

Goal: Want to have variability in the swimming resistance design to allow for more personalized resistance training.

Table 1: Requirements for Personalization

Requirements for Personalization (R1):			
<i>Requirement</i>	<i>Metric</i>	<i>Evaluation Criteria</i>	<i>Justification</i>
<p>R1.1 Levels of Resistance: The design shall provide at least 5 levels of resistance between 148.69N and 356.28N.</p>	N	<p>EC 1.1 A better design is one which can provide more than 5 distinct levels of resistance, or a continuous range of resistance values.</p>	<p>The resistance provided by reference designs ranged from 146N to 407.18N. Hence, the design should be able to provide resistances comparable to existing alternatives. [LINK] Additionally, alternative reference designs considered generally provided three to four discrete levels of resistance, with only the power tower providing a continuous range of resistances. The design should hence provide greater personalization of resistance than existing alternatives.</p>
<p>R1.2 Difference between Resistance Levels: The difference between two resistance levels shall be less than 10% of the lower bound resistance load.</p>	N	<p>EC 1.2 A better design has a smaller difference between resistance levels.</p>	<p>5-10% load increments are considered optimal for progressive strength training for youth athletes [National Library of Medicine]. This allows for increased personalization to each swimmer's unique training regime while progressing to greater levels of resistance.</p>
<u>Additional Evaluation Criteria</u>			
<p>EC 1.3 Duration of Continuous Resistance: A better design is one which provides continuous resistance for more than 25m (length of pool lane). (Metric: metres)</p>			<p>The shortest competitive event for all strokes is 50m. As the HP swim team only trains in 25m short course pools, a better design is one which allows swimmers to practice swimming the full race distance with resistance applied to better prepare them</p>

	for racing conditions. [LINK]
<p>EC 1.4 Speed-Independent Resistance: A better design is one which provides constant resistance that is independent of the swimmer's speed. (Metric...)</p>	<p>This will give swimmers greater control over the resistance provided by the training equipment, aligning with the team's value to make the design as personalizable as possible to every swimmer.</p>

Goal: Want a safe design that will not endanger or harm the swimmer in any way.

Table 2: Requirements for Safety

Requirements for Safety (R2):			
<i>Requirement</i>	<i>Metric</i>	<i>Evaluation Criteria</i>	<i>Justification</i>
<p>R2.1 Water Proof Ability The system shall maintain full operational functionality and structural integrity when submerged in water at a depth of 5 meters for a continuous duration of at least 30 minutes, without water ingress or performance degradation (satisfying IP68).</p>	Yes/No	N/A	Devices with electrical components embedded in aquatic environments shall not have electrical failure and outcomes that harm other people. The requirements of 5 meters and 30 minutes aligns with the IP68 levels as defined in IEC-60529[Z]
<p>R2.2 Impact on Pool Water: The water with the device shall pass the black disc test [X].</p>	Yes/No	N/A	Poor water clarity indicates high turbidity, which reflects a high concentration of suspended particles in the water. When turbidity is high, water appears cloudy, dull, or discoloured because suspended particles scatter light and reduce visibility. [X] This requirement helps ensure that the design does not release visible materials or particulates into the pool that would degrade water clarity. One way to assess this is through a black disc test, which evaluates water clarity by measuring visibility through the water [X].
<p>R2.3 Impact on pH: The design shall not modify the acidity of the pool outside of the range of 7.0-7.8</p>	pH of water	N/A	The device changing the pH of the water will affect how chlorine and bromine act in the water [X], potentially reducing the neutralization of germs and bacteria.
<p>R2.4 Resistance to Extreme Force:</p>	Newtons of force	EC2.4 A better design is one which can withstand a greater	The design should be able to withstand the force of the

The design shall be able to withstand a force of 515.03 N without failure.		amount of force without failure.	swimmer while in use without breaking, as a broken design may injure the user or nearby swimmers. The 95th percentile of swimming force is 515.03 N [X]. Therefore, the design shall withstand a force of 515.03 N without failure.
--	--	----------------------------------	---

Goal: Want a design that will offer variable resistance without interfering with swimmer technique, and will promote the training of the swimmer.

Table 3: Requirements for Functionality

Requirements for Functionality (R3)			
<i>Requirement</i>	<i>Metric</i>	<i>Evaluation Criteria</i>	<i>Justification</i>
<p>R3.1 Effect on Stroke Length: The device shall not reduce a swimmer's stroke length by more than 10% relative to that swimmer's baseline at the same target speed or stroke rate.</p>	Decrease in stroke length percentage relative to the swimmer's baseline.	EC3.1 The less the effect on stroke length, the better.	<p>Dragunas et al. emphasize the importance of maintaining technique and stroke integrity while performing resistance training. Therefore, the design should not affect the stroke length of the swimmer. [X] From Escobar et al, typical stroke length decreases due to fatigue for individuals in competition swimming are 10%. Since the device is meant to simulate competition conditions, the swimmer's stroke length shall not decrease by more than 10%. [X]</p>
<p>R3.2 Additional Attachments: The design shall provide varied levels of resistance without requiring additional attachments.*</p> <p>*For instance, parachutes only provide variable resistance by changing the parachute attachment that is tied to the swim harness.</p>	Yes/No	N/A	<p>Reducing the number of attachments will simplify the use of the design, allowing swimmers to learn how to use it faster. It will also lessen clutter near the pool edge which will reduce tripping hazards.</p> <ul style="list-style-type: none"> - Reduce setup time - More intuitive to use - Lessen clutter near pool edge (tripping)

			<p>hazard), reduce storage space</p> <ul style="list-style-type: none"> - More points of failure
<p>R3.3 Adjustability: A design that is attached to the swimmer’s waist shall be adjustable to fit waist sizes ranging from between 65.5 cm to 105.9 cm [X].</p> <p>A design that is attached to the swimmer’s mid-arm shall be adjustable to fit mid-arm sizes ranging from between 21.9 to 40.1 cm.</p>	Centimetres	N/A	<p>The design must be able to fit the HP members at the Mississauga Aquatic Club. The competitions that the HP members compete in are for ages 14-18 [X]. The mean 5th percentile waist circumference for 14-year-old girls is 65.5 cm, and the mean 90th percentile waist circumference for 18-year-old men is 105.9 cm. The mean 5th percentile mid-arm circumference for 14-year-old girls is 21.9 cm, and the mean 95th percentile mid-arm circumference for 18-year-old men is 40.1 cm. Designing adjustability for this range should allow the design to be used by the majority of HP aquatic swim members.</p>
<p>R3.4 Setup Time: The time taken to change between two resistance levels should be less than 30 seconds.</p>	Seconds	EC3.4 A better design is one which requires less than 30 seconds to change between two resistance levels.	<p>HP swim practices are fast paced. The training equipment should not interfere with the pacing of these practices and hence there is a need for resistance levels to be swapped quickly. The time threshold is based on the time taken for drag socks to be put on and removed with an approximated transition time of 30 seconds.</p>

Goal: Want a design that will fit into available storage space at the centre.

Table 4: Requirements for Storage

Requirements for Storage (R4)			
<i>Requirement</i>	<i>Metric</i>	<i>Evaluation Criteria</i>	<i>Justification</i>
R4.1 Portability The design shall fit into a 13 x 13 x 11-inch space.	Inches	EC 4.1 A better design is one which can be stored in a space smaller than 13 x 13 x 11 inches.	Current resistance training equipment is stored in a crate measuring 13 x 13 x 11 inches [X]. To maintain compatibility with current storage procedures, the design should fit within this space.

Goal: Want a design that can endure the pool environment and specifically immersion in water.

Table 5: Requirements for Durability

Requirements for Durability (R5)			
<i>Requirement</i>	<i>Metric</i>	<i>Evaluation Criteria</i>	<i>Justification</i>
<p>R5.1 Use Cycles: The design shall withstand 18400 use cycles without failure.</p>	Use cycles until failure	EC 5.1 A better design can withstand more than 18400 use cycles without failure.	ISO 20957-1:2024 requires equipment to maintain safe performance under repeated use conditions representative of commercial environments. Based on training practices, a design is expected to last two years, corresponding to 18400 use cycles (46 weeks, 200 uses per week), it ensures equipment remains functional for a similar amount of time as existing equipment [X].
<p>R5.2 Withstanding Chlorine: The design shall contain material(s) with a breaking force retention of 100% with chlorine exposure in accordance with ISO-17608.</p>	Yes/No	N/A	Equipment located in aquatic facilities are exposed to chloramines, chlorinated water, high humidity, which accelerate corrosion in metallic and inorganic material [X]. To ensure long-term structural integrity, material selection shall maintain strength following chlorine exposure as specified in ISO-17608 [Y].