International Journal of Innovation, Creativity and Change. www.ijicc.net
Volume 13, Issue 8, 2020

Human Enhancing Technology: Fast Tech Suits

Dr Deborah Trevallion
The University of Newcastle, Australia.

Human enhancement technology can be described as the natural, artificial, or technological alteration of the human body in order to enhance physical and / or mental capabilities. Human enhancement is a blossoming topic in applied ethics. With continuing advances in science and technology, some basic parameters of the human condition might be changed. One way in which the human condition could be changed is through the enhancement of basic human capacities like swimming. The aim of this research is to investigate the suggestion that a fast tech swim suit, like those used to break swimming records at the Olympic games, is a form of human enhancing technology? Are the worlds Olympians, who hate drug cheats, using the fast tech suits as a form of "technical doping"? This article explains just what a fast tech suit is and how it works, it traces the origin of the modern fast tech swim suits and discusses developments, noting important features and how these benefit the swimmer. The environmental impact of these suits is considered as is whether these suits actually make a difference. The article analyses Olympic records and explains The Federation International Swimming Association (FINA) response, giving ethical consideration to human enhancement technology.

Keywords: *Fast tech suits, Technical doping, Olympic swimming records, Applied ethics, Human enhancement technologies, Compression suits.*

1. Introduction

To win Olympic gold is a lifelong dream for elite athletes. The desire to win Olympic gold has pushed some Olympians to their limits and beyond. The culmination of years of training and dedication and means that sponsorship will be assured for these elite athletes. In Australia, to win Olympic gold in swimming is to become a celebrity, a superstar, an Australian hero. The sponsorships that accompany the glory of gold can provide lifelong financial stability so the importance of wearing the best possible swimsuit or fast tech suit as they are now known cannot be underestimated.

Naturally the competitors want to use every advantage available to them. This includes, the best coaches, the latest training techniques, the most efficient swim styles, the greatest fitness level, and the best equipment available, this includes fast tech swimsuits. Some, desperate to win, take illegal performance enhancing drugs and supplements. The question is 'If performance enhancing drugs are illegal should using technology to enhance performance also be banned?' People have labelled fast suit use as 'technical doping'. In competitive elite swimming the difference between gold and silver is measured in one hundredths of a second in electronic timing. With the international governing body for swimming, FINA (Federation Internationale de Nation), FINA, legalising the use of some fast swimsuits, all competitors, world-wide must decide which suit they will use.

2. Historical influences on Australian swim suits

If today's female Olympic swimmers were still weighted down by the swimming costumes of the 1890s, women would be swimming in no less than stockings, bloomers and a short-sleeved dress. It took movie star and athlete Annette Kellerman boldly sashaying onto a beach in a one-piece in 1907 to make an important cut to swimsuits. Without her, women might still be sinking like stones in the water and Kellerman was arrested for her troubles (The National Film and Sound Archive of Australia-NASA, 2016)

Fast forward to the 1970s, male swimmers wore spandex briefs the size of dinner napkins, following the idea that less material brought about faster times. Australian swimwear manufacturer, Speedo Australia, designed and made the men's and women's costumes for the Australian team that competed at the 1988 Seoul Olympic Games. These costumes were abandoned because the original fabric design used unauthorised inclusion of Indigenous motifs. The Powerhouse Museum in Sydney, Australia, has an extensive collection of Speedo swimwear and accessories dating from the 1930s to the present including designs produced for the Australian Olympic Games team from 1964 to 2004, the Australian Commonwealth Games team from 1970-2002 and numerous international Olympic teams. This collection is complemented by the Speedo archive which includes scrapbooks, catalogues, posters, newsletters, stickers, photographs, video footage and badges.

Speedo's origins lie in MacRae Knitting Mills, manufacturer of cotton and wool knitwear. So successful was a staff member's catchy slogan 'Speed on in your Speedo', they changed the company name to Speedo. From the beginning Speedo were focussed on producing competitive swimwear complemented by a range of leisure swimwear and knitted apparel. The Powerhouse Museum's Speedo collection and archive illustrates the evolution of swimwear styles and fabrics designed to reduce water resistance and enhance speed. By the 1980s most of the world's top competitive swimmers were competing in Speedo's. Swimsuits again approached full-body coverage, this time trying to resurface the swimmer's body to be better than the swimmer's body. Winning now comes down to winning by hundredths of a second. Manufacturers are changing materials, fit, and collaborate with scientists about fluid dynamics, to try to supply that precious hundredth of a second. Suits are welded, computer-modeled and

tested in wind tunnels. When the finishes are so close, it's hard to say what brings about the difference: suit, skill, psychology or chance.

3. What is a fast tech swim suit?

Fast tech suits do make a difference. These suits are designed to enhance physical performance in the water. They can increase blood flow through muscles, connect important muscle groups, increasing power and reduce drag. This adds up to give you a competitive advantage in the water.

The Aqua lab is the laboratory used as Australia's research and development facility. Here the team continually push the boundaries of sport science and technological innovation to create leading edge technological swimsuits. The design team, work with experts from diverse industries such as: aerospace, engineering, medicine, sport science, textile technology, garment construction and the Australian Industry of Sport. The resulting innovations are rigorously tested with partner athletes. Fast tech suits are designed using data provided from the body scans of hundreds of elite international swimmers. In order to virtually analyse the drag and flow of water around swimmers, testing and analysis includes a highly sophisticated process called Computational Fluid Dynamics (CFD) and from this create a virtual swimmer inside a computer. The overall fit of the suit was engineered from the body scan data of hundreds of elite swimmers resulting in an optimum biomechanical fit.

The technologies surrounding racing swimsuits are aimed at:

i. Reducing drag in the water,
ii. Creating fabrics,
iii. Stitched, Bonded, Welded seams
iv. Replicating a shark's dermal denticals to reduce drag and increase speed although this technology has more recently been replaced.

i. Reducing drag

The emerging technology is a fabric that is extremely light weight. It is a high density microfibre fabric woven from chlorine resistant elastane and ultra fine nylon yarn. Rob Hicking (2019), Speedo brand director and a leader in the field in the development of this technology explains that this fastTechnological skin allows for various water flow patterns over the whole body, this enforces a smoother swim and reducing drag by up to 4%.

Wilkinson, 2018, a fluid mechanics engineer at The National Aeronautics and Space Administration (NASA) explains water makes it hard to swim fast, with invisible fluid forces, slows you down. Fluid forces push against your motion that they're collectively called drag.
The strongest force pushing you backward is pressure drag (or form drag). As you push on the water, the water pushes back. The wall of water, called wave drag, adds to the pressure pushing you backward. The lower you float, the higher the wall, and the worse your wave drag. A weaker force is viscous drag also called skin friction drag. As you swim, a sheet of water sticks

to your body and moves with you. Farther away, the water is still. The still water pulls on the water attached to you, slowing you down, creating eddies. The eddies travel in a few-centimetre halo around your body slowing you even more. Viscous drag worsens with the amount of surface area you have in contact with the water.

Parkes, 2019, explains that you can lower drag by controlling how you move in the water. If you dive in sleekly, keep your body in a horizontal line as you swim and don't allow your legs to sag, you've done a lot to reduce pressure drag. You can cut wave drag starting with your dive. When swimmers dive off a block, they spend a long time underwater, here they have a much lower drag because there's no surface wave. Once you surface, if you float higher in the water, you'll push up a smaller wave in front of you. Shaving your body hair also cuts drag by smoothing the skin surface. Working at the gym builds strong abdominal muscles that will help you stay straighter and float higher in the water, a strong upper body, means less drag and more powerful strokes. Once your technique and your body are in top form and you still want to swim faster, then you consider a fast tech suit.

ii. Creating fabrics

The fast tech suit fabric is made from nylon which is a hydrophobic (water hating) molecule. The fabric was made to cling to the body, repel water, compress muscles and mould the shape of the body. This means that very little water enters the fibre. These fibres are then manufactured into fabric and a finishing process is applied. The finishing is a bonding process that produces a durable, long lasting, water repellent finish. The fast suit is made from super stretch fabric to improve the suits fit while compressing muscles. It is laser pulse which means it is extremely light weight and water resistant fabric and this only 1-2mm thick. It has very low skin friction and the result is a reduction of drag and muscle vibration, which increases productivity. As an additional feature, in 2006, gripper fabric was incorporated as fast skin along the forearm area. The gripper fabric is used to mimic skin and replace the swimmer's sensitivity, increasing the feel and grip of the water through stronger friction. This friction is required for the swimmer to pull themselves through the water using strong arm movements.

The fast tech suit is smoother than hairy or shaven skin because it's advantageous to squeeze into the suit rather than to swim in briefs. The smoothness comes from the materials; Speedo's woven spandex has a flatter structure than knitted material, and the panels, which were tested, developed and optimized in NASA wind tunnels, are like Glad wrap. It's not only the fast tech suit material that has been made smoother, but the swimmer inside it has less drag. The curves of swimmer’s bodies and muscles add to pressure drag. The tightness of the suit will smooth a swimmer's body by making the suit compressive. Testing was carried out on swimmers' oxygen use in the suit to make sure they didn't build up so much compression that the swimmer couldn’t breathe effectively. The research found that swimmers do breathe normally in the suit, but some swimmers find that the tightness takes getting used to and new training techniques whilst wearing the suits have been developed. Fast tech suits contain a core stabilizer. This is a girdle where the material is doubled up. Swimmers use their core muscles to find the posture in the

water that helps them find their balance and float easier and reminding swimmers to engage their abdominal muscles during long races.

iii. Stitched/Bonded/Welded seams

To make the suit smoother, the seams on the initial fast suits were initially engineered to follow the direction of the water flow to help reduce drag. Comfort and freedom of movement is created by the incorporation of the super stretch thread. There are 22 stitches in every inch of seam, created in an anatomic/dynamic pattern where seams act like tendons and provide tension in the suit while the fabric panels act like muscles, stretching and returning to their original shape. These stitched seams were replaced by bonded/welded seams in the chase to create smooth fast suits. Fast suits are constructed from three pieces of fabric to minimize seams and welded, rather than sewn, together. Welding cuts friction drag by 6 percent as compared to sewing. The fast tech suit now has a low profile zip, bonded seams that are weld bonded and smooth, a hydro form compression system which produces a hydrodynamic, compressed shape across whole body that allows a range of movement and is energy efficient.

iv. Replicating the dermal denticals

The shark is a creature that is fast in water and it initially was used as a model for the Fastskin swimsuits. The dermal denticals were replicated to reduce drag and increase speed although this technology has more recently been replaced. The shark's quickness is attributed to V-shaped ridges on its skin called dermal denticles which decrease drag and turbulence around its body. It was thought to allow the body to move through the water more smoothly allowing the surrounding water to pass over it more effectively. In 2003, this feature was introduced into the fast tech suit modelled after shark skin. It has since been found that making suits super smooth led to bigger overall reductions in drag. This resulted in removing the shark skin texture from the suits. No more dermal denticals. This current specifically designed spandex weighs 100 grams per square metre, four times less than standard swimsuit material. The spandex is also coated with a water-repellent substance, so it doesn't retain water, making it lighter. It is maintained that the suit doesn't increase buoyancy but it also doesn't make swimmers sink. In simulated race conditions, swimmers swam 4 percent faster and used 5 percent less oxygen in the fast tech suit.

4. Impact of fast suit technology on the environment

The fast tech suits are custom made for each elite athlete, with individualized patterns being created resulting in suits that cannot be mass produced. Each panel is cut and formed specifically according to the tested pattern creating environmental issues such as manufacturing pollution, extreme wastage, and increased cost. Obsolescence is an issue because the suits are easily torn and stretched after a few wears, once this is done the suit is no longer usable/effective, they cannot be repaired and become obsolete. The fabric is made from elastomeric fibres that are made from petroleum, and oil, fossil fuels that are continually being depleted. They are from a non-renewable source. This is not an example of responsible or sustainable design and the carbon footprint made through manufacturing these is notable.

5. Benefits of a fast tech suit

Fast suits have many performance-enhancing features. They contribute to faster swims by improving physical capabilities, as well as enhancing the psychological side of things. Every competitive swimmer should be investing in a new fast tech suit every season or two. Fast suits are constantly getting better and it's important to make sure that you aren't being placed at a disadvantage to your competition. Fast suits enhance performance, they don't create performance, you still need to push harder in practice. Following are some of the physical benefits:

i. Muscle compression enhances blood circulation and improves swimming performance.

All fast suits provide some form of compression. Some suits provide slightly more compression while others provide slightly less. Compression is a critical feature to have in a tech suit since it allows blood to circulate through your muscles at a higher rate. This blood will then resupply your muscles with oxygen and nutrients, while also removing lactic acid and other toxins. At the end of the day, this will allow you to swim at higher speeds for longer durations, ultimately allowing for faster swimming times and more personal bests and gold medals.

ii. Fast suits increase stroke rate and stroke length while swimming.

A study by Hartmutt Sandner, involving 15 elite French swimmers, conducted by the Faculty of Sport Sciences at the University of Rouen in France looked at the effects of fast tech suits on factors such as buoyancy, passive torque, glide, and arm coordination. The final conclusion of the study showed evidence that fast tech suits had the effect of improving glide and reducing drag while swimming. This essentially created conditions where swimmers were able to produce faster stroke rates, ultimately improving their performance in the water.

iii. Fast tech suits decrease drag and friction in the water.

Fast tech suits are engineered to effectively reduce drag and resistance while swimming as much as possible. A reduction in drag will ultimately result in higher swimming speeds and better times when racing. Fast suits decrease drag in many ways, but we will be taking a quick look at 3 common and effective methods used in the design with the first being the use of water-resistant fabrics and treatments. This stops water from permeating the fabric and increasing overall weight that can possibly weigh you down. The second-way tech suits decrease drag is by using ultra-lightweight fabrics and designs. This will ensure that you stay as light as possible while racing. And the third way tech suits reduce drag is by almost completely removing seams or at least placing them in optimized areas. This will allow your tech suit to be more like an advanced second layer of skin, ultimately keeping you smooth and fast in the water.

6. Do Fast Tech Suits make a difference?

A statistical study on swimming world records since the 1970s carried out by Joel Stager, a professor of kinesiology at Indiana University, Bloomington in 2019, found the number of world records broken has gently curved upward, and record times have gently curved downward, but both, as expected are reaching plateaus. The year 2008 was a curve-cracking

anomaly. More than 40 records were set in 2008, double the average for the last 30 years. The fastest men in the 100-meter freestyle at the Beijing Olympics swam, on average, almost four standard deviations faster than predictions. Swimmers set significantly more records in February and March 2008 than during those months in the past 30 years. These results cemented the dominance of fast suit maker Speedo who claimed their fast tech suit as worn by 98% of the swimmers who medalled that year.

Stager pulled a case study from Japan. In April 2008, at the Japan Olympic trials, no swimmers wore LZR Racers, Speedo's record breaking, now banned fast tech suit. Two months later, at the Japan Open, swimmers competed in these fast tech in the same pool. Swimmers swam significantly faster at the Open, although they were trying for faster times at the trials and sprinters improved significantly more than distance swimmers. These results cemented the dominance of fast suit maker Speedo who claimed their fast tech suit as worn by 98% of the swimmers who medalled that year.

Human skin is not very efficient at moving through water, especially when compared with the hides of aquatic creatures. After a few years of experimentation Speedo discovered that coating swimsuits with polyurethane created an exceptionally hydrodynamic surface. But to figure out how to make the most of the material, Speedo reached out to an organization known for cutting-edge suits of a different kind: NASA.

Speedo dubbed the new suit the LZR Racer, and the end result was a jet-black swimsuit that reached from the shoulders to the calves and hugged the skin like a vise grip, a skinsuit on steroids. The LZR (pronounced "laser") compressed its wearers' bodies into seamless, hydrodynamic tubes. That extreme compression came with an annoying disadvantage, though: just putting on the suit was an ordeal that could take upward of 20 minutes. Some swimmers resorted to putting plastic bags on their feet to reduce the friction as they stuffed themselves inside. Another emerging problem showed that once a swimmer managed to squeeze in, it felt like paper, not cloth, which revealed after a few races it would tear or stretch beyond usefulness. Since an individual suit cost anywhere between $200 and $500, it was too expensive to be disposable for unsponsored swimmers. But soon these suits would become mandatory for world-class swimmers who wanted to win. These fast tech suits soon became a mandatory item for all world class swimmers.

As for the sharkskin patterns Speedo had marketed for a decade? They did nothing for swimmers. In 2012 George Lauder, a professor of ichthyology at Harvard University, published a paper that showed artificial sharkskin had no effect on drag. He concluded that fast suits definitely worked but not because of the shark biomimicry. After the Beijing games Speedo's competitors scrambled to reverse-engineer the fast tech suit. The effects of this sportswear arms race were undeniable. In 2009 the world records set at the Beijing Olympics were blown to smithereens at the World Swimming Championships. Nearly every competitor wore some variation of a full-body polyurethane suit.

Since then Speedo and its competitors have shifted the focus from the banned polyurethane to elastic suits that help conserve energy by compressing leg muscles and preventing unnecessary movement. It's worth noting that swimsuits aren't the only example of technological "doping" in the swimming world. Olympic pools, for instance, are now built to reduce the pushback from waves created by swimmers displacing water. Lane dividers divert the waves down and under athletes into the empty buffer lanes on either side of the pool.

If swimmers are swimming faster, what do the world experts have to say? Jeremy Kipp, the Head swimming coach at the University of Southern California-USC, 2020 suggests the reasons swimmers are faster are because coaches are better and there is clearer and more specific video feedback from a number of angles available. He emphatically states that the fast tech suit is really the only thing that has changed. Speedo's, Jason Rance (2017), states lower times could be attributed to improvements in training methods such as high-altitude conditioning, he explains that there now more specialized centers worldwide dedicated to training and there are more swimmers who swim full-time. Rance says that it's a combination of factors, of which the fast tech suit has been one.

Data like these, support but do not prove that the fast tech suits makes swimmers faster and the data focus on swimmers who are already fast. Rance, (2017) further explains that a fast tech suit is the icing on the cake for athletes at the top of their game. It's not going to make everyone into superstars. Children are told to focus on getting your feet into the pool and doing the lengths on the swim team with a coach. Kipp, (2020), further supports this by adding "I wouldn't necessarily go out and play golf with Tiger Woods's clubs, if you don't learn the techniques, and you don't train appropriately, the suits are not going to help you."

7.What does The Federation International Swimming Federation (FINA) have to say?

Leaders of the International Swimming Federation realized they had a problem. When swimmers dove underwater, they floated back to the surface. Why? Tiny air pockets were getting trapped between their skin and the fabric of their suits. These air pockets allowed swimmers to float as if they were wearing a very thin life jacket. Because friction from water is so much greater than friction from air, even a small increase in a swimmer's surface area above water makes a huge difference in top-tier races.

Following the December 2008 European Short Course Championships in Croatia, where 17 world records fell, it was felt there was a need to modify the rules surrounding swimsuits. The combined effects of the LZR both compressing the body and trapping air for buoyancy led to many competitors who used the LZR wearing two or more suits for an increased effect. This led to some claiming that the LZR was in effect "technological doping". Anger spread among both swimmers and spectators, who recoiled at the idea of technological doping. The suits seemed to embody a competitive imbalance in a sport already dominated by athletes from wealthy countries. Those who could not afford the new swimsuits were racing at a

disadvantage. They were deemed to provide an unfair advantage to the wearer by FINA, which led to a ban on all swimsuits of a similar nature.

At its meeting in Dubai in March 2009, FINA stipulated that swimsuits should not cover the neck, must not extend past the shoulders and ankles, and also limit the suits' thickness and buoyancy. In a statement, FINA stated that by avoiding all questions of fabrics, permeability, and buoyancy, FINA chose to deal with this situation by simply ruling on the lengths of swimsuits. FINA wishes to recall the main and core principle that swimming is a sport essentially based on the physical performance of the athlete.

In an abrupt reversal of opinion, the FINA Congress voted almost unanimously to revert its previous policy and ban all body-length swimsuits. The decision was taken in Rome on 24 July 2009, during the 2009 World Aquatics Championships. The new policy states that men's swimsuits may maximally cover the area from the waist to the knee, and women from the shoulder to the knee. All full-body polyurethane suits would be banned from international competitions. Governing bodies in most countries followed FINA's lead. Only swimsuits made out of permeable textiles that could not capture air bubbles would be legal. They also ruled that the fabric used must be a "textile" or a woven material and that a suit may not have any fastening devices such as a zipper (drawstrings on male jammers are allowed). FINA did not specify what they meant by "textile". The new regulations took effect on 1 January 2010.

The ban was made in the interest of equal access to equipment, but it also maintained the gradual progression in the sport. Competitive swimmers are not only racing the other swimmers in the pool; they are racing every swimmer who has previously set a world record. Before the LZR Racer, records were being broken roughly every four years. After the LZR Racer, records were being broken first in preliminary heats and then again in the finals of the same event. The ban turned back the clock to before 2008, but the damage had already been done to the record books. Eight years on, swimmers at the Rio Olympics were only just starting to catch up to the times set in Beijing.

If swimming times are being doctored through pool design and other technologies, should polyurethane fast tech suits have been banned in the first place? Back in 2009 most swimmers and coaches thought so, but swimsuit companies did not. One could argue that FINA overreacted to a temporary bubble in swimming records by enacting regulations that will be circumvented someday. It's only a matter of time before a new field of research (perhaps nanotechnology) is applied to swimsuits, leading to drastically improved performances without breaking the current rules.

As for the original justification for the ban—accessibility and competitive balance—the swimming community just stopped talking about it. Inequality is a sad reality. Talented swimmers are more likely to succeed in wealthy countries that can afford to scout athletes from a young age and invest in the equipment and resources necessary to train them. Most of us see

men and women with unique abilities competing within a set of rules that fairly determines the best of the best. Although all body-length swimwear has been banned from FINA competitions, swimmers are still permitted to compete in LZR Racer jammers and knee skins.

The one thing that hasn't changed since the Olympics were first held in ancient Greece is human skin. If FINA really wants to maintain the integrity of the sport, perhaps they should have swimmers compete the same way the Greeks once did: in the nude.

9. Conclusion

Are we good enough? If not, how may we improve ourselves? Must we restrict our self to traditional methods of training or should be we use science and technology to enhance ourselves directly? Over the last decade, human enhancement has grown into a major topic of debate in applied ethics. Interest has been stimulated by advances in biomedical science. To many it is increasingly feasible to use medicine and technology to reshape, manipulate and enhance many aspects of human biology, even in healthy people. To the extent that such innovations are on the horizon, or already there. The question in competitive sports like swimming is where do you draw the line? The answers to these questions might not only help us be better prepared when technology catches up with imagination, but they may be relevant to many decisions we make today, such as decisions about how much funding to give to various kinds of research.

Human enhancement technologies are opening up tremendous new possibilities. But they're also raising important questions about what it means to be human. These technologies are currently geared towards upgrading or restoring physical and psychological abilities as well as embellishing performance. The experts report the urgent need to introduce unified regulations among different governments before the use of these new technologies degenerates. Although using human enhancement technology is very much an individual choice, it also has an impact on society as a whole.

There remains a number of obstructions to the widespread use of the fast tech suit, a human enhancement. When establishing ethical guidelines, it is crucial to clarify the perspective in order to understand the breadth of the ethical concern. At all levels, it is crucial to establish some general principles that govern the ethical conduct of human enhancement. These should involve global, widespread, independent consultation and investment into research principles. Perhaps the most pressing issue is the degree to which the use of human enhancements requires a global response. While such work has become research leadership in a number of countries around the world, there is still much more to achieve before a clear sense of the global implications of human enhancement has been achieved.

References

D'Addona, D., Ross, A. 2020. Jeremy Kipp Hired as USC head coach. SW Swimming world Magazine (21st May 2020). Retrieved from https://www.swimmingworldmagazine.com/news/usc-swimming-begins-energetic-era-with-jeremy-kipp-taking-reigns-from-salo-kase/

Benjamin, J. (2020). 15 Best Suits to dominate swimming, Swim Competitive, Retrieved from https://swimcompetitive.com/racing-suits/top-10-tech-suits/

Federation Internationale de Nation, FINA (2019) FINA approved swimwear, retrieved from http://www.fina.org/content/fina-approved-swimwear

Hicking, R. (2019), Speedo-New Generation 2019 fast suits, retrieved from https://speedo.com.au/blog-article/?cid=the-new-generation-is-here-introducing-fastskin-lzr-pure-intent-and-fastskin-lzr-pure-valor-speedos-smartest-ever-swimsuits

Lauder, G. (2012), A swimsuit like a sharkskin? Not so Fast, The Harvard Gazette https://news.harvard.edu/gazette/story/2012/02/a-swimsuit-like-shark-skin-not-so-fast/

NASA, (2016) Spinoff Database: Space Age Swimsuit Reduces Drag, Breaks Records NASA, Retrieved from https://spinoff.nasa.gov/Spinoff2008/ch_4.html

Nasr, S. (2019) Do Fast suits make a difference? Retrieved from https://science.howstuffworks.com/swimsuit-swim-faster.htm

Parkes, H. (2019) Swimming strokes: which is the fastest? New Scientist 23 October 2019 *London, UK* Retrieved from https://www.newscientist.com/lastword/mg24432531-200-swimming-strokes-which-is-the-fastest/#ixzz6NnVFZzKh

Rance, J., 2016 The national film and sound archive of Australia, retrieved from https://www.nfsa.gov.au/

Roberts, J. (2017). "Winning Skin". Distillations. 2 (4): 8–15. Retrieved 22 March 2018 from https://www.sciencehistory.org/distillations/magazine/winning-skin

Sandner, H. (2020) Institute of Applied Training Science (IAT)Research for Elite Sport, https://www.iat.uni-leipzig.de/organisation/fachbereiche/information-kommunikation-sport

Stager, J., 2019. The Bloom Magazine Feb 16th, 2019 retrieved from .http://www.magbloom.com/2019/02/joel-stager-swim-coach-researcher/

The National Film and Sound Archive of Australia-NFSA (2016) The Kellerman One piece bathing suit retrieved from: https://www.nfsa.gov.au/collection/curated/kellerman-one-piece-bathing-suit

Université de Genève. "Human enhancement: Is it good for society?." ScienceDaily. ScienceDaily, 11 February 2019. <www.sciencedaily.com/releases/2019/02/190211114300.htm>

Wilkinson, S. (2018) "NASA History Overview." Nasa.gov. (Sept. 27, 2018) retrieved from https://go.nasa.gov/2OUdFqD