Hockey 'Fitness' Testing

for adolescent players

The good.
The bad.
The irrelevant.

A little history ...

The inglorious history of hockey fitness tests

Hockey endurance is nothing like marathon endurance.

HOCKEY ENDURANCE is the maintenance of skating speed, quickness, and agility, along with stick skills, decision-making, strength, and gritty competitiveness – each shift and for an entire game.

Picture a fast shift in the Stanley Cup playoffs – the bursts to full speed, physical battles, stops, starts, turns, accelerations, decelerations, and coasting when it's smart.

Running or bicycling in marathon competitions also requires great endurance, but a different kind. It doesn't include physical battles or random sprints to 100% speed. So why should a hockey player's endurance be evaluated from a test for marathoners? Why monitor maximum volume of oxygen consumed per minute (Max Vo_2) while running or biking?

The answer is simple: hockey fitness can NOT be evaluated this way,

but it has been for 70 years, and it still is (eg: NHL combine). In 1978, on the basis of bicycle tests it was stated in the Medical Tribune (Toronto) by a prominent physiologist, that Hockey is a 'physiological cakewalk.' So, extra fitness training on a bike was recommended. Five years later, Howard Green's team showed that if testing was done on-ice, there was no advantage to adding bike training after practice for the entire season (Daub 1983).

If teenagers do slow 'cardio' as a workout – biking or jogging – that's time and energy that could be invested in building speed and hockey-endurance instead of slow habits.

Of course, kids are encouraged to run or ride bikes for Fun and Mobility.

But training workouts need to be fast intervals.



Whether we call this a 'cardio-respiratory' test or leave the lower body out of the photo – it's the same mistake we've made for 70 years of testing hockey players: ignoring what the legs are doing …

… as if all that matters in a fitness test is what the heart and lungs contribute, and it doesn't matter whether he is skating, swimming, running, biking … or just sitting.

Of course, it matters. Metabolism in Gluteus Medius and Maximus, the large muscles of skating hip abduction, contributes a great deal to expired CO_2 and uptake of O_2 measured at the mouth piece.

Hockey Fitness Requires HIIT {High Intensity Interval Training}

So, fitness testing must measure the effects of HIIT

There are no substitutes; Slow 'Cardio' doesn't prepare you for hockey endurance as HIIT does, but both are important for a long, healthy life!!!

How laboratory testing led to mis-characterization of hockey fitness

***Swimmers said**, we don't run or ride bikes for long distances, so if you test, please test what we do.*

***Hockey assumed** it was known that in every shift of a hockey game there are:*

- *High-Intensity Intervals, not slow, steady distances;*
- *frequent short sprints to full speed – like a 40-yard dash;*
- *accelerations, decelerations, changes of direction;*
- *stick skills and creative decisions;*
- *physical battles for the puck, heavy hits – and – by the way;*
- *games are played on skates, not stationary bikes or treadmills.*

Does it matter?
Adolescent players have been advised to train incorrectly for Hockey endurance for 60 years. It's called 'Cardio.'
High Intensity Intervals on-ice are required in testing, training.

Can mathematical manipulation of research data change it's meaning?

Beware! It is common to report research findings after the original data has been massaged or 'arithmetized' beyond recognition – altered by multiplying, dividing, or adding body mass. This can drastically distort relationships (comparisons, correlations) and mislead athletes and coaches who use the information to plan training programs.

Example 1:

Suppose player A gets beat in short sprints when (s)he races player B, but A is much heavier – actually obese. When body mass is multiplied by average acceleration, it turns out that A generates more force (F=m•a). If told to train for force (or power) you might respond, "I'd rather train to win the race."

Example 2:

Player A above doesn't jump as high as B, but if body mass is factored in by Sayer's regression equation (1999), player A might claim to have greater power – with a lower jump. This has biased plans for heavy strength and power training. It is jump height, not power, that is highly related to skating speed, quickness, and agility.

Example 3:

In fitness tests $V0_{2\ Max\ or\ peak}$ is most often expressed as a fraction (ml of O_2 per minute / body mass). Researchers might not be careful to include the units each time in their report. So we often ignore the fact that this fraction is as much a reflection of body mass as oxygen consumption.

So, what does this mean? If a player loses body weight, the fraction is increased, and (s)he'd be patted on the back for improving $Vo_{2\ max}$ without having greater O_2 uptake.

Furthermore, the range of body weights on a football, basketball, or hockey team is too great to compare individuals correctly using this criteria, or to compare aerobic fitness of Hockey players to marathoners.

3/4 is not 3

If a class of fourth graders is told to write the fraction 3/4, no one would write just the number '3' . Considering a similar fraction (squat strength / body mass) it is common for researchers to simply report 'squat strength,' and not mention the denominator body mass.

AI steered me to a research article that claimed to find a relationship between maximum squat strength and skating speed in a group of elite teenage hockey players. That's what the article said; but in fact they found the fraction (squat strength / body mass) was related to skating speed, not squat strength by itself. Ignoring the denominator, body mass, is just plain wrong. And whoever reads this title and ignores the faulty math throughout the article – is led to believe that squat strength is related to skating speed.

Other researchers and strength coaches might assume the title is factual. They might recommend maximum squats as a way to skate faster. Similar neglect has misled athletes for decades.

In fifty years, our research data never found that squat strength is related to skating, but body mass is ! Heavier players were slower. Taller players were also slower. Of course, there are always heavier or taller players who are fast (Tom Wilson for example). But this consistent relationship is one reason why the fraction (squat strength / body mass) is related to skating speed: THE DENOMINATOR IS!!!

Squats can be a valuable lift. of course.

Squat strength and stability are valuable for contact in a game. But there is little reason, and no evidence to believe they build speed. Why? (1) The range of motion does not include the large muscles that abduct the leg at the hip. (2) Holding the bar prevents arms from multiplying lower body force naturally. (3) Like all lifts, squats are slow, and there's deceleration in the last half of the motion; acceleration is required.

One solution? Supersets alternating one- or two-leg jumps with squats.



What to expect from High Intensity Interval Training on the ice and off

- √ **Greater skating speed, quickness, agility for the most important games.**
- √ **Speed while executing stick skills.**
- √ **Quicker decision-making, required by, and learned from, increased speed in Overspeed practices.**
- √ **Integrated whole-body strength, not just strong individual muscles built by isolating them.**
- √ **Heart, respiratory, metabolic improvements earlier and greater than from slow distance training.**
- √ **Increased hockey endurance = maintenance of all the above.**

Fast-twitch (type 2) muscle fibers are recruited

Greater force production: FT muscle fibers and nerves undergo structural improvements from HIIT training – visible microscopically – in order to increase speed and strength.

Greater endurance capacity of FT muscle fibers was considered unlikely before the 1970s when George A Brooks' lab began to show that lactate is an important fuel, not metabolic poison as the athletic and scientific communities believed (Brooks, 2009). Later, Brooks and others (Torma 2019) showed that HIIT training added mitochondria, a process called biogenesis.

This is a game-changer!

It is in the mitochondria where enzymes of aerobic metabolism of lactate produce much more ATP than from anaerobic glycolysis!!! (Discussed next).

Bottom line: Limiting the depletion of muscle glycogen storage for long games also increases endurance on consecutive days

Lactate levels in the blood are commonly used to determine if a given workload is 'anaerobic.' Is it a metabolic poison?

No. Lactate is an important fuel during hockey games, and fast interval training prepares the body to recycle it more efficiently.

Note: The end product of glycolysis (the breakdown of Glucose) is Lactic Acid (and pyruvate to a lesser extent). Lactic acid splits almost entirely in the muscle's water into Lactate$^-$ and Hydrogen (H^+) ions.

It is not my intention throughout this book to duplicate the volumes *written about the biochemistry-physiology of exercise. We'll discuss Lactate metabolism, because it is often misrepresented or left out of discussions, and is super-important for hockey.* ***Feel free to skip paragraphs (1-5).***

To review some of the metabolic factors that are commonly discussed, look up the following topics in Khan Academy videos or Google. Focus on the bottom line, the beginning and end of a metabolic pathway, not the names of enzymes.

1) *Compare Type-II Fast-twitch muscle fibers (FT) to Type-1 Slow-Twitch (ST) fibers. FT fibers are the light-colored ones (like the white meat of a turkey) that contract-relax faster and more powerfully. They don't have the endurance of the reddish ST fibers. Near maximum effort is essential to recruit FT fibers to improve speed, strength, and explosive acceleration. Appropriate interval training at young ages can increase blood supply and enzymes for improved endurance in FT fibers, giving them the best characteristics (endurance and explosiveness) of both ST and FT fibers.*
2) *Adenosine-tri-phosphate (ATP) supplies energy for muscle contraction (and for other cell functions in the body). It is the 'cleaving off' of the 'third' phosphate from ATP, that provides energy. This leaves ADP (…-di-phosphate) and AMP (mono-P), which must be re-converted to ATP by various metabolic pathways (below).*
3) *Breakdown of fuels. Look up 'fatty acid or protein catabolism,' glycogenolysis, glycolysis, the Krebs cycle, electron transport chain. Don't be distracted by details. Just understand the beginning and end of each part – the significance of that part in energy supply.*
4) *Some ways inorganic phosphate (PO_4^{3-}) is added to ADP to return it to its high energy state, ATP: (a) For short bursts of exercise, like sprints or jumps or lifts, Creatine Phosphate (stored in the muscle) donates it's phosphate to ADP. (b) Glycogenolysis is the breakdown of Glycogen (carbohydrate stored in muscle) to Glucose; then Glycolysis is the catabolism of Glucose to Pyruvate or lactate for (c) Aerobic metabolism of pyruvate or lactate in the mitochondria (see Khan Academy for video details of the Krebs cycle and the electron transport chain). (d) Fat or protein catabolism generates energy aerobically, the final steps similar to those for Glucose. The fate of Lactate will be discussed on the next page. Given the intermittent nature of hockey, it is like no other sport in terms of energy metabolism.*

5) *Hydrogen ions (H^+) are simply protons split off from Lactic Acid. They would increase the acidity of blood dangerously if not for the buffering system, in which bicarbonate (HCO_3^-) already in the blood combines with (H^+), and through chemical reactions (H_2CO_3 is an intermediate) eventually produces Carbon dioxide which speeds up breathing and is exhaled with each breath. The effectiveness of this buffering system at high workloads is one of many ways to delay fatigue.*

Lactate metabolism is an important factor in 'hockey conditioning.'

An adaptation that is often left out of the discussion, is the productive use of Lactate for energy with increased training **intensity**. For rather technical reviews, G.A. Brooks *(2009, 2024),* and Gladden *(2004,2008)* have discussed the history and evolving perspectives on blood and muscle lactate held by physiologists over the past century. Because high levels of lactate exist in the blood as exercise intensity increases, it was incorrectly assumed that lactate was the cause of fatigue. This was no more correct than to assume high heart rates cause fatigue, simply because HRs are high. It is not uncommon to hear fitness gurus speak of distinct aerobic or anaerobic levels of work. This is a misnomer.

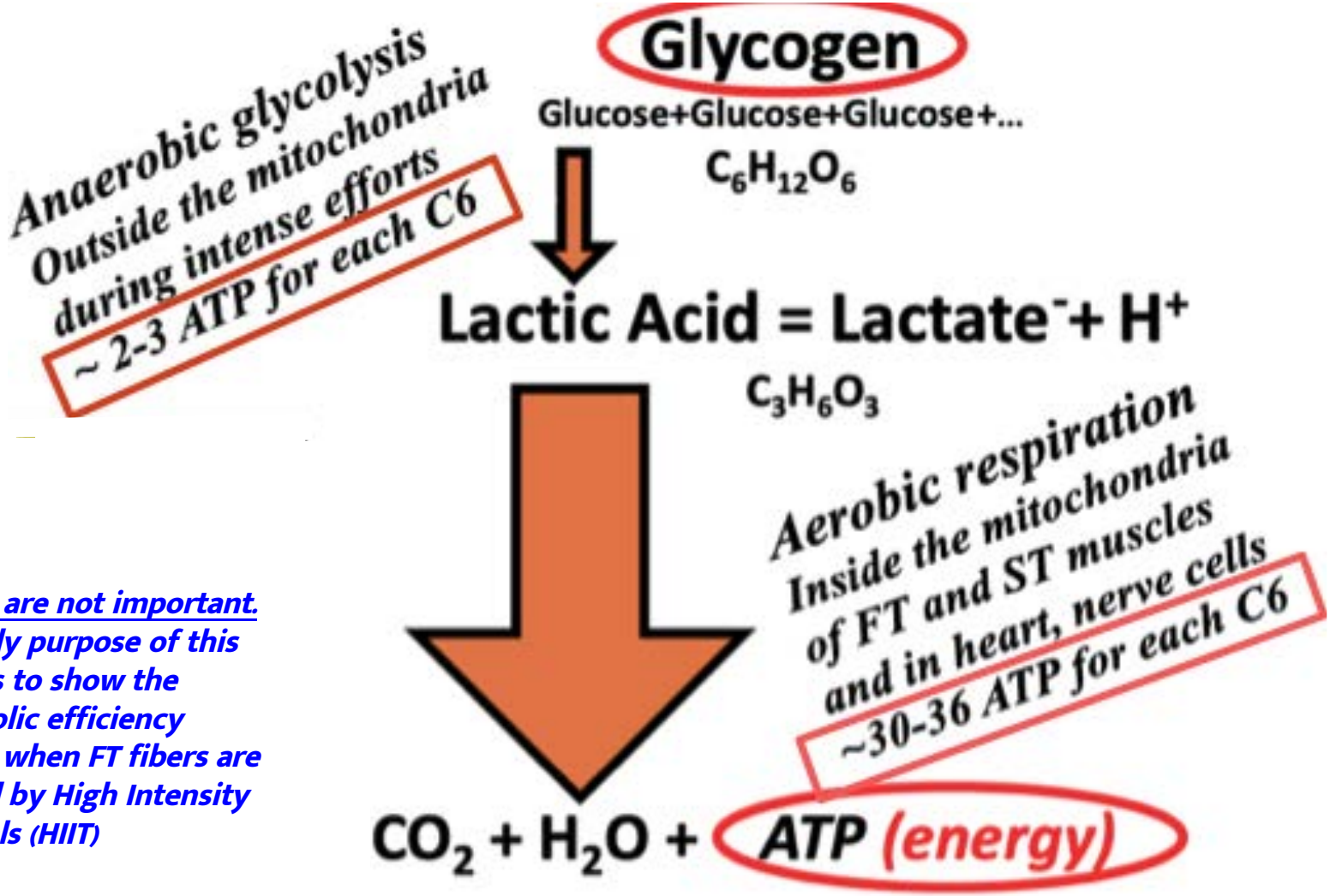
Both types of metabolism occur – to different extents – at every workload. Aerobic metabolism doesn't end at a certain high intensity, and certainly slow-twitch muscle fibers do NOT just take a break when a person is exercising at these highest levels. All hands are on deck, of course when workloads are near maximum. High-intensity exercise, given the pseudonym 'anaerobic work,' occurs every shift of a hockey game; yet oxygen utilization might reach a maximum. All muscle fibers (Type-1, Type-2, and adapted Type-2 oxidative fibers in between) are presumably operating near capacity when effort reaches maximum.

More recently, with modern (radioactive tracer) technology, it has been shown that lactate can be: (1) a fuel in muscle cells that produced it anaerobically if they have sufficient mitochondrial enzymes, (2) shuttled in the blood to other cells like slow-twitch muscle (Type-1), and to nerve, glial, liver, brain, and heart muscle cells; (*Brooks,2009; Gladden,2008; Rogatzki,2015)*, **or**, (3) converted back to Glucose in the liver (Cori-cycle) *(Brooks,2009; Gladden,2004)*.

Hockey endurance is dependent to a great extent on how efficiently we can recycle Lactate aerobically. The more skating-specific interval training we do, the better equipped the Fast Twitch (type2) muscle fibers become, because mitochondrial enzymes are enhanced.

Lactate shuttle: *mitochondrial enzymes burn lactate as a fuel aerobically, in heart, nerve, and ST muscle – also in FT muscle fibers that have been HIIT trained.*

Notice how much more energy (ATP) is produced aerobically!!!



Details are not important. The only purpose of this chart is to show the metabolic efficiency gained when FT fibers are trained by High Intensity Intervals (HIIT)

College Pre-season Dryland Training Study !!!

Six weeks of HIIT {*High-Intensity Interval Training* 3x per week} improves on-ice and off-ice explosiveness, plus lab and skating measures of *'Fitness'*

After 6 weeks of high speed dryland training by a college hockey team, tests showed improvements in off-ice explosiveness: (40-yard dash, vertical jump, Wingate power). This was the focus of each workout *(Blatherwick, Knoblauch 1989).*

Skating acceleration and endurance also improved, even though there were no organized skating practices during this time.

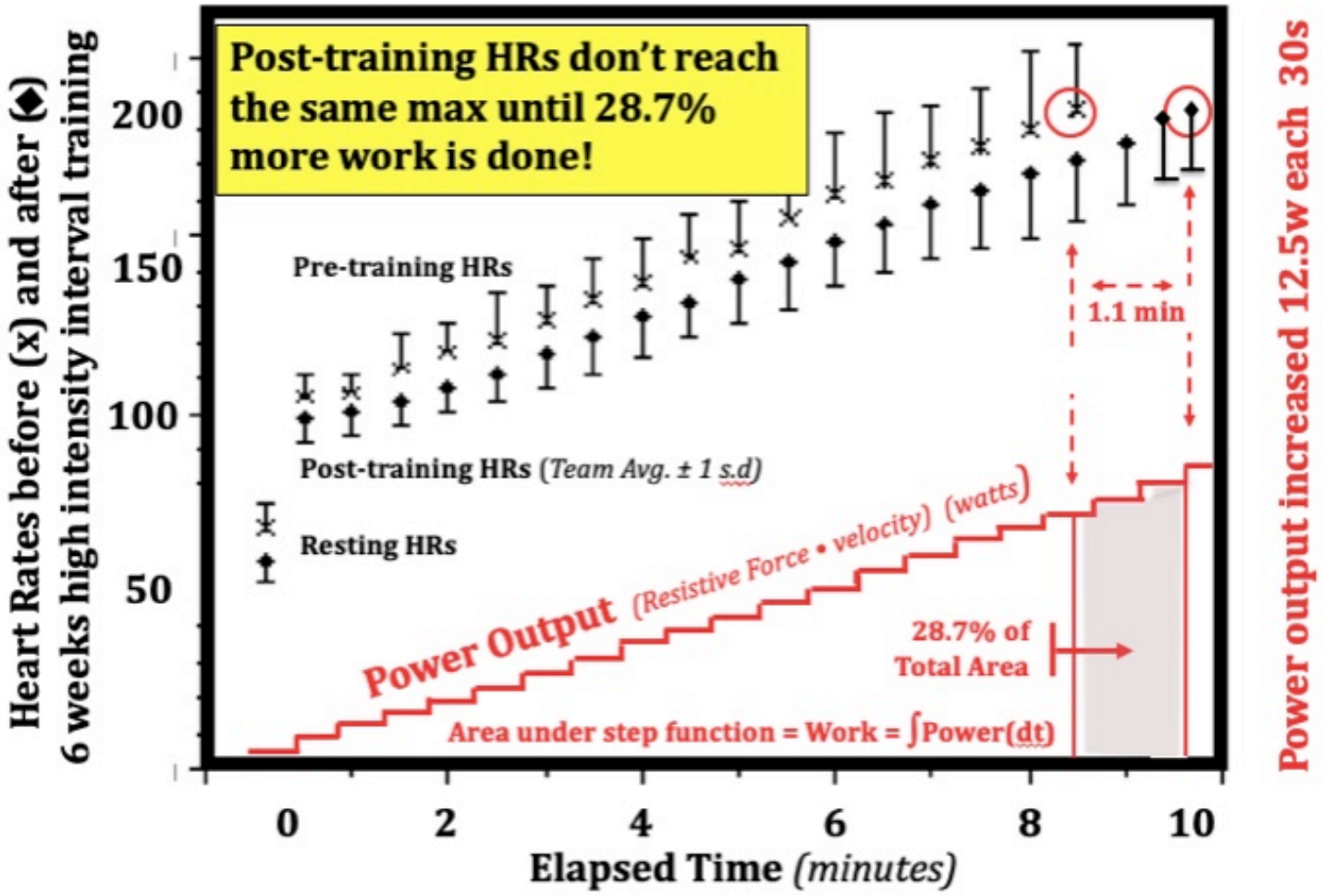
What was not expected were the significant improvements in laboratory measures of: (1) Cardiovascular efficiency and (2) Total Work Capacity (aerobic+anaerobic metabolism) a remarkable result given that bike tests under-evaluate a skater's true metabolism.

In all training sessions, short sprints were emphasized early in the workout (6-10s : starting every 45-60 sec), longer sprints toward the end (20s work : 100s rest), intense uphill sprints (6-12s work : 60s rest), and a variety of weighted and unweighted squat jumps (one- or two-legged). Workouts were 3 times per week, lasting 60 minutes in the first week of training, and 90 minutes by the sixth week. These were extremely intense interval workouts with 100% effort on each sprint or jump.

Improvement was seen comparing Pre-Post stationary bicycle Graded Exercise Tests designed to measure endurance, even though it was not a priority in this training.

Of all the improvements measured during the Graded Exercise Test, the most important for hockey endurance is TOTAL WORK DONE increased by 28.7% even though Max HRs were identical in the Pre-Post testing. Total Work is a function of both aerobic and anaerobic metabolism – including the ability to shuttle and use Lactate for aerobic energy production. This recovery ability is super-important in a hockey game and season.

On a traditional graded exercise test (GXT on a bike) more work is done, and heart rates are lower after six weeks HIIT training 3x/wk. All off-ice intervals were designed to improve explosive skating.



This is why two US Olympic Gold Medal teams trained with HIIT

Physiological Efficiency is evident in the preceding graph.

The graph of Pre-to-Post HRs shows remarkable improvement!
Players did 28.7 % more work before HR reached max. Imagine this advantage in a game.

It is common for aerobic training studies to show that the post-training heart rate (HR) is lower at rest and at each workload. The amount of energy needed to achieve any given work load is the same. Therefore, a lower HR after training represents improved <u>efficiency</u> in two parameters:

(1) <u>Cardiovascular</u>: a stronger, more efficient heart muscle pump and increased vascular density;

(2) <u>Metabolic</u>: more efficient utilization of O_2 by the muscles, including the 'Lactate shuttle' where lactate is burned aerobically as a fuel.

So, High intensity interval training improved explosive speed – and hockey endurance.

In 6 weeks of 'Speed/Power' interval training designed to improve skating-running-jumping explosive power, Max Vo_2 also increased by 6%. This compares favorably with 6-week training studies where the focus is entirely on improving aerobic endurance. However, slow endurance training does <u>NOT</u> improve explosive power, because it does not target the FT fibers.

Most importantly, measuring TOTAL WORK that can be done with lower HR's gives a clear picture of the athlete's endurance capacity – a real-world competitive advantage. It requires a combination of anaerobic and aerobic work – like a HOCKEY game.
These findings are consistent with HIIT research before and since this study *(reviewed by F.Torma, 2019)*

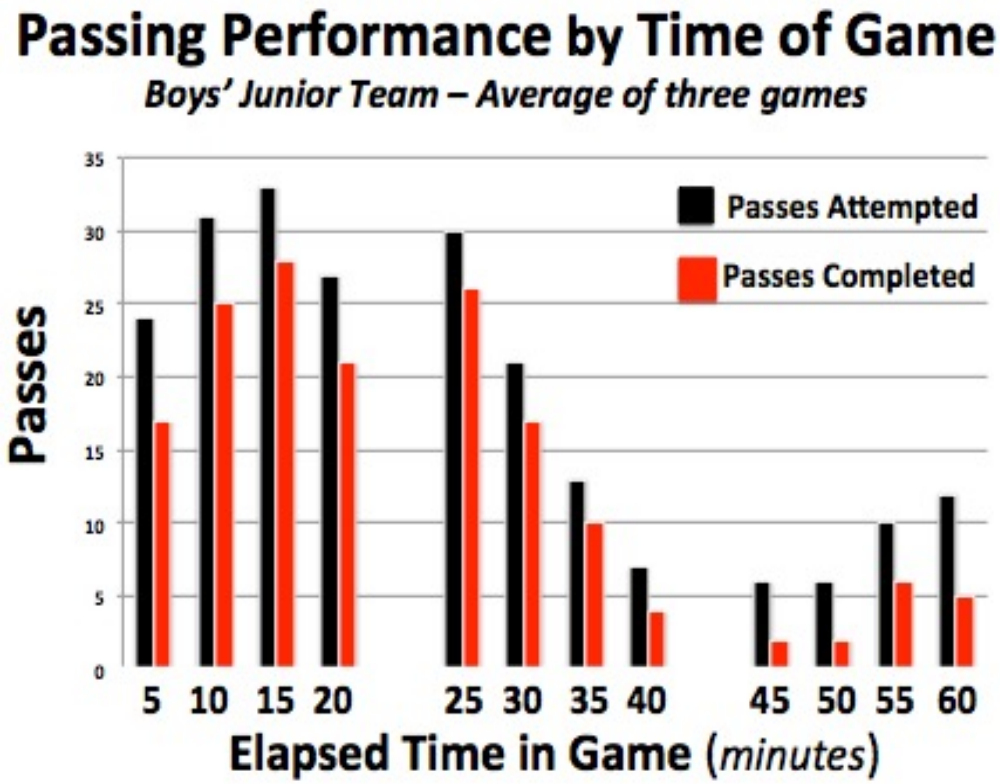
It should be mentioned that testing on a bike is vastly different than skating.
However, endurance timed electronically on the ice improved by 5.3% . **!**

Is the erosion of skills an endurance failure?

Brett Strot, a former college and professional player, was Associate Coach with Robb Stauber on the USA Gold Medalist women's team, 2018. He was asked to do an analysis of a boys' junior team that was losing games too often in the third period. Among several factors he studied was passing proficiency. His thoughts about endurance are similar to all hockey coaches.

Near the end of a game, coaches want skills, decisions, competitive toughness, speed, strength, and agility to be just as good as at the beginning.

There can be many explanations, of course. Perhaps the team had a lead, and coaches told players to avoid passes, to "chip it out; dump it in; keep it simple." That's common 'wisdom' at every level … spelled d-u-m-b



This might be a physiological weakness, but the solution is NOT hours of bikes or skating the lines.

The solution is obvious:

"They need fast practices with thousands of passes."

Herb Brooks said that as we drove home from an overly-defensive college game – listening to the college coach explain a loss with the standard garbage about system breakdowns, defensive lapses, turnovers.

Brooks continued "Yes, defense wins games but not when you have the damn puck!"