

Do Wetsuits Affect an Individual's Performance in Aquatic Activities?

Sophie Taylor

2000324

Word Count – 4,522

BA Product and Furniture Design

Matthew Archer

Contents

Abstract.....	2
Introduction.....	2
Evolution of Wetsuits.....	2-3
Technology of Wetsuits.....	3
Lifecycle of Wetsuits.....	3
Biomimicry and Design.....	3-4
Types of Wetsuits.....	4-5
Covid-19 and Wetsuits.....	5
Materials and Manufacturing Processes.....	5-7
Future Aims.....	7
Conclusion.....	7-8
References.....	9-11

This assignment explores how the design, manufacture, and overall comfort of a wetsuit play a role in the overall experience for a consumer. The understanding of how wetsuits have evolved and developed with the use of materials will enable a greater understanding of how the technology works within the water and allows discussion to take place on how it affects an individual's performance. Additionally, there will be a brief discussion of how biomimicry has influenced other aquatic clothing and whether there is potential for wetsuits to adapt using the same or similar bioinspired design. It will generate questions and inquiry to enable an understanding of the purpose of wetsuits and their suitability for other purposes other than heat insulation, examining the impact they have on speed, drag time, and buoyancy. Furthermore, this assignment will also outline existing technologies being trialled to improve the performance of individuals wearing wetsuits and how future technologies will improve the quality of the product in relation to efficiency and sustainability. By the end of this assignment, the research will hopefully support the belief that wetsuits can improve an individual's performance.

Primarily, A wetsuit provides swimmers with an outer shell to retain their body heat, to ensure the individual does not develop hyperthermia while in the water for a prolonged period. Due to the elevated levels of heat loss occurring from immersion during freezing water activities a wetsuit will allow users to maintain a stable level of normothermia (Castellani, 1998). The material used to manufacture a wetsuit is Neoprene, a rubber-like fabric, which allows a layer of water between the skin of the user and the Neoprene (Rutledge, 2022). The layer of water trapped between the user's skin and the Neoprene layer rises just below body temperature making a thermal barrier so the individual stays warmer for longer (Naebe, 2013). Depending on water conditions such as temperature or roughness then a different thickness of the wetsuit will be required (Rutledge, 2022). Adding another layer of Neoprene to the skin surface reduces heat leaving the body during outdoor water activities (Wakabayashi, 2008). However, the thicker the wetsuit the less movement for the swimmer which may hinder their overall performance as they will not be able to get a full-length stroke which requires increased energy to be exerted by the swimmer and may become fatigued (Rutledge, 2022). Past studies show that a wetsuit permits longer submersion time and has benefitted physiology (Kang, 1983) (Shiraki, 1986) this allows a longer period of time in the water at a comfortable temperature. Additionally, previous experiments that aimed toward triathletes proved that individuals wearing wetsuits had a higher body temperature in comparison to those who were not wearing a wetsuit (Groeller, 1990). The findings reinforce the claim that the technology within a wetsuit enables the user to complete an activity with the assurance that they are protected from the cold and are not at risk of hypothermia.

Wetsuits were first developed in the 18th Century. The suits were hardware for divers to help with the atmospheric pressure (Magic, 2020). A gas supply was also attached to the suit to help aid the divers with their breathing, this meant the buoyancy needs of the diver were met due to the weight of the gas tank compared to how buoyancy is provided in wetsuits today, so a weight system was put in place to even it out (Magic, 2020). The official material was sourced in World War 2 when the military researched different types of rubbers and found Neoprene was the lightest and most appropriate material choice (Magic, 2020) Neoprene is the fabric used today to create wetsuits. As the development of the wetsuit proceeded, the intention of the design was not to become a mass-produced product, however, a new design was adopted for the Navy, so the existing design was never used due to a lack of divers and surfers at that time (Magic, 2020). Moreover, a few decades on Bob Meistrell a surfer and diver enthusiast invested in a surf shop in Redondo Beach, he was a surf instructor who worked with films providing them with suits for actors and supporting staff

within the water (Magic, 2020). The owner of the Surf shop Bev Morgan came across the rejected wetsuit designs and implemented them within her shop and then began to sell them (Magic, 2020). Following involvement in films that incorporated wetsuits for prop purposes Bob Meistrell became aware of the market potential for wetsuits and embarked upon their production creating the business Body Glove that sold the wetsuits and slowly added to the brand products that surfers and divers would benefit from in the 1960s (Magic, 2020).

Society underestimates the technology of wetsuits, with an estimated 500,000 surfers in the UK in 2007, according to the Department of Environment, Food and Rural Affairs (Mills & Cummins, 2015) with many believing the purpose of the technology is to keep the user dry, when ultimately it does the opposite. Firstly, when the technology was beginning to evolve there was originally no inner lining, thus leading to a fragile design that was prone to tear this making consumers reject wetsuits as they were not created for longevity (Magic, 2020). When the wetsuit design developed further, the lining incorporated nylon, thus making the wetsuit texture a lot smoother which can suggest an improvement in performance due to it being more comfortable for the user. Equally, however, it is suggested that this reduced the wetsuit's flexibility, with the nylon lining (Magic, 2020) which can affect how an individual moves through the water. Then, in the 1970s wetsuits were developed by double backing the wetsuit with neoprene stitches, with binding techniques also developed to enable a robust seam, such as taping, glueing, and binding (Magic, 2020). Blind stitching is the newest technique which entailed a curved needle that does not go straight through the Neoprene which means punctures will not occur. However, compared to the normal way of sewing, which meant punctures occurring in the fabric favoured this method, making the wetsuit more comfortable (Magic, 2020). Furthermore, Body Glove then adapted the wetsuit by producing a zipless suit, materials at this time were also developing, such as thermoplastics and spandex which were being incorporated so that the wetsuit was flexible and creating a tight fit, especially in warm water (Magic, 2020). Lastly, titanium is a regular material used in wetsuits today as it aids the process of thermal insulation (Magic, 2020) thus contributing to longer and more pleasurable swims for individuals who participate in long-distance swimming events to protect them from hypothermia.

Moreover, the typical life cycle of a wetsuit is between 4 and 10 years this depending on the brand quality and usage by the user, however a cheaper wetsuit with low quality will not last half as long as a more expensive higher quality wetsuit will mean repeat purchasing by the consumer (ADMIN, 2017), there are many factors a wetsuit may fail; not being rinsed after being used in chlorine or salt water, zippers may corrode due to salt water and if torn slightly may create a greater hole (ADMIN, 2017). However, a blog from Wetsuit Wearhouse (2019) states,

“Triathlon wetsuits are completely made of smooth skin material...that can equal fingernail tears if you’re not careful pulling it on or taking it off...they are extra stretchy.”

So, for longevity wetsuits need to be managed with care. For example, depending on what the water sport is the user must ensure the wetsuit is suitable for water environments to ensure the water does not weaken the neoprene which will increase the chances of tearing, these factors being a consideration needed for consumers to ensure their suit will be appropriate for the usage they require it.

Further developments in wetsuit design saw the introduction of biomimicry and certain animal adaptations to influence the designs of wetsuits. Biomimicry is the use of natural processes to adapt our own technology to create new ways of creating products to become more efficient. For example, Otters and Beavers have a way of separating their body from freezing water by using their fur to contain warm air bubbles (D.Lumb, 2016). A source by Engadget also states that

“MIT engineers have devised a wetsuit featuring a similar hairy layer made of rubber to insulate divers and surfers.”

This was a remarkably similar technology to how the average wetsuits operate, however it may be more effective and make for a better outcome. However, if it is being considered a new technology adaptation when reflecting on the mass production of wetsuits currently, and again the market is estimated to reach 3.8 billion Dollars by 2030 (Research, 2022). This, leads to the question of if wetsuits incorporate Beaver fur technology, then will the sales still increase by 2030? Also, there will be a need to assess whether the price would be affected as currently on the market they range from \$50-\$500 (Collison, 2017) so adapting the wetsuit may mean a further increase in prices, but more market research will need to be collected for manufacturers to analyse whether consumers are willing to spend more for a more technical and heat efficient wetsuit. Moreover, the market size for wetsuits is extensive and mass-produced to meet market needs, this prompts the question - can the suits with beaver fur be manufactured for mass production, or is it a method that can only be implemented by handcraft? The answer is vital to understand how this product would sell within the market, whether it replaces wetsuits that are currently on the market or if they will be a bespoke product made only when specified by the consumer. Although biomimicry has only had a small impact, the full extent of its impact is still yet to be fully recognised. It could be believed that the introduction of sharkskin wetsuits could be beneficial to a swimmer's performance, proven to reduce drag time for swimmers due to the friction between the swimmer's body and the water (Kapsali, 2016). Sharkskin was incorporated with swimwear thus allowing a swimmer to move smoothly through the water, due to the V-shaped ridges (denticles) that would be inserted in the swimwear. However, it may not be an option for wetsuits, as just producing the technology brought along a lot of controversies, as some believed it to be unethical within the swimming community, as people believed it enhanced the swimmer's performance meaning it puts others to a disadvantage. An article from illumin (2017) states that

“80% of medals won were awarded to swimmers wearing Speedo's fast-skin suits”.

Thus, making it clear that it did have an impact on swimmers' individual performance and therefore a possibility for wetsuit design. However, it does depend on whether there is research and technology behind the adaptation for it to be successful in wetsuits (California, 2017). What is more, there are still biometric adaptations that are yet to be considered, such as animals' webbed hands and feet and whether they can be utilised when wearing wetsuits accessories enabling swimmers to glide through the water more efficiently as water will no longer pass through their fingers being beneficial to their stroke length with the material being the same as within a wetsuit. There is evidence to suggest that wearing an adaptive swimsuit will significantly advantage a swimmer in comparison to those wearing standard swimsuits due to the reduction in “total hydrodynamic resistance” (Januvatra, 2001). As much as it is a beneficial way of increasing pace and decreasing time, it may hinder an individual's performance due to it being an uncomfortable product. Equally, if they are to become loose during the swim it may distract the swimmer resulting in inferior performance.

Moreover, wetsuits are used for both surfing and swimming and there are diverse types for different uses. For example, spring suit wetsuits are transitional wetsuits that are commonly used between Spring and Autumn. Their design is short arms and legs (Warehouse, 2022). However, spring suits also come with long arms and short legs to protect individuals from freezing conditions. These may also be considered more for surfers as the reduction in leg coverage may mean a smoother movement from water to board. Furthermore, hooded full wetsuits are purpose-made wetsuits for surfers in freezing waters, containing body heat which is one of the main points that

loses body heat. Next, a full wetsuit is used in cold to cool water environments, so it is not necessary to protect the head from heat loss. These are the main types of wetsuits for surfers where the emphasis is on protection rather than buoyancy or swimming practicality (Today, 2022).

Conversely, for swimming wetsuits, there are more individual factors to be considered such as weight, buoyancy, and brand. The difference between a swimmer and a surfing wetsuit is all down to the weight. This is due to a swimmer needing a lighter suit enabling them to pull through the water, in addition to buoyancy and flexibility. The key to the suitability of a swimmer's wetsuit is avoidance of extra work hence the need for additional support in designated areas of the body. Wetsuits come in different weights depending on what the swimmer requires, a 3:5 wetsuit is one of the most popular ones for amateur swimmers, the three indicates 3mm thickness on the upper body and the five is 5mm on the lower part (Andy, 2022). The difference in thickness allows for the legs to rise in the water to allow the suit to make the swim more efficient and improve swim time (Andy, 2022). A 3:8 thickness wetsuit is for swimmers who will need more lift for their legs and is recommended for muscular competitors. Lastly, a 4:4 thickness is considered neutral as the thickness does not change throughout the wetsuit, however, due to the equal thickness throughout the suit, it means the suit has more buoyancy throughout, so the full body is likely to rise in the water when individuals are competing (Andy, 2022). This indicates that the choice of wetsuit is dependent upon the desired type of swim with the thickness of the suit determining the level of performance. This clearly indicates the crucial role wetsuit thickness plays in the design of the product which inevitably affects the overall outcome of the swim, this theory is supported by a study on how wetsuits affect drag time within a triathlon swim, the researchers discovered that wearing a wetsuit decreased drag time by 14%, making it easier for individuals to move through the water, this is due to the buoyancy and hydrodynamic features a wetsuit offers (Toussaint, 1989).

Within the last few years, wetsuits have come back into fashion. This is potentially due to Covid-19 and its impact on society. When Covid first became known, we were isolated in our home environments unable to go out and socialise. Then the restrictions eased, which enabled society to socialise again, witnessing an increased engagement by the population in seeking out the great outdoors, more so the coast participating in activities such as paddle boarding, open water swimming, surfing etc. This witnessed an increase in sales of wetsuits with the market valued at 1.8 billion which is estimated to double by 2030 (Research, 2022). A magazine article states that "wetsuit manufacturers have experienced a surprising boost when the rest of the financial world has been counting their pennies" (STAB, 2020) thus proving that since the pandemic wetsuits have become a must-have product. This has influenced all wetsuit brands such as Orca, HUUB and Zone 3, these being the most popular brands and most dependable for different experiences within the water world. Orca is the most popular amongst triathletes due to its technology which introduces compression, increasing blood flow and reducing muscle fatigue whilst the athlete is swimming (Wiggle, 2019). This is the ultimate wetsuit for triathlon performance. Similarly, all three major brands promote different suits depending on your athlete status and the duration of your swim. They also consider the weather conditions influencing the thickness on which the suit is designed, as it will affect the performance of the swimmer.

Additionally, there are multiple materials that are used to manufacture a wetsuit. Firstly, the most common would-be Neoprene, which is a "synthetic rubber material..." and is a "popular choice amongst wetsuit manufacturers due to how buoyant, flexible and stretchy the material is." Neoprene "contains small bubbles of nitrogen gas thus reducing heat moving around and leaving the wetsuit (Engineer, 2010). Neoprene has a variety of different thicknesses from 2-6mm, "the thicker the suit the warmer the suit" (Engineer, 2010). This means the colder the water, the thicker the suit

you will need to protect the body from hypothermia. Moreover, there is another use for Neoprene within wetsuits called “Yamamoto.” The quality of this neoprene is considered high as it is a much denser type and can offer more thermal insulation compared to regular Neoprene (Warehouse, 2022). Yamamoto neoprene can also stretch “ten times the amount of human skin” (Warehouse, 2022). A wetsuit that is manufactured for colder climates use thermoplastics as it is considered strong and when used underneath the main suit it “offers additional protection and warmth” (Warehouse, 2022). Thus, making a swimmer comfortable especially when the climate is not on their side. This can then affect the performance, as a swimmer who is comfortable within their suit, is likely to enjoy and improve their time. The lining of a wetsuit tends to be exceptionally soft as it is where the skin and material meet. Jersey is a material that is used to line the inner side of the wetsuit, chosen as a material that is considered “is good for sensitive skin” (Warehouse, 2022). This means the user is likely to have a more pleasurable experience as the use of a soft material means no friction or chafing will occur within the suit. Jersey is also a collaborative material and commonly gets paired with titanium which is due to titanium being a good heat retainer and provides extra strength within the wetsuit (Warehouse, 2022). Furthermore, nylon is also used within wetsuit linings due to its durability and as it offers more support for “weaker wetsuit materials which have been damaged” (Warehouse, 2022). However, one flaw of using nylon is that it reduces the flexibility within the wetsuit which will then restrict the user and hinder their performance and the wetsuit will not move as well with the body. Consequently, if nylon is not an option, then manufacturers will look to use spandex as it offers more flexibility to the wetsuit, although if it is used throughout the suit then the wetsuit can only be used in warmer climates as it does not retain heat as well compared to neoprene (Warehouse, 2022). Even if it is not used for the main body of the suit, it will still be incorporated within the seams to offer a highly flexible wetsuit (Warehouse, 2022). So, to clarify, although wetsuits do have a variety of different material options, a user must be certain the materials within their suit are suitable for them flexibility-wise. Equally, when considering whether and climates consideration should be given to the appropriateness of the materials in retaining heat especially if it is to be worn in colder climates. These are steps an individual must take to ensure their performance will not be restricted by the suit.

Additionally, the use of these materials above makes for an incredibly detailed construction of a wetsuit. Firstly “once the neoprene, laminated fabrics and thickness is chosen” then the “patterning, seams and other features are decided.” (Collison, 2017). In relation to designs with the placements of zippers, and ankle and wrist cuffs, watertight systems are all made for comfort and durability, thus ensuring swimmers can compete or enjoy without the stress of the suit. The two most common constructions of a wetsuit are glued and blind stitched (GBS) or Flatlock. The GBS technique glues the seams together, to begin with, then a sewing machine made for this technique is used to stitch halfway through the neoprene seams producing watertight seams (Collison, 2017). A higher standard wetsuit will have a double stitch internally and externally and by adding liquid tape which will ensure (Placeholder1) no leakage or fill points (Collison,2017). This technique may be something a swimmer should consider when using a suit for performance purposes as the additional security in a higher standard of suit eliminates the risk of their suit failing during a competition. However, this may mean an increase in cost, raising the question as to whether wetsuits can be made using the same techniques but at a lower cost, especially as some swimmers who are not competing may still want the same level of assurance. On the other hand, flat locking seams are commonly used for “price point, rental and warm water suits” with the thickness of these suits ranging from 1.5mm-3mm, making them “durable but not watertight (Collison, 2017). Flat locking seams are two seams laid over one another and then stitched together making a solid seam and less likely to break (Tilbury, 2020). In considering the benefit of a design, the individual needs to consider

what purpose they aim to use the wetsuit for, whether that is flexibility, durability, buoyance, warmth, or comfort. This is how they can assess whether their choices will provide the best wetsuit for their overall performance.

In the future, the design of wetsuits looks promising as researchers reflecting upon current materials available say that “new data would allow the group to develop a new wetsuit design that could be tailored to specific requirements of the sport” (Engineer, 2010). Although this is a huge breakthrough as it enables athletes to have unique wetsuits made to increase the pace and reduce time, it could be argued that such developments could be considered as cheating, infringing upon all swimmer’s ability to engage on an even playing field with some participants advantaged by enhancing their performance through attention to the design of a product. However, if the wetsuit is used for enjoyment, then these characteristics will not matter, but it depends on what level the wetsuit has been purchased for whether for a recreational accessory or for competitive purposes.

This assignment aimed to discuss how wetsuit design has evolved and how evolution has impacted individuals’ performance in aquatic sports. Although the research evidence suggests it improves an individual’s performance due to its heat insulation, making it comfortable for individuals in cold climates, the smart technology behind the wetsuits allows consumers to be immersed longer in water and stay warm while only having a thin layer over them (Naebe, 2013). Although this is the main function of a wetsuit, further research exposes additional functions which highlight how thickness and material choices influence buoyancy with the thickness subject to what level and area of support is required by the suit. This is indicated by the assigned ratio awarded to the relevant area of the body indicating which area of the body is to receive the greatest support. For example, a buoyancy of 3:8 supports the lower limbs of the individual, moreover, an additional advantage of having a thicker wetsuit enables the individual to be warmer in the water (Engineer, 2010). Further highlighted within another study that swimmers with wetsuits on benefitted more than those without (Groeller, 1990). Although it can be argued it is not an essential function for swimmers who are new to open water, it could be argued that it awards swimmers with extra support making them feel comfortable in a new environment. Furthermore, examining the manufacturing process and assessing how wetsuits are manufactured to be as sustainable as possible, by developing it over time, adding inner linings to decrease chances of the wetsuit taring extending the longevity of the product for individuals especially in a triathlon setting as during transition stages the competitors need to remove the wetsuit within seconds which can result in tares if not done efficiently (Magic, 2020). This factor impacts upon performance as the need of an individual to change suits in every competition or training session will demotivate the individual and will not enable them to break the wetsuit in for competition day which may potentially result in inferior performance. Furthermore, the process of manufacture is quite unique for a mass-produced product due to the attention to detail needed in a wetsuit, this is due to it only being partially stitched so that it was a completely sealed suit from the outside (Magic, 2020). This approach may not be the most efficient usage of time, although it allows the wetsuit to function at a higher level due to the high quality during the production process. Conversely, it could be argued that the manufacturing process is not as modern compared to other textile products, so over time the skill set needed to manufacture to the same quality especially when technology develops further into the future. When reviewing the materials used to create a wetsuit it is apparent that neoprene is the most appropriate due to it being beneficial for buoyancy and known for its flexibility (Engineer, 2010). As established previously neoprene is available in many thicknesses allowing it to support swimmers in all water activities (Engineer, 2010), making it a multi-functional material, considering all these factors leads to the belief that neoprene is the ideal material for swimmers. In addition, exploring bio-inspired design enabled the analysis of how biomimicry and how could be

incorporated into wetsuit design to improve the performance of swimmers, the current research into beaver fur will give wetsuits further insulation providing swimmers the protection they need from hypothermia (D.Lumb, 2016). In contrast however not all animal adaptations have been given ethical approval such as Sharkskin, however, with further development in technology within the design and manufacturing process, it could be argued that future incorporation of this adaptation would receive ethical approval for usage within aquatic clothing equally benefitting water activities. To summarise, the question this assignment was set to discuss was,

“Do wetsuits affect an individual’s performance in aquatic activities?”

This assignment has answered that question, as many would believe a wetsuit's purpose is to keep individuals dry however this should be disregarded, as a wetsuit provides individuals with the buoyancy needed to support them throughout their swim, likewise a wetsuit provides warmth to protect individuals from cold climates especially in a triathlon setting as it is open water environments. Drag time was also a focus within this assignment and wetsuits are a factor that reduces drag time as the friction between the suit and water permits swimmers to glide through the water with ease. Furthermore, the wetsuit reduces time spent within the water as speed is increased as the wetsuit provides a barrier making movement within the water more efficient as they are Hydrodynamic, this would suggest further research in the potential of animal adaptations in wetsuit design to benefit performance. Until further research into other options for swimming clothing, a wetsuit is a beneficial accessory as the technologies used provides substantial support and protection.

References

(n.d.).

ADMIN. (2017). *How Long Should a Wetsuit Last?* Retrieved from Completetri: [Online] Available at: <https://completetri.com/how-long-should-a-wetsuit-last/#:~:text=On%20average%2C%20a%20good%20wetsuit,things%20like%20zippers%20become%20issues>. (Accessed 20th October 2022)

Andy. (2021). *Wetsuits for open water swimming and triathlons- a beginners guide*. Retrieved from Turner Swim [Online] Available at: <https://www.turnerswim.co.uk/open-water-wetsuits/> (Accessed 12th October 2022)

Andy. (2022). *Wetsuits for open water swimming*. Retrieved from Turner Swim: [online] Available at: <https://www.turnerswim.co.uk/open-water-wetsuits/> (Accessed 12th October 2022)

California, U. O. (2017) *Shark Skin to Speed*. Retrieved from Illumin Magazine: [Online] Available at: <https://illum.in.usc.edu/from-shark-skin-to-speed/> (Accessed 26th October 2022)

Castellani, J. W. (1998). *Human Thermology Responses during Serial Cold-water Immersions*. *Journal Of Applied Physiology*, 204-209. [Online] Available at: <https://journals.physiology.org/doi/epdf/10.1152/jappl.1998.85.1.204> (Accessed 10th October 2022)

Collison, L. (2017). *How Are Wetsuits Made? Here's the Inside Scoop*. Retrieved from Wetsuitswearhouse: [Online] Available at: <https://www.wetsuitwearhouse.com/blog/how-are-wetsuits-made/#:~:text=MATERIALS%3A%20Wetsuits%20are%20made%20with,uses%20and%20price%20specific%20situations>. (Accessed 10th October 2022)

Collison, L. (2017) *How much does wetsuit cost?* Retrieved from Wetsuit Wearhouse: [Online] Available at <https://www.wetsuitwearhouse.com/blog/how-much-does-a-wetsuit-cost/> (Accessed 10th October 2022)

Lumb, D. (2016) *MIT engineers make beaver-inspired wetsuits to keep surfers warm*. Retrieved from Engadget: [Online] Available at <https://www.engadget.com/2016-10-05-mit-engineers-make-beaver-inspired-wetsuit-to-keep-surfers-warm.html> (Accessed 2nd November 2022)

Engineer, T. (2010, May 21). *NPL tests materials for warmer wetsuits*. Retrieved from The Engineer: [Online] Available at: <https://www.theengineer.co.uk/content/news/npl-tests-materials-for-warmer-wet-suits> (Accessed 2nd November 2022)

Groeller, H. (1990) *The Effects of Wearing a Wetsuit in the Thermoregulatory and Cardiovascular Responses Observed during a Triathlon in Elite Male Competitors*. University of Wollongong. [Online] Available at: <https://ro.uow.edu.au/cgi/viewcontent.cgi?article=3841&context=theses> (Accessed 13 th October 2022)

Januvatra, B. (2001). *Comparison of buoyancy, active and passive drag with full length and standard swimsuits*. *Biomechanics symposia*, 105-108. [Online] Available at: <https://ojs.ub.uni-konstanz.de/cpa/article/view/3878> (Accessed 26th November 2022)

- Kang, D. H. (1983). *Energetics of wetsuit diving in Korean Women Breath-Hold Divers*. *Journal of Applied Physiology; Respiratory, Environmental, and Exercise Physiology*, 1702-1707.[Online] Available at:<https://journals.physiology.org/doi/abs/10.1152/jappl.1983.54.6.1702>(Accessed 13th November 2022)
- Kapsali, V. (2016). *Biometrics For Designers* . London: Thames and Hudson.(Accessed 9th December 2022)
- Magic, O. (2020, March 31). *Wetsuits: A Brief History*. Retrieved from Ocean Magic: [Online] Available at:<https://www.oceanmagic.co.uk/wetsuits-a-brief-history>(Accessed 10th October 2022)
- Mills, B., & Cummins, A. (2015). *An Estimation of the Economic Impact of Surfing in the United Kingdom*. In *Tourism In Marine Environments* (pp. 1-17). Cognizant Communication Corporation.(Accessed 20th November 2022)
- Naebe, M. N. (2013). Assessment of Performance Properties of Wetsuits. *Journal of Sports Engineering and Technology*, 255-264 [Online] Available at:<https://journals-sagepub-com.ezproxy.uwtsd.ac.uk/doi/epub/10.1177/1754337113481967>(Accessed 15th November 2022)
- Research, P. M. (2022). *Wetsuit Market- Growth, Covid-19 Impact, anf Forecasts* . Leeortega.
- Rutledge, K. (2022). *Wetsuit*. Retrieved from National Geographic: [Online] Available at:<https://education.nationalgeographic.org/resource/wetsuit> {Accessed 18th November 2022}
- Shiraki, K. S. (1986). *Energetis of Wet-suit Diving in Japanese Male Breath-Holding Divers*. *Journal of Applied Physiology*, 1475-1480. {Online] Available at:<https://journals.physiology.org/doi/abs/10.1152/jappl.1986.61.4.1475>(Accessed 20th November 2022)
- STAB. (2020). *The Surf Industry Relish In Pandemic Boom*. Retrieved from StabMag: [Online] Available at:<https://stabmag.com/news/parts-of-the-surf-industry-relish-in-pandemic-boom/>
(Accessed 22nd November 2022)
- Tilbury, E. (2020, March 03). *Wetsuit Seams Explained*. Retrieved from Wetsuit Outlet: [Online] Available at: <https://www.wetsuitoutlet.co.uk/blog/wetsuit-seams-explained-zjwygvn.html#:~:text=Flatlock,which%20can%20let%20water%20in.>
(Accessed 16th November 2022)
- Today, S. (2022). *The different types of wetsuits*. Retrieved from Surfer Today: [Online] Available at:<https://www.surfertoday.com/surfing/the-different-types-of-wetsuits>(Accessed 20th November 2022)
- Toussaint, H. M. (1989). *Effect of a triathlon wetsuit on drag during swimming*. Retrieved from Pub Med [Online] Available at: <https://pubmed.ncbi.nlm.nih.gov/2733583/>(Accessed 10th November 2022)

- Wakabayashi, H. K. (2008). *Effect of Non-uniform Skin Temperature on Thermoregulatory Response during Water Immersion*. *European Journal of Applied Physiology*, 175-181. [Online] Available at: <https://link-springer-com.ezproxy.uwtsd.ac.uk/article/10.1007/s00421-008-0714> (Accessed 22nd November 2022)
- Warehouse, W. (2022). *Wetsuit Materials*. Retrieved from Wetsuit Warehouse: [Online] Available at: <https://wetsuitwarehouse.com.au/pages/pages-wetsuit-materials#:~:text=Neoprene%20is%20a%20synthetic%20rubber,Neoprene%20the%20warmer%20the%20suit.> (Accessed 12th November 2022)
- Wiggle. (2019). *The ORCA Wetsuit Technologies*. Retrieved from Wiggle: [Online] Available at: <https://guides.wiggle.co.uk/node/844#:~:text=The%20ORCA%20Wetsuit%20Technologies&text=Featuring%20in%20the%20top%20of,and%20muscle%20fatigue%20during%20exercise.> (Accessed 13th December 2022)