! Sprinting and tumbling speed is basic for saltos. The reason for the relationship between speed and D-score is that during take-off, horizontal kinetic energy accumulated during the sprint and tumbling is converted into flip and height (angular and vertical kinetic energy), making the airborne phase. Consequently, the goal must be to begin the take off with the highest possible speed in the direction of the salto.
- A salto take-off is an optimization problem: making as big a vertical impulse as possible, for as high a salto as possible, while at the same time reducing as little as possible the angular impulse that flips the salto during the take-off for the fastest flipping salto possible. This optimization task is the biomechanical problem of the salto take-off and in general, of all transition phases between preparatory skills and airborne skills: not too much, not too little, but just right.

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