

Spotting

How Effective is Rescue Spotting?

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Hand spotting is a unique aspect of gymnastics training and performance that has received considerable scrutiny in recent years. The advent of the foam pit may have resulted in a reduction in the amount of hand spotting that occurs in typical gymnastics training (2), but I believe that most would acknowledge that hand spotting is still an important and sometimes essential aspect of safe gymnastics training and performance. Spotting has been defined in various ways and includes a variety of purposes:

- *Physically demonstrating proper (desired) body positions.*
- *Physically identifying important changes in body position or transitions.*
- *Reminders or cues to the athlete – use a light touch and/or verbal cues.*
- *Physically assisting the performance of the whole (or part) of a skill or series.*
- *Motivation - to alleviate fear and build confidence.*
- *As a “safety spot” – ready to assist if necessary. (7, p. 3)*

Moreover, although spotting is considered an extremely important asset for safe gymnastics training and performance (1), spotting is not considered a “fail-safe” (i.e., a guarantee of safety) (7). It has also been acknowledged that the primary concern of the spotter is the prevention of catastrophic injury, and that even when a spot is applied a gymnast may still be injured (3, 7).

Spotting, in general, can be applied in many different formats and involve very complex skills on the part of the spotter and the athlete. My principle concern in this document is hand spotting, specifically rescuing a gymnast from an unplanned fall (i.e., a rescue spot). The majority of spotting is not of this type, but it is this particular skill that often results in litigation due to accusations that the coach should have somehow managed to snatch the gymnast from the air and prevent the injurious fall. The majority of spotting is a type I would call “assistive” which refers to the idea that the coach intends to touch the gymnast from the outset and that the coach and athlete have a well choreographed spotting and performance duet that will be executed within rather narrow performance limits by both spotter and gymnast. In most assistive hand spotting the coach manipulates (i.e., touches and partially supports) the gymnast throughout most or all of the skill in question. In a rescue spot, the coach does not plan to touch the gymnast unless something unforeseen and potentially harmful occurs. The rescue spot technique is largely created at the moment of the gymnast's fault in order to rescue the falling gymnast. Sadly, recent experiences has demonstrated that there is a broad misunderstanding of what a human being can do in applying rescue spotting techniques to catch and protect a falling gymnast.

Although spotting has been considered a vital adjunct to safe progressions in gymnastics once being referred to as a “Sacred Trust” (3), there is little information on the actual effectiveness of hand spotting in rescuing an unplanned fall. Several studies have indicated that the proportion and rate of injury in gymnasts was greater when they were unassisted (i.e., not spotted) (1). However, gymnastics training and performance presents a dilemma

because although the gymnast may be safer when a coach is assisting the movement, the point of gymnastics training is to increase the competence of the gymnast to the point that he/she can perform the skill unassisted. Thus, a tension between spotting assistance and complete performance freedom is inevitable. This tension places a considerable burden on the judgment of the coach and athlete – how competent is competent enough? Examining over 30 elbow injuries including fractures, dislocations, and fracture-dislocations, Priest noted that over 30 percent of the injuries occurred with a spotter present (5). If the work of Priest is somewhat typical of the outcome of spotting, then clearly the potential reasons for the failure of spotting to prevent an injury is worth examining.

Freely Falling Bodies – Physical Constraints

Are there constraints on what a spotter can do with hand spotting while performing a rescue spot? The biomechanics of a falling gymnast can be fairly easily determined based on the principles of falling bodies and trajectories of bodies in flight. If we ignore air resistance (a safe assumption here) then we can calculate the amount of time the gymnast spends in the air, the height of his/her flight, and the speed of the gymnast at any moment of the ascent or descent. The flight of a gymnast is constrained by gravity and his/her launch or take off velocity and direction. I will provide some simple examples below assuming that the gymnast is simply falling straight down from a known height. If a gymnast simply falls directly downward from a known height we can calculate all relevant physical parameters (4). For example, if a gymnast's center of mass falls 10 feet to the floor mat, he/she will require 0.79 seconds for the center of mass to descend the 10 feet.

$$\text{time of fall} = \sqrt{2 * \text{height} / 32.2 \text{ ft/s}^2}$$

where height = height in feet

32.2 ft/ s² = acceleration due to gravity

Moreover, if I watch a video tape of a gymnast falling and count the frames (using frame advance feature), I can determine how far the gymnast fell. The time between frames of a standard video occupies 1/30th of a second. For example, if a gymnast falls from a maximal height and requires 15 frames in which to fall (1/2 second), then the gymnast fell approximately 4.0 feet.

$$\text{distance of fall} = 0.5 * 32.2 \text{ ft/s}^2 * \text{time of fall}^2$$

The only thing left to know is how fast the gymnast is falling at any given instant. This can be determined by knowing the acceleration due to gravity and the duration of the gymnast's fall. If the gymnast falls for 1/2 second, then the gymnast will achieve a velocity of 16.1 feet per second downward.

$$\text{instantaneous velocity} = 32.2 \text{ ft/ s}^2 * \text{time of fall}$$

With a little more complex set of equations I could also determine the height of a gymnast who takes off from a tumbling skill and lands at roughly the same height. Or, how high a gymnast goes in a balance beam dismount by knowing the height of the gymnast and counting the frames from the video tape. None of these problems involve difficult calculations and all are reasonably precise in determining the various parameters of a

gymnast in flight. Thus, the parameters of the fall or flight of the gymnast can be known within a relatively small amount of error. Now, I would like to turn to information on human reaction time.

Catching a Falling Body – Human Constraints

There are several things that the spotter must do before a rescue spot can be effective. Assuming that the spotter has the skill and the strength to catch a falling gymnast, the spotter must be capable of detecting a flawed performance, select an appropriate action, and then implement the action. In motor learning/control circles, these stages are called the “stimulus-identification stage,” “response-selection stage,” and “response-programming stage,” respectively (6). The area is called “information processing” (6). A spotter must implement the concepts of information processing in order to perform a rescue spot effectively.

The concepts of information processing in the case of rescue spotting primarily involve the various types of reaction time. You are probably familiar with reaction time from driver education courses that often provide tables and explanations of how long it takes the driver to hit the brakes once a threat has been identified. Reaction time is important in many aspects of sports, particularly rescue spotting. It simply requires a certain amount of time for a stimulus (i.e., falling gymnast) to be correctly identified by the spotter. Then it takes a separate amount of time to select an appropriate response, finally a third and again separate amount of time is required to perform the movement(s) needed to effectively catch the falling gymnast.

Stimulus-identification stage

The first stage, stimulus-identification, occurs when a spotter perceives the gymnast. An array of sensors from vision, hearing, and balance must act in concert to quickly and correctly inform the spotter that the gymnast is in danger. The duration of this stage of information processing has been shown to be affected by stimulus clarity and stimulus intensity (6). It may seem obvious that the clearer the stimulus (i.e., most focused), the better the reaction time. Stimulus intensity such as the loudness of a noise or the brightness of a light have also been shown to influence reaction time (6). Practice is also important in stimulus-identification. It is important that a spotter attend to what is relevant in the execution of a skill and filter out irrelevant information that is present. This can be a very difficult information processing skill to learn particularly when one doesn't often perform rescue spots on all skills, or for all gymnasts. The uniqueness of the rescue spot results in making most rescue spots a novel skill performed usually for the first time. Because of the large amount of information coming to the spotter while viewing the gymnast performing a skill, the stimulus-identification stage is probably more akin to pattern recognition than simply identifying a single item in the performance. Patterns in gymnastics skills are not always easy to identify, particularly when a range of movement patterns is usually successful in skill performance. In short, it takes a lot of practice on the part of the coach to be able to extract the important safety features from a skill while it is being performed. Unfortunately, the coach who is providing the rescue spot is usually standing so close to the gymnast, that a clear view of the movement is often impossible thus making identifying inappropriate movement patterns very difficult.

Response-selection stage

At the end of the stimulus-identification stage, the spotter has presumably identified an appropriate feature of the movement that gives the spotter the “knowledge” of what is happening in the movement. It is not clear whether the stimulus-identification stage and the response-selection stage can occur in parallel or must occur in serial order or if some facets of the two stages are shared (6). The response-selection stage involves “processing” of the information obtained in the stimulus-identification stage and thus selecting an appropriate response based on knowledge of the movement. Response-selection has been studied quite extensively and this information can help us understand the biological limitations that a spotter brings to the rescue spot situation. The Hick-Hyman law indicates that as the number of choices of a response increases the time required to make an appropriate response also increases. Hick and Hyman separately discovered that a nearly linear increase in reaction time (on the average approximately 150 milliseconds although this can vary widely) was observed every time the number of response choices doubled. This suggested that the relationship between choice reaction time and the logarithm of the number of stimulus-response alternatives will be linear (6).

What about a single response?

This is called simple reaction time and is interpreted as the intercept of the slope of the line of increasing reaction time and the $\text{Log}(2)$ (number of stimulus-response alternatives). The intercept of the slope of the line is approximately 180 ms. The average reaction time for humans to a simple stimulus (e.g., light) and pressing a button when the stimulus appears is approximately 180 ms (0.18 seconds). From this intercept you can add, on average, 150 ms to the simple reaction time for every doubling of stimulus-response alternatives (now called choice reaction time). Without going into the information processing theory of reduction of uncertainty by virtue of the number of bits of information provided in a stimulus-response alternative, we can see that as the number of stimulus-response alternatives (i.e., complexity) increases, the longer it takes for someone to determine a correct response. It is very difficult to determine the number of stimulus-response alternatives that are present when viewing a skill from a hand spotting position, but let's just assume that a pattern observed in a gymnastics skill has only eight possible performance alternatives (surely less than actual).

Given the assumption above, we can determine roughly the duration of the first two stages of information processing. Given that there are eight possible performance alternatives, the $\text{Log}(2)(8) = 3$ (i.e., $2 \times 2 \times 2 = 8$). Thus, on average, we start with 180 ms and then add 3 x 150 ms. The total time required for this scenario to simply select the appropriate response is approximately 630 ms, or 0.63 seconds. If you recall from above, a gymnast falling 10 feet requires only 790 ms (0.79) to complete the fall. If the spotter can detect that the gymnast is in trouble at the moment of the beginning of the fall, then the spotter will require 630 of the 790 ms to simply select an appropriate response (the spotter has not moved yet). These figures indicate that approximately 80 percent of the fall is consumed by information processing by the spotter and no movement has yet begun to rescue the gymnast, in fact the spotter has only 160 ms to make a meaningful movement. By this time the gymnast has fallen 6.4 feet leaving only 3.6 feet before striking the floor/mat. At 630 ms of the fall the gymnast is moving at 20.29 ft/sec (almost 14 miles per hour). And again—**the spotter has not moved yet.**

Response-programming stage

The actual movement time (response-programming stage) has been shown to be dependent

on the complexity of the response to be performed. Simple responses (like pushing a button) can be as short as 95 ms, while complex movements can require as long as 465 ms (6). If we assume a middling value of 280 ms for the movement time, our total choice reaction time comes to 910 ms. Movement time in most choice reaction time tests involve simply moving the arm/hand to touch or strike something—not moving the entire body into position to catch a gymnast. In 910 ms the gymnast will fall 13.3 feet. Unfortunately, the gymnast only had 10 feet of fall before striking the floor/mat. This means that the gymnast hit the floor and probably bounced before the spotter could complete any meaningful rescue attempt. Moreover, although I chose 10 feet, there are many circumstances where the gymnast falls less than 10 feet and is potentially injured, thus constraining available time further. Perhaps most important, all of the calculations above were assuming relatively simple responses—certainly simpler than deciding what to do with a falling gymnast that weighs as much or more than the spotter. Moreover, this does not account for rotation of the gymnast, distance from the spotter to the gymnast, speed of the spotter, balance of the spotter, skill of the spotter, strength of the spotter, footing under the spotter, and on which body part the gymnast is going to land. Sadly, it is possible that the gymnast will strike the floor/mats and the spotter will not have moved.

Summary

I hope that this information shows that the act of rescue spotting is at the very least extraordinarily difficult. The fact that coaches can perform a rescue spot at all is astonishing (and I have seen some spectacular saves, even been the recipient of a few from my coach a million years ago). However, I believe that the coach, athlete, parent, and legal communities must come to understand the inherent limitations that constrain rescue spotting. Not only is not spotting a fail-safe, sometimes hand spotting of an unplanned fall effectively is IMPOSSIBLE. The impossibility of some hand spotting should be communicated to coaches, athletes, and parents so that all understand the physical and biological constraints on hand spotting and no one expects more from the spotter than the spotter can deliver.

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