



UNLEASH YOUR SUPER THROW: WHOLE BODY MOVEMENTS TO THROW SAFER, BETTER, AND FASTER!

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KONSTANTIA

AGE: 11



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VICTORIA

AGE: 8

Have you ever tried to throw a ball as fast as a professional baseball pitcher? Professional baseball pitchers throw over 160 km/h! This is almost as fast as a car, but they can do it without an engine. How can they throw so fast, and what is the science behind this? In this article, you will discover that you must use your whole body to throw as fast and safe as possible. Throwing starts at your feet and energy moves through the legs, hips, trunk, and arm before you release the ball. To move these body parts, the muscles are important—especially the muscles around your chest. These muscles accelerate your arm but also keep the shoulder in the right position. Throwing at high speeds can result in injuries around the elbow and shoulder, and no athlete wants injuries. By understanding human motion, we can

try to enhance throwers' performance and reduce injuries in sports like baseball.

THROWING IS A WHOLE-BODY MOVEMENT

Have you ever tried to throw a ball as far and as hard as you can? Did you use only your arm, or did you use your whole body? Here is a fun way to find out: grab a ball and throw it twice. The first time, throw it while standing still and using only your arm. The second time, use your whole body by, for example, stepping forward before releasing the ball. You will probably notice that you throw the ball farther when you use your whole body.

Baseball pitching is a great example of a thrower using their whole body (Figure 1A). The pitching motion is very powerful. Professional pitchers can throw a baseball at speeds up to 160 km/h. Their legs, arms, and all body parts in between work together in an optimal way to throw the ball as fast and as accurately as possible [1]. This does not happen only in baseball, but also in other overhead sports movements where athletes use their entire bodies to throw or hit an object in the best way. Examples include javelin throwing, serving a tennis ball, and smashing in padel, volleyball, and badminton [2]. The question is, how can a person throw or hit an object so fast and so accurately? To understand this, we study these motions using **biomechanics**.

BIOMECHANICS

The study of forces acting on and generated within the body. Like how your muscles and bones work together when you walk, run, or jump. It can help us understand how to prevent injuries.

WHAT ARE BIOMECHANICS?

First, what does biomechanics mean? We can break the word into two parts: "bio" and "mechanics". "Bio" refers to living things, and "mechanics" deals with how bodies move when forces act on them. So, biomechanics is the study of how living things move and how forces affect them. When we look at overhead sports, "bio" refers to the athlete who throws or hits a ball, and "mechanics" involves applying the laws of motion to the athlete's body.

THE KINETIC CHAIN

To make studying body movements easier, we often represent the body as a simple stick figure (Figure 1B). You can see that each body part is drawn as a line, square, or circle. The joints, which connect body parts, are drawn as dots.

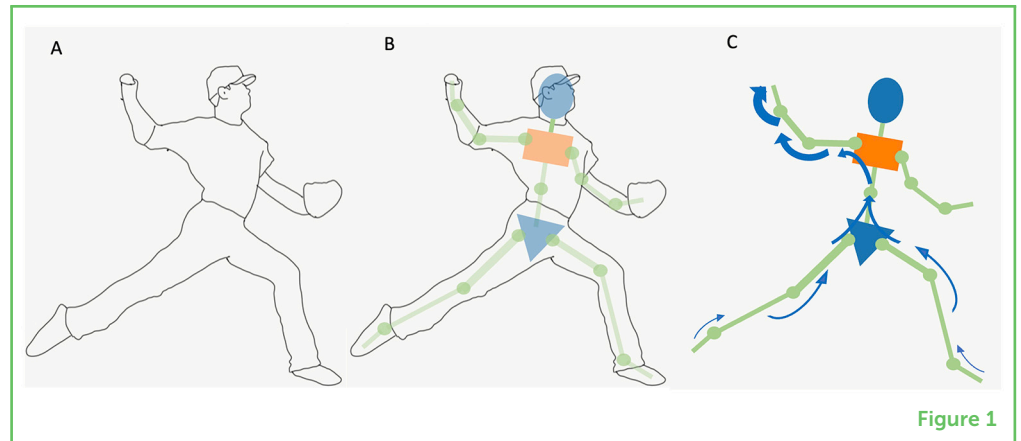
In overhead movements, energy starts in your legs, then moves through your hips and trunk, and finally reaches your arms. This process is called the **kinetic chain** [2]. The blue curved arrows in Figure 1C show the sum of energy, starting from the feet all the way to the hand. One way to observe the kinetic chain is by measuring

KINETIC CHAIN

How different body parts work together in a sequence to make you throw or hit faster.

Figure 1

(A) A drawing of a pitcher. (B) A stick figure that models the pitcher. (C) Arrows show how energy is sequentially built up in the legs and transferred to the hand: through the hips to the trunk and then from the upper arm to the forearm to the hand.

**Figure 1**

ROTATIONAL SPEED

How fast something is turning or spinning. For example, when you spin a basketball on your finger, its rotational speed is how fast it spins around.

how fast different body parts rotate and when these parts rotate fastest relative to each other. It is believed that each body part rotates faster as it gets closer to the end of the kinetic chain—which is your hand when throwing a baseball or the racket in tennis. So, a higher **rotational speed** of the body parts will increase ball speed, but what is rotational speed?

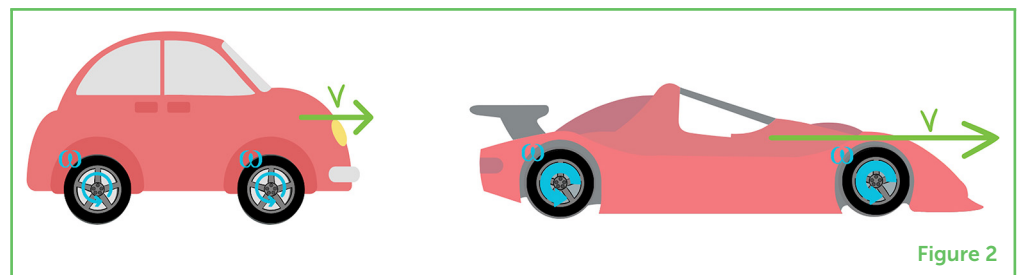
LINEAR SPEED AND ROTATIONAL SPEED

Figure 2

When a car drives in a straight line, it moves with linear speed (green arrows and the letter V for velocity). At the same time, the car's wheels are spinning with rotational speed (curved blue arrows and the letter ω , omega). (Left) This car moves slower, and its wheels spin slower, indicated by thinner/shorter arrows. (Right) This car moves faster, represented by a longer green arrow, and its wheels spin faster, shown with thicker blue curved arrows. The faster a car moves, the faster its wheels must spin and thus the higher the linear and rotational speeds.

When you think about speed, you probably think of how fast your parents' car goes or how fast you can run. This is known as **linear speed**. Linear speed describes how fast something is moving in a straight line. But there is another kind of speed called rotational speed, which describes how fast something is spinning or turning around. Imagine you are spinning a top. If it spins quickly, that is high rotational speed. If it spins slowly, that is low rotational speed. So, rotational speed tells us how fast something is going around in circles. Figure 2 shows linear and rotational speed in a car.

The same idea applies to a baseball pitcher. To throw a ball (which is the linear speed), the pitcher's body parts need to rotate quickly, just like the wheels of a car. To throw the ball with higher linear speed, the rotational speed of the body parts—just like the car's spinning wheels—needs to be high to make the throw faster.

**Figure 2**

LINEAR SPEED

How fast something is moving in a straight line. For example, if you are riding your bike down the street, your linear speed is how fast you are going from one place to another.

Figure 3

An overview of how the pectoralis major muscle stores and releases elastic energy during an overhead throwing motion. **(A)** At the start of the pitch, the muscle is at its normal length. **(B)** During the pitch when the upper arm of the pitcher is rotated the furthest behind his head, the pectoralis major is stretched. The muscle is released during the pitch, to accelerate the arm and throw the ball as fast and accurately as possible. **(C)** After the throw, the pectoralis major returns to its normal length. The bottom images in each panel show the length of the muscle.

PECTORALIS MAJOR

A big chest muscle that helps you move your arms, like when you push something. Important for activities like throwing a ball, lifting heavy object or arm wrestling.

MUSCLES ARE THE MOTORS OF THE BODY

The stick figure helps us understand how the human body moves and how the body parts work together. But to make these “sticks” move and transfer energy from one body part to another, something needs to produce power. What provides the power in a person’s body? Yes, the muscles! When we activate our muscles at the right times, they produce and transfer energy through the kinetic chain.

ELASTIC ENERGY IN THE MUSCLES

Muscles can do more than provide energy—they can also store energy in their tendons. This stored energy is especially important in the shoulder during throwing. When your arm is in an extreme rotated position, with your hand and arm far behind your ears (Figure 3B), energy is stored in the muscles of the upper trunk, like the large chest muscle named **pectoralis major** [3, 4].

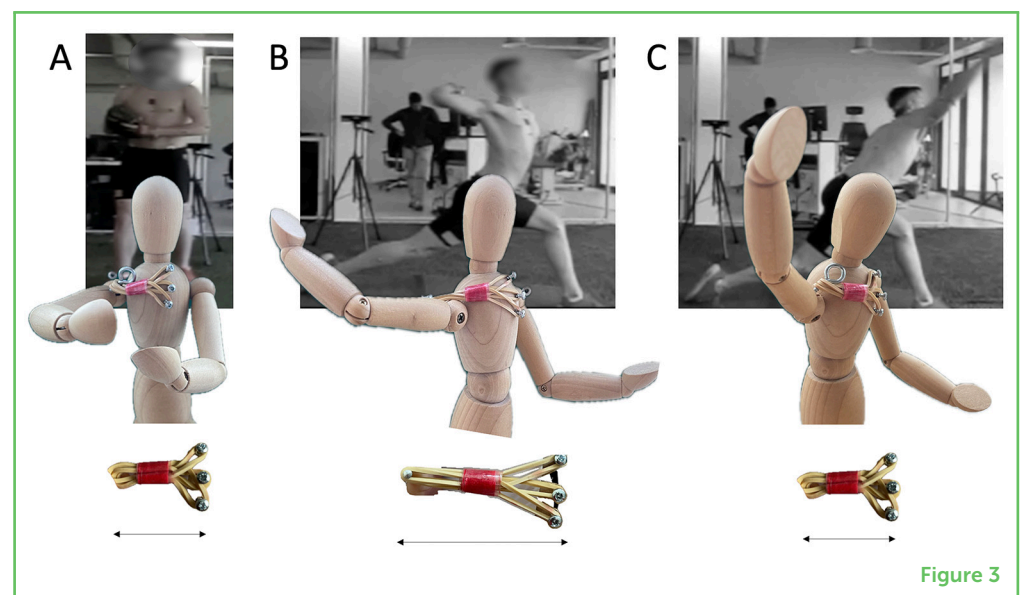


Figure 3

This stored energy is known as **elastic energy**. You can think of it like a rubber band between your thumb and index finger. To understand this concept, we built a model to visualize how this works for the pectoralis major (Figure 3). When you are standing still, the muscle is relaxed, just like the rubber band (Figure 3A). When you rotate your arm behind your ears, the pectoralis major stretches, similar to how the rubber band stretches when you pull it back between your thumb and index finger (Figure 3B). The pectoralis major is now longer. When you accelerate your arm forward, from behind your ears past your face, to throw the ball as fast as possible, the elastic energy in the pectoralis major is released, just like when you let go of the rubber band and it snaps forward (Figure 3C). The pectoralis major muscle then has its normal length again, just as in the beginning of the pitch.

ELASTIC ENERGY

Energy stored in your muscles and tendons when they stretch and release, like a rubber band stretching and snapping back, helping you jump higher or run faster.

LOAD

The amount of weight or force your body must handle when you lift, push, or carry something, like the force on your knees when you pick up a heavy backpack.

LOAD CAPACITY

The amount of weight or force your body can safely handle without getting hurt, like knowing how heavy a backpack you can carry without straining your muscles.

PERFORMANCE VS. INJURIES

What can we do with the knowledge of biomechanics in overhead sports? Athletes aim to find the right balance between performing at their best and preventing injuries. When the kinetic chain works smoothly, it results in a pitch, serve, or throw that releases the ball with high speed and accuracy. Professional athletes are skilled at using the kinetic chain in the right way. They know how to activate and release their strong muscles at the right moment during a throw. Through training, they make their muscles stronger, and they practice optimizing the speed of each body part in the kinetic chain, improving their performance.

There is a downside of training a lot and throwing with great force—it puts a lot of stress on the arm used for throwing or hitting. Combined with a high number of repetitions, this stress can lead to overuse injuries, especially in the shoulder and elbow, which are common in overhead sports [5, 6]. To help athletes avoid overuse injuries, it is important to activate the kinetic chain in the right way. Another important factor is maintaining a good balance between **load**, the amount of force put on your body, and **load capacity**, which is the amount of load your body can handle without getting hurt [7]. This means finding the right balance between training and rest. When this balance is right, muscles, tendons, and ligaments can recover properly. With enough recovery time, your body becomes even stronger after heavy training [5]. Training again too soon, before your body has recovered, can lead to injuries [7].

A WEARABLE EARLY WARNING SYSTEM

In biomechanics, wearable sensors are often used. These are small devices you can put on your body to help track how you move and how hard you are working. Wearable sensors help athletes measure the load on the body. By tracking an athlete's load and understanding their load capacity or the time an athlete needs for optimal recovery, we hope to prevent injuries in the future with an early warning system [5]. This system could help athletes maintain the correct balance between training and rest and alert them when they are overtraining or moving their bodies in the wrong way. Our research group and others are busy developing such wearable warning systems. These systems contain sensors that can be attached to an athlete's shirt and trousers, to measure the hip and trunk rotational speeds, or in a sleeve to measure the arm rotational speed. We developed the PitchPerfect system, which measures hip and trunk rotational speed—watch [this video](#) to see how it works. The Pulse sensor is a different sensor that measures arm rotational speed—watch [this video](#) to see how Pulse works. Engineers, biomechanics, and human movement scientists are developing these systems to reduce injuries and improve performance.

in the future. Do you want to become one of these biomechanical engineers or scientists in the future?

AI TOOL STATEMENT

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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YOUNG REVIEWERS

KONSTANTIA, AGE: 11

Konstantia is an 11-year-old girl who has lived in several places around the world. She loves the *Percy Jackson* and *Harry Potter* book series. She practices karate and participates in track and field. She also speaks three languages. In her free time, she enjoys reading and crocheting. She also likes helping out on her grandparents' farm. Her favorite animal is the wolf because it is courageous, smart, and loyal.

OLIVIA, AGE: 11

Hi, I am Olivia from Germany. I am an 11-year-old girl who loves reading books, playing chess, and playing the piano and violin. I am curious about nature and enjoy watching educational children's shows like "Checker Tobi". I also have lots of fun doing crazy things with my younger sister.

VICTORIA, AGE: 8

Hi! I am Victoria, and I am in 3rd grade. My favorite subject is math. I love reading stories, playing the piano, and dancing. I also like playing chess sometimes. I am super curious about everything around me! I enjoy making crafts, playing with my friends, and spending time with my big sister.

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Prof. Dr. DirkJan (H.E.J.) Veeger is a Dutch scientist working at the Department of Biomedical Engineering of the TU Delft. He studies how our bodies move. He teaches biomechanics at Delft University of Technology, a field of study that tries to understand how the body works, based on the principles of mechanics. He mainly works on the question of how our shoulders and arms work and in sports like baseball and wheelchair sports, but also for shoulder injuries. He has been recognized for his work with a royal award in 2024 for his contributions to science and society.