The Fifteen Second Rep

This article was inspired by one simple question: *when a goaltender is performing a continuous skating drill at full speed, how long should the drill last?* This article will be a basic look at the specific physical demands of the position and ways to target these demands in training.

Power-skating should be a crucial aspect of any goaltenders training regimen. The term "power-skating" implies two things: Power, which is synonymous with other terms like explosive movement, agility, weight transfer, quickness, and foot-speed, and Skating which as we all know is a crucial backbone to the success of any goaltender with their ability to get around in control. In kinesiology, power generally refers to generating maximum force as quickly as possible. Generating maximum force is something we are all able to do, but it is important for goaltenders to be able to shorten the time in which they generate this force to be able to explode across the crease when it counts. Goaltenders train to perform quick, explosive movements, with quick and agile direction changes from forward to backward, side to side, up and down, or any combination of these dimensional movements.

Acceleration

Just what is acceleration and why is it important here? Goaltenders need to be able to accelerate from stationary to full-speed, or full-speed in one direction to full-speed in another direction. As mentioned in the previous paragraph, goaltenders have to be able to be able to generate maximum force between their skate blade and the ice in a very short period of time when pushing to a new angle for a quick shot.

Force is a product of two factors: The mass of a goaltender (how much the athlete weighs with all the gear on) and the rate at which they are able to accelerate from one velocity to another. This is represented Newton's second law of motion in the well-know formula

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

Over the course of a game or practice, a goaltenders mass stays relatively constant (assuming proper hydration and no deer hair stuffed in the pads), so the variable in the equation is the rate of acceleration a goaltender is able to use when moving.

Acceleration is <u>not</u> the same thing as speed. Speed (or velocity) is a constant term that describes the rate at which something is moving at a particular instant, while acceleration is a *derivative* of velocity, meaning it describes the rate at which the velocity *changes*. This change can be positive acceleration, like accelerating from a stationary position to some velocity, or negative acceleration like coming to a stop or slowing down. In both instances there is an initial velocity and a final velocity, but the important factor in the acceleration formula is the *time* in which this change in velocity occurs.

$$a = \frac{(speed_{end}) - (speed_{start})}{time}$$

The time in which this change in velocity occurs is the most important variable here. Assume the (arbitrary) final velocity is 30 m/s and the initial velocity is 0 m/s, in other words the athlete starts moving from a stationary position. If this change in velocity happens in a longer time period like 5 seconds, that gives us an acceleration value of 6 m/s^2. Now shorten the time window to get to the same final velocity to say 2 seconds. That gives an acceleration value of 15 m/s^2, a significant increase just from shortening the time. This means that shortening the amount of time to reach a certain velocity means an increase in the rate of acceleration, which can be a very good thing in the world of goaltenders. (Keep in mind that the time it takes to execute a quick T-push or butterfly slide is significantly less than 2-5 seconds, those values were just used as examples.)

So we see the importance of decreasing the time to reach a maximum velocity with regards to acceleration. Because Force is a product of mass and acceleration with a goaltenders mass staying the same, a higher force output depends on a higher rate of acceleration, which depends on decreasing the time it takes to reach a maximum velocity.

Linking this physics and calculus mumbo-jumbo back to goaltending, it essentially translates to "A quick, explosive goaltender is one who is able to reach a high rate of speed in a short amount of time". When we're in the crease and have to get from one angle out to another to make a save, **time is everything and shooters don't wait**. When the game is on the line and we have to be on a new angle, we have to be able to get there as fast as possible while ideally staying as controlled as possible. This means being able to accelerate up to full speed in a small time window, which might be pushing in to a butterfly slide from standing-and-set to follow a rebound, or stopping your slide in one direction and exploding to a slide in the opposite direction to follow a pass, deflection, rebound, etc. The next question is, what measures can we take to properly train for this?

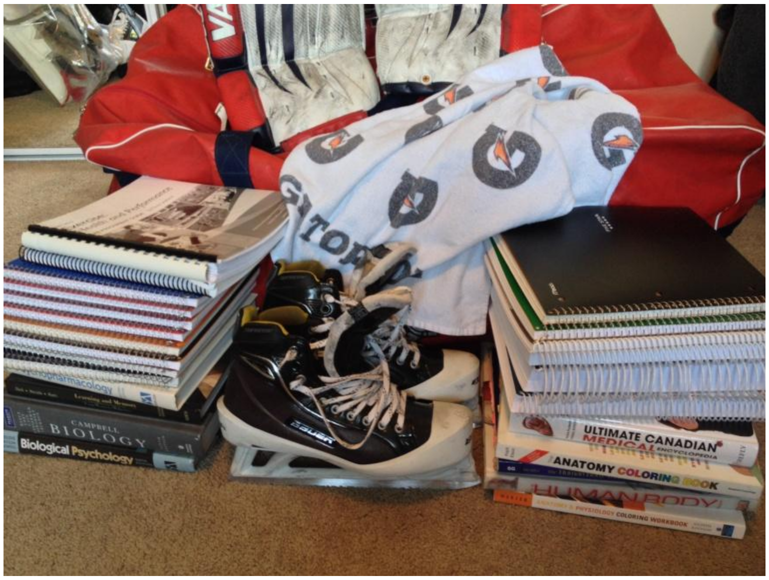
SAID Principle

If you want to be fast, train fast. This is essentially the underlying concept of the SAID Principle (Specific Adaptations to Imposed Demands). When training goaltenders, we obviously want to be efficacious in the sense that we have moved the goaltenders outside of their comfort zone during training which calls for a neuromuscular adaptation in some way. What this means is that if a goaltender wants to stay the same speed, they should train at a speed that is already comfortable to them. If a goaltender wants to improve and get faster, they have to train at a higher speed and make their body adapt to working at those higher speeds **and higher force outputs**, quicker weight transfers and direction changes. Essentially, the goaltender has to get *comfortable with being uncomfortable* if they want to experience constant improvement. It is not always a fun, comfortable, or enjoyable type of training, but the benefits to athletes like goaltenders are so numerous that the components of the SAID principle need to be incorporated in to physical on-ice workouts.

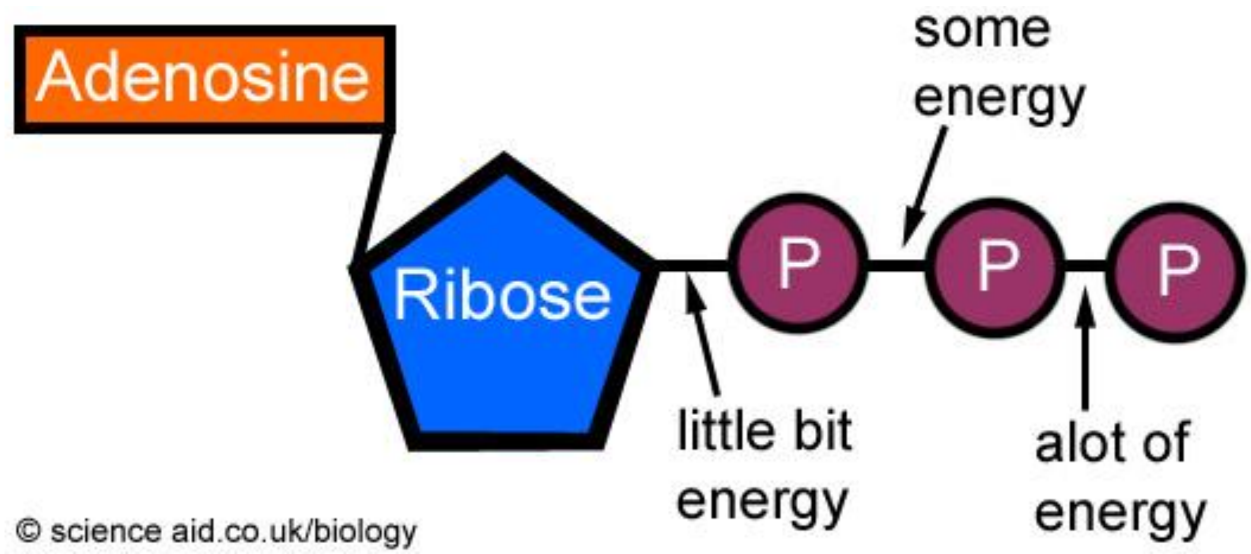
Not every drill done on the ice is done to increase a goaltender's acceleration, nor should they be. Just as drills can target something technical or tactical, there is also a component for state-specific physical fitness when moving with the resistance of all of the equipment that cannot be done off the ice in the gym. It is during these physical fitness drills designed to increase foot-speed, quickness, agility, etc. that the proper energy systems should be a major focus. Some energy systems are responsible for sustaining movements for long periods of time, and others are responsible for short duration, high-speed, high-intensity movements. So what is an "energy system" and how can we target them?

Energy Systems

Bear with me as I comb through my old kinesiology resources now to provide a basic and hopefully digestible explanation of human energy systems, which will lead to why it's important for a goalie (coach) to know about them.



For us to do any kind of movement, we have to call on one of our body's energy systems. No movement is free, every time we do some movement as small as blinking or as big as an Olympic lift, our muscles are driving that movement, and our muscles need fuel. Just as a car uses gasoline and oxygen in a combustion process to power the wheels, our muscles use a molecule called Adenosine Triphosphate (ATP) as the immediate source of fuel to power our muscles. The cool thing with ATP is that the molecule is held together with high-energy bonds, and the energy released when these bonds are broken is essentially what drives our muscles.



But we don't have an unlimited supply of ATP, and it takes some time to re-fill our ATP stores as our muscles are working. If muscle contraction is to continue, our bodies must continuously rebuild the ATP molecule, and replenish the ATP stores. The metabolic processes for producing ATP can be broken down in to two main categories: Aerobic, and Anaerobic.

Aerobic essentially means a chemical process that requires the presence of oxygen delivered by the bloodstream.

Anaerobic is just the opposite, it means a process that does **not** require the presence of oxygen delivered by the bloodstream.

Within these metabolic processes are the three major energy systems:

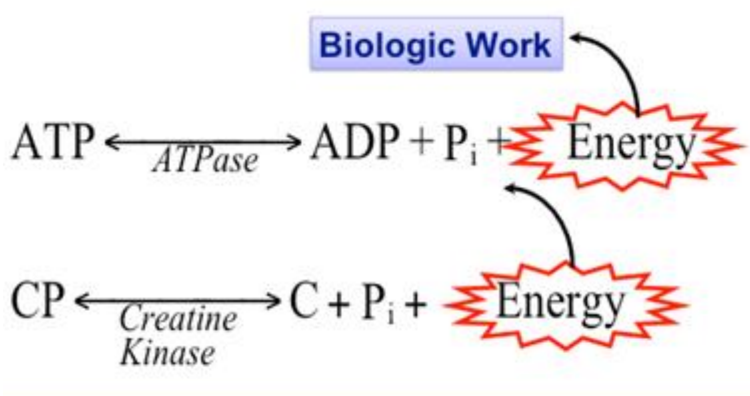
(Some researchers suggest branching these in to 4 or 5 systems depending on the percentage of use, but for the sake of this article we'll assume the three major categories)

1) *Oxidative system*- The aerobic system. This is the system used when the demand of the exercise is low enough that there is enough oxygen present to allow the required ATP to be produced before used up by the muscles and completely depleted. Think low-intensity, long-duration movements like walking, or in the case of goaltenders doing a light warm-up skate at 50% speed. The aerobic system also has access to a wider variety of fuels, mainly fats, carbohydrates, and proteins.
2) *Glycolytic system*- An anaerobic system that uses glucose as the primary fuel. The breakdown of glucose (and lactate) here produces about 2 or 3 molecules of ATP. This

anaerobic glycolysis is able to rapidly produce ATP to help meet energy requirements during more intense exercise, when oxygen demand is greater than the body's ability to transport and supply oxygen. However, this high rate of ATP production cannot be sustained for very long, only about 60 to 90 seconds.

3) *Phosphagen system*- The rocket fuel system of our bodies. As the name implies, the phosphagen system makes use of the phosphate bonded to the ATP molecule. The third phosphate is held to the ATP molecule by a very strong, high-energy bond. Once this third phosphate is released, ATP turns to ADP (Adenosine Di-Phosphate), with the energy from this bond being used to power the muscles. Our bodies have a limited amount of ATP available for use in high-intensity exercise, and must be replenished once depleted. ATP is stored right in the muscle fibers, providing an immediate supply of energy. When performing an all-out power exercise like sprinting (or movement drill like full-speed butterfly- recover- T-push- repeat), our muscles only have enough ATP stored to sustain this type of exercise for about 10 seconds. Thus, **this phosphagen system dominates for high-intensity, short duration exercise.**

What this all translates to is that an anaerobic breakdown of fuels produces far fewer ATP molecules (2-3 molecules per molecule of "fuel") than aerobic breakdowns, which produce 36-40 molecules of ATP per molecule of "fuel". **The takeaway message is that the ATP fuel stores are depleted much faster than the can be replenished during intense exercise**, where low-intensity exercise produces a near-continual source of fuel that allows us to sustain the exercise for much longer.



Source: Leyland, 2010.

Now take a midget or junior aged goaltender (15 to 21 years old). By this stage in their careers, the basic movements that often need to be done at full-speed like butterfly slides, t-pushes, shuffles, and recoveries should be practiced enough that the movements are fairly automatic and require minimal conscious thought to execute the subtle mechanics of the movement. The technique will require fewer technical changes as they get older, so most of the training will be done at becoming faster and more efficient.

On the other hand, younger goaltenders will still need to take the time to get the reps in to build a proper technique. These technical adjustments require more conscious intervention for the smaller details like performing the proper movement sequence (leading with the head, hands, stick, getting a proper rotation, recovering with the proper leg, etc). Speed isn't as much of a priority as it means sacrificing proper habits at an early age.

***With the older goaltenders, there are going to be times in practice where the focus is on getting faster and more explosive with our basic movements**. We can design any number of movement drills to target this element, but I believe we have to be aware of the capacity of our energy systems when executing the drills. Skating drills that call for "game-speed" movement at 100% output designed to increase power should be timed to actually increase power! The drills we use have to be valid and improve what they are actually meant to improve. **Because this type of movement is almost exclusively reliant on the anaerobic phosphagen energy system, we must be aware of the fact that they are depleting their ATP stores in about 10 to 15 seconds**. If a drill like this is timed for 60 seconds or longer, the goaltender physically cannot maintain the high rate of speed they start at for that amount of time, **and only the first 25% of the drill is done at the desired speed. This means the majority of the drill (~75%) is done at a slower speed than the goaltender is trying to perform at!** Just because the goaltender is sweating and breathing hard, it doesn't mean they are actually getting faster. They might be improving the capacity of another energy system like their Oxidative system (which is by no means a bad thing, unless it is the phosphagen system that is the focus), but this will have little if any impact on their explosive foot-speed. **Train fast, be fast. Train slow, stay slow**. **Performing a 15 second drill at 100% speed will be far more beneficial than performing a 60 second drill at 70% speed if the intent is to increase foot-speed!**

To clarify, I am not suggesting that goaltenders must only train using drills lasting 10-15 seconds. Like most sports, we use all of our energy systems and goaltending is no exception. Much of the game is spent relying on either the Oxidative or Glycolytic systems, but it is important to recognize the type of movement that relies on these. Any movement that can be sustained for a long period of time will rely on the Oxidative system (watching the play at the other end, skating out to stop dump-ins while on the power-play, following the puck as your defensemen regroup in the neutral zone, etc.). Plenty of movement is also reliant on the Glycolytic system, something more intense that can only be sustained for a couple of minutes like holding a deep stance following play in your d-zone like during a penalty-kill. It is important for goaltenders to train in all three energy systems and have a good aerobic base and muscular endurance, but we have to know that when training a specific component like explosive speed, it is trained differently than the other energy systems.

Table 6.2
Percentage Usage of Three Energy Systems by Duration

Duration	% Phosphagen	% Glycolytic	% Oxidative
5 seconds	85	10	5
10 seconds	50	35	15
30 seconds	15	65	20
60 seconds	8	62	30
2 minutes	4	46	50
4 minutes	2	28	70
10 minutes	1	9	90
30 minutes	Negligible	5	95
60 minutes	Negligible	2	98
120 minutes	Negligible	1	99

Data from McArdie, Katch, & Katch, 1996, p. 129 and the Coaching Association of Canada, 1990.

Different sports rely on different energy systems, but that is not to say that one of the three energy systems is either relied on 100% or not used at all, just that the ratio of use between the three systems changes. Here is a simple chart describing the reliance of some sports on the different energy systems:

Table 6.9
Primary Metabolic Demands of Various Sports

Sport	Phosphagen system	Anaerobic glycolysis	Aerobic metabolism
Baseball	High	Low	—
Basketball	High	Moderate to high	—
Boxing	High	High	Moderate
Diving	High	Low	—
Fencing	High	Moderate	—
Field events	High	—	—
Field hockey	High	Moderate	Moderate
Football (American)	High	Moderate	Low
Gymnastics	High	Moderate	—
Golf	High	—	—
Ice hockey	High	Moderate	Moderate
Lacrosse	High	Moderate	Moderate
Marathon	Low	Low	High
Mixed martial arts	High	High	Moderate
Powerlifting	High	Low	Low
Skiing:			
Cross-country	Low	Low	High
Downhill	High	High	Moderate
Soccer	High	Moderate	Moderate
Strength competitions	High	Moderate to high	Low
Swimming:			
Short distance	High	Moderate	—
Long distance	—	Moderate	High
Tennis	High	Moderate	—
Track (athletics):			
Short distance	High	Moderate	—
Long distance	—	Moderate	High
Ultra-endurance events	Low	Low	High
Volleyball	High	Moderate	—
Wrestling	High	High	Moderate
Weightlifting	High	Low	Low

Note: All types of metabolism are involved to some extent in all activities.

The important note here is at the bottom where it states "All types of metabolism are involved in some extent in all activities". Just because one system might be dominate in a particular movement, it doesn't mean the others are shut off. Some movement calls for a lot of power very quickly (exploding back to the post to get a pad on a rebound/ deflection/ bounce off the boards), in which case the phosphagen system would be used. Other types of movement call for a smaller amount of power over a long period of time (sitting at a desk to type out a 12 page article), so the oxidative system would be used.

Anaerobic Phosphagen Drills: Duration and Recovery Time

When we do decide that it's time to work on our foot-speed and explosive movement, what is the work to rest ratio? As mentioned before the research suggests that an extremely high intensity event that relies exclusively on the phosphagen system will deplete ATP in 0-6 seconds. I would suggest it would be difficult to find a movement that would deplete a goaltender's ATP in 6 seconds, and that this type of event would be something more along the lines of an Olympic lift that requires the athlete to move a constant load with full-body involvement. Goaltenders moving at full-speed probably don't deal with enough resistance to deplete the ATP in 6 seconds, which is why the movement can be sustained at peak output for a bit longer like 10-15 seconds.

I would lean more towards 15 seconds as there will be a time in between the actual explosive pushes that the goaltenders have to regain balance and shift the center of mass appropriately to allow a maximal exertion in another direction. But another benefit of training fast is these weight-transfer shifts will be forced to happen quicker and more efficiently, causing a neuromuscular adaptation so essentially these faster shifts become more comfortable over time.

Table 6.8
Five Areas of the Energy Continuum

Duration of event	Intensity of event	Primary energy system(s)
0-6 seconds	Extremely high	Phosphagen
6-30 seconds	Very high	

In the literature, the research suggests a work to rest ratio of between 1:5 and 1:20. The Olympic lift would probably require the longer rest interval, so for an activity that lasts 6 seconds the rest interval would be about 2 minutes**. Depending on the skating ability of the goaltender and their ability to move in such a way that they are actually able to deplete their ATP in a 15 second window, they should be resting for anywhere from about 75 seconds to 3 minutes.** For goaltenders midget and older, a good place to start is likely around 15 seconds on and 2 ½ minutes rest if the intention is to increase explosive foot-speed. Some judgment is involved when determining the skating ability of the goaltender and if they are agile enough to be able to shift their balance quick enough to explode in another direction and deplete their ATP in that amount of time. Younger goaltenders who still need to think about the mechanical nuances of their movement won't be able to reach this peak output the same way they would if they were sprinting up a set of stairs, as the movement is not yet automatic enough to perform without thinking, and the shifts in balance take slightly longer as well. This agility will improve over time if drills are done at the proper work to rest ratio to allow the goaltender to move at whatever their full-speed is at that time.

As for the number of sets, 3 or 4 is a good place to start but there are other factors at play here. One factor is limited time, so with a 2-3 minute rest the goaltender might run out of time allocated to them during a team practice or ice-time. Also the goaltender will start to fatigue after a few sets and the top speed at the onset will slowly start to decrease.

TABLE 6.10
Recommended Recovery Times for Various Processes

Recovery process	Minimum	Maximum
Restoration of ATP & CP	2 min	3 min
Repayment of alactacid EPOC (rapid phase)	3 min	5 min

TABLE 8.1
Interval Training Variables

% of Maximum Power	Primary System Stressed	Work Interval Time	Range of Work Interval/Rest Interval Ratio
90–100	Phosphagen	5–10 s	1:12 to 1:20
75–90	Glycolytic	15–30 s	1:3 to 1:5
60–75	Glycolytic and Oxidative	1–3 min	1:3 to 1:4
20–35	Oxidative	>3 min	1:1 to 1:3

So after all that, my takeaway message is this: **Train fast, be fast. Train slow, stay slow.** With the skating drills done to focus on increasing foot-speed, explosive power, weight transfers and direction changes, it is important to work smart as well as hard. Don't expect to be able to perform a maximal exertion drill at 100% speed for 60 seconds. If the intent is to become faster and force your body to be able to perform at a higher speed than it is currently used to, the drills must be designed to allow for this. **If doing a 60 second maximal-output skating drill is done at top speed, it will only be for the first 10-15 seconds and rapidly decline for the remaining 45-50 seconds. The goaltender is training to move at this slower speed as they have spent the majority of the drill back inside their comfort zone, which isn't facilitating a lot of improvement.**

I hope this article was informative and useful in some way, and didn't put anyone to sleep or bring back any bad memories from high-school science classes. For further discussion, contact me via the custom submission page or ek.coretexgoaltending@gmail.com

Thanks for reading!

Evan Kurylo

Most of the information on ATP and energy systems is from Anthony Leyland, M.Sc., kinesiology Professor at Simon Fraser University. Bio at http://www.sfu.ca/~leyland/. Literature available upon request, including referenced information, charts, and graphs.

All of the information is taken from university lectures, academic articles, courseware, personal contact with physiology professionals, and relevant textbooks from several kinesiology and neuroscience classes from Simon Fraser University. All references are available upon request. Information is from academic, scientific, peer-reviewed sources, and not simply the result of a Google search or speculation.