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DEPARTAMENTO DE EDUCACIÓN FÍSICA Y DEPORTIVA

PROGRAMA DE DOCTORADO 3161
ACTIVIDAD FÍSICA Y DEPORTE

TESIS DOCTORAL

VALIDACIÓN CONCURRENTE Y DE CONSTRUCTO DE UNA ESCALA PARA VALORAR EL ESFUERZO PERCIBIDO DE HOMBRES JÓVENES DURANTE EL CICLISMO ACUÁTICO.

PRESENTADA POR:
D.ª ROXANA MACEDO BRASIL

DIRIGIDA POR:
DR. D. JUAN CARLOS COLADO SÁNCHEZ

Valencia, 2022

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El Dr. D. Juan Carlos Colado Sánchez, profesor Catedrático de la Universitat de València, adscrito al Departamento de Educación Física y Deportiva de la Universitat de València.

CERTIFICA:

Que el presente trabajo, titulado ***"Validación concurrente y de constructo de una escala para valorar el esfuerzo percibido de hombres jóvenes durante el ciclismo acuático"*** ha sido realizado bajo su dirección en el *Departamento de Educación Física y Deportiva* de la *Universitat de València* para optar al grado de Doctor. Habiéndose concluido, y reuniendo a su juicio las condiciones de originalidad y rigor científico necesarias, autoriza su presentación a fin de que pueda ser defendido ante el tribunal correspondiente.

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I would like to express my sincere gratitude: to the subjects of this research, who corroborated their intention to improve the technical quality of aquatic cycling as well as the safety of the activity; to my thesis director, Dr. Juan Carlos Colado, who, by being such a disciplined and committed professional and an example to be followed, did not let me give up; to Dr. Marcia Ramos-e-Silva for welcoming me at the international internship and her contributions regarding formatting; to Dr. Victor Tella for his trust and support for me to come here.

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Preface

The present doctoral thesis was performed in the Faculty of Sciences of Physical Activity and Sports of the Universitat de Valencia. Dr. Juan Carlos Colado (Research Group in Prevention and Health in Exercise and Sport, University of Valencia) was the director of this work, with also the valuable scientific support and guidance of Dr. Víctor Tella. Before recruiting the sample, the objectives, hypotheses and variables to be measured were predefined and approved by local ethics committee.

Each participant read and signed a free and detailed consent form, in which all information pertinent to the study was included in accordance with the Helsinki Declaration of 1975, modified in 2008. The present study was submitted to and approved by the Ethics Committee of the Universitat de Valencia (protocol H1369642832747) and met the rules of research with human beings. None of the enrolled subjects abandoned the study during its course.

Publications and scientific dissemination of this Doctoral Thesis

Articles published in scientific journals.

Concurrent and construct validation of a scale for rating perceived exertion in aquatic cycling for young men.

Colado, JC and Brasil, RM

Dec 2019 | JOURNAL OF SPORTS SCIENCE AND MEDICINE 18 (4), pp.695-707.

Scimago Journal Rank: Sports Science Q2.
Journal Citation Reports: Sport Sciences Q3.

Discussion of "Concurrent and construct validation of a scale for rating perceived exertion in aquatic cycling for young men" response.

Colado, JC and Brasil, RM

Mar 2020 | JOURNAL OF SPORTS SCIENCE AND MEDICINE 19 (1), pp.232-234.

Scimago Journal Rank: Physical Therapy, Sports Therapy and Rehabilitation Q1. Sports Science Q2.
Journal Citation Reports: Sport Sciences Q2.

Noninvasive determination of anaerobic threshold based on the heart rate deflection point in water cycling.

Pinto SS, Brasil RM, Alberton CL, Ferreira HK, Bagatini NC, Calatayud J, Colado JC.

Feb 2016 | JOURNAL OF STRENGTH AND CONDITIONING RESEARCH 30 (2), pp.518-524.

Scimago Journal Rank: Sports Science Q1.
Journal Citation Reports: Sport Sciences Q2.

Presentations at scientific congresses

Correlation between Borg Scale (6-20) with a new water cycling scale (Brasil Scale).

Brasil RM, Pinto SS, Calatayud J, Colado JC, Benavent J, Rogers ME.

61st Annual Meeting of the American College of Sports Medicine.

May 2014 | MEDICINE AND SCIENCE IN SPORTS AND EXERCISE 46 (5), pp.942-942

Scimago Journal Rank: Sports Science Q1.
Journal Citation Reports: Sport Sciences Q1.

Chapter of book

I participated as author of the writing of the book chapter: Manual da Hidroginástica. ISBN: 978-65-252-2164-9; DOI:10.48021/978-65-252-2159-5 with the name of the Aquatic Cycling chapter.

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INDEX OF ABBREVIATIONS

ACS: Aquatic Cycling Scale

ACSM: American College of Sports Medicine

BP: Blood Pressure

BL: Blood lactate concentration

SBP: Systolic Blood Pressure

DBP: Diastolic Blood Pressure

HR: Heart Rate

LAC: Lactate

VE: Pulmonary ventilation

VO_2: Oxygen uptake

VO_2máx: Maximal oxygen uptake

RPE: Rating of perceived exertion

IC: Indoor Cycling

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ABSTRACT

Physical activity in the aquatic environment with vertical body positioning has been recommended in a variety of physical exercise programs and activities due to its positive health and physical performance benefits. This has attracted and increased the number of apparently healthy individuals of different age groups and sex, and even those with special needs who exercise in the aquatic environment. In addition to the advantages of training in the aquatic environment for general physical conditioning, there has been an expansion in the universe of "aqua fitness" due to the appearance of various types of equipment developed to enhance the benefits of the specific physical properties of water. As a result of the acceptance of materials intended for physical conditioning in the aquatic environment in vertical positions, even other equipment/materials that to date were more typical of the land environment have been adapted, such as aquatic bicycles, the aqua step, mini trampolines, treadmills, aqua poles, oars and elliptical machines, etc. In this sense, water cycling is a form of physical conditioning that can be incorporated by people interested in maintaining or improving, among other aspects, cardiorespiratory fitness. Knowing that this type of activity can be applicable to all age groups and levels of physical conditioning. In general, it is known that in order to achieve a better prescription, control and safety of physical exercise, the most used parameters to monitor intensity during sessions and / or activities are usually the heart rate (HR) and the ratings or ratios of the character of the perceived exertion (RPE) during the realization of physical exercise. To monitor RPE during physical exercise, the Borg (1982) scale has been applied and based on it, other scales have been validated for different age groups and types of exercises, many of them applicable both to the field of fitness as well as clinical areas. These scales have been validated for exercises on land after establishing their adequacy through correlations with various physiological variables. However, there is still not specifically validated RPE scale for cycling developed in the aquatic environment. Therefore, the present thesis aims to validate a scale of perceived exertion rate to control the intensity during water cycling developed by young, healthy and fit men. Therefore, in this study, thirty young, healthy and physically active men performed a water cycle ergometer protocol with progressively increasing load. Concurrent validity was established by correlating the Aquatic Cycling Scale (ACS) with oxygen uptake, pulmonary ventilation (VE), HR, and blood lactate concentration (BL) responses to the maximal load incremental test. Construct validity was established by correlating the RPE derived from the ACS (0-10) with that obtained with the

Borg Scale (6-20). Overall RPE, maximal oxygen uptake (VO_2max), body weight indexed oxygen uptake (VO_2), VE, HR, and BL were measured during each stage of exercise. The range of responses to exercise in the incremental test was: VO_2max = 1.07–3.55 L/min; VO_2 = 14.26-46.89 ml/Kg /min; VE = 23.17-138.57 L/min; HR = 99.54–173.31 beats/min; BL = 1.18-11.63 mM; Global RCT = 1.11-9.33. Correlation/ regression analyzes showed ACE as a positive linear function of VO2max (r = 0.78; p <0.05), VO2 (r = 0.87; p <0.05), VE (r = 0.86; p <0.05), HR (r = 0.77; p <0.05) and BL (r = 0.85; p <0.05). The ACE was distributed as a positive linear function of the RPE-Borg scale (r = 0.97; p <0.05). The ANOVA indicated that an incremental pedaling cadence of 15 beats per minute (bpm) caused significant differences (p <0.05) with respect to previous stages in most of the variables analyzed. In conclusion, the ACS is an appropriate tool to monitor the intensity of effort during cycling developed in the aquatic environment in young, healthy and fit men. In an applied way, it was observed that a brief increase in the water pedaling cadence of 15 bpm will increase the intensity of the exercise during water pedaling.

Keywords: water cycling; character of perceived exertion; intensity control; maximum oxygen consumption; pulmonary ventilation; heart rate; blood lactate.

RESUMEN

Se ha recomendado la actividad física en el medio acuático con colocación vertical del cuerpo en una variedad de programas y actividades de ejercicio físico debido a sus positivos beneficios relacionados con la salud y el rendimiento físico. Esto ha atraído y aumentado el número de individuos aparentemente sanos de diferentes grupos de edad y sexo, e, incluso, aquellos con necesidades especiales que realizan ejercicios en el medio acuático. Además de las ventajas del entrenamiento en el medio acuático para el acondicionamiento físico general, se ha producido una expansión en el universo del “aqua fitness” debido a la aparición de varios tipos de equipos o materiales desarrollados para potenciar los beneficios de las propiedades físicas específicas del agua. Fruto de la aceptación de los materiales destinados al acondicionamiento físico en el medio acuático en posiciones verticales, se han adaptado incluso otros equipos/materiales que hasta la fecha eran más propios del medio terrestre, como por ejemplo así son las bicicletas acuáticas, el “aqua step”, los mini trampolines, las cintas de correr, los “aqua postes”, los remos y máquinas elípticas, etc. En este sentido, el ciclismo acuático es una forma de acondicionamiento físico que puede incorporar personas interesadas en mantener o mejorar, entre otros aspectos, la aptitud cardiorrespiratoria. Sabiendo que este tipo de actividad puede ser aplicable a todos los grupos de edad y niveles de acondicionamiento físico. En general, es conocido que para que se pueda conseguir una mejor prescripción, control y seguridad del ejercicio físico, los parámetros más utilizados para monitorizar la intensidad durante las sesiones y/o actividades suelen ser la frecuencia cardíaca (FC) y las calificaciones o ratios del carácter del esfuerzo percibido (RPE) durante la realización de ejercicio físico. Para monitorizar la RPE durante el ejercicio físico se ha aplicado habitualmente la escala de Borg (1982) y, en base a ella, se han validado otras escalas para diferentes grupos de edad y tipos de ejercicios, aplicables muchas de ellas tanto al ámbito del fitness como a áreas clínicas. Dichas escalas han sido validadas para ejercicios en tierra tras establecer su adecuación mediante correlaciones con diversas variables fisiológicas. Sin embargo, todavía no existe una escala de RPE específicamente validada para el ciclismo desarrollado en el medio acuático. Por tanto, la presente tesis tuvo como objetivo validar una escala de tasa de esfuerzo percibido para controlar la intensidad durante el ciclismo acuático desarrollado por hombres jóvenes, sanos y en forma. Por tanto, en este estudio, treinta hombres jóvenes, sanos y físicamente activos realizaron un protocolo de cicloergómetro acuático con aumento progresivo de la carga. La validez concurrente se estableció correlacionando la Escala de Ciclismo Acuático (ECA) con la captación de oxígeno, la ventilación pulmonar (VE), la FC y las respuestas de concentración de lactato en sangre (LS) a la prueba de carga incremental máxima. La validez de constructo se estableció correlacionando la RPE derivada de la ECA (0-10) con la obtenida con la Escala de Borg (6-20). Se midió la RPE general, el consumo máximo de oxígeno (VO_2máx), el consumo de oxígeno indexado al peso corporal (VO_2), VE, FC y LS durante cada etapa del ejercicio. El rango de respuestas al ejercicio en la prueba incremental fue: VO_2máx = 1.07–3.55 L / min; VO_2 = 14.26–46.89 ml / Kg / min; VE = 23.17–138.57 L / min; FC = 99.54–173.31 latidos / min; BL = 1,18-11,63 mM; ECA global = 1,11-9,33. Los análisis de correlación / regresión mostraron la ECA como una función lineal positiva de VO_2max (r = 0.78; $p < 0.05$), VO_2 (r = 0.87; $p < 0.05$), VE (r = 0.86; $p < 0.05$), HR (r = 0,77; p <0,05) y BL (r = 0,85; p <0,05). La ECA se mostró distribuida como una función lineal positiva de la escala RPE-Borg (r = 0,97; p <0,05). El ANOVA indicó que una cadencia de pedaleo incremental de 15 batidos por minuto (bpm) provocó diferencias significativas ($p < 0.05$) con respecto a etapas previas en la mayoría de las variables analizadas. En conclusión, la ECA es una herramienta apropiada para monitorizar la intensidad del esfuerzo durante el ciclismo desarrollado en el medio acuático en hombres jóvenes, sanos y en forma. De manera aplicada se observó que un breve incremento en la cadencia de pedaleo acuático de 15 bpm aumentará la intensidad del ejercicio durante el pedaleo acuático.

Palabras clave: ciclismo acuático; carácter del esfuerzo percibido; control de la intensidad; consumo máximo de oxígeno; ventilación pulmonar; ritmo cardiaco; lactato sanguíneo.

RESUM

S'ha recomanat l'activitat física al medi aquàtic amb col·locació vertical del cos en una varietat de programes i activitats d'exercici físic a causa dels seus beneficis positius relacionats amb la salut i el rendiment físic. Això ha atret i ha augmentat el nombre d'individus aparentment sans de diferents grups d'edat i sexe, i, fins i tot, aquells amb necessitats especials que realitzen exercicis al medi aquàtic. A més dels avantatges de l'entrenament al medi aquàtic per al condicionament físic general, s'ha produït una expansió a l'univers de l'aqua fitness a causa de l'aparició de diversos tipus d'equips desenvolupats per potenciar els beneficis de les propietats físiques específiques de l'aigua. Fruit de l'acceptació dels materials destinats a l'acondicionament físic al medi aquàtic en posicions verticals, s'han adaptat fins i tot altres equips/materials que fins ara eren més propis del medi terrestre, com per exemple així són les bicicletes aquàtiques, l'aqua step, els mini trampolins, les cintes de córrer, els aqua pals, els rems i màquines el·líptiques, etc. En aquest sentit, el ciclisme aquàtic és una forma de condicionament físic que pot incorporar persones interessades a mantindre o millora, entre altres aspectes, l'aptitud cardiorespiratòria. Sabent que aquest tipus d’activitat pot ser aplicable a tots els grups d’edat i nivells de condicionament físic. En general, és conegut que perquè es pugui aconseguir una millor prescripció, control i seguretat de l'exercici físic, els paràmetres més utilitzats per monitoritzar la intensitat durant les sessions i/o activitats solen ser la freqüència cardíaca (FC) i les qualificacions o ràtios del caràcter de l’esforç percebut (RPE) durant la realització d’exercici físic. Per monitoritzar la RPE durant l'exercici físic s'ha aplicat habitualment l'escala de Borg (1982) i, en base a ella, s'han validat altres escales per a diferents grups d'edat i tipus d'exercicis, moltes d'elles aplicables tant a l'àmbit del fitness com a àrees clíniques. Aquestes escales han estat validades per a exercicis a terra després d'establir la seua adequació mitjançant correlacions amb diverses variables fisiològiques. No obstant això, encara no hi ha una escala de RPE específicament validada per al ciclisme desenvolupat al medi aquàtic. Per tant, aquesta tesi té com a objectiu validar una escala de taxa d'esforç percebut per controlar la intensitat durant el ciclisme aquàtic desenvolupat per homes joves, sans i en forma. Per tant, en aquest estudi, trenta homes joves, sans i físicament actius van fer un protocol de cicloergòmetre aquàtic amb augment progressiu de la càrrega. La validesa concurrent es va establir correlacionant l'Escala de Ciclisme Aquàtic (ECA) amb la captació d'oxigen, la ventilació pulmonar (VE), la FC i les respostes de concentració de lactat a la sang (LS) a la prova de càrrega incremental màxima. La validesa de constructe es va establir correlacionant la RPE derivada de la ECA (0-10) amb l’obtinguda amb l’Escala de Borg (6-20). Es va mesurar la RPE general, el consum màxim d'oxigen (VO2màx), el consum d'oxigen indexat al pes corporal (VO2), VE, FC i LS durant cada etapa de l'exercici. El rang de respostes a l'exercici a la prova incremental va ser: VO2màx = 1.07–3.55 L/min; VO2 = 14.26–46.89 ml/kg/min; VE = 23.17–138.57 L/min; FC = 99.54–173.31 batecs/min; BL = 1,18-11,63 mM; ACA global = 1,11-9,33. Les anàlisis de correlació/regressió van mostrar la ECA com una funció lineal positiva de VO2max ($r = 0.78$; $p<0.05$), VO2 ($r = 0.87$; $p<0.05$), VE ($r = 0.86$; $p<0.05$), HR ($r = 0,77$; $p<0,05$) i BL ($r = 0,85$; $p<0,05$). La ACA es va mostrar distribuïda com una funció lineal positiva de l'escala RPE-Borg ($r = 0,97$; $p<0,05$). El ANOVA va indicar que una cadència de pedaleig incremental de 15 batudes per minut (bpm) va provocar diferències significatives ($p<0.05$) respecte a etapes prèvies a la majoria de les variables analitzades. En conclusió, la ACA és una eina apropiada per monitoritzar la intensitat de l'esforç durant el ciclisme desenvolupat al medi aquàtic en homes joves, sans i en forma. De manera aplicada es va observar que un breu increment en la cadència de pedaleig aquàtic de 15 bpm augmentarà la intensitat de l'exercici durant el pedaleig aquàtic.

Paraules clau: ciclisme aquàtic; caràcter de l’esforç percebut; control de la intensitat; consum màxim d'oxigen; ventilació pulmonar; ritme cardíac; lactat sanguini.

RESUMEN EXTENDIDO

Se ha demostrado que la práctica de ejercicio, en varios modos y configuraciones, se correlaciona de manera inversamente proporcional con la aparición de factores de riesgo de morbilidad y mortalidad, especialmente en relación con las complicaciones cardiovasculares o respiratorias. A pesar de esta evidencia y de la aparente preocupación y concienciación de la población sobre la necesidad de mejorar la calidad de vida y la importancia de la actividad física, millones de individuos siguen siendo esencialmente sedentarios.

El sedentarismo afecta a una gran parte de la sociedad moderna, ya que las personas no practican los niveles mínimos de actividad física recomendada. Debido a los diversos cambios que se han ido dando en la sociedad, han surgido nuevos hábitos y estilos de vida, haciendo más sedentaria a la población y reduciendo así la actividad física. Por tanto, el sedentarismo se puede definir como la ausencia, disminución o falta de actividad física regular, es decir, cuando una persona realiza solo actividades que no requieren gasto energético. Es por esto que se le llama individuo sedentario. Y se le asocia a nuestro comportamiento cotidiano como consecuencia del bienestar que nos proporciona la vida moderna.

La actividad física regular se considera un componente esencial de un estilo de vida saludable, asociado a un amplio espectro de beneficios en diferentes dimensiones de la salud (Garber et al., 2011). Debido al creciente número de estudios, el estilo de vida saludable asocia directamente la salud con el ejercicio físico, impulsando la búsqueda de productos y actividades que satisfagan esta necesidad (Colado, 1996). En este sentido, se ha generado una mayor oferta de actividades relacionadas con el ocio, el entretenimiento y la salud, entre las que destaca la práctica del acondicionamiento en medio acuático de forma integral (Colado & Moreno, 2001).

La actividad física en el medio acuático manteniendo la posición erguida ha sido recomendada por sus beneficios relacionados con la salud y el rendimiento físico, lo que ha atraído el interés de personas de todas las edades, grupos aparentemente sanos, e incluso aquellos con necesidades especiales, circunstancia que sugiere que las prácticas físicas en el medio acuático hoy en día son variadas. Y es que las respuestas fisiológicas agudas y crónicas generadas por la práctica de la natación (Santhiago et al., 2011), el entrenamiento acuático en aguas profundas (Killgore et al., 2010; Meredith-Jones et al., 2011) y el realizado en aguas poco profundas (Nagle et al., 2017), han sido bien documentadas.

Además de las ventajas del entrenamiento en el medio acuático para el acondicionamiento físico general, se ha producido una expansión en el universo del “*aquafitness*” debido a la aparición de varios tipos de equipamientos o materiales desarrollados para potenciar los beneficios obtenidos a raíz de las propiedades físicas específicas del agua. Los beneficios de los ejercicios acuáticos están asociados a las características físicas del agua. El ejercicio en el agua puede producir reacciones fisiológicas diferentes a las generadas por el terrestre, principalmente por dos razones: el efecto hidrostático del agua sobre el sistema cardiorrespiratorio y su capacidad de intensificar la pérdida de calor en comparación con el otro entorno (Torres-Ronda & del Alcázar, 2014).

Varios estudios en la literatura sobre ejercicios acuáticos realizados en posición vertical analizan el comportamiento de las variables hemodinámicas, de la biomecánica del ejercicio y los efectos del entrenamiento. Los más investigados han sido la hidrogimnasia, el ejercicio en aguas profundas, la marcha en aguas poco profundas, las cintas de correr subacuáticas y las bicicletas ergométricas (Dionne et al., 2017). Dichos programas han sido ampliamente prescritos debido a sus numerosos beneficios para los profesionales. Entre ellos, mejoras en: acondicionamiento musculoesquelético (Ambrosini et al., 2010); acondicionamiento cardiorrespiratorio (Alberton et al., 2016; Kruel et al., 2013); sistema cardiovascular (Colado & Brasil, 2019); sistema hormonal (Cadore et al., 2009; Di Masi et al., 2014); composición corporal (Colado et al., 2009); flexibilidad (Moreira et al., 2019); y también equilibrio (Devereux et al., 2005).

Con respecto a las propiedades físicas del agua, éstas son: masa, peso, gravedad específica, densidad, flotabilidad, presión hidrostática, tensión superficial, refracción y viscosidad (Killgore, 2012). Para cualquier programa desarrollado, el conocimiento y la comprensión de los principios físicos relacionados con el medio acuático son relevantes para obtener eficacia y adecuación, ya que éstos mejoran los objetivos fisiológicos establecidos (Colado et al., 2012). Vale la pena señalar que la temperatura también influye en los aspectos fisiológicos. Fueron abordadas las propiedades físicas más relevantes para esta tesis.

La industria del *fitness* también ayudó a impulsar la aparición de equipos adaptados al entorno acuático y a la aceptación de los materiales destinados al acondicionamiento físico en el medio acuático en posiciones verticales. Incluso se han adaptado otros equipos/materiales que hasta la fecha eran más propios del medio terrestre. Ejemplos son las bicicletas acuáticas, el “*aqua step*”, los mini trampolines, las cintas de correr, los “*aqua postes*”, los remos y máquinas elípticas, etc.

El desarrollo de las secciones del marco teórico, que sustenta esta tesis con base científica, destaca los vacíos actuales a los que el estudio pretende abordar. Así, una bicicleta es un vehículo de tracción humana a pedales que desde principios del siglo XIX ha sido un medio para facilitar el transporte en comparación con caminar (Ferreira et al., 2012). Es uno de los medios de transporte más populares del mundo, y tiene también el mayor crecimiento en número de usuarios, ya sea para el ocio, el entrenamiento físico, la rehabilitación o la práctica competitiva (Becker & Cole, 2000).

El ciclismo acuático es una clase de ciclismo combinado con los efectos terapéuticos de la inmersión en agua, similar a una clase de "*spinning*" que se realiza sumergido en agua, generalmente hasta la apófisis xifoides. Fue introducido originalmente por una empresa italiana que inició la tendencia del *fitness* en Europa a principios de la década de los 2000. Si bien la modificación de los cicloergómetros estándar para uso bajo el agua ha existido desde la década de 1960 para asuntos como la fisioterapia, la rehabilitación (Frangolias y Rhodes, 1996) y la simulación de ingravidez prolongada, no fue hasta hace poco que el ciclismo acuático se convirtió en otra modalidad para mantener y mejorar la condición cardiorrespiratoria. En la actualidad, está apareciendo en gimnasios de toda Europa, Brasil (fue el primer país de América Latina), Estados Unidos y algunos países de Asia (Rewald et al., 2017).

En este sentido, y sabiendo que este tipo de actividad puede ser aplicable a todos los grupos de edad y niveles de acondicionamiento físico, el ciclismo acuático es una forma de acondicionamiento físico que puede permitir a personas interesadas en mantener o mejorar, entre otros aspectos, la aptitud cardiorrespiratoria. Andar en bicicleta bajo el agua proporciona un ambiente de bajo impacto y la resistencia proporcionada por el agua permite altos niveles de gasto de energía con poca tensión musculoesquelética en el cuerpo (Rebold et al., 2013). Si se tiene en cuenta que es ampliamente adecuado para un público muy numeroso, incluidas las personas con lesiones o discapacidades musculoesqueléticas, discapacidades neurológicas, ancianos o atletas en recuperación (Garzón et al., 2015), es posible que el ejercicio físico aumente en popularidad como una forma alternativa de ejercicio para mejorar la condición física (Costa et al., 2017).

Otro punto relevante es el ajuste del equipo, ya sea con el propósito de competir, acondicionamiento físico general o simplemente por placer, la bicicleta (terrestre o acuática) debe ajustarse para el propósito previsto. Según la literatura específica (libros y revistas especializadas), y considerando las medidas cuantitativas de regulación del equipamiento, se ha observado que los paseos han ido configurando las bicicletas basándose únicamente en sensaciones subjetivas (Bini et al., 2011; Carpes et al., 2009).

Dichos ajustes deberán centrarse en el sillín en relación con la posición horizontal y vertical, la posición del manillar y el tamaño de la biela, que suelen ser las partes móviles de la bicicleta (Bini et al., 2011). Estos ajustes merecen especial atención, ya que estas partes móviles pueden regularse según la dimensión del cuerpo del ciclista. La geometría del complejo ciclista-bicicleta puede influir en la magnitud y dirección de la fuerza aplicada al pedal, la técnica de pedaleo, la estrategia neuromuscular adoptada, la economía de movimiento, la probabilidad de lesiones y, más directamente, la sensación de comodidad sobre la bicicleta (Carpes et al., 2009; Kleinpaul et al., 2010).

Una especificidad del ciclismo acuático es el movimiento combinado de los miembros superiores según las posiciones del cuerpo, de pie o sentado. En este sentido, la orientación del instructor es muy importante para garantizar la buena postura del ciclista, especialmente cuando se producen cambios bruscos de medios con distintas densidades. La película que se forma en el agua tiene un ligero efecto de resistencia, pero en los movimientos balísticos, en los que hay un cambio brusco de medios, los ciclistas pueden ser susceptibles a lesiones provocadas por las diferentes densidades de los medios y la fuerza aplicada para romper esa película.

Comprender los efectos fisiológicos del agua en los cuerpos sumergidos, incluso en reposo, es fundamental para todos los profesionales del *fitness* acuático. Debido al alto grado de especificidad de las actividades físicas en el agua, el control de la intensidad del ejercicio a través de extrapolaciones de indicadores fisiológicos obtenidos fuera del agua y transferidos al medio acuático puede evitar errores que podrían afectar la calidad de la prescripción (Graef & Kruel, 2006).

En general, es conocido que para que se pueda conseguir una mejor prescripción, control y seguridad del ejercicio físico, los parámetros más utilizados para monitorear la intensidad durante las sesiones y/o actividades suelen ser la frecuencia cardíaca (FC) y las calificaciones o ratios del carácter del esfuerzo percibido (RPE) durante la realización de ejercicio físico. Para monitorizar la RPE durante el ejercicio físico se ha aplicado habitualmente la escala de Borg (1982) y, en base a ella, se han validado otras escalas para diferentes grupos de edad y tipos de ejercicios, aplicables muchas de ellas tanto al ámbito del *fitness* como a áreas clínicas. Dichas escalas han sido validadas para ejercicios en tierra tras establecer su adecuación mediante correlaciones con diversas variables fisiológicas. Debido a la dificultad para controlar y, muchas veces, medir ciertas variables, la Percepción Subjetiva de Esfuerzo (SPE) está indicada para la prescripción de ejercicio, incluso en medio líquido, debido al alto grado de correlación y linealidad de la FC con SPE (Colado et al., 2018). También se deben observar otros aspectos relacionados con la SPE en los ejercicios físicos, por ejemplo, el volumen de masa muscular activado en las pruebas específicas; diferencias individuales según género, edad cronológica, embarazo; condiciones de prueba que implican privación del sueño y temperatura ambiente; así como la interacción entre los tipos de ejercicios acuáticos o terrestres y sus protocolos que pueden interferir con los resultados finales (Fujishima et al., 2003).

Sin embargo, todavía no existe una escala de RPE específicamente validada para el ciclismo desarrollado en el medio acuático. Por lo tanto, la presente tesis tuvo como objetivo general validar una escala de tasa de esfuerzo percibido para controlar la intensidad durante el ciclismo acuático desarrollado por hombres jóvenes, sanos y en forma. También tuvo como objetivo específico evaluar si durante la práctica de ciclismo acuático es posible realizar una validación concurrente entre las variables fisiológicas (VO2 máx, VE, FC y Lac) y una nueva escala para ciclismo acuático Y evaluar si durante la práctica de ciclismo de agua es posible realizar una validación de constructo entre la escala de Borg 6-20 y una nueva escala para ciclismo de agua.

En el estudio participó una muestra de conveniencia de 30 estudiantes universitarios varones. El tamaño de la muestra se determinó utilizando el *software* G* Power 3.1 (Faul et al., 2009). El cálculo indicó que se necesitaban 30 voluntarios para cumplir con la potencia requerida de 0,85, $\alpha = 0{,}05$, coeficiente de correlación de 0,5, corrección de no esfericidad de 1 y tamaño del efecto moderado. Este análisis previo de potencia estadística se realizó para reducir la probabilidad de error tipo II y determinar el número mínimo de participantes necesarios para que esta investigación rechazara la hipótesis nula al nivel de confianza de $p < 0{,}05$ (Beck, 2013).

Los participantes fueron hombres físicamente activos, pero no hubo deportistas ni practicantes de ciclismo acuático ni de ninguna otra actividad ciclista. No tenían enfermedad cardiovascular, antecedentes osteoarticulares, ni contraindicaciones clínicas, neuromotoras o cognitivas para la realización de las pruebas físicas. Todos los sujetos eran practicantes regulares de ejercicio físico (>160 minutos por semana) y no fumadores (ACSM, 2010).

Cada sujeto participó en dos sesiones, consistentes en familiarización y protocolo experimental. La primera sesión de familiarización se realizó entre 48 y 72 horas antes de la recolección de datos durante el protocolo experimental. Se impusieron varias restricciones a los voluntarios: no consumir alimentos, bebidas o estimulantes (es decir, cafeína) 3 o 4 horas antes de las sesiones y no realizar actividad física más intensa que las actividades diarias habituales 12 horas antes. Se les animó a dormir al menos 8 horas la noche anterior a la recolección de datos. Todas las mediciones fueron realizadas por los mismos investigadores y siempre se realizaron en la misma instalación deportiva.

Anteriormente se ha publicado una descripción detallada de los métodos empleados en este estudio (Mays et al., 2010; Robertson et al., 2004; Utter et al., 2004). Así, teniendo en cuenta las indicaciones previas de Robertson et al. (1996), el siguiente es un resumen de los métodos que pertenecen específicamente a los aspectos de inmersión en agua del experimento general.

Los participantes asistieron a sesiones para familiarizarse con la bicicleta acuática (Hydrorider®, Bolonia, Italia, 2011) con la resistencia que producen las cuatro paletas del mecanismo de pedaleo ajustado al máximo. La altura del sillín se ajustó después de que cada participante se sentara en la bicicleta con el talón presionado el pedal del pie en el punto más bajo y la pierna extendida (Leone et al., 2014); manos posicionadas en la parte inferior del manillar, que caracteriza la posición 2 en el ciclismo acuático (Brasil et al., 2011); y la altura del manillar que queda por encima de la altura del sillín. La profundidad de inmersión adecuada se fijó en el proceso xifoides (inmersión a nivel del pecho) (Yazigi et al., 2013), utilizando para ello los raíles móviles que tenían las bicicletas en su base de apoyo que permite ajustar la altura de la misma.

De acuerdo con los estrictos criterios de estudios previos (Mays et al., 2010; Robertson et al., 2004; Utter et al., 2004), los investigadores instruyeron a los participantes sobre el uso adecuado de ambas escalas de esfuerzo percibido. Los sujetos vieron por separado las escalas Borg y ACS cuando se leyó su respectivo conjunto de instrucciones. Se les dijo que respondieran con categorías numéricas solo sobre su percepción de esfuerzo corporal general indiferenciada utilizando una señal manual para cada escala. Las escalas siempre se colocaron a la vista frente a los sujetos. Debido a que este estudio utilizó una prueba máxima incremental de carga continua, en la sesión de familiarización se explicaron cuidadosamente todos los procedimientos para evitar que el rendimiento físico pudiera disminuir inconscientemente cuando llegaba la fatiga. Para reducir este riesgo, también siempre se requirió el máximo esfuerzo consciente del sujeto y los investigadores apoyaron la prueba con estímulo externo (Wittekind et al., 2011).

La altura de los participantes se determinó utilizando un estadiómetro portátil (IP0955, de Invicta Plastics Limited, Leicester, Reino Unido). La masa corporal total y el porcentaje de grasa se midieron mediante análisis de impedancia bioeléctrica (Body Composition Analysis, Tanita BF-350, Tanita Corp., Tokio, Japón) según estudios y procedimientos previos (Colado et al., 2013). Se indicó a los participantes que usaran pantalones cortos o bañadores de hombre y calzado específico (es decir, calcetines acuáticos) (Athletech, EE. UU.). Luego, los sujetos pedalearon en la bicicleta acuática a diferentes cadencias progresivas, de manera similar a la prueba que se usó durante la sesión del protocolo experimental. Mientras pedaleaban, los sujetos también utilizaron la máscara de recolección de gases para familiarizarse con su uso. Previamente se explicaron todos los detalles técnicos que se deben tener en cuenta para la ejecución de este ejercicio.

Los sujetos participaron en una prueba máxima incremental de carga continúa cambiando la cadencia de pedaleo, que fue controlada por un metrónomo acústico digital (grabado en un disco compacto). La prueba máxima de ciclismo acuático se inició a un ritmo de 100 latidos por minuto, con una etapa inicial de 3 minutos y con incrementos posteriores cada 2 minutos de 15 latidos por minuto en la cadencia de pedaleo acuático hasta llegar al agotamiento (Pinto et al., 2016). Se instruyó a los sujetos para que ejecutaran un ciclo de pedaleo completo (es decir, 0-360º) en dos tiempos (un tiempo para la pierna izquierda y otro para la pierna derecha), considerando que el tiempo es un pulso constante que se repite cíclicamente durante un minuto, y esto determina el ritmo del movimiento [por ejemplo, 100, 115, 130, etc. latidos por minuto (bpm)].

Este aspecto suele emplearse durante las actividades de ciclismo acuático cuando se utiliza la música para controlar la intensidad del ejercicio y establecer la cadencia de pedaleo. Por tanto, un ciclo completo de pedaleo de 360º se ha considerado como el equivalente a una revolución por minuto en nuestro estudio, por ejemplo 160 bpm equivaldrían a 80 rpm. Un investigador siempre estaba en el agua verificando visualmente que este se cumpliera estrictamente para garantizar un cambio uniforme en la prueba máxima incremental de carga (Borreani et al., 2014; Colado et al., 2009).

Utilizando el procedimiento de Pinto et al. (2016) durante el ejercicio acuático, los participantes estaban conectados a un metabolímetro portátil (K4b2; Cosmed, Roma, Italia) que medía el VO2max (l/min) y el VO2 indexado al peso corporal (ml/kg/min) y la ventilación pulmonar (VE) (l/min) respiración a respiración. El metabolímetro se encerró en una bolsa impermeable (Aquatrainer; Cosmed, Roma, Italia) suspendida frente a cada participante. Los analizadores de gases y el flujómetro de los instrumentos respiratorio-metabólicos fueron calibrados antes de cada prueba siguiendo las instrucciones del fabricante. Según Yazigi et al. (2013), se midió la FC por telemetría (Electro Oy, Polar, Kajaani, Finlandia) durante todo el test, y se recogió una muestra de sangre del lóbulo de la oreja cada dos etapas de la prueba y se analizó la BL (mM) con un medidor de lactato portátil. Analizador (Lactate Pro; Arkray Inc., Japón).

La temperatura del agua por encima de los 30ºC provoca un menor confort térmico y limita la tolerancia al ejercicio ciclista probablemente causado por una mayor carga térmica (Yazigi et al., 2013). Sin embargo, para ejercicios realizados en agua termoneutral, el RPE del sujeto parece ser un índice efectivo para la prescripción de la intensidad de la misma forma que lo es para actividades en tierra (Fujishima & Shimizu, 2003). Así, durante todo el experimento, las temperaturas del aire y del agua se mantuvieron termoneutrales a 24° C y 30° C respectivamente (Alberton et al., 2011; Pinto et al., 2015; Pöyhönen & Avela, 2002).

Los RPE de las dos escalas se registraron en orden equilibrado durante los últimos 30 segundos de cada etapa del protocolo. Para ambas escalas, el esfuerzo percibido se definió como la intensidad del esfuerzo, la tensión, la incomodidad y/o la fatiga que el sujeto sintió durante el ejercicio, representando el cuerpo en general (independientemente de las regiones del cuerpo) (Noble & Robertson, 1996; Pinto et al., 2016). La prueba para cada participante finalizó cuando: a) el participante se detuvo voluntariamente debido al agotamiento, b) el investigador detectó que el participante no estaba manteniendo el ritmo de pedaleo fijo en la etapa pertinente, es decir, se perdía la cadencia por 10 segundos consecutivos, o c) el participante se detuvo cuando usó la mano para señalar el agotamiento. Además, la evaluación se consideró válida cuando al final de la prueba se cumplía alguno de los siguientes criterios: tiempo promedio entre 8 y 10 minutos, RPE de al menos 18 en la escala RPE de Borg de 6 a 20, tasa de intercambio respiratorio de (RER) >1.15, y la frecuencia respiratoria máxima fue de al menos 35 respiraciones por minuto (Pinto et al., 2016).

La validez concurrente se estableció correlacionando la Escala de Ciclismo Acuático (ECA) con la captación de oxígeno, la ventilación pulmonar (VE), la FC y las respuestas de concentración de lactato en la sangre (LS) a la prueba de carga incremental máxima. La validez de constructo se estableció correlacionando la RPE derivada de la ECA (0-10) con la obtenida con la Escala de Borg (6-20). Se midió la RPE general, el consumo máximo de oxígeno (VO_2máx), el consumo de oxígeno indexado al peso corporal (VO_2), VE, FC y LS durante cada etapa del ejercicio. El rango de respuestas al ejercicio en la prueba incremental fue: VO_2máx = 1.07–3.55 L / min; VO_2 = 14.26–46.89 ml / Kg / min; VE = 23.17–138.57 L / min; FC = 99.54–173.31 latidos / min; BL = 1,18-11,63 mM; ECA global = 1,11-9,33. Los análisis de correlación / regresión mostraron la ECA como una función lineal positiva de VO_2max ($r = 0.78$; $p <0.05$), VO_2 ($r = 0.87$; $p <0.05$), VE ($r = 0.86$; $p <0.05$), HR ($r = 0,77$; $p <0,05$) y BL ($r = 0,85$; $p <0,05$). La ECA se mostró distribuida como una función lineal positiva de la escala RPE-Borg ($r = 0,97$; $p <0,05$). El ANOVA indicó que una cadencia de pedaleo incremental de 15 batidos por minuto (bpm) provocó diferencias significativas ($p <0.05$) con respecto a etapas previas en la mayoría de las variables analizadas.

En conclusión, la ECA es una herramienta apropiada para monitorear la intensidad del esfuerzo durante el ciclismo desarrollado en el medio acuático en hombres jóvenes, sanos y en forma. De manera aplicada se observó que un breve incremento en la cadencia de pedaleo acuático de 15 bpm aumentará la intensidad del ejercicio durante el pedaleo acuático. El presente estudio valida un sistema de percepción del esfuerzo de aplicabilidad inmediata para el ciclismo acuático, superando algunas limitaciones específicas que parecen haber tenido escalas previamente validadas cuando se aplican a esta actividad acuática específica (Robertson et al., 1996; Robertson et al., 2004).

Por lo tanto, una diferencia importante entre la ACS y las escalas RPE anteriores es el uso de una figura pictória específico con descriptores de ciclismo acuático y enfatizarlo en los rasgos faciales asociados con el nivel de intensidad del esfuerzo requerido. Se ha demostrado que las señales visuales adecuadas (es decir, información comprensible para el sujeto) pueden, en ocasiones, mejorar la comprensión de las puntuaciones y la practicabilidad (Rogers, 2006). En consecuencia, ACS será una herramienta adecuada para mejorar la calidad del control de intensidad durante las actividades de ciclismo acuático.

Se utilizan diferentes ritmos durante las actividades de ciclismo acuático (es decir, pedaleo lento a rápido), por lo que la intensidad del ejercicio fluctúa de niveles bajos a altos. La validación de la Escala del Ciclo Acuático es necesaria porque agregará una herramienta de monitoreo fácil para pruebas, entrenamientos o autorregulación de la intensidad. A continuación, se describen los principales resultados de esta investigación y se comparan con las hipótesis iniciales planteadas.

H1: Existirán diferencias estadísticamente significativas en el comportamiento de las variables fisiológicas y de percepción de esfuerzo durante el desarrollo del protocolo.

El VO2max, VO2 y VE mostraron diferencias estadísticamente significativas en todas las cadencias de pedaleo a partir de 115bpm. Tal comportamiento también se observó en el ACS y en la Escala de Borg RPE. Por lo tanto, confirmamos la hipótesis propuesta 1. La FC mostró significancia estadística solo en cadencias de pedaleo a partir de 145bpm y BL solo en cadencias de 175bpm y 190bpm. Las dos situaciones también confirmaron la hipótesis planteada, especialmente al considerar las condiciones fisiológicas requeridas para la evolución de las dos variables.

H2: La percepción del esfuerzo derivada de la nueva escala para el ciclado del agua se distribuirá como una función lineal positiva respecto a la respuesta de las variables fisiológicas (frecuencia cardíaca, consumo de oxígeno y ácido láctico).

Los datos corroboran la hipótesis 2, ya que todas las correlaciones fueron significativas (p<0,05), independientemente de la intensidad (R2), por lo que el ACS pudo explicar, aunque sea parcialmente, las variaciones en las variables fisiológicas incluidas en el presente estudio.

H3: La percepción subjetiva del esfuerzo derivado de la nueva escala para ciclismo de agua y la Escala de Borg 6-20 durante el aumento de la carga en el protocolo utilizado puede estar correlacionada positivamente.

La hipótesis se cumplió, dado que el objetivo de esta tesis es la validación concurrente y de constructo de la escala de valoración del esfuerzo percibido en ciclismo acuático. Por lo tanto, RPE-ACS tiene una correlación lineal positiva de la Escala RPE-Borg (r=0,97; p<0,05).

Los resultados de esta investigación ofrecen a los profesionales las siguientes aplicaciones prácticas:

1. La ACS es factible y fácil de aplicar en clases grupales, pequeños grupos e individuales. No requiere recursos tecnológicos, preparaciones previas, incluido el medio ambiente. Cabe destacar que la familiarización es fácil, debido a las características lúdicas e intuitivas de la escala. En este sentido, la inversión es significativamente baja; un letrero resistente al agua parece ser suficiente.
2. La prescripción del ejercicio se basa comúnmente en pruebas de ejercicio cardiopulmonar, lo que requiere un equipo costoso que depende de los procedimientos de calibración y, por lo general, no está disponible para su realización en entornos acuáticos. Además, el control de la intensidad del ejercicio a través de herramientas como el reloj inteligente puede no ser accesible para la población general y la palpación digital de las arterias superficiales ha demostrado una calidad de medición deficiente en el entorno acuático. Asignar o señalar una nota a un esfuerzo particular en una escala creciente parece reducir la dificultad.
3. Desde otra perspectiva, se debe considerar que a veces los deportistas están entrenando con compañeros o en una situación de grupo masivo donde se realiza una cadencia de pedaleo fija para todos. En esta situación práctica, y debido a que habitualmente los diferentes deportistas pueden tener distintos niveles de acondicionamiento físico, es necesario cambiar la resistencia de la actividad de ciclismo acuático aumentando o reduciendo las fuerzas de arrastre mediante la modificación de las partes móviles de la bicicleta acuática, lo que permite tener una mayor o menor fuerza de arrastre logrando así una mejor adaptación del ejercicio para cada uno de los deportistas.
4. En este caso práctico habitual en los entornos acuáticos de todo el mundo, se necesitan también herramientas que puedan ayudar a monitorear la calidad del estímulo del entrenamiento. Así, en estos casos específicos, y teniendo en cuenta la necesidad de procedimientos fáciles y económicos que puedan ser empleados en cualquier lugar y para cualquier persona, además de emplear la frecuencia cardíaca como indicador del nivel de

intensidad, se necesitan otras herramientas, como es el caso de la escala RPE. Con esta escala RPE los técnicos y los usuarios podrán tener una buena estimación de la intensidad del ejercicio, y de esta manera, podrán hacer la práctica de manera más eficiente y segura.

5. En definitiva, pensamos que, si se analizan todas estas consideraciones desde un punto de vista global, el ACS es otro tipo de herramienta precisa que puede ayudar fácilmente a monitorizar la seguridad y eficiencia de las aplicaciones prácticas de las actividades de ciclismo acuático. Como el ciclismo acuático se ha convertido en una tendencia de acondicionamiento físico reciente en Europa, EE. UU., América del Sur y sigue creciendo en todo el mundo, muchas piscinas públicas y también privadas ofrecen ciclismo acuático a una población saludable, grupos con trastornos musculoesqueléticos y cardíacos podrán usar estas herramientas de entrenamiento. Se abre así la oportunidad de participar en un programa de ejercicios moderno y popular.

Cabe mencionar que, en la actualidad, si bien existen diferentes dinámicas en las intervenciones, en particular el uso de coreografías, miembros superiores y equipamientos adicionales, el uso de la escala RPE no se ve comprometida. Es decir, es aplicable a la modalidad. En definitiva, refleja el esfuerzo general percibido por el practicante durante la práctica deportiva.

CHAPTER I:

INTRODUCTION

1. INTRODUCTION

Regular physical activity is considered an essential component of a healthy lifestyle, associated with a broad spectrum of benefits in different dimensions of health (Garber *et al.*, 2011). Due to the increasing number of studies, healthy lifestyle directly associates health with physical exercise, boosting the search for products and activities that meet this need (Colado, 1996). In this regard, there has been a greater offer of activities related to leisure, entertainment and health, amongst which the practice of conditioning in aquatic environment in a comprehensive way (Colado & Moreno, 2001).

Exercise, in various modes and configurations, has been shown to be inversely proportional to mortality, especially in relation to cardiovascular or respiratory causes (Paffenbarger Jr *et al.*, 1986). Despite this evidence and apparent concern and awareness of the population regarding the need of improvement in the quality of life and the importance of physical activity, millions of individuals remain essentially sedentary.

Physical activity in the upright position in aquatic environment has been recommended due to its benefits related to health and physical performance (Meredith-Jones *et al.*, 2011; Raffaelli *et al.*, 2010), which has attracted the interest of people of all age groups, apparently healthy, and even those with special needs (Colado *et al.*, 2009; Raffaelli *et al.*, 2010).

General conditioning benefits provided by exercise programs performed in water are related to different ways professionals explore aquatic this medium and equipment (Pinto *et al.*, 2011). In this respect, the augment of the aquatic fitness universe has also been due to the development of different equipment to maximize physical properties of water. The most common types of equipment are buoyant (less dense than water), drag (resistance for all submerge movements), rubberized (similar benefits are seen on land), weighted (similar to land-base) and flotation (create neutral buoyancy). As a result of the acceptance of these of these implements aimed at water aerobics, other specialized equipment has been adapted to be used, such as: water bikes, aqua steps, mini trampolines, aqua poles, aqua boxing bags, aqua wall stations, stand-up paddle boards and elliptical machines (Torres-Ronda & del Alcázar, 2014).

This suggests that physical practices in the aquatic environment nowadays are varied (Colado, 2004; Meredith-Jones *et al.*, 2011). In the literature, acute and chronic physiological responses to swimming (Santhiago *et al.*, 2011), deep water aquatic exercises (Killgore *et al.*, 2010; Meredith-Jones *et al.*, 2011) and also in the shallow (Nagle *et al.*, 2017), have been well documented. However, few studies on physiological responses during water cycling (Di Masi *et al.*, 2007; Giacomini *et al.*, 2009) can be found. Although few studies have examined objective criteria for controlling intensity in this latter type of practice (Brasil *et al.*, 2011; Pinto *et al.*, 2016; Yazigi *et al.*, 2013), the applicability of activities or specific prescriptions in safe and effective manner is limited.

Aquatic cycling is a program for individuals interested in maintaining or improving cardiorespiratory fitness being applicable to all age groups and levels of conditioning **(Figure 1)** (Rewald *et al.*, 2017). Consequently, respecting biological individuality and establish safe bases that contribute to the control of training intensity is crucial (Brasil *et al.*, 2011; Di Masi *et al.*, 2007; Giacomini *et al.*, 2009). Aquatic stationary bicycles do not favour measuring athletes resistance to the load because there is no system to control this resistance (load). Thus, the magnitude of the resistance depends mainly on pedalling frequency and body position (Giacomini *et al.*, 2009).

As a result, for better prescription, control and safety of exercise, heart rate (HR) and rating perceived exertion (Cardoso, Mazo, & Balbé, 2010) seem to have been the usual parameters to monitor intensity during sessions (Tibana *et al.*, 2019; Brasil *et al.*, 2011). Such application is based on the linearity between RPE and physiological variables (Alberton *et al.*, 2011). RPE has frequently been used as a valid and reliable indicator to monitor individual’s tolerance when working on the target zone (Nakamura *et al.*, 2009).

Figure 1. Aquatic cycling class for a group. (Personal photo, Acapulco-México, 2006)

To monitor RPE during aerobic exercise, Borg RPE scale (Borg, 1982) has usually been applied. The Borg scale is one of the examples of simplified models of OMNI perceived exertion scales (Robertson *et al.*, 2005; Robinson *et al.*, 2004; Utter *et al.*, 2002). From this scale, others were validated for different age groups, both for fitness and clinical use. These scales were validated for land-based exercises and had their correspondence made from the establishment of relations with physiological variables during the protocol.

In the study to validate the OMNI-Cycling Scale construct and concurrent validity modes were used (Robertson *et al.*, 2004). For the former, the correlation between the

Borg scale (6-20) (criterion variable) and the OMNI scale (conditional variable) was identified. For the second, the physiological variables of oxygen consumption (VO_2) and heart rate (HR) (criterion variables) were correlated with perception of central, peripheral and total exertion (competing variables) obtained in this OMNI-Cycling Scale. Ultimately, it was determined that the OMNI-Cycling Scale could be used to estimate RPE for female and male adults during training on the exercise bicycle (Robertson *et al.*, 2005).

As can be seen, and after a thorough review of the literature until now, there appears to be a gap in knowledge regarding the validation of a specific instrument to monitor RPE in aquatic programs, particularly for aquatic cycling. Articles point to the practical use of the 6-20 Borg scale (Borg, 1982) or the CR-10 for: adapted swimming activities (Psycharakis, 2011), deep-water gymnastics (Killgore *et al.*, 2010) shallow-water gymnastics (Alberton *et al.*, 2011; Colado & Triplett, 2009), and, even, water cycling (Brasil *et al.*, 2011). Nonetheless, no specific scale has yet been validated in this respect, which highlights the originality of this work.

CHAPTER II:

THEORETICAL FRAMEWORK

2. THEORETICAL FRAMEWORK

Here follows the development of the sections of the theoretical framework, which provides the scientifically based thesis and highlights the current gaps to which the study intends to address.

2.1. Historical Perspective of Exercise in the Aquatic Medium

It is known that aquatic exercises are not privileges of modern man. The earliest evidence available on the relationship between man and water dates back to 4500 BC. Some rock paintings were found in a cave in southwestern Egypt (Sahara Desert) and they are depicting a group of humans swimming. Some researchers defend the hypothetical existence of a large lake or river there in prehistoric times, prior to its desertification. This cave was named "Cave of Swimmers" by its discoverer, Count Laszlo Almasy (Bierman, 2005).

It is also known that the earliest civilizations were established on the banks of large rivers (Indus, Tigre, Euphrates, Nile), and, therefore, the existence of a relationship between man and water can be presupposed. The Harappa culture emerged around 2500-1800 B.C. and it pertains to this culture the city of Mohenjo-Daro where was found what historically and archaeologically is the first swimming pool. The structure, with dimensions of 11.7 m of length by 6.9 m of width and 2.4 m in its deeper zone as well as the very construction characteristics (bricks and impermeable features), suggests that it was in fact a swimming pool (Belloch *et al.*, 2012).

The therapeutic role of water was present in many cultures due to its relation to mysticism and religions. Historical archives mention ancient Japanese and Chinese civilizations performing rituals to worship running water and having immersion baths for long periods (Brody & Geigle, 2009). Records from 2400 B.C. suggest Proto-Indians used water for hygienic purposes; Egyptians, Assyrians and Muslims used mineral water for curative purposes; and Hindus, in 1500 B.C., fought fever with water. It is worth mentioning some swimming scenes of Assyrian soldiers. They were the only ones allowed to bath in the river, since, in those civilizations, rivers were considered sacred, which gave them a clear advantage in the war during displacements in aquatic environments. In addition, Assyrian civilization provided the first archaeological evidence of an auxiliary material used in aquatic locomotion: a full balloon to increase buoyancy (Campion, 2000).

It can be said that Greek and Roman cultures were very prolific in aquatic practices, for there are a myriad of records preserved by writing and art. In 500 BC Greek civilization ceased to see water mystically and began to use it for specific physical treatment, hygiene and disease prevention. Hippocrates (460-375 BC) used immersion in hot and cold water to treat diseases such as muscle spasms and rheumatic diseases (Becker & Cole, 2000). The Lacedaemonians created, in 334 B.C., the first public bathing system that became part of social activities (Brody & Geigle, 2009).

Greek civilization was the first to recognize the value of baths and developed bath centers near natural springs and rivers. They seem to have noticed the benefits of bathing and recreation to body and mind (Becker & Cole, 2000). The Greeks included swimming in their educational program, associating exercise to a differentiated intellectual level. And, despite never having included in Pan-Hellenic Games of antiquity - although it is known that swimming and aquatic trials were part of the athlete's preparation, there is evidence, from some texts of the Greek historian Pausanias, of the existence of swimming competitions once a year in Hermione's polis (Belloch *et al.*, 2012).

With the decline of the Roman Empire, the use of the famous bathing system started to be abandoned and, by the year 500 A.D., it was almost extinguished. During the Middle Age, due to the influence of religion, which considered the use of physical strength (except for knights with war aims) and baths as pagan acts, the bathing system continued to be disregarded until the fifteenth century when there was a slight resurgence. In 1538, the first printed book on swimming, "Colymbetes, sive of art natandi dialogus et festivus et iucundus lectu", written by Nicholas Wynman (Moreno, 2000) appeared in Augsburg, Germany. From this publication to the nineteenth century, numerous treaties on swimming were written in Germany, Britain, France, and in what later became the United States of America (Belloch *et al.*, 2012).

Concomitantly, therapeutic use of water gradually increased in the early 1700s when a German physician, Sigmund Hahn, and his sons advocated using water to treat leg ulcers and other medical problems. That new medical practice was named hydrotherapy which, according to the definition of Wyman and Glazer, consisted in the application of water in any form for treating diseases. The earliest publications related to scientific hydrotherapy were in 1697 by Sir John Floyer (An Inquiry into the Right Use and Abuse of Hot, Cold and Temperate Baths - An Investigation into the Correct Use and Abuse of Hot, Cold, and Temperate Baths (Brody & Geigle, 2009).

Baruch believed that Floyer's treatment had influenced the teachings of Heidelberg University through Professor Fridrich Hoffmann, who included Floyer's doctrines in his teachings. Those teachings were taken to France and England by Professor Currie, who wrote several scientific papers on hydrotherapy. Although Currie's work had little acceptance in England, the opposite happened in Germany. John Wesley, the founder of Methodism, wrote a book in 1747 based on water as a healing medium. Hot steam baths followed by cold baths were popularized and became a tradition in Scandinavian and Russian culture for many generations (Brody & Geigle, 2009).

In the mid-nineteenth century, hydrotherapy school and a research center in Vienna was founded by professor Winterwitz, where he conducted scientific studies that established an acceptable physiological basis for hydrotherapy at that time. Some important contributions to the study of the physiological effects of heat and cold and on the thermoregulation of the body in the application of clinical hydrotherapy was brought. Such protocols served as a major impetus for the implementation of whirlpool baths and underwater exercises, which only came into regular use in the early twentieth century (Brody & Geigle, 2009).

One of the first Americans to devote his studies to hydrotherapy was Dr. Simon Baruch. He developed out his work from his studies with Dr. Wintirwitz in Europe and published books such as "The Use of Water in Modern Medicine" and "Principles and Practice of Hydrotherapy." Baruch was the first professor at Columbia University to teach hydrotherapy. From that time on, water was no longer used passively through immersion baths and began to be used more actively with the use of flotation property for performing exercises (Brody & Geigle, 2009).

The introduction of spas in Europe and the United States began to widespread and there was room for rehabilitation treatments with specific health professionals in addition to traditional treatments. Later in Europe, in 1898, the concept of aquatic exercise was recommended by Von Leyden and Goldwater, and included the use of individual's active participation in-water exercises instead of receiving passive treatments by health professionals (Ruoti, 1997).

However, those exercises were only systematically developed in the 20s. In 1928, physician Walter Blount described the use of a motor-driven swirl tank, which became known as the "Hubbard Tank." This innovation was created for the exercises execution by the patients in the water, which, in turn, brought to Europe great development of aquatic treatments techniques, such as the method of the Bad Ragaz rings and the Halliwick method (Campion, 2000).

Although aquatic rehabilitation has made great strides since the beginning of the 20th century, it is necessary to intensify the use of this therapeutic practice by health professionals who believe in its benefits, stimulating the incorporation of aquatic rehabilitation into therapeutic treatment programs (Cha *et al.*, 2017).

2.1.1. Development of the Bicycle

A bicycle is a human-powered, pedal-driven vehicle that since the early 19th century has been a means of facilitating transportation when compared to walking (Ferreira *et al.*, 2012). The bicycle is one of the most popular means of transportation in the world, and has also the fastest growing number of users, either for leisure, physical training, rehabilitation or competitive practice (Becker & Cole, 2000).

The debut of the first bicycle seems to be inaccurate, there are still questions as to its "date of birth" and inventor. Leonardo Da Vinci and Count Sirvac are appointed as inventors, but there are representations in bas-reliefs in ancient Egypt and Babylon, as well as in Pompeii frescoes (Ferreira *et al.*, 2012). The French Count Sirvac, in 1791, presented the *celerifere* **(Figure 2)**, which was a two-wheeled vehicle, made of wood. It had four wheels instead of two and a seat. A rider would power forward by using their feet for a walking/running push-off and then glide on the *celerifere* (Ferreira *et al.*, 2012).

Figure 2. Celerifere (Nabinger, 2006).

In 1817, a German, Baron Karl Drais, presented an improved version of the *celerifere*, the Draisine bicycle **(Figure 3),** which had a handlebar allowing change of direction. It had no pedals and a rider would need to push his or her feet against the ground to make the machine go forward (Turpin, 2013).

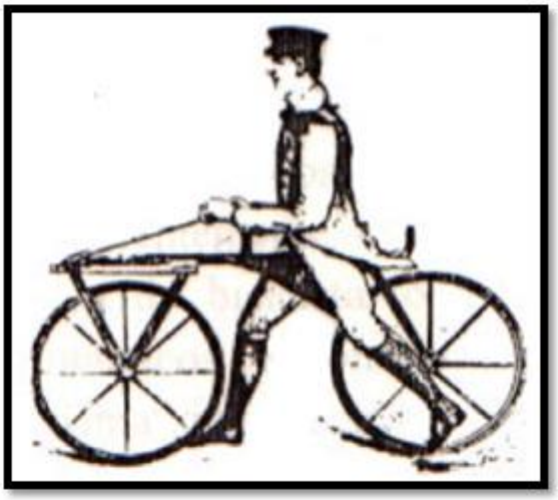

Figure 3. Draisine Bike (Hinault, 1988).

Several models developed from the Draisian bike, but none as prominent as the Lallement model (USA, 1866). The Frenchman Pierre Lallement presented the first record of improvement on a bicycle **(Figure 4)**. He added a transmission mechanism on the axle of the front bicycle wheel. This transmission mechanism consisted of a rotary crank and pedals, with a one to one relationship between the wheel and the pedals (Petty, 2007).

Soon after the launch of the pedal bike, the larger front-wheeled bike came in 1870 **(Figure 5)** to answer the need for covering greater distances. A larger diameter wheel was essential to do so in a single pedalling cycle, since the relationship between pedals and the wheel remained the same (Ahmed *et al.*, 2015).

Around 1885, the Englishman J. K. Starley produced, with great commercial success, the first bicycle like those of today **(Figure 6).** Wheels were the same size and there was a chain-driven system through which the turn of the pedals moved the rear wheel (Durie & Huggins, 1998).

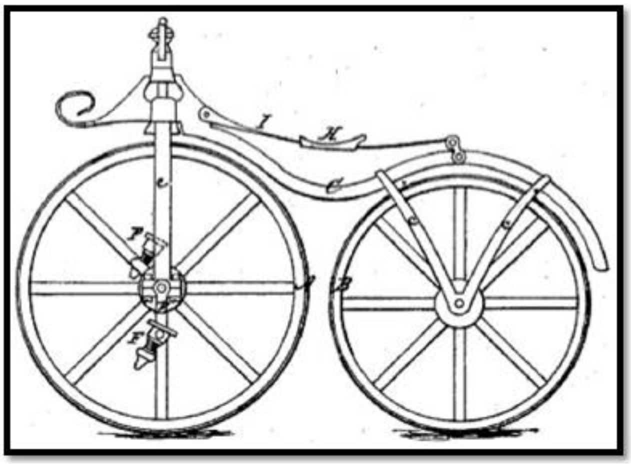

Figure 4. Lallement Bicycle (Hinault, 1988).

Figure 5. Bicycle with very large front wheel and smaller back wheel (Hinault, 1988).

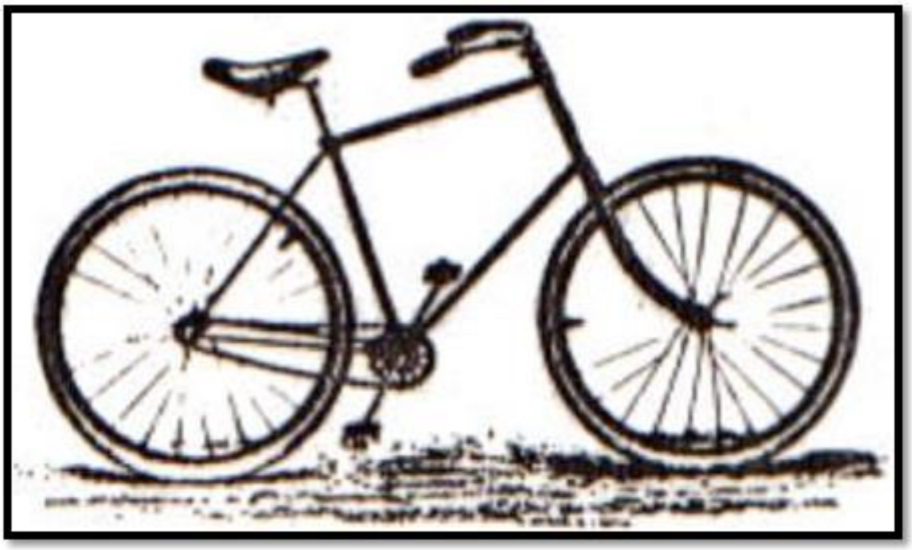

Figure 6. Ordinary Bicycle (Nabinger, 2006)

It is easy to notice that after more than a century, the basic structure of the bicycle remains, and most changes today refer to accessories and materials involved in the manufacture of parts, and the introduction of gears that provide variation of the transmission ratio between pedalling and wheel action (Ahmed *et al.*, 2015).

Several exercise devices allow people to train indoors, for example, the stationary bike **(Figure 7a),** considered one of the best machines for cardiovascular fitness programs. However, conventional models are rigidly mounted in fixed position and unable to simulate angular movements, leading cyclists to be unwilling to continue exercising after a short time. Based on that, Chang's invention aimed at optimizing the training proposing a swaying model. **Figure 7b** shows possible angular displacements of the bicycle (Pequini, 2005).

Indoors bikes have become one of the most popular exercise tools to save time; highlighted that, because, they include bases mounted on fixed chassis, they cannot move or sway during pedalling action (De Lorenzo & Hull, 1999). Therefore, when using this type of bicycle, riders cannot feel the swaying movements provided by outdoor bikes.

Afterwards, a new design for indoor exercise bikes, which makes them unstable, but has a system to control instability, simulating the feeling of riding an ordinary bike (Pequini, 2005).

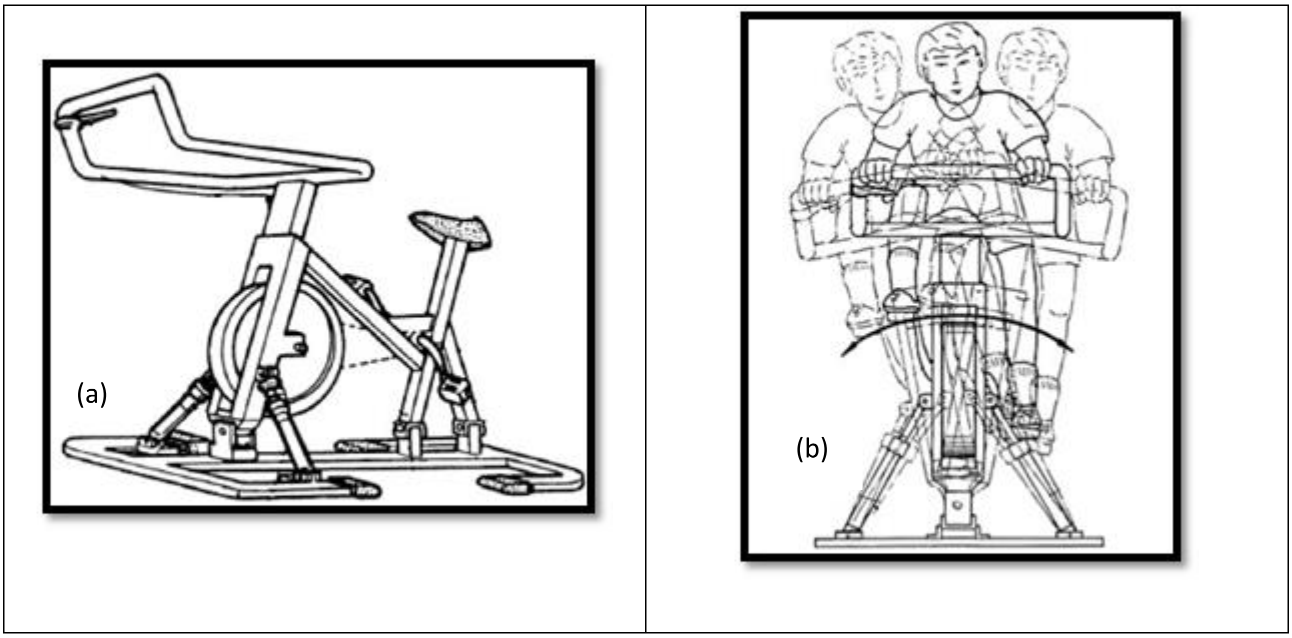

Figure 7. Equipment proposed by the author: **(a)** stationary bike, **(b)** angular displacements (Nabinger, 1997).

Devices to perform a simulated cycling exercise appear later **(Figure 8).** The design features a bike frame and handlebars. It includes an assembly of rotational pivot bearings, handlebar stem and elements, which result in a bicycle, that allows a combination of lower (legs) and upper (De Carlo & Armstrong, 2010) limb exercises at the same time, providing a closer outdoor cycling (Pequini , 2005).

Shortly after, an articulated stationary bicycle for physical exercise, especially indoor **(Figure 9).** This machine has a hinge between two elements of a structure, to allow their relative angular displacement and provide both a combination of balance and freedom sensitive to the forces applied, in order to decrease the impact in the bone and nervous structure of the human body providing comfort to the user (Pinzon, 2012).

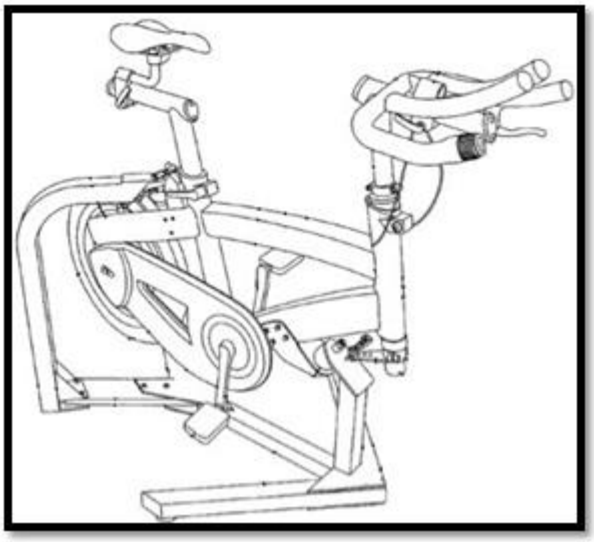

Figure 8. Exercise bike for multiple elements (Nabinger, 2006).

Figure 9. Articulated stationary (Nabinger, 2006).

Cyclist’s activity can be performed on stationary indoor bikes or regular outdoor bikes with appropriate accessories. For example, **(figure 10a)** a mechanical brake bike, **(Figure 10b)** a Swin brand “velodyne” system with electromagnetic brake coupled to a speed bike and an ordinary machine **(Figure 10c)** on a bike roller (Pinzon, 2012).

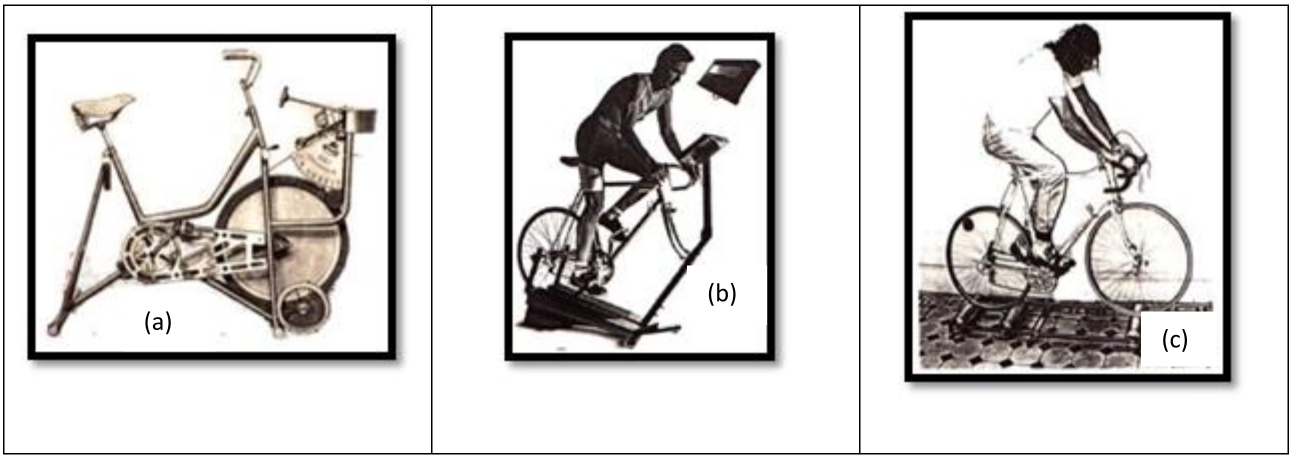

Figure 10. Stationary Cycling: **(a)** stationary bike, **(b)** Swin Velodyne **(c)** bike on rollers (Nabinger, 1997).

There are also called cycle ergometers, which measure control variables objectively. One of the most contemporary equipment was proposed, as a cycle ergometer called Biobike. It provides a dynamic adjustment of frame size to the rider, as well as diverse biomechanical variables in real time through specific software (Farjadian *et al.*, 2013).

In stationary cycling, indoor cycling (IC), as popularly known, is one of the most usual modalities in sports centers and gyms. This activity is conducted by a Physical Education professional for a group of people ranging in age, gender and physical fitness on stationary bikes with varying aerobic and anaerobic endurance training. Generally speaking, indoor cycling is performed at a specific location and has vascular conditioning purposes (Di Prampero, 2000).

2.1.2 Indoor Cycling in Gyms

For this Olympic sport, bicycles are used in competitions on different terrains, such as track, dirt and ice, among others. Competitors are categorized according to age, gender, and amateur and professional levels. Besides being used for competitions, bikes are also used for artistic, recreational and physical conditioning purposes. With the development of various bicycle models, stationary bicycles appeared in departments of ergometry in gyms, medical clinics and sports centers; and the indoor cycling, as it more commonly known, became popular. IC has shown rapid global growth in recent years (Farjadian *et al.*, 2013).

Safety and practicality of this activity have led an expressive amount of people towards its practice, as well as raised their interest in the potential of this modality in programs to control body mass, improve physical conditioning and performance (Alejandro *et al.*, 2003).

In stationary cycling, two major categories of bicycles emerge: those with free sprockets and those with fixed sprockets. Sprocket is a profiled wheel with teeth (or cogs) that mesh with a chain, track or other perforated or indented material and connects the wheel to the chain set and chain rings. The free sprock*et al*lows the wheel to rotate independently of the pedals whereas the fixed sprocket causes the wheel to rotate concomitantly with the pedals. There is a second subdivision related to the type of wheel braking: mechanical, magnetic or aerial. Free-sprocket stationary bikes are upright or recumbent bikes. Those equipped with fixed sprockets are bicycles used in the IC **(Figure 11**), where all load control is done subjectively (Zhao *et al.*, 2019).

Studies refer mostly to free-sprocket and magnetic braking bikes, which may seem awkward considering the wide use of the fixed-sprocket bikes in physical conditioning programs and the specificity of the motor gesture developed with its usage. It is noteworthy that for the performance of a protocol or exercise, the load imposed during the pedalling cycle must be known, since that is the only possible way to analyse a riders' physiological response, and this can easily be done with the use of cycle ergometers (Zhao *et al.*, 2019).

Correct bike setting is important for safety. Although the fixed sprocket helps participants improve pedalling, good technique is also required. This fixed tool allows out of the saddle and standing pedalling. Most bikes allow change of height and position of saddle as well as height and position of handlebars. In any case, however, the IC bike does not allow measurements and, consequently, cannot be classified as a cycle ergometer. Limitations, therefore, stand on the prescription of training intensities in IC and, mainly, on the aspects studied by physiology and biomechanics of exercise (Zhao *et al.*, 2019). Thus, IC bike is a type of stationary bicycle with its geometry inspired by road cycling bicycles. It differs from cycle ergometers basically on the following features: its fixed sprocket on the steering wheel, frame geometry, and absence of a device for setting workload, making this workload measurement totally subjective (Mestre *et al.*, 2011).

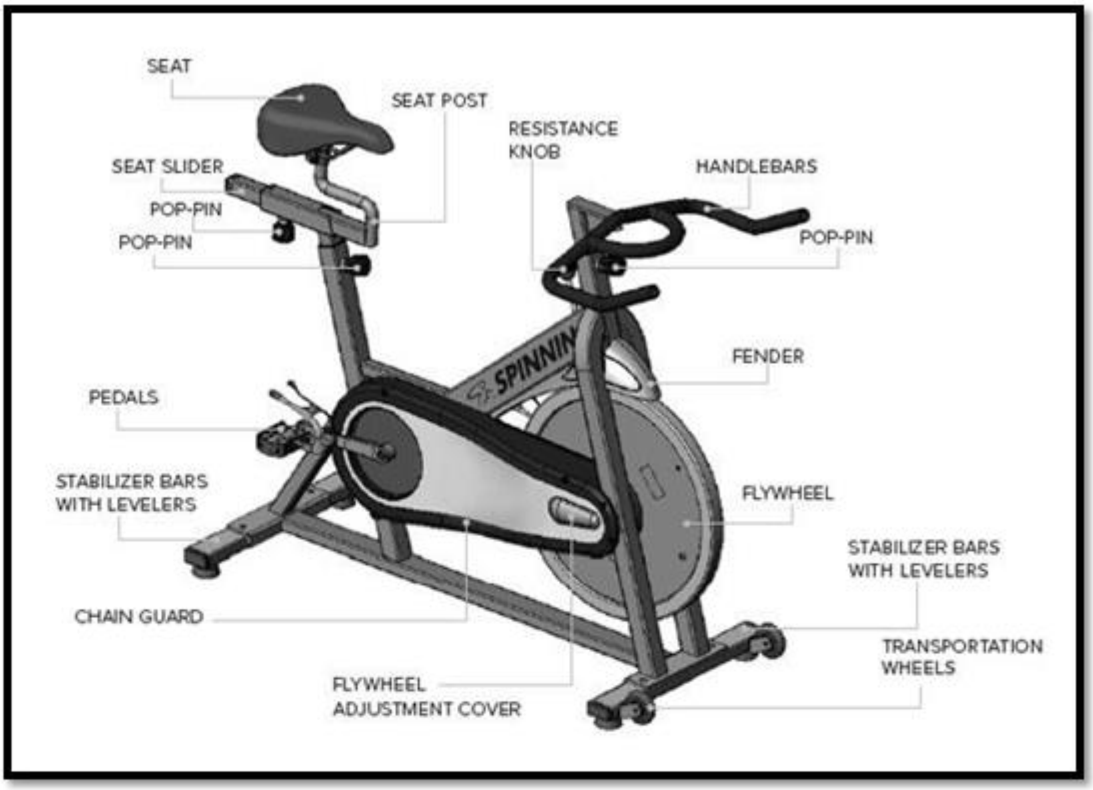

Figure 11. Indoor Cycling (IC) (Nabinger, 2006).

When in use, indoor cycling bikes generate power on their pedals that move together with the wheel. This joint movement only ends when the resistance between the wheel and the braking device, as well as the friction on the other parts, is sufficient to cease the existing kinetic force. So, if this power (load) is not enough to decelerate the wheel, the rider will have his lower limbs projected ahead in an uncontrolled cyclic movement, not by voluntary contraction but by the inertia generated by the wheel of the indoor cycling bike, which may cause a harmful movement to the rider (Mestre *et al.*, 2011).

In addition to the fixed sprocket, the geometric arrangement of the frame differentiates indoor cycling bikes from cycle ergometers. The former had its conception based on road cycling bikes, which have their frame design aimed at aerodynamic gain. In this sense, indoor cycling bikes differ from cycle ergometers in biomechanical terms, which may influence the performance of the user. Such influence, both for road cycling and for stationary usage, has already been reported in the literature. Examples of this are the energy expended by the cyclist in climbing conditions, the values of produced power and maximum oxygen consumption, pulmonary ventilation responses, heart rate, oxygen consumption and work produced and, in the electromyography (EMG) signal generated in lower limbs when pedalling in different models of stationary bicycles (Östergård, 2011).

Jonathan Goldberg, also known as Johnny G., a South African native and former professional athlete, used to train for road cycling competitions (**Figure12**). At a certain moment, he began to simulate training at his garage to escape heavy rains and not to leave his wife alone at home due to her pregnancy. He designed a road cycling bike adapted to the stationary medium and used it for his indoor trainings. With the idea of this bike consolidated, Goldberg began to train some private students in his garage. Soon, his indoor bike became successful, and the indoor sport emerged, which resulted in him developing the now hugely popular indoor cycling program (Albuquerque, 2006).

Later, companies in the fitness market became interested in manufacturing this new bike. In 1995, the American company, Mad Dogs Athletics, registered and patented the IC training method entitled "Johnny G. Spinning Program", in partnership with the American bicycle factory Schwinn. Subsequently, the progress of the IC, specifically the Johnny G.

Spinning Program, culminated in a worldwide success present in more than sixty countries The search for health, quality of life, aesthetics and athletic capacity has generated a marked growth and multiplication of spaces, including virtual, through technology, for these classes / protocols to succeed (Albuquerque, 2006).

Figure 12. Johnny G (American Council on Exercise (ACE) (Goldberg, 1999).

2.1.3 Indoor Cycling in the Current Scenario

Contemporary active lifestyle has helped in the proliferation of fitness centers where Physical Education professionals guide their students through different types of physical activities (Wickham *et al.*, 2017). Among them, IC has showed great development in recent years, also known as spinning, is a physical activity offered in most gyms. Participants of different ages, body mass indices (BMI), and physical fitness cycle on modified stationary bikes following the music rhythm and the instructions of the IC trainer. The choreography of the music plays an important role in IC because it may modify the participant’s motivation and the intensity of the exercise (Elliott *et al.*, 2004).

Interestingly, indoor cyclists have an interest in the potential of the modality, not only in physical conditioning programs, but also for weight control (Kang *et al.*, 2005). Several studies have analysed the effect of IC on several parameters related to health, such as maximal oxygen consumption, blood pressure, body composition, as well as biochemical markers such as HDL or LDL (Chavarrias *et al.*, 2019).

Of the characteristics of IC, activities of considerable effort stand out. They range between 55.00% and 92.00% of the maximum heart rate and are alternated with active recovery and correlated with music. The popularity of IC seems to be linked to the kinesthetic experience of pedalling outdoors with the use of techniques that create virtual roads with challenging terrains, in addition to using sports training strategies to motivate its participants to quest for results (Chavarrias *et al.*, 2019). The exodus from the streets of cyclists can explain this, insertion of new fans in search of safety and practicality, and, also, the emergence of new bike models and types of programs, including those delivered through digital platforms (Meireles & Ribeiro, 2020).

It is noteworthy that in recent years, there has been an increase in the interest of researchers in evidence describing the acute and chronic responses of IC. Some studies used ordinary IC bicycles in their experiments, which resulted in the impossibility of quantifying the workload, since most IC bicycles do not have measurement devices. Others used cycle ergometers equipped with free sprockets, which do not reflect the real characteristics of the modality. However, in real time, the power generated during the pedalling on IC bicycles, where a potentiometer (a measuring instrument) was used in the sealed cartridge bottom bracket of the bicycle. Nonetheless, as the load was not established as a prescription parameter of exercise intensity - it was only recorded and presented in mean values, little has been added to the description of acute and chronic responses of IC (Caria *et al.*, 2007).

Regarding cardiopulmonary and metabolic responses during IC classes, oxygen consumption (VO_2), heart rate (HR), rating perception of exertion (RPE) and blood lactate (Lac) concentrations were compared under constant and, variable intensity conditions. No difference was found, except for the variable Lac, which was higher ($p \leq 0.05$) at the end of the exercise with varying intensity (Kang *et al*, 2005). Although with relevant VO_2 results, due to the intensity used and pedal cadence alternations, the absence of load patterns at percentage levels does not allow concluding whether the volunteers were submitted exactly to the same stimulus.

Therefore, metabolic differences between protocols can hardly be established. In another study, cardiovascular and metabolic responses were measured in two 45-minute sessions of IC with different sequence of exercises and pedalling techniques. A difference ($p < 0.05$) was identified for the variables of VO_2, rate of gas exchange and HR.

Lower scores were found in seated flat and standing flat (or run) exercises when compared to seated climb, standing climb, jumps and sprinting (Richey *et al.*, 1999). It may be concluded that the variations observed derived from pedalling technique, adjustments in the load and the very exercise routine, which was considered arduous. The intensity of the proposed exercise, although variable, generated values between 50.00 and 85.00% of the maximum oxygen consumption.

In line with the previous study, CF and Lac were compared applying different techniques used in the IC, interspersed with active rest of three minutes. The sprinting and standing flat (or run) techniques presented values of 6.21 ± 0.58 mmol/l and 151.00 ± 4.75 bpm; 8.21 ± 0.60 mmol/l and 166.00 ± 3.24 bpm, lactate and HR respectively (Uchida *et al.*, 2002). Data show techniques have different characteristics, and the IC should consider them professional. The authors highlight those variations observed are largely due to load changes; however, despite the impossibility of determining these variations due to bicycle limitation, results offered great contribution to understanding the overload when using different pedalling techniques.

It is worth mentioning that the non-quantification of the magnitude of the load used precludes the affirmation and extrapolation that the same would happen to all those who used the same techniques and intensities. Blood lactate concentrations were compared at the intensities of 70.00% and 80.00% of maximum HR, in an aerobic interval class, with or without pre-class physical exercises. Results showed inadequacy among the mean values of blood lactate found 3.05 ± 1.15 mmol/L (70.00%); 5.81 ± 3.92 mmol/L (80.00%) in the first class and 8.51 ± 3.36 mmol (70.00%) and 8.30 ± 2.50 mmol (80.00%) in the second class, having a difference ($p < 0.05$) been observed at the intensity of 70.00%.

In the studied situations, no linearity between the increase in blood lactate concentrations and heart rate is observed. Results show sustained acidosis issue, which was already expected. However, again, the absence of balance of the load makes it impossible to determine whether all subjects were submitted to the same metabolic demand.

In another study, metabolic and cardiovascular alterations during a 50-min IC class were evaluated. Results obtained regarding power produced, cardio ratio and VO_2 demonstrated that, for both genders, the exercise was of medium to high intensity. Due to a high impact on cardiovascular function, it was suggested that IC is inappropriate for sedentary individuals with comorbidities or at older ages (Caria *et al*, 2007). It was observed that IC practiced under the influence of a cycling video, when compared to IC without video, generated positive attitudes on the part of the volunteers. The video significantly altered ($p < 0.05$) the perceptions of individual effort, the VO_2 and the HR (Robergs *et al.*, 1998).

Nevertheless, despite the excellent experimental design and the important contribution regarding the understanding of the influence of a visual stimulus for IC riders, no substantial increase in blood lactate concentrations occurred. Again, a cycle ergometer (electromagnetic braking) with very different characteristics of standard upright exercise bike was used.

The adequacy of the intensity of effort in an IC class was analysed according to the recommendations of the American College of Sports Medicine (ACSM, 2010) [85.00% of the maximum HR or 78.50% of HR reserve, or 64.3% of VO_2reserve]. The analysis demonstrated that 73.00% of those tested were within the target zone proposed by the ACSM (2010). Based on the lactate, HR and VO_2 concentrations, it could be confirmed that the IC does not present an exclusively aerobic character, since 40.00% of those tested strongly requested anaerobic metabolism, with the average of lactate above 8.00 mmol/L (Baptista, 2002). In view of the results, it is rightly suggested that more studies should be done in order to better clarify the findings, especially regarding the alternation of load according to musical cadence, type of class and alternation of metabolic pathways; even more so if we consider that the load has not been normalized **(Figure 13).**

Figure 13. Indoor Cycling Class (Mello *et.al.,* 2003).

In an IC class with intervals, HR, blood pressure and rating pressure product (RPP) and behaviours were analysed in relation to referenced values of normality and abnormality. Results showed that the studied variables were significantly different ($p < 0.05$) from those at rest, but not different in training from 5 to 45 minutes; the diastolic blood pressure was the only one showing no difference at rest or during exercise. The mean value of the double product was 23.421, well below the cut-off point (30.000) for coronary risk. Results demonstrated normal physiological behaviours for the studied variables and showed small cardiac overload. However, it is known that the delimitation of intensity only by heart rate is a poor procedure in terms of research. On the contrary, if there were the delimitation of the gross value of the load used, then the results would have been more enlightening (Fornitano & Godoy, 2006).

Eighteen young women volunteers (33.50± 5.00 years; 58.97± 7.52 kg; 20.10± 3.80% fat mass) including six-month indoor cyclists had their heart rate response studied during 9 IC sessions. Cardiac monitoring occurred between 5 and 45 minutes with 5-minute intervals showed that in 75.00% of the session’s subjects remained above 80.00% of their expected HRMAX for age. The activity was considered intense (Nogueira & Santos, 2000). According to the authors, it may be considered that the modality presents selective characteristics in relation to exercisers (heterogeneous classes), since people who have poor cardiorespiratory fitness would hardly perform such type of activity.

A study compared the glycemic of cyclists in different types of IC classes. The monitoring of HR and blood glucose every five minutes demonstrated no differences ($p < 0.05$) of pre- and post-class blood glucose levels at the different intensities used. In addition, the impact of IC on blood glucose and the importance of the use of a hydro electrolytic drink during the class were analysed. Analysis showed that, for lessons under these conditions, no supplement for the purpose of maintaining glycemic is necessary (Miguel de Arruda *et* *al.*, 2006).

Despite some methodological limitations, these two studies made two more important contributions to the development of the IC. However, again, only HR was used for secondary monitoring of workloads, which shows limitations. Once again, it is emphasized that the absence of a device on the bikes for setting resistance and levelling them for riders make extrapolations unfeasible.

Another study investigated the glycemic kinetics of a patient with type I diabetes in four different IC classes. The sessions were: Class 1- Continuous aerobic training (65.00-70.00% HRmax); Class 2 - Continuous Intensive Training (80.00% HRmax); Class 3 – Anaerobic Interval Training (65.00-90.00% HRmax); Class 4 – Controlled training. Blood glucose levels decreased in all classes, except in the Controlled Training class, and the largest delta was observed in the Continuous Intensive Training. Again, although the potential of IC for the control of hyperglycemia of type I diabetic evident limitations in the study occur due to heart rate percentages being the only way of assessing intensity of classes (Silva *et al.*, 2006).

In this sense, it seems that the planning of IC classes (training) plays a fundamental role to lead students (athletes) to achieve their full potential in physical, technical and psychological aspects, within a rational planning (periodization) that allows individual objectives to be reached. Training sessions vary duration, intensity and alternation of stimuli according to the level of conditioning and age of athlete (Vercoshansky, 2018).

Another relevant point is the effect of musicality, since most selected songs for IC classes have a correlation with terrain, training planning and entertainment. Songs with lower cadence and lower light are recommended, as they result in a greater sense of pleasure and less perception of effort during class. However, they do not interfere with HR or energy expenditure (Shaulov & Lufi, 2009). Nonetheless, something different was noted when eight volunteers (3 men and 5 women), in training for 6 months, attended a class divided into three stages: (1) 5' adding load until reaching 85.00% of HRmax; (2) 5' same load without musical stimulus; (3) same load with musical stimulus. The cadence was fixed at 90 rpm, the musical stimulus was “Dance”, and the HR was measured every minute.

The models of 220-age (men) and 226-age (women) were adopted to calculate the working HR. It was observed that HR remained higher when there was musical stimulus, and no significant difference was observed for p<0.05. Nevertheless, the volume of the songs becomes worrying (Palma *et al.*, 2009). Variations between 74.40 and 101.60 decibels were measured in IC classes, well above the 55.00 decibels recommended for health. Therefore, strategies such as the use of earplugs or strategic positioning of speakers are recommended for instructors’ welfare.

In another study was verified the influence of music introduced in different moments in a 5-km time-trial cycling (TT5KM) on psychophysical variables, ten trained cyclists participated (24.00±1.00 years; 73.50±10.40 kg; 180.00±12.00 cm). They performed the TT5KM in three distinct conditions: music during warm-up (MW), music during the protocol (MP) and control (C). During all conditions the time (T), power output (W), heart rate (HR) and rating of perceived exertion (RPE) was evaluated, and the mood state was assessed with the BRUMS questionnaire. None of the variables showed any difference between groups (p>0.05), but there is a possibility of RPE to be smaller when the subject listen music during (90.00%) or before (93.00%) the test compared with control condition. The results showed that regardless the time of application (i.e., before or during exercise), music did not affect performance and psychophysiological parameters during (TT5KM) (Bigliassi *et al.*, 2012).

The study showed that music either during warm-up or during exercise only resulted in greater performance. However, under similar circumstances, the use of music during warm-up and during exercise has shown significantly ergogenic effects, resulting in an augmented performance. The difference in music rhythm, type, volume, as well as time of exposure of subjects from study to study makes it difficult to draw conclusions (Bigliassi *et al.*, 2012). Maybe the fact of this subjects to be trained must have influenced the physiological response regarding the use of music. Probably, in non-professional individuals the impact of the ergogenic resource is more evident.

Another recurring issue regards energy expenditure; so, in order to establish the metabolic cost of an interval training IC class, ergospirometry was used. It was found that IC is an adequate exercise model for fitness programs and body mass control, considering the average energy expenditure of 458 kcal. Notwithstanding, results obtained cannot be extrapolated since the load was subjectively delimited, and this prevents affirming that the volunteers had used the same workload (Lima *et al.*, 2003).

The energy cost of an IC class was also investigated through the association of ergospirometric assessment and data obtained through an IC session. It was found that carbohydrate was the predominant energetic substrate, representing around 84.90% for men and 68.58% for women, although the anaerobic metabolism of men was responsible for only 29.03% of it and the anaerobic metabolism of women for 45.16%, resulting in a class predominantly aerobic. Due to the non-normalization of the load in the sample, these results cannot, under any circumstances, be extrapolated to the population of IC athletes. Although no studies establish differences between genders, regarding energy expenditure, sweat production is twice as high in men (Hazelhurst & Claassen, 2006).

Another perspective for the utilization of IC training is the structuring and applicability of planning. Sports Training suggests two general models for structuring: linear and non-linear training. The linear model proposes progressive loads with migration from large volume and low intensity to low volume and high intensity over several weeks, while in the nonlinear model high volume and low intensity are used interspersed with high intensity and low volume during the training week (Montero *et al.*, 2009).

These models are widely used in the physical preparation of athletes from different sports. However, the goals of the gym goer or those who have classes using technological devices, applications and social media differ from the ones of high-performance athletes. Thus, periodization aimed at the gym environment is better understood as a temporal organization of training, guided by scientific principles of sports training, but with attention focused primarily on improving levels of adherence, preventing injuries and promoting and / or maintaining health.

Adherence refers to the level of commitment of physical exercisers (PE) with scheduled training routine and its formats, i.e., whether individual or in groups. The high turnover of PE exercisers in fitness centers is latent, and these reduced levels of adherence are justified by the lack of understanding –on the part of exercisers - of the expectations and methods of the professional who guides them, and by the absence of training planning, or overtraining (Silva *et al.*, 2003).

Adherence can be impacted by the time people dedicate to PE, but also by the strong influence of media on the exercisers desires as it disseminates goals associated with aesthetics and healthy lifestyle (Silva *et al.*, 2003). Thus, training programs in general, no matter if face-to-face or online training, shall consider these aspects. Another point, there was a shift to at-home exercise, likely due to the systemic changes as a result of the pandemic, leading to more time spent at home and less accessibility to usual PE spaces. There are many activities that lend themselves to at home exercise including yoga, bodyweight training, active video gaming (exergaming) or aerobic exercise, such as dancing or stationary bike (Carvalho & Gois, 2020).

Regardless of the plethora of activities, some barriers were suggested, including limited equipment or space to conduct PE, and a decrease in intensity of PE compared to their usual routine. Development of future interventions aiming to increase PE among emerging adults should prioritize home workouts while considering these participant-identified barriers. One mode of home exercise that warrants further research is exergaming, which is comparable in intensity to other forms of PE and is found to be enjoyable by participants (Sallis & Saelens, 2000). These features could increase adherence; exergaming also requires little space, equipment requirements are minimal and certain forms can be free, thereby circumventing+ many identified barriers to PE.

2.1.4. Aqua Cycling

Aqua cycling is a cycling class combined with the therapeutic effects of water immersion, similar a “spinning” class performed immersed in water, typically up to the xiphoid process. It was originally created by an Italian company that started the fitness trend in Europe in the early 2000’s **(Figure 14a)**. While the modification of standard cycle ergometers for underwater use has been around since the 1960’s for things such as physical therapy, rehabilitation (Frangolias & Rhodes, 1996), and simulating prolonged weightlessness, not until recently has aqua cycling caught on as another modality for maintaining and improving cardiorespiratory fitness. It is appearing in fitness studios all over Europe, Brazil (was the first Latin America country), United States and some countries from Asia (Rewald *et al.*, 2017).

Cycling underwater provides a low impact environment and the resistance provided by the water allows for high levels of energy expenditure with little musculoskeletal strain on the body (Rebold *et al.*, 2013). Aqua exercise to increase in popularity as an alternative form of exercise to enhance physical fitness (Costa *et al.*, 2017) as it is widely suitable for numerous populations, including individuals with musculoskeletal injuries or disabilities, neurological disabilities, the elderly or recovering athletes (Garzon *et al.*, 2015).

Figure 14a. Hydrorider® professional bike (www.hydrorider.com).

Due to the success of the equipment, different water cycling companies emerged It could be one possible reason for inconsistencies in the literature for aquatic aerobic exercise, and more specifically for aquatic cycling, may be due to the variations in equipment used. Initial studies conducted on underwater cycling placed a stationary bike in a swimming pool, which was connected by a chain to a standard dry land cycle ergometer. With this setup, subjects could not change resistance themselves and it required extensive modifications to the land-based bike. Now, in order to change resistance during underwater cycling one must either alter their pedal cadence or attach varying sized blades, which increases the frontal surface area and as a result increases the resistance one must pedal against. This adjustable frontal surface area underwater bike design (Hidrocycle®, Brazil) was demonstrated to work in eliciting a strong linear relationship between %VO_2 peak versus %HRpeak (Costa *et al.*, 2017).

Giacomini *et al.* (2009) compared the cardiovascular responses to pedalling at different intensities on four different water stationary bikes and demonstrated that different models of water stationary bikes can elicit very different cardiovascular responses. This indicates that the type of equipment used plays a major role in the results of each study and can help explain perhaps some of the inconsistencies in the data concerning cardiorespiratory responses in aquatic exercise **(Figure 14a, b).**

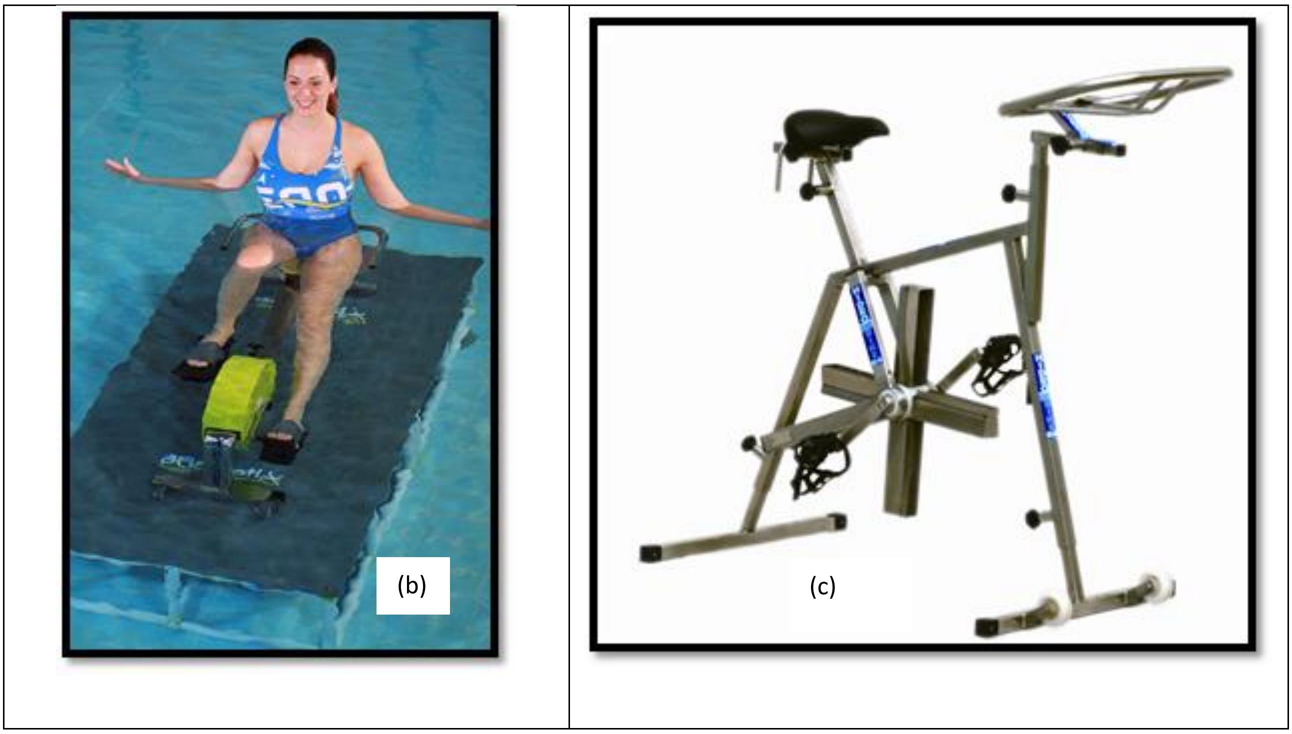

Figure14 (b). Aqua horizontal bike Aqquatix (Itália) (www.aqquatix.com,.it) **(c)** hidrobike professional (Brazil) (www.hidrobike.com.br)

2.1.5. Evolution of exercise in aquatic medium

Several studies on vertical aquatic exercises in the literature analyze the behavior of hemodynamic variables, of exercise biomechanics, and the effects of training. The most investigated have been hydrogymnastics, deep water exercise, walking in shallow water, underwater treadmills and cycle ergometers (Dionne *et al.*, 2017).

Such programs have been widely prescribed due to their numerous benefits to practitioners. Amongst them, improvements in: musculoskeletal conditioning (Ambrosini *et al.*, 2010); cardiorespiratory conditioning (Alberton *et al.*, 2016; Kruel *et al.*, 2013); cardiovascular system (Colado & Brasil, 2019); hormonal system (Cadore *et al.*, 2009; Di Masi *et al.*, 2014); body composition (Colado *et al.*, 2009); flexibility (Moreira *et al.*, 2019); and also balance (Devereux *et al.*, 2005).

2.1.6. Hydrogymnastics

Water aerobics is an alternative form of physical conditioning and consists of specific aquatic exercises based on the use of water resistance force as an overload. Hydrogymnastics defined as a sum of exercises with precise and well-oriented movements in a medium where micro-traumas, common to physical practice, are less frequent, resulting in an activity that interacts automatically in affective, cognitive and motor dimensions (Junior *et al.*, 2017).

Hydrogymnastic exercises present low impact when compared to exercises performed out of the water providing protection and preservation of joints. In this way, water aerobics becomes a viable and safe exercise for diverse populations, such as: the elderly (Sato *et al.*, 2009), pregnant women (Bacchi *et al.*, 2018) and people with fibromyalgia (Zamunér *et al.*, 2019).

In addition, it is possible to infer that water aerobics may be a viable alternative exercise for individuals suffering from arthritis and / or orthopedic dysfunctions and have difficulty sustaining body weight (Rewald *et al.*, 2016). Water aerobics may be recommended for people with different fitness levels who aim to maintain or improve their cardiorespiratory endurance (Neiva *et al.*, 2018).

2.1.7. Strength Training in water

Strength training is one of the most popular physical activities for neuromuscular development, fitness and health (ACSM, 2011). Physiological adaptations due to muscle strength training result in increased strength level, muscle fiber hypertrophy, increased lean body mass and decreased fat body mass, increased bone mineral density, connective tissue health and improvement in physical performance (Cadore *et al.*, 2014).

Regarding strength training in the aquatic environment, related studies emphasize that it involves few muscle groups, and its progression is achieved by increasing the number of sets of each exercise, with a decrease in the number of repetitions (Pöyhönen & Avela, 2002). It is understood that in water there is no exact quantification of the load used during the training and that the movement; and, besides, it is squared and directly proportional to the resistance force in the fluid equation (Alexander & Goldspink, 1977). Therefore, studies which aim at strength training progression based only on the number of repetitions, without controlling the speed of movement, present considerable methodological failure for the prescription of strength training in water.

Many researchers investigated benefits of strength training in aquatic environment and identified positive responses to training in this environment (Pöyhönen & Avela, 2002; Kruel *et al.*, 2005; Ambrosini *et al.*, 2010; Graef *et al.*, 2010; Souza *et al.*, 2010). Since any movement performed in water suffers a resistance imposed by the fluid, for many years, researchers have explored ways to maximize the benefits of aquatic exercise for muscle strength.

Water and air are differentiated fluids and the execution of exercises in the aquatic environment has specific characteristics, such as density. The density of pure water at four degrees Celsius is 1000.00 Kg/m^3, while that of air at sea level is 1.20 kg / m^3 (Hall, 1993). For this reason, a certain amount of water weighs more than the same amount of air. Also, due to the viscosity of the liquid, the motion of a body in the aquatic environment is more difficult than in the terrestrial environment.

Other physical characteristics of water also influence the practice of exercises in this environment, such as buoyant force and hydrostatic pressure. The net upward force can be explained by the principle of Archimedes which demonstrates that any object, partially or fully, immersed in any fluid is pushed by a force equal to the weight of the volume of liquid displaced by this fluid, in the opposite direction of the gravitational force of the earth. Therefore, the net upward force (upthrust) is an opposite force to the downward force of gravity in the liquid media and aids in buoyancy. Hydrostatic pressure refers to Pascal's Law, which determines that a liquid exerts identical pressure on all areas of the surface of any submerged object, at rest, and at a certain depth (Hall, 1993).

In view of these specificities of the aquatic environment, exercises performed in this environment are not liable to have the load of a given movement accurately measured in kilograms. Hence, to manage overload, resistance to motion (R) should be emphasized. That can be expressed by the general equation of fluids dynamics: $R = 0.50 \times p \times A \times V^2 \times Cd$, in which “p” is the density of the fluid, “A” is the projected surface area, “V” is the velocity (speed of motion) and Cd is the coefficient of drag (Alexander & Goldspink, 1977).

Based on the understanding of this hydrodynamic principle, it is known that the required force to overcome drag is mainly affected by the surface area and the speed of motion. Thus, to increase the intensity of exercises to generate muscle power, two ways can be applied: increasing the projected area (A) with equipment to enlarge the area of contact between the object and the fluid or increasing the speed of motion (V^2). When the speed of motion is doubled, the resistive force is quadrupled, since, in the fluid equation, speed is squared. The following chapters will address these two ways of controlling the intensity of exercises in the aquatic environment: the speed of execution and the use of equipment to extend the projected area.

About increasing the speed of execution, studies by Alberton *et al.* (2010) and Pinto *et al.* (2011) show that the higher the speed of execution, the greater the neuromuscular response. Basically, in several studies on strength training in the aquatic environment, the “maximum speed” guidance has been applied and proved to be efficient to enhance muscle force (Costa, 2018). For example, studies by Graef *et al.* (2010) and Takeshima *et al.* (2002), who utilized exercises for specific muscular groups performed at the maximum possible speed. In the study of Graef *et al.* (2010), elderly women, after 12 weeks of training, had a 10.89% increase in levels of maximum dynamic strength in the muscle group of horizontal shoulder flexors. Likewise, after 12 weeks in Takeshima *et al.* (2002) study, increases in strength ranged from 4.00 to 13.00%.

Other studies, with young or middle-aged women, employed the Borg Rating of Perceived Exertion (RPE) scale for intensity control and found positive increases in muscle strength. As examples, see the studies by Ambrosini *et al.* (2010) and Souza *et al.* (2010), who, in their training programs, proposed exercises for specific muscle groups and to determine intensity, correlated the RPE with number 19 on the Borg Scale, which represents an extremely strenuous exercise. In the study by Ambrosini *et al.* (2010), elderly women -with or without using resistance equipment-, after a 12-week training, during which the RPE was maintained at number 19, presented average gains of 17.11% in horizontal shoulder flexion. Similarly, Souza *et al.* (2010) used RPE number 19 in specific exercises of upper, lower limbs and abdominal limbs. By evaluating the 1RM in exercises of lateral shoulder elevation, knee extension and flexion, flat bench press, rowing, hip adduction and abduction, the subjects presented significant increases in muscle strength, ranging from 12.53 ± 9.28% to 25.90 ± 17.84% ($p< 0.05$).

When the objective is to increase the intensity of exercises in the aquatic environment, the way of expanding the projected area is also widely chosen and, in this case, also equipment which broadens the frontal area or even exercises for a larger segment area may be selected.

Analysing different water aerobics exercises performed with large and small projected areas, Alberton *et al.* (2007) verified that exercises performed in the same cadence (60 bpm) with larger projected areas resulted in higher HR and VO_2. Similar behaviour is found in the analysis of exercises performed with and without equipment, i.e., HR and VO_2 rise when resistance equipment is incorporated into exercise and enlarge the projected area (Pinto *et al.*, 2008).

It is worthy of mention that, in the literature, few studies analyse neuromuscular activity through EMG (data is expressed in RMS [root mean square] values and was normalized by maximal voluntary contraction and all executions were recorded by portable electromyographic and by kinematics) signals during the performance of exercises in the aquatic environment. In Black's research (2006), young women performed hip flexion and extension exercise with and without resistance equipment at cadence of 40, 60, 80 bpm and maximum speed. The author concluded the increase in the speed of execution generated greater neuromuscular activation at maximum speed and presented no significant difference independently of whether exercises had been executed with equipment.

Another study analysed stationary running exercise with elbow flexion and extension in three ways: without equipment, with resistance training equipment and with floating equipment (Pinto *et al.*, 2011). Regarding neuromuscular activity, the authors found no significant difference in the rectus femoris and biceps brachii (biceps) muscles regardless of whether the movement had been executed at submaximal intensities without equipment, with resistance equipment or with floating equipment. These results demonstrate that, in the aquatic environment, performing exercises with equipment is not synonymous of increased muscular activity.

When investigating the chronic effects of water aerobics training with and without equipment to analyse the influence of projected area on the increase in intensity, the results of Ambrosini *et al.* (2010) demonstrate that both the group who performed hydrogymnastics training with resistance equipment and the group who trained without equipment presented similar strength gains. The authors point that probably the subjects who trained without equipment were able to impose higher speed on movement, what would explain the similarity in the strength gain.

Corroborating these results, the study by Kruel *et al.* (2005), with two groups of adult women who underwent specific strength training in the aquatic environment with and without resistance training equipment for 11 weeks, concluded that both groups obtained increases, ranging from 10.00 to 28.00%, in strength levels of hip adductor muscles, flexors and elbow extensors.

Additionally, aiming to compare water aerobics training with and without equipment, Katsura *et al.* (2010) conducted a training of eight weeks with elderly women (4 males and 16 females; age 69.10 ± 4.50 years, healthy elderly individuals who did not exercise regularly) divided into two groups, one with and the other without resistance equipment on lower limbs. These authors performed a series of functional assessments before and after training. In the post-training evaluations related to muscular strength of knee extensor, triceps sural and tibialis anterior muscles, significant increases were found only in the triceps sural muscles, both for the group with equipment (pre: 32.30 ± 6.80N and post: 43.80 ± 6.50N), and for the group without equipment (pre: 40.40 ± 6.70N and 48.10 ± 9.60N), with no difference between groups.

A longer duration of training in an aquatic environment, 24 weeks with three weekly sessions, was evaluated on the muscle strength of elderly women. Strength exercises had a focus on the upper and lower limbs with the use of resistive equipment. The training prescription was proposed by controlling the number of sets and repetitions, in which only the number of sets varied, going from two to three of 12-15 repetitions. The intensity was controlled through the execution rhythm, starting the training with 60 bpm and ending with 120 bpm. The maximum isometric torque of the knee flexors and extensors was evaluated by a dynamometer and the dynamic strength was evaluated using the 3 maximal repetitions test. As a result, there was a significant improvement in the maximum isometric torque of knee extension (10.50%) and knee flexion (13.40%) and even greater increases in the dynamic strength of knee extension (29.40%) in the exercise leg press (29.50%) and bench press (25.70%). The percentage increases in strength were greater than other findings in the literature with this population, which can be attributed to the longer intervention time of this training (Tsourlou *et al.*, 2006).

Colado *et al.* (2012) performed a comparison between strength training in the aquatic environment with equipment (STA) and strength training with elastic bands (STB) and training in machines (STM) in the terrestrial environment with postmenopausal women and Group Control (GC) (age: CG n=10: 53.9 ± 0.59; STM n=14: 51.07 ± 1.82; STB n=21: 54.14 ± 0.63; STA n=17: 54.71 ± 0.45). All groups had the same prescription for 10 weeks. The intensities were established by the OMNI-RES effort perception scale and 20 repetitions were performed.

In the first four weeks, the subjects performed the 20 repetitions at intensity 5 of the scale (Somewhat hard), and in the last 6 weeks at intensity 7 (Hard). In the aquatic environment, the execution speed was organized to increase the intensity. To assess muscle strength, functional tests were performed: knee flexion, 60 seconds squat and abdominal. After the intervention, all groups improved muscle endurance (STA: Knee flexion: 98.04%; Squats: 40.26%; Abdominals: 18.18%; STB: Knee flexion: 30.62%; Squats: 27.40%; Abdominals: 16.27%; STM: Knee flexion: 62.62%; Squats: 21.14%; Abdominals: 31.11%), demonstrating that training in the aquatic environment can provide strength gains like this like the terrestrials. Anyway, the authors highlight, however, the difficulty of performing load control in strength training in the water, as well as Pilates and also body weight training.

Still keeping control of repetitions and sets Colado *et al.* (2009) conducted a short-term training, just 8 weeks, with active young men. During training, there was an increase in volume and intensity, in which sets varied from 3 to 5, and maximum repetitions from 8-15. Exercises were performed for the upper, lower and trunk limbs, and the individuals used resistive equipment to increase drag and thus intensity. The execution rhythm was individually controlled, by imposing a cadence for each subject to reach muscle fatigue at the end of each series. As a result, the authors found an increase in muscle power (3.00%) and maximum strength in bench press (5.10%), lateral elevation (9.70%) and high row (10.90%). The authors highlight the importance of controlling the load of strength training in the aquatic environment, suggesting that controlling the cadence of execution is an adequate alternative to achieve goals such as increased maximum strength, muscle hypertrophy and endurance.

Using execution time and cadence control to prescribe intensity, a 12-week training course in hydrogymnastics was carried out with the elderly (men and women), able to walk and perform their daily tasks independently volunteered. Classes were held three times a week and consisted of aerobic and strength exercises. These consisted of: knee flexion and extension; hip adduction and abduction; and ankle dorsiflexion and plantar flexion (Bento *et al.*, 2012).

In the first four weeks, the exercises were performed for 40 seconds with an interval of 20 seconds between them, at a moderate speed (Borg 12). In the second mesocycle, the intensity was advanced by increasing the execution speed and including resistive equipment (Borg 12-14). In the last mesocycle, the exercises were performed at maximum speed (Borg 14-16). The results showed an improvement in the peak torque of the hip extensors (40.00%), hip flexors (18.00%) and plantar flexors (42.00%). An increase in the rate of torque development of the hip extensors (10.00%), knee extensors (11.00%) and plantar flexors (27.00%) was also observed. The authors justify these results by increasing speed during training, highlighting the physical properties of water as an important factor to increase endurance (Bento *et al.*, 2012).

Hence, some studies on strength training prescribe hydrogymnastics as an alternative and personalized way of accomplishing periodization in the aquatic environment. By drawing an analogy with the type of prescription for dryland done through maximum effort throughout the training, exercises aiming at strength gains in the aquatic environment are always performed at maximum speed and, consequently, being the series; however, performed without a time limit (Schoenell *et al.*, 2016).

The series duration is mainly related to the percentages of anaerobic system contribution throughout the activity. The estimate energy contribution percentage by the anaerobic system in single maximal stimuli 0-30, 0-20, 0-15 and 0-10 seconds is 73.00%, 82.00%, 88.00% and 94.00%, respectively. In addition, the interval between sets is always the time required for each muscle group to rest for 3-5 min, since this seems enough time to ATP-CP metabolic pathway recovery, which is being worked on this type of training (Gastin, 2001).

Three metabolic pathways are known: alactic anaerobic (phosphocreatine system), lactic anaerobic (glycolytic system) and aerobic (oxidative system). These three systems have the function of converting the chemical energy from ingested food into the energy needed to produce adenosine triphosphate (ATP), which is the predominant energy source in sustaining muscle contraction during exercise. The intensity, duration and modality of exercise are critical in determining which energy system will be imperative during exercise. However, among these variables, exercise intensity stands out as the most important related to which energy system is predominantly activated to produce energy for muscle work (Wilmore *et al.,* 2008).

After examining the data collected by these studies, it can be noted that the muscular strength gain occurs with and without the use of equipment and, therefore, is not reliant upon its utilization. Even though the studies had not controlled the speed of movements with and without implements, the authors speculate that when they are used, speed of execution decreases greatly in relation to the same exercise performed without them due to the greater resistance to movement caused by their usage. Therefore, more recent studies have proposed the use of maximum speed and execution time to emphasize specific metabolic pathways (alactic anaerobic and lactic anaerobic) and promote adequate levels of strength (Gastin, 2001; Wilmore *et al.*, 2008).

Bioenergetic specificity is a fundamental concept in the field of training. If the training has a defined objective, it must be worked on the metabolic pathways used for this, considering the intensity and duration of the activity. The prescription of strength training in the aquatic environment is not well elucidated in the literature, but some recent studies have shown that the use of the principles of metabolic pathways is a tactic to achieve satisfactory results.

2.1.8. Concurrent Training and Aqua Fitness

Concurrent training a combination of strength training and aerobic training in a systematic periodic program in hydrogymnastics is also a relevant topic, because, despite the few references, it seems to be very efficient in promoting health in the elderly (Cadore *et al.*, 2012; Pinto *et al.*, 2015) and young people (Schaun *et al.*, 2018). Manipulation of combined training order has been pointed as being possibly responsible for its interference in musculoskeletal system adaptations. The effect of interference is defined as the lower power gains during combined training when compared with those obtained in single strength training (Izquierdo-Gabarren *et al.*, 2010).

Takeshima *et al.* (2002) investigated the physiological responses of elderly women to awell-rounded exercise program performed in water (WEX). The participants were randomly divided into a training (TR) group (N15: 69.3±4.5years) and a control group (N15: 69.3±3.3years). Were realized 12 weeks supervised WEX program, consisted of 20 min of warm-up and stretching exercise, 10 min of resistance exercise (with equipment a series of 10-15 repetitions, performed at maximal speed), 30 min of endurance-type exercise (walking and dancing, using HRLV2 determined in progressive cycle ergometer test on land), and 10 min of cool-down exercise.

The WEX led to an increase ($p < 0.05$) in peak VO_2 (12.00%). Muscular strength (evaluated by a hydraulic resistance machine) increased significantly at resistance for knee extension (8.00%), knee flexion (13.00%), chest press (7.00%) and pull (11.00%), shoulder press (4.00%) and pull (6.00%), and back extension (6.00%). Vertical jump (9.00%), agility (22.00%) and trunk extension (11.00%) also increased significantly. There were no significant changes in these variables in the control group. Those results suggest that WEX elicits significant improvements in cardiorespiratory fitness and muscular strength water-based exercise appears to be a very safe and beneficial mode of exercise that can be performed as part of fitness in older women. The control of the intensity used for aerobic training based on parameters determined in a land environment stands out as a negative point, observing that the beacon variable used was HRLV2, a method not considered ideal, given that the HR in the aquatic environment tends to be lower compared to the land environment (Alberton *et al.*, 2013).

Zaffari (2014) investigated the chronic effects of combined training of elderly women. Thirty-five women were divided into three training groups of water- based exercise: combined training (CT n=11: 64,18±3,60 years), resistance training (RT n=14: 67,86±4,20 years) and aerobic training (AT n=11: 66,45±4,23 years), and performed those trainings for 12 weeks, twice a week. During the combined training, the intensity of the strength intervention corresponded to the maximum execution speed, with a progressive increase in sets and a decrease in the time of sets during the periodization in the execution of the exercises of the upper and lower limbs. The aerobic training was performed in percentages of HRLV2 (90.00-100.00%). Before and after the training period, the subjects were evaluated on neuromuscular, cardiorespiratory and functional responses, furthermore nine subjects made part of a control period of four weeks before the beginning of the training, performing the main evaluations before and after this period. Regarding the neuromuscular variables, a significant improvement was found in maximal strength of 1RM (1.00-9.00%), muscle endurance of knee extensors and flexors (60.00% 1RM), as well as in maximal isometric contraction (13.00%) ($p<0,05$) and in neuromuscular economy (lower recruitment of muscle fibers) for vastus lateralis and rectus femoris (34.00% and 37.00%, respectively) for the concurrent training group ($p>0,05$). As for cardiorespiratory variables, significant differences were observed for rest HR (-7.00%) and maximum test exhaustion time (27.00%) after training for the same group ($p<0,05$), while the peak oxygen uptake and the oxygen uptake relative to the ventilatory thresholds did not increase significantly ($p>0,05$). In the functional capacity variables, significant improvements were verified in the concurrent training group in the tests of: sit and reach (206.00%) and sit and stand (36.00%) ($p<0,05$) without significant increases on the agility test ($p>0,05$).

It is important to highlight that; the responses founded in all variables were similar between the three training groups, without significant differences between them ($p>0,05$), except for muscular economy on vastus lateralis muscle, which showed better values in TF group compared to TA ($p <0.05$). Those three training methods on water-based exercise were effective to promote benefits in several parameters of physical fitness of elderly women, at the same magnitude.

Some studies were concerned with investigating the chronic effects of different orders of concurrent training on different performance variables. Pinto *et al.* (2014) was the first study to investigate the chronic effects of the order of combined training in the aquatic environment on neuromuscular adaptations. Young women (25.10±2.90 years) formed two training groups with the same number of subjects (n = 13) resistance prior to (RA) or after (AR) aerobic training. Strength training was controlled by the execution time of the sets, starting with 3 sets of 20 seconds each in the first four weeks, going to 4 sets of 15 seconds in the following four weeks, ending with 6 sets of 10 seconds in the last 4 weeks. To evaluate maximum strength, the 1RM test was performed, peak torque was performed in an isokinetic dynamometer and muscle thickness was performed using ultrasonography.

Both RA and AR groups increased the upper and lower-body 1RM, while the lower-body 1RM increases observed in the RA was greater than AR (43.58±14.00 vs. 27.01±18.05%). RA and AR showed MT increases in all muscles evaluated, while the lower-body MT increases observed in the RA were also greater than AR (10.24±3.11 vs. 5.76±1.88%). There were increases in the maximal EMG of upper and lower body in both RA and AR, with no differences between groups (p<0,05). Performing resistance prior to aerobic exercise during water-based concurrent training seems to support the lower-body strength and hypertrophy, while was observed that both orders of combined training in the aquatic environment result in improvement of neuromuscular parameters in young women. The authors believe that there may be residual fatigue from aerobic training, influencing the performance of strength exercises that should be performed at maximum speed.

Also investigating muscle strength, Pinto *et al.* (2015) compared the effect of strength and aerobic training orders in the same session in postmenopausal women. The training was carried out for 12 weeks, with two weekly sessions. Twenty-one healthy postmenopausal women (57.14 ± 2.43 years) were randomly placed into two water-based concurrent training groups: resistance training prior to (RA, n = 10) or after (AR, n = 11) aerobic training. Strength training was controlled by the execution time of the sets, starting with three sets of 20 seconds in the first four weeks, going to four sets of 15 seconds in the following four weeks, ending with six sets of 10 seconds in the last four weeks. Upper (elbow flexors) and lower-body (knee extensors) one-repetition maximal test (1RM) and peak torque (PT) (knee extensors) were evaluated. The muscle thickness (MT) of upper (*biceps brachii*) and lower body (*vastus lateralis*) was determined by ultrasonography. Moreover, the maximal and submaximal (neuromuscular economy) electromyographic activity (EMG) of lower body (*vastus lateralis* and *rectus femoris*) was measured.

The groups RA and AR groups increased the upper- and lower-body 1RM and PT, while the lower-body 1RM increases observed in the RA was greater than AR (34.62 ± 13.51 vs. 14.16 ± 13.68 %). RA and AR showed similar MT increases in upper and lower body muscles evaluated. In addition, significant improvements in the maximal and submaximal EMG of lower-body muscles in both RA and AR were found, with no differences between groups. Both exercise sequences in water-based concurrent training presented relevant improvements to promote health and physical fitness in postmenopausal women. However, the exercise sequence resistance–aerobic optimizes the strength gains in lower limbs.

The study by Reichert *et al.* (2020) compared the effect of combined training between two groups, since equipment was used as a progression in the strength segment in one group and, in the other, the progression was performed through the increase of sets, being the same training protocol for the groups. The study took place over a period of 16 weeks, twice a week and sessions lasted 45 minutes. Comorbidities were diversified, such as: hypertension, type 2 diabetes, dyslipidaemia, depression and hypothyroidism. BP measurements were performed before and after 8 and 16 weeks of training, 72 hours after the end of the last session. In the first 8 weeks, the training protocol was similar for both groups in that they performed 30s of each exercise with intensity 19 on the Borg Scale.

From the 9th week, the group that increased the number of sets from 1 to 3 sets performed 20 seconds of intense exercise, 1 minute and 40 seconds of passive interval and 2 minutes of passive interval between blocks and the number of sets increased from 1 to 3.

The training duration increased from 5 minutes to 12minutes and 40 seconds. In the group with equipment, from the 9th week, resistance equipment was used for 20 seconds of exercise, maintaining intensity 19 on the Borg scale throughout the training, 2 minutes of passive interval between blocks and of 5 minutes, reduced to 4 minutes the total duration of the session. In aerobic training, stationary running, cross-country, ski and front kick exercises were performed with different combinations of upper limb exercises. The volume was 6 sets of 5 minutes, 4 minutes of high intensity stimulus and 1-minute recovery with lower intensity. The total duration of the aerobic training was 30 minutes. Interval training until the 12th week was used. In strength training, flexion and extension of elbows and knees, shoulder extension, hips distributed in blocks were performed.

Reductions in SBP were 10 mmHg for the combined equipment progression group and 10 mmHg for the combination whose progression was performed with multiple sets. In DBP, the reductions were 4 mmHg for the equipment progression group and 6 mmHg for the multiple series progression group. Both training protocols were efficient to reduce both SBP and DBP, being considered adequate training protocols for the treatment of HAS in elderly women.

Several benefits were seen from different combined trainings. Within this context, different models of training in the aquatic environment have been investigated in recent decades, bringing important and positive information for health both in neuromuscular parameters and in cardiorespiratory conditioning. In this direction, such studies have identified that aerobic training in the aquatic environment promotes neuromuscular adaptations like combined or strength training in individuals who do not previously practice periodized exercise, a fact that may attribute a characteristic to aerobic training in the aquatic environment (Fedor *et al.*, 2015; Whelton *et al.*, 2017).

In addition, scientific evidence pointing to neuromuscular benefits arising from aerobic training performed alone in the aquatic environment is recent. It is believed that this adaptation occurs due to the physical properties of the aquatic environment, such as the drag force generated by the movement. The resistance to movement in the aquatic environment can be favoured when there is an increase in the projected area, or even more sharply, when there is an increase in the speed of execution of the movement. Therefore, increased resistance imposes greater load on moving limbs, a fact that can generate stimuli that cause these active muscles to gain strength. Therefore, aerobic training in the aquatic environment, in addition to promoting cardiorespiratory adaptations, can also provide sufficient stimuli to develop neuromuscular parameters in sedentary individuals (Martínes-Carbonell *et al.*, 2019; Andrade *et al.*, 2020).

On the other hand, there is no scientific evidence to support even when a periodization only with aerobic exercises in the aquatic environment, not making up the aquatic cycling exception, can generate positive chronic neuromuscular adaptations. In view of this, interventions with training in the aquatic environment with longer periods and with comparisons of different training models are still necessary considering the importance of exercise programs.

2.1.9. Water Walking

Aquatic activities, due to physical properties of water, especially buoyancy, can be alternative training options as they reduce impact on joints responsible for bearing the weight of the body. Among modalities, the deep-water walking stands out. It simulates the walking performed on land, without the contact of the feet with the pool bottom and can be performed with or without floating device. Additionally, the viscosity of this fluid intensifies the resistance to displacement (drag). Thus, aquatic walking, besides reducing strain on joints, requires high energy expenditure to overcome the resistance imposed by water (Chu & Rhodes, 2001).

The other possibility of water walking is in a shallow pool, where, regardless of the exercise performed, it seems to generate different neuromuscular and cardiorespiratory responses compared to walking on land (Barela *et al.*, 2006). It is worth mentioning the emphasis in relation to investigations regarding neuromuscular responses of walking in the aquatic environment. During shallow water walking training sessions, researchers have manipulated speed and type of frontal displacement as main influencers of the resistance imposed on the movement of the subjects since these factors can directly affect exercise intensity (Masumoto *et al.*, 2007).

Neuromuscular responses, investigated through EMG tests of both postural and propulsive muscles, seem lower during walking in aquatic environment compared with walking on dry land when only a self-selected speed of effort (mild, moderate or high) is used. During the task, surface electromyographic (EMG) data were collected from tibialis anterior (TA), gastrocnemius medialis (GM), vastus lateralis (VL), long and short head of the biceps femoris (BFLH and BFSH, respectively), tensor fasciae latae (TFL), rectus-abdominis (RA), and erector spinae (ES) at the first lumbar vertebrae (L1 level) muscles of the right side. They were used passive disposable dual Ag/AgCl snap electrodes with a 1 cm diameter of each circular conductive area and a 2 cm center-to-center spacing (dual electrode #272, Noraxon). Extreme care was necessary to insulate electrodes for the water condition trials. For these we used a 10 · 12 cm^2 transparent dressing (Tegaderm, 3M), and placed it over the electrode and the cable connection near the electrodes. The body segments adjacent to the electrode areas and cables were lightly bandaged with elastic bands to avoid cable movement. The EMG signals were registered with an 8-channel telemetric EMG system (Telemyo 900, Noraxon), which had again of 1000 times, bandwidth (-3 dB) of 10–500 Hz, and common mode rejection ratio >85 dB. EMG signals were sampled at 1000 Hz using the APAS software and these signals were synchronized with the video images using a homemade trigger. This possibly occurs because, for the same self-selected speed of effort (moderate), the speed of horizontal displacement in the aquatic environment is always lower than that of the terrestrial environment (Barela *et al.,* 2006).

This lower speed of horizontal displacement in water- walking probably occurs due to the higher density of the environment. Since water resistance increases squarely in relation to increasing speed, the low speed recorded in this environment would justify the reduced neuromuscular activity. Associated with low horizontal displacement velocity is the reduction of hydrostatic weight as a result of immersion, caused by the presence of the up thrust force. This low hydrostatic weight may result in low propulsive forces and postural maintenance during walking in the aquatic environment (Myoshi *et al.,* 2006).

Similar responses to the activation of propulsive muscles are found in investigations with fixed velocity (same physiological intensity of exercise) and reduced frontal displacement (treadmill) in muscles responsible for movement propulsion. It is worth mentioning that to obtain the same physiological intensity of effort in both environments, the speed of the land-based training needs to be twice the speed of that of the aquatic exercise, such as: land: 2.40 km/h vs water: 1.20 km/h (Masumoto *et al.*, 2008). Resembling, the reduced activity of muscles, such as gastrocnemius, anterior tibialis, vastus medialis, rectus femoris and biceps femoris, have been justified by the reduction of velocity during aquatic exercise and, consequently, the decreasing resistance to the displacement of individuals (Shono *et al.*, 2007; Masumoto *et al.*, 2008).

Another noteworthy topic is the comparative neuromuscular analyses between walking on land and deep water walking. Kaneda *et al.* (2007) evaluated neuromuscular responses of individuals walking at different self-selected speeds of effort (mild, moderate and high) and free frontal displacement. The results showed that, in all self-selected velocities, EMG activity of the soleus and gastrocnemius muscles during the terrestrial walk was intense. In contrast, the biceps femoris was more activated during deep water walking. It is worth mentioning that horizontal displacement velocities were not presented, although they have probably been lowering in the aquatic environment throughout the training.

The reduced activity found in the gastrocnemius and soleus muscles in aquatic exercise was justified by the absence of contact with the pool bottom, and the consequent absence of vertical forces during deep-water walking. Thus, it can be suggested that these muscles lose their characteristic of propulsion in this type of aquatic exercise. On the other hand, the high activity of the biceps femoris muscle was attributed to the possible greater range of motion of the hip and knee during aquatic walking (Kilding *et al.*, 2007).

Walking in water is an effective rehabilitation exercise for patients with various diseases and for cardiorespiratory responses. However, how the mechanical properties of water alter the temporal parameters of human walking is still unclear. Under these conditions, cardiorespiratory responses to aquatic exercise are mainly dependent on depth of immersion of individuals and speed of exercises. In a study of Sato *et al.*, (2017), ten healthy male subjects walked on land and in water at slow (2.40 km/h) and moderate (3.60 km/h) speeds. Subjects' movements were recorded using a digital video camera. Durations of stance, single- stance, and double-stance phases relative to gait cycle were calculated. Relative stance phase duration was significantly shorter in water than on land, whereas relative single-stance phase duration was significantly longer in water than on land. It was revealed that the buoyance effect of water alters the longer duration of single-stance phase in water compared with on land.

These findings suggest that, when using the same speed for aquatic and terrestrial walking, HR may be increased in the aquatic environment due to the greater physiological recruitment necessary to move the body in water, since density of this fluid is much higher than that of air and makes exercising in water much more intense (Poyhonen *et al*., 2001). Probably, this higher HR in the aquatic environment is due to some mechanism of immersion that could affect the autonomous nervous system. Thus, greater withdrawal (inhibitory mechanism) of the parasympathetic tone could occur in mild exercises (such as walking), which would explain that great increase in HR response (Pohl & Mcnaughton, 2003).

One theory is that the phenomenon is a result of an interaction between the baroreceptor and Bainbridge reflexes. If the level of immersion is sufficient to increase the hydrostatic pressure on the thoracic cavity, a redistribution of blood centrally can be expected. Thus, the resulting increase in stroke volume would prompt a decrease in HR via the baroreceptor reflex. It is possible that during low-moderate intensity exercise the increased atrial pressure acts to offset the bradycardia. Another possible explanation is that water immersion may affect the autonomic nervous system. During exercise, HR is controlled by both divisions of the autonomic nervous system and is elevated by simultaneously increasing sympathetic and decreasing sympathetic activity.

The initial increase in heart rate (up to 100 beats/min) during exercise is due to parasympathetic neural withdrawal, whereas sympathetic neural outflow should have a greater impact on HR at higher work rates (Powers & Howley 2001). This would imply that HR while walking in waist-deep water was mainly controlled by parasympathetic with-drawl but running was controlled by sympathetic stimulation. It has been suggested that sympathetic neural outflow is reduced in water, which would imply that HR during running might be lower than expected. The values of HR for walking are less affected because this condition would rely less on sympathetic stimulation. The increase in HR between walking and running in thigh-deep water was not depressed, which may imply that the level of immersion was not sufficient to cause a decreased sympathetic response (Pohl & Mcnaughton, 2003).

However, when individuals are immersed to the level of the xiphoid process, similar HR responses can be expected during moderate and high-speed exercises. The greater effect of buoyant force at this depth may be the reason, since the displacement speed may be reduced, compared to the speed on the treadmill, bringing about less resistance to aquatic exercise. This phenomenon is commonly observed during running exercises. Furthermore, HR responses during shallow-water walking can be attenuated with colder water temperatures (approximately 28°C) and increased with warmer water temperatures (approximately 36°C) (Hall *et al.,* 1998).

Similar HR responses can also be found in both environments (aquatic and terrestrial) when different speeds are utilized on treadmill walking exercise. In this sense, the speed of aquatic exercise must be exactly half the speed of the exercise performed on land and with individuals immersed up to the xiphoid process (land = 2.40km/h, 3.60km/h and 4.80km/h versus water = 1.20km/h, 1.80km/h and 2.40km/h). This strict speed control is possible in investigations using underwater treadmills. In any case, these findings suggest that HR responses may be similar in exercises performed in both environments provided they are executed at different walking speeds. In this case, the effect of the higher resistance provided by the density of the aquatic environment would be equated with the higher intensity of effort demanded for a high-speed exercise on land (Matsumoto *et al.*, 2008).

Regarding oxygen consumption (VO_2), responses seem like those found for HR. When individuals walking on a treadmill are compared with those walking on an underwater treadmill at the same speed, VO_2 responses have been higher in the aquatic environment. Such responses can be expected at different depths (malleolus, patella, thigh and umbilicus) and immersion temperatures (28 and 36°C). Nonetheless, they are found only at moderate and high walking speeds (above 4.0 km/h), since, at lower speeds, responses seem similar in both environments (Hall *et al.*, 1998).

This can be expected due to the low effort needed during low-speed-water-walking when drag forces are minimized, reducing resistance and significantly influencing VO_2 responses. Although VO_2 is higher in the aquatic environment compared to the terrestrial environment in the same conditions, the level of body immersion can interfere with this magnitude. VO_2 in the aquatic environment during walking seems higher for individuals immersed at thigh depth when compared to individuals immersed at waist depth (Pohl & Mcnaughton, 2003).

According to the authors, deeper immersion of individuals results in greater reduction of hydrostatic weight, which, consequently, reduces the energy cost (lower oxygen consumption of postural muscles) to support body weight at great depth of immersion. In any case, when VO_2 responses are compared and analysed based on different walking speeds in water and on land, modifications occur (Shono *et al.,* 2001).

Regarding deep water walking, cardiorespiratory responses analysed seem consensual despite the small number of studies. Green *et al.* (1990), controlling the speed (mild, moderate and high) of terrestrial and aquatic walking at similar cadences, and with free horizontal displacement, found HR responses always lower in the aquatic environment. Robert *et al.* (1996), again, controlling the (moderate) speed of walking at similar cadence in both environments and with free frontal displacement, verified lower HR and VO_2 during aquatic exercise.

Although the speed of horizontal displacement of individuals was not presented in any of these studies, possibly for the same exercise cadence, speed is lower in the aquatic environment due to fluid resistance. Thus, the lower HR response found during deep water walking is suggested by a combination of factors such as increased venous return because of hydrostatic pressure on the body in immersion, and the baroreceptor reflex, along with the lower resistance offered to movement caused by the low speed of displacement. Regarding the lower VO_2 observed, it can also be a result of the low speed of displacement together with the reduced recruitment of antigravity muscles to support body weight in the water due to the use of the floating device. This is probably a preponderant factor for the decrease in metabolic cost of walking in water when compared to walking on land (Nakanishi *et al.*, 1999).

While just being immersed in water causes physiological changes, cardiorespiratory variables also differ during exercise in water compared to on land. First, the overall training effect has been shown to be greater in water than on land (Handa *et al.*, 2016). In this study, middle-aged women thirty-one women (59.00 ± 5.00 years old) were divided into two groups, a land-based walking group or a water-based walking group. They performed an eight-week walking exercise program consisting of sets of fast and slow walking, staying within a rating of 16-18 on the 6-20 Borg scale while fast walking. The study found that the women were able to exercise at a higher exercise intensity in the water than on land due to improved subjective feelings, which resulted in greater gains in physical (all, $p < 0.05$) (Handa *et al.,* 2016).

In another study the authors would like to check the effectiveness of a water-based exercise (WE) program and a walking on land (WL) program was evaluated in older women (aged 62.00-65.00 years). Fifty healthy sedentary women were randomly assigned to sedentary (S), WE and WL groups. The two groups were exercised for 12 weeks at 70.00% of the age-predicted maximum heart rate (HR). The subjects were evaluated before and after the training period, and measurements of bodyweight, HR at rest, maximum aerobic power (VO_2max) mL/kg per min) and neuromuscular performance (upper and lower body strength; agility; upper and lower body flexibility) were included. After training, bodyweight was unchanged in both programs.

The WE decreased the HR at rest by 10.00%. Both WL and WE enhanced VO_2max by 42.00% and 32.00%, respectively. However, for the WE group the VO_2max values were significantly higher compared with the WL group ($p < 0.05$). All neuromuscular parameters improved after exercise, but only the WE group showed a significant improvement on the upper body strength and lower body flexibility. Besides, the upper and lower body strength and upper and lower body flexibility were significantly higher in the WE group compared with the WL group ($p < 0.05$), respectively. Current results indicate that the WL programs and WE improved the cardiorespiratory and neuromuscular fitness of older women. Furthermore, when the effectiveness of the training programs was compared, it was verified that the WE program was more powerful in inducing changes in physical fitness versus the WL program (Bocanili *et al.*, 2008).

Shallow water walking and deep water walking have been considered rich possibilities of water exercises. Therefore, considering the difficulty in controlling the intensity of exercises in the aquatic environment, it becomes of fundamental importance for professionals in the area the knowledge of neuromuscular and cardiorespiratory responses for different strategies of water walking.

Neuromuscular and cardiorespiratory responses are very dependent on the speed of shallow water walking. The magnitude of muscle activity, especially of the muscles that contribute to propulsion, may be higher during exercise in the aquatic environment when speeds like those of terrestrial exercise are utilized. The same can be expected in relation to HR and VO_2, indicating the possibility of using this exercise to increase energy expenditure of individuals, without overloading their musculoskeletal system.

In this sense, the comparison between deep water walking and on land walking reveals a great difference in muscle activity. The differences in muscle recruitment for the propulsion of movement in aquatic exercise make deep water walking an exercise alternative mainly for strengthening the quadriceps. On the other hand, cardiorespiratory responses always seem smaller when compared to those of walking on land for the same execution cadence due to the difficulty in moving at speeds like those of terrestrial exercise.

Shallow water walking (SWW) generates changes in cardiorespiratory parameters in comparison to terrestrial exercise, and these changes are highly dependent of immersion depth. The stride frequency, however, was similar at waist and reduced at xiphoid depth. As expected, the ground reaction forces were reduced according to the buoyance forces acting. SWW appears to increase muscular activity. Importantly, the depth-related increase in energy expenditure of SWW seems to involve a major role of resistive forces compensating the reduced task of support the body weight. Besides the benefits of water immersion as reduced joint impact and safety, biomechanical alterations on force production may produce additional long-term gains in functional mobility (Ivaniski-Mello *et al.*, 2020).

2.1.10. Deep Water Exercises

Deep Water exercise is an option widely chosen by populations, which prefer the practice of aerobic exercises in the aquatic environment. It is largely indicated for individuals who need activities with less impact and overload on joints, such as obese and injured athletes. This less overload can be attributed to the physical properties of the water (buoyancy) and the depth of the pool, which prevent the contact of the feet with the ground. Within the universe of deep water exercise, the most popular is Deep Water Running (DWR), which is jogging in water deep enough that the feet do not touch the bottom, using or not flotation devices (Kanits *et al.,* 2021).

In this sense, besides the alteration in the load exerted on the joints, the physical properties of water also seem to influence different cardiorespiratory variables, such as the maximum heart rate (HRmax) and the maximum oxygen consumption (VO_2max). Some studies have compared the different physiological responses between treadmill running (TR) and deep water running (DWR), suggesting that, in general, a lower cardiorespiratory demand is necessary in DWR (Town & Bradley, 1991, Frangolias & Rhodes, 1995, Nakanishi *et al.*, 1999).

Nonetheless, even if different studies have observed similar results- reduced cardiorespiratory responses in the aquatic environment-, their protocols differed substantially. While Town and Bradley (1991) and Nakanishi *et al.* (1999) increased intensity incrementing stride frequency, Frangolias and Rhodes (1995) used a pulley system with different load increments. In addition, the most common samples were men and women athletes or only active men (Town & Bradley, 1991, Frangolias & Rhodes, 1995, Nakanishi *et al.*, 1999).

When comparing the maximum cardiorespiratory variables between treadmill running (TR) and DWR in active young women familiar with progressive loads, until their exhaustion, the values of VO_2 ($p < 0.01$), Ve ($p = 0.027$) and HR ($p = 0.042$) obtained in the DWR for maximum effort were significantly lower than in TR. This probably occurred due to the hydrostatic effects of aquatic environment and the different pattern of muscle recruitment. Consequently, it can be inferred that, when compared to TR in maximum effort protocol, DWR demands less cardiorespiratory effort for the variables studied in young women familiar with progressive loads (Tiggeman & Kruel, 2007).

Water temperature and hydrostatic pressure can affect HR in the liquid medium. When in water, the body increases its blood volume in the core due to the redistribution of venous blood and extracellular fluid from the lower limbs to the heart. With plasma volume expansion in the core, the heart and vessels of the circulatory system are distended, stimulating the receptors of volume and pressure of these tissues. Thus, the readjustment in the cardiovascular system increases central venous pressure, cardiac output and stroke volume, in order to finally reduce HR per minute (Tiggeman & Kruel, 2007).

Thermal conditions of the aquatic environment are also part of the mechanism for reducing HR in an immersed body, due to the facilitation of heat exchange between the body and the environment. The demand for blood in the body periphery decreases, causing the plasma volume to concentrate in the core (thorax and abdomen), becoming another factor of stimulation to the receptors of volume and pressure of the heart and circulatory system (Craig & Dvorak, 1966).

Possible mechanism responsible for reducing HR of a body submerged in water is related to the principle of hydrostatic equilibrium, which reduces the weight of bodies. Due to this reduction, probably, less muscle recruitment is needed to sustain standing position, thus reducing the need for blood supply to the lower limbs and causing blood concentration in the central region of the body. Since antigravitational muscles of lower limbs are not needed in the water to support body weight, the metabolic cost of running in deep water decreases when compared to treadmill running (Nakanishi *et al.*, 1999).

Factors such as water temperature (Graef *et al.*, 2005), body position (Kruel *et al.*, 2005) and immersion depth (Kruel *et al.*, 2002) can potentiate and mitigate such responses. It is noteworthy that due to the hemodynamic changes that occur in the aquatic environment, HR in water exercises should not be the same as that of land-based exercises. In this sense, for an adequate prescription of HF, maximum performance tests in the water are required (Graef & Kruel, 2006).

Deep water aerobic exercise training seems to be effective for improving pain symptoms and reducing the disability of people with chronic low back pain. Therefore, Kanits *et al*. (2021) aimed to verify the influence of training intensity in the aquatic environment on pain, disability, physical capacity, and quality of life in patients with chronic low back pain. A randomized clinical trial. Subjects: Twenty-two patients with chronic low back pain of both sexes (13 women and 9 men) participated in the study. One group performed deep-water walking/running training at moderate intensity (MIT) and a second group performed deep-water walking/running training at high intensity (HIT). Pain, disability and peak oxygen uptake (VO_2peak) were assessed before and after an intervention. Decreases in pain and disability were observed within both groups, without differences in these parameters between training groups. VO_2peak did not change in either group after the training intervention. Effort perception of 19 [Borg Rating of Perceived Exertion (RPE) Scale, scale range of 6-20)] was appraised.

Thus, aerobic exercise of deep-water walking/running may be indicated for patients affected by chronic pain. Furthermore, for the participants in this study who were classified as having good-to- excellent physical fitness, the two intensities, moderate and high, can also be indicated without any impairment in the parameters of pain or disability. As for improvement in cardiorespiratory fitness, the authors suggest a higher weekly frequency of training. Nonetheless, it is emphasized that the interventions were effective in maintaining cardiorespiratory fitness.

Another study investigated the chronic effects of aerobic training and deep water running concurrent training on cardiorespiratory and muscle strength responses in the elderly. Sedentary elderly men participated in 12 weeks of aerobic training (n = 16) with a frequency of three weekly sessions. Aerobic training (running in deep pool) was performed at intervals with sets of four minutes performed at high intensity (85.00-100.00% FCLV2) and another minute of recovery (<85.00% FCLV2). The results obtained by the study were all positive, except for the maximum dynamic strength of the knee flexors, which did not show significant differences for both groups. Improvements were observed for the aerobic group in the maximum strength (1RM) of the knee extension (10.00%), in the resistance strength (60.00% of 1RM) of the lower limbs (8.00-18.00%), in the HRrep (-9.00%), in VO_2peak (41.00%) and in VO2LV2 (35.00%) (Kanitz *et al.,* 2015).

Overall, the adaptations resulting from aerobic training and concurrent training were similar, apart from VO2LV2 which resulted in a significantly greater improvement in the aerobic group (α=0.05). It is noticed that the two training models produced increases in cardiorespiratory parameters and lower limb muscle strength; however, aerobic training in running in deep pool performed alone has better increases in cardiorespiratory responses, with similar strength responses. It seems to be interesting to add the effort perception table for better intensity control during aquatic exercise practice.

Reichert *et al.* (2016) investigated the chronic effects of 28 weeks of two aerobic programs (continuous and interval) of running in a deep pool on the functional capacity and blood pressure responses of the elderly. While one group participated in two weekly sessions of interval training (n = 13) another group participated in two weekly sessions of continuous training (n = 12). The two training sessions were prescribed based on the Borg scale, with variations from 13 to 17 for continuous training and 15 to 18 for the interval training stimulus. After the training period, both groups improved their performance in the standing, going and returning (12.00%), elbow flexion (42.00-48.00%), 6-min walk (4.00-12.00%), sit and stand (47.00- 50.00%), and systolic and diastolic blood pressure (7.00-12.00%).

Although the study by Reichert *et al.* (2016) have investigated the chronic effects of aerobic training in the aquatic environment lasting more than 12 weeks, it is noteworthy that it was performed in the deep pool running modality and did not consider any neuromuscular variable. In parallel to aquatic cycling, there is still no work that uses intensity control and that observes the chronic effects of this modality.

DWR is an alternative for patients who cannot receive impact when performed at high speeds. However, it is worth noting that due to the biomechanical changes this modality may require more trunk muscle activation and coordination. It’s already a given that DWR promotes recovery from injury, reducing impact on joints and even muscles. However, it’s not only comparable to typical sports training and weightlifting, but it may competitively be even more beneficial.

2.1.11. Aqua Bike Settings

Whether for the purpose of competing, general physical conditioning or simply for leisure, the bicycle (land or water) must be adjusted for an intended purpose. According to specific literature (books and specialized journals), and considering the quantitative measures for regulating the equipment, it has been noted that rides have been setting their bikes based only on subjective sensations (Bini *et al.*, 2011; Carpes *et al.*, 2009).

Such adjustments shall focus on the saddle in relation to the horizontal and vertical position, position of the handlebar and size of the crank, which usually form the moving parts of the bicycle (Bini *et al.*, 2011). These adjustments deserve special attention, as these moving parts can be regulated according to the body dimension of the rider. Geometry of the cyclist-bicycle complex can influence magnitude and direction of force applied to pedal, pedalling technique, neuromuscular strategy adopted, motion economy, probability of injuries, and, more directly, the feeling of comfort on the bike (Carpes *et al.*, 2009; Kleinpaul *et al.*, 2010).

The overall height of the bicycle can be adjusted to adapt to a depth ranging from 1.10m to 2.00m. Although studies have reported partial immersion, while the student is sitting on the bike, could be between calf to chin, riders should be immersed up to the waist and/or the xiphoid process for better effectiveness of technique (Rewald *et al.*, 2017). That justifies the importance of accurately knowing the depth of the pool where the aquatic cycling program will be implemented. In general, total mass of the stationary apparatus used in the activity ranges from 22 to 25 kg; therefore, density favours its placement at the floor of the pool, because the material (stainless steel), denser than water, makes the apparatus submerge.

In aquatic cycling, resistance is provided by a paddle system between the pedals or by the pedal system itself (depending on the bicycle model/brand), which may reduce or expand the area of friction with water (viscosity) becoming an option to increase resistance. Another option is to increase pedalling speed (Giacomini *et al.*, 2009). Saddle adjustment must be the first to be done. It is the main support for the rider, and its position relating to the central movement (shaft of the crank) will determine the ergonomic conditions for leg movement. The saddle height is related to the length of the lower limbs of the rider. The knee should be slightly flexed at the lowest point of the pedal stroke, preserving the last 10 to 25º of flexion (Swart & Holliday, 2019).

The cadence variability of pedalling occurs due to the specificity of the environment and the assumed body positions (seated or standing). During seated pedalling, constant seat exits may occur, due to the buoyant force, causing complete extension or unnecessary hyperextension of the knee joint. This may occur more frequently in individuals with high fat percentage (greater buoyancy), mainly as a result of fat accumulation in lower limbs and hips. In standing positions, by contrast, hydrostatic weight is not so reduced; however, the difference between pedalling in and outside water is still noticeable (Leone *et al.*, 2014). In addition, refraction makes important for the aquatic cycling instructor to be in the water observing the pedalling technique closely, as well as the position of the riders' lower limbs (Brasil *et al.*, 2011).

The distance between the seat and the handlebar can be adjusted in two ways: so that the alignment of the patella is directly on the pedal shaft or with the hands on the handlebar in such a way that elbows are slightly bent. Anyway, the rider needs to be comfortable. The handlebar height should be above the saddle height for beginners, on the same line as the saddle for intermediate and advanced, and below the height of the saddle for cyclists and athletes, leaving upper limbs as relaxed as possible. As for the foot-holding cage, the rider should place the foot on the pedal, having as reference the base of the metatarsals directly over the pivot arm of the pedal (Garzon *et al.*, 2015) (**Figure 15**).

The pedalling cycle is divided into 4 phases that can be represented by a clock. Cyclists who control these different cycling cycles will considerably improve their performance. A step by step on the mechanic of pedalling describing how to pedal through a single revolution and what to expect. Good pedalling technique begins with a push through the ball of the toe and happens at 12:00 (push). At 3:00 the toes automatically go downward from momentum so the force and current which assist in pushing the foot to the bottom of the clock or at 6:00 (lower phase of the push). Try to cue your students into keeping those toes lifted and feet parallel to the floor of the pool. At 6:00 the current has reached a peak and it is time for you to work harder (beginning of traction). This is where it is necessary to pull up with the force of the foot equivalent to the force of the down stroke on the toe clip or cage.

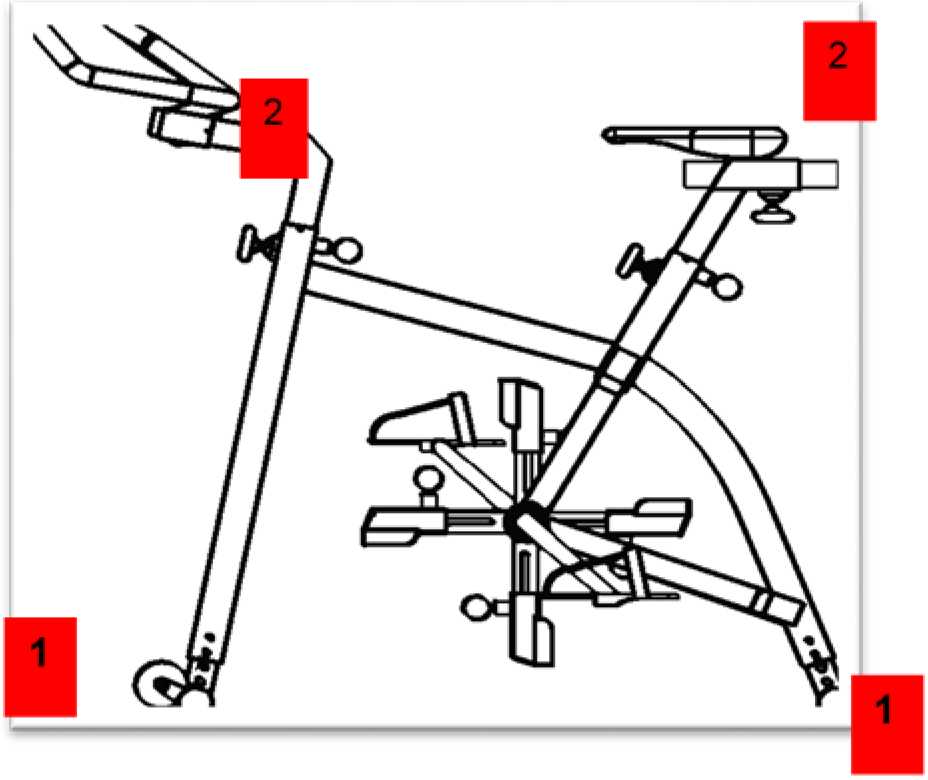

Figure 15. (1) Total height depending on the depth of the pool and (2) Customized adjustments for different heights (Hydrorider®, 2021).

Continuous resistance is accomplished by the properties of an aquatic environment (density and evenly maintained body surface pressure). The buoyancy effect of the aquatic environment has the tendency to push us upward, adding to the resistance. Concentrate on drawing circles with the feet and avoiding or diminishing torque in the pedal stroke. Feet remain parallel to the floor of the pool. The upstroke is a dead zone for power and so continuous force through a single revolution is the key to power pedalling and the ability to turn the crank without torque **(Figure 16)**.

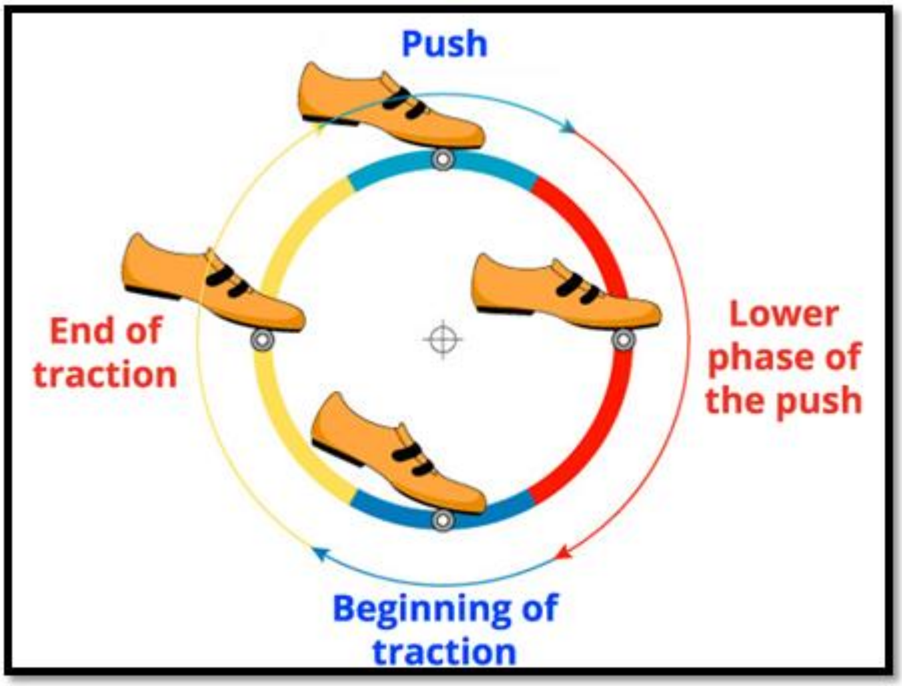

Figure 16. Pedalling focal points (Hydrorider®, 2021).

The Hydrorider® was used on this research, it is a stationary water bike used in swimming pools. The ideal pool depth is 3’7’’ to 4’8’’ (110-145 cm). For depths from 4’9’’ to 6’11’’ (146-165cm) a longer base is provided at request. Water level should be between waist and chest line. It is made of Italian Marine Stainless Steel AISI 316L to allow continuous use in pools. The use of correct water apparel and shoes are strongly recommended. To maintain optimum use, they suggest: Pedal straps and saddle cover to be replaced periodically; screws should be checked regularly; rinsed with water and dried in order to avoid spots; should be used only in the water, never on dry land.

2.1.12. Aqua Bike Body and Hand Positions

Strategies used in water cycling lessons are combinations of two body positions (seated: **Figure 17a**) and / or standing: **Figure 17b**) with hands on the handlebar or not. Hand positions (rider) may vary throughout the training session. The most frequent types used in water cycling classes are the following:

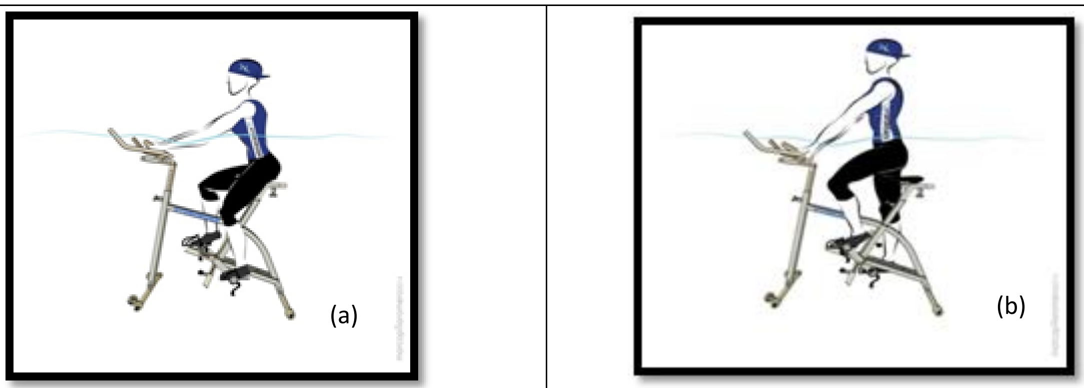

Figure 17. Seated position (a) and standing position (b) in water cycling (Hydrorider®, 2021).

Rider 1: Seated or standing, keeping shoulders and elbows relaxed; hands are together in the middle of the handlebar. It is noteworthy that standing is only used in water (**Figure 17c**).

Rider 2: Seated or standing, hands are apart aligned with shoulders at the bottom outer corners of the handlebars (**Figure 17d**).

Rider 3: Standing, hands are on the farthest position up on the handlebars; rider should not sit to avoid overload on the lower back (**Figure 17e**).

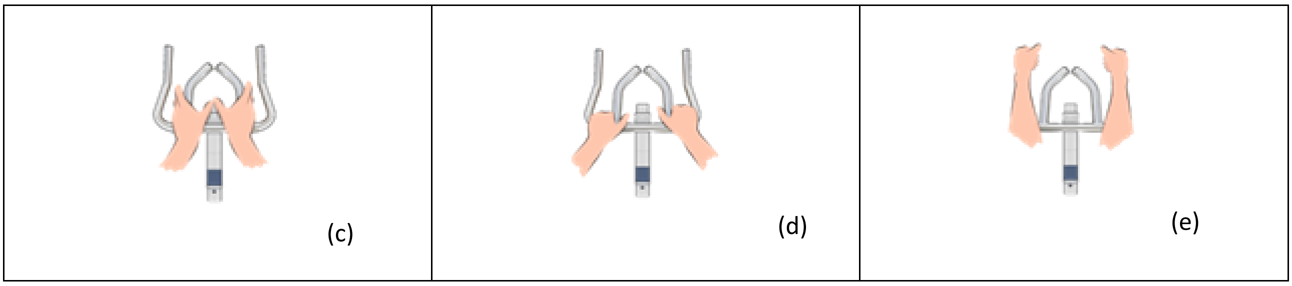

Figure 17. Hand positions used in water cycling classes (c) position 1 (d) position 2 (e) position 3. (Hydrorider®, 2021).

In addition, the rider may go behind the saddle, and hold the saddle or a specific support, simulating a recumbent bike; (**Figure 17f**) In the aquatic environment it is also possible to keep hands free for a sculling or "racing" in the water (**Figure 17g**). This position requires more skills and is recommended for advanced participants.

A specificity of aquatic cycling is the combined movement of the upper limbs according to body positions, standing or seated. In this sense, the instructor's guidance is very important to guarantee the rider's good posture, especially when sudden changes of media with different densities occur. The film formed in water has a slight effect of resistance, but in ballistic movements, in which there is sudden change of media, riders may be susceptible to lesions caused by different media densities and the force applied to break that film.

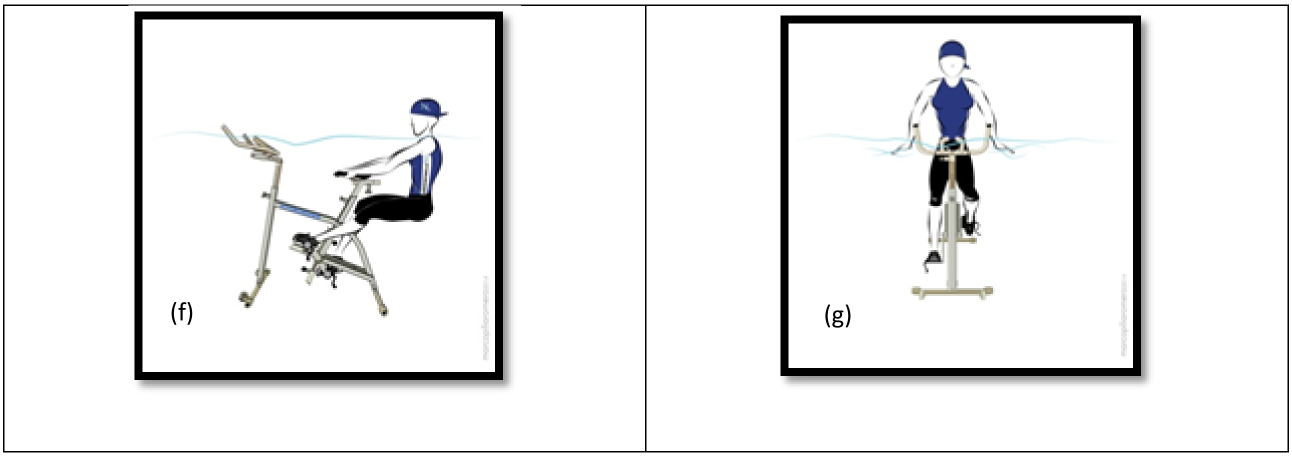

Figure 17. Other positions for water cycling training sessions (Hydrorider®) (f) seat back (g) flowing. (Hydrorider®, 2017).

2.2. Properties of Water

Aquatic exercises benefits are associated with physical characteristics of water. Exercising in water can produce physiological reactions different from that outdoors for two reasons: the hydrostatic effect of water on the cardiorespiratory system and its ability to intensify heat loss compared to air (Torres-Ronda & del Alcázar, 2014).

The physical properties of water are: mass, weight, specific gravity, density, buoyancy, hydrostatic pressure, surface tension, refraction and viscosity (Killgore, 2012). For any program developed, knowledge and understanding of physical principles related to aquatic environment are relevant in order to obtain effectiveness and adequacy as these principles enhance the physiological goals established (Colado *et al.*, 2012). It is worth noting that temperature also influences physiological aspects. Next, the most relevant physical properties for this thesis will be addressed.

2.2.1 Density and Viscosity

Despite being two distinct physical properties, density and viscosity matter in the capacity of water to conduct heat making this capacity about twenty-five times greater than that of air in equal circumstances (Meredith-Jones *et al.*, 2011). The density of a substance is defined as its mass per unit volume, or the relationship between the mass of a substance and its volume. Density is a temperature dependent variable. Water reaches its maximum density at 4° C and becomes less dense below the freezing point (0° C) (Becker, 2009).

Density results from the relationship between the mass of a body (kg) and the volume it occupies (m^3). Human body density (974 kg/m^3) is slightly lower than water density (998 kg/m^3) at 20°C and 1atm atmospheric pressure; however, it is noteworthy, other variables may influence these numbers, such as gender, race, age or lung capacity. Lean mass has an average of 1100 Kg/m^3, whereas fat mass has an average density of

900 Kg/m^3. So, individuals with privileged lean mass and little adipose tissue tend to have density greater than 1000 Kg/m^3, while obese or sedentary people tend to have lower density (Becker, 2009).

In aquatic cycling, density favours fixing the apparatus on the pool floor because the material (steel) of witch it is made is denser than water and causes its submersion (Torres-Ronda & del Alcázar, 2014). Another relevant aspect is technique applied: when riders are in recumbent position (**Figure 18**), which simulates a horizontal bicycle, they feel safer to perform the maneuver because they are more stable.

Figure 18. Seat back position, also called recumbent position. (Hydrorider® ,2017).

Viscosity is a type of resistant force between molecules of a liquid causing resistance of that same liquid to movement. Any high viscosity liquid flows slowly and those of low viscosity, such as water, at certain temperature, do it more quickly because they offer less resistance. Resistance to movement is determined by substance viscosity, since its molecules tend to adhere to the surface of the body where they are on (Methajarunon *et al.*, 2016).

Increasing water temperature decreases its viscosity, as heat reduces cohesion between molecules and facilitates muscle work. Training load in aquatic exercises relates to water viscosity. Increasing movement speed substantially increases workload and generates greater power in exercise. This resistance of water to movement is called "drag". Several factors interfere with the amount of "drag" a body experience while moving; some of them will be addressed, as they are more specific to the objectives of this work. For example, by doubling speed, resistance to effort becomes about four times greater. Movement against or with the flow of water also interferes with resistance, increasing or decreasing the drag exertion respectively (Meredith-Jones *et al.*, 2011).

2.2.2 Hydrostatic Pressure

When a body is immersed in water, it receives pressure from all sides. This pressure increases according to fluid density and depth. Therefore, pressure exerted by water in the sea is greater than in a pool, and the perceived pressure in lower limbs is greater than in upper ones, taking as reference the bipedal posture. Hydrostatic pressure increases according to fluid density and depth. Consequently, pressure exerted by water in the sea is greater than in a pool, and, when bipedal posture is used as reference, the perceived pressure in lower limbs is greater than in upper ones (Torres-Ronda & del Alcázar, 2014).

To aquatic exercises, hydrostatic pressure adds the most important and notable contribution. Increased by water depth and density, it provides immediate stimulation of peripheral circulation helping in venous return and directly affecting internal organs. In addition, it provides resistance to movement (natural overload), massaging effect and relaxation (Wilcock *et al.*, 2006). Hydrostatic pressure also contributes to central blood volume increase by altering intrathoracic pressure and is probably one of the reasons for reduced HR in the aquatic environment. All these responses are mediated by the fact that this pressure causes blood to travel upward through the lymphatic and venous system: firstly, in the muscles; then in the vessels of the abdominal cavity; and, finally, in the large vessels of the thoracic cavity and heart. Consequently, and in a nutshell, return circulation is greatly facilitated (Pendergast *et al.*, 2015).

According to studies, central blood volume expands by 0.70l and cardiac volume about 27.00% to 30.00%, causing blood ejection volume growth of 35.00% even at rest, which allows an enhancement in oxygen availability and muscle nutrients, as well as a greater diffusion of muscle-created metabolites in the blood (Torres-Ronda & del Alcázar, 2014). This blood ejection volume gain is the best explanatory alternative to understand the drop in HR of between 12.00% and 15.00% (an average of 10 beats per minute) when human body is introduced into aquatic environment. These facts create ideal conditions for water to be considered adequate means for rehabilitation in case of cardiovascular and respiratory diseases, such as edema and varicose veins, as well as rehabilitation after myocardial infarction and ischemic heart disease (Becker, 2009).

It should be recalled that hydrostatic pressure deeply affects respiratory system during body immersion to chest level. This is caused by the displacement of blood from extremities to core of body, and to compression of rib cage by water (Pendergast *et al.*, 2015). It has been observed hydrostatic pressure profoundly changes respiratory mechanics and central hemodynamic of an immersed body, providing total respiratory work increase of 60.00% (Becker, 2009).

In this sense, applying specific inspiratory muscle training to habitual swimmers did not show improvement their inspiratory strength when compared to another control group of swimmers without specific respiratory training. It is thus suggested that, by performing their usual training in water, these swimmers would have apparently reached their maximum in this variable due to hydrostatic pressure. Hypothetically, for an athlete accustomed to training on land, water training would imply a greater workload for his breathing muscles, which could improve his breathing efficiency and, as a result, his athletic performance (Becker, 2009).

Immersion causes changes in central hemodynamic such as cardiac output enhancement of 32.00%, and a central blood volume raise of 0.70 l, increasing intrathoracic blood volume. Also, in immersion with water up to xiphoid process, abdomen is pushed inside and ribcage expands at final expiration (Mourot *et al.*, 2008).

Consequently, the diaphragm grows in length, giving it a contractile advantage. This displacement also causes a reduction in expiratory reserve volume and residual volume. Inspiratory intercostal muscles, however, are shortened due to contraction, even at the end of exhalation, presenting a contractile disadvantage (Becker, 2009). Expiratory reserve volume is reduced by displacement of the diaphragm muscle in the cephalic direction, together with hydrostatic pressure action on rib cage (Pendergast *et al.*, 2015).

Inspiratory load increases immersion in water to shoulder level, leading to a decrease in pulmonary compliance (degree of distension) of around 50.00% (Pendergast *et al.*, 2015). Expiratory reserve volume decreases about 54.00% when body is immersed. This is easily noticed in the attempt to exhale the remaining air in the lungs at the end of a normal expiration, when the expiratory reserve volume reduces to 11.00% of the body vital capacity (Nagle *et al.*, 2019).

Hydrostatic pressure works as a load for diaphragm contraction during inspiration, resulting in an exercise for this musculature. Hydrostatic pressure also assists in diaphragm elevation and exhalation of air during expiration, thus reducing dead space (Mourot *et al.*, 2008). Due to the respiratory tract need for more intensive work, respiratory muscles are strengthened and breathing process can be improved. According to different maneuvers and positions adopted during training sessions, hydrostatic pressure will interfere differently in its intensity (Pendergast *et al.*, 2015).

Hydrostatic pressure also influences the body while immersed in water. The hydrostatic pressure causes vasoconstriction in the periphery, resulting in a blood shift to the chest cavity (Kanitz *et al.,* 2015). This increases venous return, which results in an increase in stroke volume via an enhanced Frank Starling mechanism (Barbosa *et al.,* 2009). There is an increase in cardiac output with a slightly reduced HR (Garzon *et al.,* 2015; Parfitt *et al.*, 2017). However, a negative effect of water immersion is a reduction in lung function (Ayme *et al.,* 2015) due to the hydrostatic pressure compressing the abdomen, raising the diaphragm, and restricting the inspiratory muscles (Reilly *et al.*, 2003).

2.2.3. Buoyancy

Buoyance concept is based on Archimedes' principle: "When a body is completely or partially submerged in liquid at rest, it is acted upon by an upward, or buoyant, force the magnitude of which is equal to the weight of the fluid displaced by the body". When in water, bodies experience the effect of two vertical forces, one from top to bottom (gravity) and one from bottom to top (upthrust) (Nagle *et al.*, 2019). Buoyancy is called up thrust and caused by an upward force generated by the displaced water volume. Buoyant force results from the pressure of a fluid that increases with depth. Thus, the upward force becomes equal to the weight of the displaced fluid (Archimedes Principle). This explains why beings and objects float when immersed in water (Pendergast *et al.*, 2015).

Magnitude of up thrust depends on size and density of a submerged body. Consequently, mass and size determine buoyancy. An individual with little muscle mass displaces small amount of water, which leads to conclude that the difference between displaced water body and body mass should be slightly small. If body weight is greater than water displaced, that individual sinks. As a result, it can be inferred that body composition influences buoyancy (Kurt *et al.*, 2018).

Buoyancy can be utilized in three ways: assistance buoyancy in which the movement is in the same direction as the floating; buoyancy in which the movement is perpendicular to the strength of the floating; and resistance buoyancy in which the movement opposes floatation. Thus, due to upthrust force, load on sustaining joints is decreased, which can help reduce pain, besides contributing to the movement of rigid joints in larger amplitudes (Becker & Cole, 2000).

When compared to dry land environment, different forces (thrust and resistive) may be experienced in aquatic environment. Thrust is experienced when body muscles try to overcome the resistance offered by water. Resistive force is subdivided in frontal force, frictional power and drag force (Campion, 2000; Ruoti *et al.*, 1997). Resistive forces correspond to the speed of movement execution, which can enable the occurrence of turbulent flow- characteristic of resistive force (Pöyhönen *et al.*, 2001; Ruoti *et al.*, 1997). Due to these forces, exercises in water provide muscle strengthening and aerobic capacity improvement, and due to the instability of this medium, water activities also assist in improving balance and proprioception (Geytenbeek, 2002).

A body submerged to the neck bears approximately 10.00% of its weight; one submerged to the chest reduces to 25.00% - 35.00% of its weight; and one submerged to waist will experience 50.00% of its weight on land. Speed and control of movements diminish considerably as the body submerges deeper (Nagle *et al.*, 2019).

Due to the buoyancy force, there is a reduction in musculoskeletal loading when immersed in water (Parfitt *et al.*, 2017), providing a low impact environment for joints (Costa *et al.*, 2017). This reduced musculoskeletal loading environment is especially important for athletes who want to avoid overtraining or injury, but still maintain the principle of specificity throughout their season (Rebold *et al.*, 2013). For example, runners or cyclists can still run or bike, but in a low impact environment which prevents overtraining and simultaneously maintains or even improves their training status. The buoyancy effect is also beneficial for the older adult population or individuals with musculoskeletal injuries (Costa *et al.*, 2017) since there is less stress on their joints while in the water, allowing them to continue getting the benefits of cardiovascular exercise without putting too much stress on the rest of their body. Furthermore, due to this reduced hydrostatic weight, the body requires less muscle recruitment to maintain posture or execute exercises while in the water (Kanitz *et al.,* 2015).

In aqua cycling, this immersion gradient varies according to different body positions. When sitting on regular bikes, lower limbs are not as much influenced by weight of the upper body. In water, this fact is accentuated because buoyancy leaves inferior limbs free to turn pedals. In upright position, weight is not so low; however, a difference between pedalling outside and inside water is still noticeable (Brasil *et al.*, 2011).

Another important aspect related to buoyancy is saddle height. For indoor cycling it is recommended an angle of 100 to 150 of knee flexion but this pattern (of kinematics) must be altered as height is changed (Garzon *et al.*, 2015). However, during water cycling classes, due to buoyant force, people frequently get off saddles, causing complete extension or unnecessary hyperextension of the knee joint. This may occur more frequently in individuals with high fat percentage (greater buoyancy), mainly attributable to accumulation of fat in lower limbs and hips. From this observation, instructors adjust the bicycle seat for greater angle of flexion (Rewald *et al.*, 2017).

2.2.4. Water Temperature for Aquatic Cycling

Aquatic environment thermodynamic characteristics can be useful in rehabilitation and sports. Heat capacity (or thermal capacity) can be defined as the amount of energy to be supplied to a given mass of a material to produce a unit change in its temperature (Nagle *et al.*, 2019). Due to its molecular structure, water has the highest thermal capacity (1000 times higher than air) resulting in great potential to retain cold or heat as well as to maintain temperature constancy. In other words, it stores more heat or cold before temperature changes (Becker, 2009; Torres-Ronda & del Alcázar, 2014).

High conductivity of water produces higher heat transfers in aquatic environment. Compared to basal metabolism, heat transfer in water can become five times higher than on land. In order to maintain body temperature, in view of high heat loss to the aquatic environment, body metabolism increases from 20.00% to 100.00%, according to the density of adipose tissue. The increase in energy rate remains high for a period even after body leave water.

In addition, water is also an excellent conductor as it transmits heat 25 times faster than air (Becker, 2009). Based on the aforementioned, and aware that heat capacity of human body is lower than that of water (0.83 kcal/ kg·°C compared to 1.00 kcal/ kg·°C), it can be inferred that human body reaches thermal balance faster than water; suggesting that it is the human body which adapts to water temperature, and not the opposite.

Another aspect concerning water temperature effects are the series of physiological reactions triggered by exercise performed in water and how they differ from those occurring outside aquatic medium. Sweat evaporation, for example, the main means for heat dissipation during land-based exercise, does not occur to the same extent when a body is surrounded by water, because in this medium heat loss or gain is most evident by convection and conduction (Peake *et al.*, 2017). Balance between production and heat loss is determinant for constancy of core body temperature of 37º C and 33° C of skin temperature. The effect of exercise intensity on core body temperature in water equals that on land.

Study verified that immersion in cold water increased blood return from lower limbs to heart, and, therefore, demonstrated that the magnitude of physiological changes was more accentuated in cold water and that the sympathetic nervous system was responsible for the changes (Vaile *et al.*, 2008). Nevertheless, at a thermoneutral temperature of around 31-33 ° C, blood flow adaptations are believed to occur simply because of immersion and not by thermoregulation. In practical terms, controlling the temperature of the aquatic environment is essential to reduce interference during water cycling practices (Barbosa *et al.*, 2009).

Therefore, a body with lower temperature than that of water, when submerged, gains heat in immersed areas and only lose heat from the blood in the cutaneous vessels and glands in the face and neck. On account of that, some considerations should be made (Broatch *et al.*, 2018). In cold water (below 25°C), physiological responses to aquatic exercise undergo some modifications, as most body fluids remain in the trunk area to keep organs warm and cardiovascular function working (Peiffer *et al.*, 2009).

Exercising in cold water compromises proper physiological response to good body functioning, because, once circulation is affected by reduced blood flow to the extremities of the body, cramp is prone to occur and lead to higher risk of muscle damage (Broatch *et al.*, 2018). Body immersion in cold water stimulates the sympathetic nervous system and increases production of norepinephrine which, in turn, induces significant body peripheral vasoconstriction (Broatch *et al.*, 2017). However, with progressive increase in exercise intensity, metabolites are released from active muscles causing vasodilation and progressively blood flow increase to the muscles (Nagle *et al.*, 2019).

On the other hand, vigorous exercise in very hot water rises internal temperature causing overheating and lowering heat dissipation signalling that hot water is more adequate to therapeutic treatments than to fitness training. In one study with obese women, when pedalling aquatic bikes at 40.00% of maximal aerobic capacity, had no change in rectal temperature during 90 minutes of trial at different temperatures (20°C, 24°C and 28°C). Diversely, women considered thin presented a progressive decrease in rectal temperature at two lower temperatures, which indicates influence of body composition (Sheldahl *et al.*, 1982).

As mentioned before, thermal properties are used in the field of sports and rehabilitation, and their implementation stages usually aim at controlling inflammation after an injury, decreasing fatigue and improving athlete recovery (Torres-Ronda & del Alcázar, 2014). For this, different techniques are used, being the most common: cold water immersion or cryotherapy, contrast baths and water immersion between 21°C and 35 °C (Broatch *et al.*, 2018).

Distinct ambient temperature ranges in water are considered suitable for different activities. This led to a concept called "thermoneutral" temperature, which can be defined as the temperature that water must have so that exerciser's thermoregulation mechanisms are not stimulated (nor limited) and there is no heat generation or dissipation (Nagle *et al.*, 2019). Although at rest this thermoneutral temperature is found at 35°C, not much consensus on it is found regarding aquatic exercise (Bergamin *et al.*, 2015).

Temperatures between 26°C and 29.5°C for what he calls strenuous exercise; nonetheless, indicates a range between 28.3°C and 31.1°C, depending on whether the aquatic fitness programs are high or low intensity. Notwithstanding, there is a consensus that Physical exercise in water at different temperatures can cause different physiological responses (Bergamin *et al.*, 2015; Nagle *et al.*, 2019).

The effect of water temperature on cardiovascular responses of healthy young people during gait-training in water at three different temperatures (29°C, 33°C and 37°C), and observed a significant increase in heart rate and diastolic blood pressure at the highest temperature (Ovando *et al.*, 2009). Physiological responses (heart rate, blood pressure and oxygen consumption) of older men during exercise at different temperatures (28°C and 36°C) and at different intensities.

Heart rate was significantly higher at higher temperature conditions, while oxygen consumption remained the same (Bergamin *et al.*, 2015). Nonetheless, when the variables: heart rate, oxygen consumption, lactate concentration and thermal comfort were evaluated in three different protocols - maximum soil cycle ergometer test, water bike at 27°C and bike at 31°C, no significant differences were registered in heart rate or oxygen consumption. However, significant increase in lactate concentration was observed in ground protocol, as well as perception, by the subjects, of greater comfort at lower temperature (Yazigi *et al.*, 2013).

In general, from the results presented in the previous studies mentioned above that analyzed the different temperatures, it can be lower that water temperatures greater than or equal to 36ºC cause an increase or no change in the behavior of HR compared to the terrestrial environment. I other hand, temperatures below 34ºC result in reduced HR, except for very low temperatures (Alberton & Kruel, 2009).

2.3 Physiological Responses to Partial Aquatic Immersion

Understanding physiological effects of water on immersed bodies, even at rest, is paramount to all aquatic fitness professionals. Due to the high degree of specificity of physical activities in water, control of exercise intensity through extrapolations of physiological indicators obtained out of water and transferred to aquatic environment may avoid errors that could affect the quality of prescription (Graef & Kruel, 2006).

2.3.1 Heart Rate

Regarding HR behaviour in aquatic habitat, literature seems contradictory (Kruel *et al.*, 2014). Some authors report tachycardia while others report no changes in HR (Ritchie & Hopkins, 1991). Still others (Graef & Kruel, 2006; Kruel *et al.*, 2009) identify bradycardia during immersion. And, although there are differences regarding origin, consistency and degree of bradycardia reduction, occurrence of this phenomenon as a result of immersion is widely accepted (Fiogbé *et al.*, 2018).

Comparison between exercises in and out of water pioneered in identifying change in HR as consequence of immersion during both land and water exercises. A significant increase in HR was found in water exercises compared to those performed on land: 31bpm for men and 13bpm for women (Johnson *et al.*, 1977).

Observing HR during running, ergo cycling, and swimming, verified decreasing HR during swimming: 15bpm for men and 14bpm for women when compared to running. Notwithstanding, in relation to cycling, reduction in HR in swimming represented 3bpm for men, and there was no report of results for women (Scolfaro *et al.*, 1998).

According to the authors, lower values in cycling in relation to running result from the different resistance of environment to body displacement. Thus, although the displacements of body in swimming and running make them similar, but different from cycling, the implications of body position and environment exert greater influence, which differentiates swimming from the other sports observed (Kruel *et al.*, 2014).

The response of HR was measured only to leg training during up-to-neck immersion and out of water. Data collected suggested that, at low exercise intensity, HR in water would be lower due to high stroke volume. However, as individuals approached maximum oxygen consumption during aquatic exercise, HR approached that observed on land because the stroke volume out of water was now approaching to that in water (Kruel *et al.*, 2014).

Ten healthy subjects, seated, immersed up to the neck or sitting out of the water, did not present significant changes in heart rate, even though the following was noted: 30.00% increase in cardiac output produced by immersion, increase of 35.00% in stroke volume and 30.00% decrease in peripheral resistance (Arborelius *et al.*, 1972). According to the authors, such results may have been reflexively produced by the activation of several receptors. Cardiac output (blood pressure vs. heart rate) increased from 30.00% to 3.00%

associated with a decrease of approximately 10 beats per minute or 4.00% to 5.00% of heart rate when individuals were standing (Fiobgé *et al.*, 2018).

HR and energy expenditure ratio obtained during aquatic exercise, when compared to that obtained from exercise on land, is of particular importance because HR is commonly used to describe and regulate metabolic intensity in the course of exercise (Kruel *et al.*, 2005). This response is partly dependent on water temperature. During mild to moderate intensity exercise, while subject is in head-out water immersion at thermoneutral temperature (31°C to 33°C), heart rate shows no difference from that observed during equal exercise on land at the same level of energy expenditure (Kruel *et al.*, 2014).

A comparison was made with responses for training on bicycles on land, at 22°C, and on bicycle in water, at neutral temperature, and cold water, at 20°C, for a period of four weeks, five days a week, one hour per day, at 75.00% of maximum oxygen uptake. During training, HR of both groups that trained in water were significantly lower (160 and 150 bpm) than in the group that trained on land (170 bpm), but the maximum oxygen consumptions were the same, being their increase from 13.00% to 15.00%. The authors concluded that the adaptation of maximum oxygen capture to training in water and on land with the same metabolic intensity was the same, even though HR of training differed by up to 20 bpm. Improvements in maximum oxygen uptake measured on the treadmill were smaller than improvements measured in the cycle ergometer, indicating that the adaptations resulted partially from the specific bike exercise. As HR differed in all three groups, but maximum oxygen uptake was the same, results indicate that HR is not a good reference regarding training stimulus provided by the exercise (Avellini *et al.*, 1983).

Another study aimed at verifying possible improvement, caused by the effect of training in hot, at 35°C and cold water at 20°C, in maximum oxygen uptake in young adults. Participants trained on stationary ergometer bicycles, immersed up to the neck, for 60 minutes, five days a week, for eight weeks, at the same maximum oxygen capture level

(60.00% of maximum oxygen uptake achieved in exercise on the bicycle). During training, HR and rectal temperature, respectively, of the group that trained in hot water were, on average, 27 bpm and 15°C higher than that of the group that trained in cold water. Maximum oxygen uptake increased by 13.00% for both groups. Training increased the oxidative capacity of the muscle to a similar degree in both groups, and blood volume did not change significantly in any of the groups.

The results of the study suggest that body's skin and rectal temperatures are not affected by metabolic and cardiovascular adaptation in water training. Alteration in plasma and blood volume may have occurred due to suppression of vasopressin, renin and aldosterone release during exercise in water. As the HR of the two groups during training differed by more than 25 bpm, the results of the study reinforce the hypothesis that HR of training would not be the best indicator of metabolic adaptations to training (Young *et al.*, 1993).

HR was analysed behaviour in 54 individuals upright, static and at different water depths. He found an average decrease in heart rate of 2bpm for knee-height water; and of 16bpm for shoulder-level water, with stabilization between 20 and 40 seconds as the body went on immersing and reaching different depths except for the anatomical points of neck and shoulders with arms out of water (Kruel *et al.*, 2005). According to the author, this variable rises during exercises with arms outside water due to the increase in hydrostatic weight of the individual, or even due to modification that may occur in venous return and blood flow according to the new position adopted. It has been observed that immersion; water temperature and different body positions can affect HR behaviour during exercise and/or recovery phases (Kruel *et al.*, 2014; Fiogbé, 2018).

2.3.2 Blood Pressure

Information on the effects of aquatic exercise on blood pressure is rare, probably for being difficult to verify this chronotropic index during partial immersion exercises. Even at rest, several cardiovascular changes, caused by immersion in water, can be observed (Reichert *et al.*, 2018). The high degree of specificities of the medium results in physiological responses to exertion and in recovery. Depth of water immersion, exercise mode, water temperature, and different postures adopted seem to influence such responses (Cunha *et al.*, 2016).

Hydrostatic pressure causes blood to flow to the core of a body in partial immersion, which creates the expectation of higher systolic blood pressure, as more blood will be ejected with each heartbeat. This sequence seems to be attenuated by a decrease in peripheral resistance of about 30.00% (Graef & Kruel, 2006). Vascular resistance is 30.00% lower in water when individuals are at rest. During immersion, cutaneous vessels momentarily constrict and raise blood pressure. After a few minutes, vasodilation occurs and BP returns to normal (Fonseca *et al.*, 2018). Immersion pressure changes are predominantly related to water temperature. Lower temperatures appear to raise blood pressure due to peripheral vasoconstriction, and, in contrast, higher temperatures appear to lower blood pressure due to vasodilation (Di Masi *et al.*, 2007; Graef & Kruel, 2006).

Exercise in cold water compromises proper physiological response to good body functioning by affecting circulation: blood flow reduces in the extremities, muscles become cold and inflexible, cramp may occur, and all this increase the risk of injury. Body immersion in cold water stimulates the sympathetic nervous system and increases norepinephrine production. This, in turn, induces strong vasoconstriction in the periphery of the body, and 10% elevation in systolic and diastolic blood pressure (Janský *et al.*, 1996).

After immersion at 40 °C, decrease in systolic blood pressure (SBP) was founded in the first five minutes of testing and a gradual and slight increase in the subsequent 20 minutes (Allison *et al.*, 1998). As for diastolic blood pressure (DBP), it decreased with immersion at the same temperature. So, if SBP for exercise in and out of water is similar, and, if vascular resistance is reduced during aquatic exercise, then, greater cardiac work would be necessary to maintain the same blood pressure during exercise outside water (Sheldahl *et al.*, 1987).

Blood Pressure was reduced in 10-minute-hot-water immersion in individuals with treated hypertension more than in normotensive individuals (Shin *et al.*, 2003). A progressive increase in cardiac output compared with values obtained on land (5.10 l/min); during immersion to hip height (5.70 l/min); xiphoid process (7.40 l/min) and head-out of water (8.30 l/min). Also, HR decreases during immersion up to hip, and in xiphoid process; and increases in head-out water immersion. It can then be concluded that in the first two stages of immersion, atrial baroreceptors play a determining role in the reduction of reflex bradycardia (Arca *et al.*, 2014).

However, during head-out water immersion, atrial receptors are responsible for its increase. Parallel to the increase in cardiac output, the same authors verified an increase in blood pressure and stroke volume for all immersion levels. It can be inferred that, within an ideal temperature range for aquatic exercise, blood pressure variations are discrete. What it is noted is most studies make their measurements at rest (Arca *et al.*, 2014).

2.3.3 Rating Pressure Product

The Rating Pressure Product (RPP) is considered the best non-invasive index to assess myocardial workload during rest or physical exertion, since it has significant correlation with myocardial oxygen consumption. RPP may vary due to changes in HR and SBP. Therefore, a better understanding of cardiovascular responses during exertion or exercise training is likely to increase the margin of safety in controllable activities (Perk *et al.*, 1996).

Unfortunately, accurate MVO_2 measurements require risky invasive surgical procedures that prove inappropriate in field situations. However, MVO_2 can be estimated during exercise from the product between systolic blood pressure and heart rate, obtaining what is conventionally called RPP (Kal *et al.*, 1999).

RPP is a variable closely related to safety of activity. It supports the handling of its absolute and relative intensity and facilitates the definition of the activity types that could be associated with higher risks of heart failure. Therefore, the importance of monitoring the control of acute cardiovascular responses transcends the universe of prescribing adequate loads to achieve the desired effects (Fonseca *et al.*, 2018). For this reason, RPP has good acceptance and finds excellent applicability in monitoring and prescribing exercises for populations that require more attention (Brasil *et al.*, 2011).

2.3.4 Lactate

During fitness training, lactic acid is produced mainly throughout glycolytic system participation for energy transformation. The glycolytic pathway involves glucose and glycogen degrading into pyruvic acid by glycolytic enzymes. In the absence of oxygen, pyruvic acid ferments to produce lactic acid, thus accumulating (Lucertini *et al.*, 2017) . Blood lactate concentration (BLC) is simply the difference between its removal and replacement index in the blood. So the increase in the concentration of BLC may not be due to its production, but to the difficulty in its output (Micheletti *et al.*, 2019).

Lactate is widely accepted and an indicator of the use of anaerobic glycolytic pathway. However, whether lactate causes fatigue and its production occur only during anaerobic exercises is a controversial issue. The growing need to measure training intensity favors the emergence of some techniques, among them lactacidemia. Such a physiological marker is also useful for more reliable training (Lucertini *et al.*, 2017).

Lactate is accepted as important predictor of acidosis on the organism during exercise, although there is evidence that this is erroneous. In fact, lactate can be considered an indirect predictor of fatigue, as it is not responsible for acidosis (Ferguson *et al.*, 2018). Despite being associated with fatigue in intense activities, lactate is positive for energy regeneration. Thus, it seems not to be a "villain" but rather an important substrate in replenishing energy reserves (Di Masi *et al.*, 2007).

The substrate eliminates dietary carbohydrate in the production of blood glucose and liver glycogen, being important in improving resistance in strenuous situations. The lactate formed enters circulation, being part of it eliminated in the muscle itself by highly oxidative fibers, and part used by the heart, liver and kidneys for energy generation. About 25.00% of lactate is converting to glucose (Ferguson *et al.*, 2018).

Regarding land-based and aquatic exercises, some comparative studies of lactate accumulation during physical exertion allow the examination of possible responses for lactate removal during water exercise (Di Masi *et al.*, 2007). On this investigated and compared physiological demands between deep water running (DWR) and treadmill running, twenty healthy men underwent maximum water and land tests, showing higher heart rate and lactate peak on land than in water. The authors comment these results are due to different muscle recruitment and hydrostatic water pressure (Nakanishi *et al.*, 1999).

Lactate accumulation between 40.00% and 80.00% of the maximum VO_{2max} intensity occurs similarly during dryland and water ergo cycling but, at higher intensities, lactate rates tend to be lower in the water (Connelly *et al.*, 1990). Ferreira *et al.* (2005), when comparing lactate in aquatic and land cycling in the same protocol, found no significant difference during the entire intervention.

When exertion is performed at 50.00 – 75.00% VO_{2max}, concentration of LAC in the blood varies little in relation to levels during rest. Above this intensity, however, there is exponential raise in LAC that may be reflected in the increase of muscle capacity to release it and/or a decrease in its removal capacity. This reflects the importance of LAC as an intermediate metabolite for various forms of carbohydrate stock, and as a final product of metabolism (CO_2 and water) (Billat *et al.*, 2003).

When comparing DWR to treadmill running at a submaximal intensity, found higher lactate in the water trial (Reilly *et al.*, 2003). Eleven subjects' lactate thresholds were determined while running at a 0.00% grade at increasing speeds on a treadmill on land or during on an underwater treadmill in a randomized crossover design. Water running resulted in a consistent shift to the left (rise in plasma lactate occurred at a lower) in the lactate threshold and elevated plasma lactate concentration at speeds between 5.50-7.50 mph despite similar metabolic and HR responses to the exercise (Jones, 2009). If lactate rate indicates lower values in water than on land, it suggests that either the removal rate has increased, or its production has decreased. In general, the authors believe that these results come from the effects of lower muscle recruitment and water physical properties (Di Masi *et al.*, 2007).

2.4 Subjective Perception of Effort

The conceptualization of Perception of Effort (PE), also known as perceived exertion, emerged from the first studies conducted by Borg and Dahlström in the 1950s. Besides Borg, amongst the leading researchers, Robertson, Pandolf, Noble, Morgan and Cafarelli can be cited as those with the greatest scientific contribution until the mid-1990s. From one of the classic early studies, in which Borg correlated the effort perception to heart rate in subjects pedalling on a cycle ergometer, new studies started to be developed in the

1990s (Morishita *et al.*, 2019).

Those initial studies on perceived exertion were inspired by the discussion of possible relationships between individuals' subjective judgment about their ability to train and objective measures (VO_{2max}, lactate, heart rate) of such ability. PE is a noninvasively method of practical applicability for measuring and monitoring the intensity of effort in areas of physical training. Although mainly used in aerobic exercises, the use of PE in strength training has been observed and being recommended by different researchers and recognized international institutions (American College of Sports and Medicine, American Heart Association, 2010) to aid in determining the intensity to be applied (Morishita *et al.*, 2019).

PE is related to vigorous muscle work involving a relatively large strain on musculoskeletal, cardiovascular and respiratory systems. Furthermore, PE is connected to the concept of exercise intensity, that is, how strenuous a physical activity is. It has been conceptualized as the subjective intensity of effort, tension, discomfort and / or fatigue experienced during - aerobic and strength exercises. Such behaviour, resulting from a multifactorial influence of PE, is defined as a type of gestalt, in which different configurations of sensations are present: tension, pain, fatigue of the peripheral muscles and respiratory system, along with other sensory signs, such as behaviour, emotional and psychological factors which seem to interfere. In addition, internal and external information from the environment is also incorporated into this gestalt (Robertson & Noble, 1997).

Within these dynamics, definitions of the terms sensation and perception are suggested. Sensation involves direct stimulation of the final sensory organ, whereas perception involves, besides pure sensation, also a complex of internal and external stimuli, which may not have direct connection to sensory organs (In this sense, it is understood that during physical efforts various sensations (heat, tension, vision, etc.) are perceived simultaneously, which makes the term "perception of effort" more appropriate (Tucker &

Noakes, 2009).

In an attempt to understand how different physiological, psychological and performance factors constitute PE, appear a theoretical model called global explanatory model of PE (Robertson & Noble, 1997). From a stimulus (exercise, for example), physiological responses serve as initial mediators for adjusting the intensity of stimulus perception (ventilation, oxygen uptake, muscle acidosis, neuromuscular signals, for example). The effect of this stimulus occurs by the alteration of the properties of strain production in skeletal muscles. Increased peripheral and/ or respiratory muscle effort during exercise requires a corresponding increase in the feed forward central commands that arise from the motor cortex. Copies of this motor command are sent to the sensory cortex and this data is subsequently integrated into the afferent peripheral information (feedback), producing the signals of perceived exertion (Marcora, 2009).

Other psychological aspects (anxiety, motivation), performance (audience effect, trainability, training history) and general symptoms of exertion (wheezing, muscle aches, etc.) motivation is always internal, are also associated with this information sent to the sensory cortex. The final mediating step of the perception process occurs when the intensification in the sensory cortex signal is combined with the contents of the cognitive perception reference filters. Such a signal is driven by matrix of past and present events that reflect the psychological and individual style characteristics (Robertson *et al.,* 2000).

Finally, there is the PE response, which can be classified as predominantly respiratory-metabolic, peripheral-local or non-specific, constituting the general PE (Tucker & Noakes, 2009). PE can be classified according to the physiological origin of the stimulus applied to both global (walking, running, etc.) and localized exercises (strength exercises) (Pageaux, 2016).

In relation to peripheral PE, there are several physiological mediators such as metabolic acidosis (blood lactate, blood and muscle PH), muscle fiber type, regional blood perfusion and reserves of energy substrates (glucose and lipids). For respiratory metabolic PE, ventilation, oxygen consumption, carbon dioxide production, heart rate and blood pressure are the main mediators. And, also, for non-specific PE, hormonal secretion (catecholamine's and beta endorphins), exercises with pain production and heightening of temperature of body and skin are involved (Robertson *et al.*, 2000).

Other authors divide PE classification into local and central (Pageaux, 2016). Although different mechanisms, whether physiological or psychological, affect PE, there is still no consensus in literature on which mechanisms are predominant for certain activities, nor on how they integrate, PE could be justified by the same neurophysiological path. In peripheral, and, possibly, non-specific signals, PE would be defined by the feedforward central commands along with the integration of the feedforward-feedback commands (Marcora, 2009).

For Feedback commands would be responsible for sending peripheral signals from muscle, joint, tendon, and skin receptors to sensory cortex. In the same line of thinking, the authors explain the relationship between PE and respiratory-metabolic aspects could be justified by greater need for inspiratory muscle work in an attempt to maintain metabolic demands of exercise. Thus, with increasing muscle tension and exercise, weakness and signs of fatigue in these muscles would increase PE response. This integration format of different types of SPE seems to depend on type of exercise, anatomical origin of different signals and number of regions involved (arms, legs, chest), environment in which activity takes place (land or water) and its metabolic intensity (Pageaux, 2016, Colado *et al.*, 2018).

Different scales were developed with the intention of measuring PE. Possibly, Borg's Ratings of Perceived Exertion scale is one of the best known and most widely applied. This scale has been constructed and validated in exercises performed outside liquid and its application in aquatic exercises has been investigated more recently (Graef & Kruel, 2006). Borg suggested a rating scale allowing individuals to relate their own levels of effort to specific points on the scale (Borg, 1982). This scale uses values ranging from 6 to 20 for representing pulse rate variation. However, other scales have been proposed in the literature, such as Borg's CR10 scale, Hogan and Fleishman's 9 degree scale, OMNI scale, and the Brennan's scale - a 5-point scale designed exclusively for water racing. Verbal descriptions of this scale range from very light to very difficult, and facilitate the incorporation of both speed work and distance work (Brennan & Wilder, 1990).

The use of PE scales establishes the relationship between a stimulus and a response. Any PE must be located between a minimum and a maximum point, and for a given stimulus a corresponding response is expected. In the category scales, the minimum and maximum points are established, and the divisions of their levels occur uniformly, being the distance between different levels represented by a corresponding sensory response. Verbal descriptions and/or figures are also used to help better understand effort levels. In this sense, the measurement of PE offers an index (number / value) of perceived exertion (Robertson *et al.*, 2004; Mays *et al.*, 2010).

Strategies for using PE scales are greatly varied and can be applied in endurance tests, prescription for exercises in and out of water, in clinical situations and in occupational activities. Such multifunctional characteristic of these scales may be justified by the high degree of correlations (r) found between the perceived exertion indexes of scales and different measures of physiological variables. In a meta-analysis of approximately 430 studies using PE, more modest results were found presenting the following correlation coefficient averages: HR = 0.62, blood lactate concentration ([la]) = 0.57, percentage maximum oxygen uptake (% VO_2max) = 0.64, VO_2 = 0.63, ve = 0.61 and fr = 0.72 (Chen *et al.*, 2002).

Due to difficulty in controlling and, often, measuring certain variables, the Subjective

Perception of Effort (SPE) is indicated for exercise prescription, including in liquid medium because of the high degree of correlation and linearity of HR with SPE (Colado *et al.*, 2018). Other aspects regarding SPE in physical exercises should also be observed, for example the volume of muscle mass activated in the specific tests; individual differences according to gender, chronological age, pregnancy; test conditions involving sleep deprivation and room temperature; as well as interaction between types of aquatic or ground exercises and their protocols witch may interfere with final results (Fujishima *et al.*, 2003).

2.4.1 Teleanticipation

Over the years, several studies have investigated factors that can guide sports performance and that are associated with tests strategies (Tucker & Noakes, 2009). In this scenario, arises the concept of communication between central and peripheral systems, which would have the ability to regulate the proposal during exercise (St Clair Gibson *et al.*, 2004).

Thereby, the level of muscle activation and intensity in exercise seem to be influenced by peripheral information and become integrated responses into the performance verification process. Therefore, the mere fact of having an intended strategy at the start of an exercise could cause some adjustments during its execution. In addition, this information continues to be processed between the brain and peripheral systems throughout the proposed task (Fernandes *et al.*, 2015).

This hypothesis corresponds to the prefix “teleo”, which was introduced by Jacob Levy Moreno (1889-1974), to name a set of perceptual processes. Such processes allow subjects to most appropriately estimate surrounding perceptions in order to anticipate the effort required to complete a given task in synchrony with internal (physiological, biomechanical and cognitive) and external (environmental) (Ulmer, 1996) responses.

Anticipation is concerned not only with harmonic bases of movement optimization, but above all, with teleoanticipation of ideal effort adjustments to avoid early exhaustion before completing a task. Afferent (or sensory) information (from the cardiovascular system, respiratory system, muscles, body temperature, among others) is identified by the central nervous system (CNS), which in turn controls the intensity of exercise for continuous adequacy of physiological levels (Carmo *et al.*, 2012).

Teleoanticipation results from complex interactions between past and current metabolic, cognitive and contextual feedback, which determine the pace to be used in each task to avoid early triggering of physiological processes responsible for fatigue. Therefore, performance of some tasks is likely to depend not only on metabolic potential, but also, above all, on elaboration of tactic to accomplish them, in order to obtain greater efficiency (Jones & Whipp, 2002).

In this sense, both physiological and psychological factors (motivation, mood, previous experience and other factors of psychological nature) would be compared at regular intervals during physical exercise to regulate intensity of effort. However, these adjustments can be perceived consciously through SPE. Thus, SPE during physical exercise may reflect the current state of the individual in relation to afferent and central information.

2.5 Bibliographic Synthesis and Genesis of the Investigation.

As a challenge, one of the concerns of the fitness industry is the development of new activities to motivate and arouse interest in those who seek physical conditioning, quality of life and health. Accessories and new programs seem to potentiate physical and commercial results; after all, the aquatic environment is extremely versatile and has attracted more and more adherents of different age groups and conditioning levels around the world. This dynamic market causes a need for adaptation of dry land equipment, which literally “invades” the space of swimming pools, such as the aquatic cycling bikes (Brasil *et al.*, 2011; Leone *et al.*, 2014; Dionne *et al.*, 2017) (**Figure 19).**

Figure 19. Group class in International Aquatic Fitness Conference (IAFC, 2015).

Understanding the physiological effects caused by water to the immersed body, even at rest, is fundamental for all professionals in the field (Rewald *et al.*, 2017). Due to the high degree of specificity of physical activities conducted in water, control of exercise intensity in this environment through extrapolations of physiological indicators observed on dry land and transferred to the aquatic environment may lead to errors that could affect the quality of prescription (Graef *et al.*, 2006).

Studies involving the use of cycle ergometers and bicycles adapted for aquatic exercise were conducted to identify the response of HR, BP, RPP, VO_2, lactate, muscle activity, energy expenditure and influence of different temperatures (Yazigi, *et al.*, 2013; Rewald *et al.*, 2017). Although few studies discuss possible health benefits of water cycling intervention, it has already been noticed that immersion, water temperature and different body positions may affect heart rate behaviour during aquatic cycling practice (Garzon *et al.*, 2016).

Aqua cycling is a promising activity to all age groups and at different levels of conditioning. In addition, it may be applicable in skeletal muscle rehabilitation or cardiac rehabilitation (Dionne *et al.*, 2017). To this end, respecting individual’s biological features and establishing safe bases for the control of training intensity is fundamental (Colado & Brasil, 2019). Nonetheless, after the literature review, it was observed that there are no studies validating, in a practical way, the control of intensity during water cycling sessions.

CHAPTER III:

OBJECTIVE AND HYPOTHESIS

3. OBJECTIVE AND HYPOTHESIS

According to the literature review developed and the scientific and professional experience accumulated during more of twenty years, next is going to be shown the objectives and hypothesis of the present study.

3.1 General Objective

The general objective of this scientific work was to perform a concurrent and construct validation of a “Scale for Rating the Perceived Exertion during Aquatic Cycling” for young and fit men.

3.2 Specific Objectives

1. To assess if during the practice of water cycling it is possible to perform a concurrent validation between the physiological variables (VO_2 max, VE, HR and Lac) and a new scale for water cycling.

2. To assess if during the practice of water cycling it is possible to perform a validation of the construct between the Borg scale 6-20 and a new scale for water cycling.

3.3 Hypothesis

Depending on the literature review and the accumulated professional experience, it can be indicated that the specific hypotheses of the present study were the following:

H1: There will be statistically significant differences in the behaviour of physiological variables and of perception of effort during the development of the the maximal load-incremental test.

H2: The perception of the effort derived from the new scale for water cycling will be distributed as a positive linear function with respect to the response of the physiological variables (heart rate, oxygen consumption and lactic acid).

H3: The subjective perception of the effort derived from the new scale for water cycling and the Borg Scale 6-20 during the increase in the load in the protocol used may be positively correlated.

H4: A fixed increment in the aquatic pedalling cadence of 15 beats or pulses per minute would be positively correlated with an increment in the VO_2max and ACS RPE responses during the maximal load incremental test.

If all these hypotheses are true, this would be the first study to provide an easy and specific tool to guarantee intensity control during performance of this aquatic activity. This new pictogram will allow clear differentiation of the intensity zones to which the participant could train during their aquatic-pedalling exercise.

CHAPTER IV:
MATERIAL AND METHODS

4. MATERIAL AND METHODS

4.1. Participants

A convenience sample of 30 male university students participated in the study. Sample size was determined using G* Power 3.1 software (Faul *et al.*, 2009). The calculation indicated 30 volunteers were necessary to meet the required power of 0.85, $\alpha = 0.05$, correlation coefficient of 0.5, nonsphericity correction of 1, and moderate effect size. This prior analysis of statistical power was performed to reduce the probability of type II error and to determine the minimum number of participants required for this investigation to reject the null-hypothesis at the $p < 0.05$ level of confidence (Beck, 2013).

The participants were physically active men, but there were no athletes or practitioners of aquatic cycling or any other cycling activities. They had no cardiovascular disease, osteoarticular history, or clinical, neuromotor, or cognitive contraindications for the performance of the physical tests. All subjects were regular physical exercise participants (>160 minutes per week) and non-smokers (ACSM, 2010).

The subjects were carefully informed about the potential risks and discomforts of the project, and they signed a written consent form before their participation in the study. The Ethics Committee of the University (H1369642832747) approved this investigation, and the study protocol was in accordance with the Declaration of Helsinki of 1975, modified in 2008.

4.2. Procedures

Each subject participated in two sessions, consisting of familiarization and experimental protocol. The first familiarization session was conducted 48–72 hours before data collection during the experimental protocol. Several restrictions were imposed on the volunteers: no food, drinks, or stimulants (i.e., caffeine) to be consumed 3–4 hours before the sessions and no physical activity more intense than the usual daily activities of living 12 hours before. They were encouraged to sleep at least 8 hours the night before data collection. All measurements were conducted by the same investigators and were always performed in the same sports facility.

A detailed description of the methods employed in this study has been published previously (Mays *et al.*, 2010; Robertson *et al.*, 2004; Utter *et al.*, 2004). Thus, taking in account the previous indications of Robertson *et al.* (1996), the following is a summary of the methods that pertain specifically to the water immersion aspects of the over-all experimental.

4.3. Familiarization Session

Participants attended sessions to familiarize with the aquatic bicycle (Hydrorider®, Bologna, Italy, 2011 **Figure 20a, b**) with the resistance produced by the four paddles on the pedalling mechanism set to the maximum length. Saddle height was adjusted after each participant sat on the bicycle with the heel pressed on the foot pedal at the lowest point and the leg extended (Leone *et al.*, 2014); hands positioned on the lower part of the handlebar, which characterizes position 2 **(Figure 21a, b**) in aquatic cycling (Brasil *et al.*, 2011); and handlebar height remaining above saddle height. The proper immersion depth was set to the xiphoid process (chest-level immersion) (Yazigi *et al.*, 2013), using for this the movable rails that the bicycles had in their support base which allows to adjust the bicycle height.

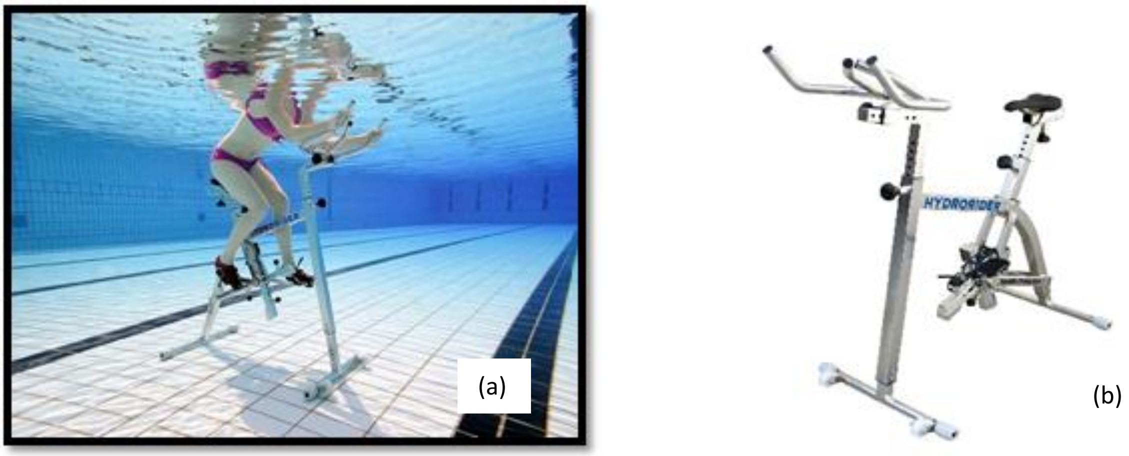

Figure 20 a and b. Hydrorider professional. (Hydrorider®, 2017)

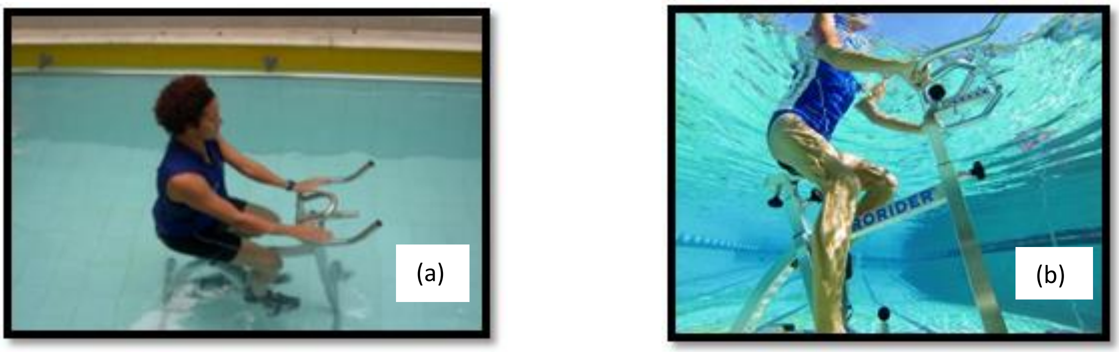

Figure 21 a and b. Position 2. (Hydrorider®, 2017).

According to the strict criteria of previous studies (Mays *et al.*, 2010; Robertson *et al.*, 2004; Utter *et al.*, 2004), participants were instructed regarding the proper use of both perceived exertion scales by the investigators. The subjects separately viewed the Borg and the ACS scales when their respective instructional set was read. They were told to respond with numerical categories only about their undifferentiated overall body exertional perception using a hand signal for each scale. Scales were always positioned in full view in front of the subjects. Due to this study used a continuous load-incremental maximal test, in the familiarization session all procedures were carefully explained to avoid that physical performance could be subconsciously decreased when fatigue came. For reducing this risk, also subject's maximal conscious effort was always required and researchers supported the test with external encouragement (Wittekind *et al.*, 2011) **(Figures 22 and 23)**.

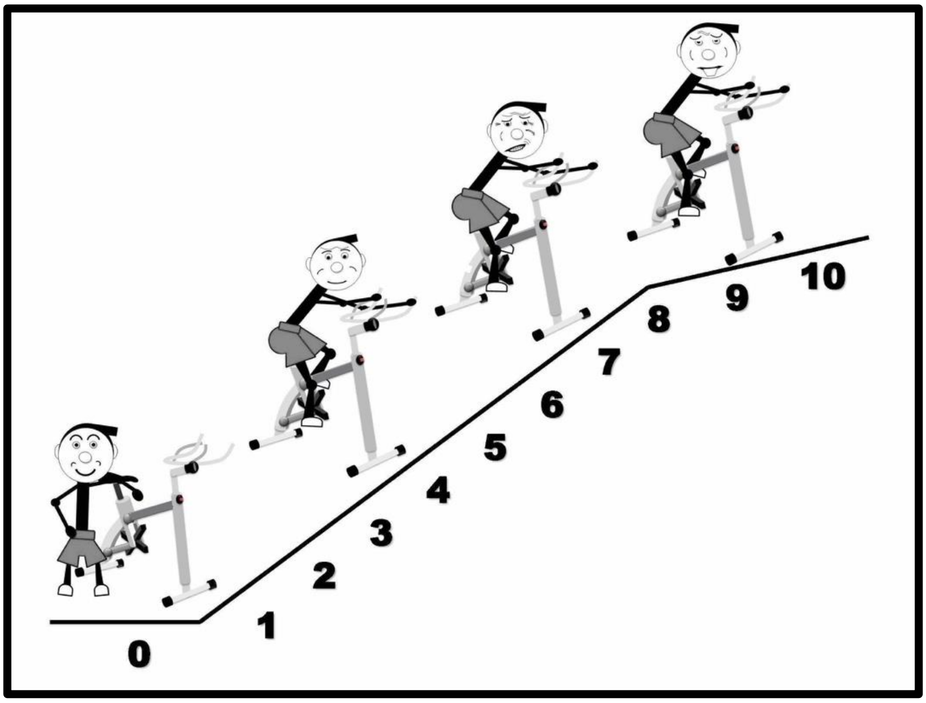

Figure 22. New scale for rating-perceived exertion during aquatic cycling**.**

Participant's height was determined using a portable stadiometer (IP0955, by Invicta Plastics Limited, Leicester, United Kingdom). Total body mass and percentage of fat was measured by bioelectric impedance analysis (Body Composition Analysis, Tanita BF-350, Tanita Corp., Tokyo, Japan) according to previous studies and procedures (Colado *et al.*, 2013). Participants were instructed to wear shorts or men's swim trunks and specific footwear (i. e. aquatic socks) (Athletech, USA). The subjects then cycled on the aquatic bicycle at different progressive cadences, similarly to the test that was used during the experimental protocol session. While pedalling, subjects also wearied the gas collection mask to be familiarized with its use. All technical details that must be taken in account while this exercise is performed were previously explained **(Figure 24)**.

PUNTUACION	VALORACION DEL ESFUERZO
6	Muy, muy ligero
7	
8	
9	Muy ligero
10	
11	Moderado
12	
13	Algo duro
14	
15	Duro
16	
17	Muy duro
18	
19	Muy, muy duro
20	Máximo, extenuante

Figure 23. Borg Scale (Borg, 1982)

Figura 24. Familiarization Session.

4.4 Experimental Protocol Session

Subjects participated in a continuous load-incremental maximal test by changing cadence of pedalling cadence, which was controlled by a digital acoustic metronome (recorded on a compact disc). The water cycling maximal test started at a rate of 100 beats per minute, with an initial stage of 3 minutes and with subsequent increments every 2 minutes of 15 beats per minute in the aquatic pedalling cadence until reaching exhaustion (Pinto *et al.*, 2016). Subjects were instructed to execute one complete pedalling cycle (i.e., 0–360º) in two beats (one beat for the left leg and one beat for the right leg), considering that the beat is a steady pulse that is repeated cyclically during one minute and this determine the pace of the movement (for example, 100, 115, 130 etc. beats per minute (bpm)).

This aspect is usually employed during aquatic cycling activities when music is used for monitoring the exercise intensity and setting the pedalling cadence. Therefore, a complete pedalling cycle of 360º has been considered as the equivalent to a revolution per minute in our study, for example 160 bpm would be the equivalent of 80 rpm. A researcher was always in the water checking visually that this strictly adhered to guarantee a uniform change in load-incremental maximal test (Borreani *et al.*, 2014; Colado *et al.*, 2009) .

Using the procedure of Pinto *et al.* (2016) during the aquatic exercise, participants were connected to portable metabolimeter (K4b2; Cosmed, Rome, Italy) which measured the VO_{2max} (l/min) and VO_2 indexed to body weight (ml/kg/min), and pulmonary ventilation (VE) (l/min) on a breath-by-breath basis. **(Figure 25).** The metabolimeter was enclosed in a waterproof bag (Aquatrainer; Cosmed, Rome, Italy) suspended in front of each participant. Gas analysers and the flow meter of the respiratory-metabolic instruments were calibrated before each test following the instructions of the manufacturer. According to Yazigi *et al.* (2013), HR was measured by telemetry (Electro Oy, Polar, Kajaani, Finland) during the entire test, and a blood sample was collected from the earlobe every two stages of the test and BL (mM) was analysed by a portable lactate analyser (Lactate Pro; Arkray Inc., Japan) **(Figure 26).**

Water temperature higher 30ºC provokes less thermal comfort and limits tolerance to cycling exercise probably caused by increased thermal load (Yazigi *et al.*, 2013). However, for exercises performed in thermoneutral water, the subject’s RPE seems to be an effective index for the prescription of the intensity in the same way that it is for land activities (Fujishima & Shimizu, 2003). So, throughout the experiment, both air and water temperatures were maintained thermoneutral at 24^0 C and 30^0 C, respectively (Alberton *et al.*, 2011; Pinto *et al.*, 2015; Pöyhönen & Avela, 2002).

Figure 25. Experimental Protocol

Figure 26. Collected dates

RPE's from the two scales were recorded in counterbalanced order during the last 30 seconds of each stage of protocol. For both scales, perceived exertion was defined as the subject's intensity of effort, strain, discomfort and/or fatigue felt during the exercise, representing the overall body (regardless body regions) (Noble & Robertson, 1996; Pinto *et al.*, 2016). The test for each participant was terminated when: a) the participant stopped voluntarily owing to exhaustion, b) investigator detected the participant was not keeping up with the fixed pedal rate in the pertinent stage, i.e., missing the cadence per 10 consecutive seconds, or c) the participant stopped when used the hand to signal exhaustion. In addition, the assessment was considered valid when any of the following criteria were met at the end of the test: average time ranged from 8 to 10 minutes, RPE was at least 18 on Borg's 6–20 RPE scale, respiratory exchange ratio was (RER) >1.15, and maximal respiratory rate was of at least 35 breaths per minute (Pinto *et al.*, 2016).

4.5. Statistical Analyses

Statistical analyses were performed using commercial software (SPSS, Version 24.0; SPSS Inc., Chicago, IL). Descriptive data for perceptual and physiological variables were calculated as mean ± standard deviation (SD). Continuous outcome variables were assessed for normality. Scatter plots were developed to identify outliers and to determine whether a linear trend was observed between the following variables across stages of the maximal load incremental test: VO_2, VE, HR, and BL and the RPE from the Borg and the Aquatic Cycling scales.

Correlation and regression analyses of data from the final minute of each of the maximal load-incremental test stages of the VO_{2max}, pedalling cadence and ACS RPE-overall were initially used to check whether the increment of the aquatic pedalling cadence corresponded with an increment in the intensity of the exercise (Yazigi *et al.*, 2013).

Evidence for both concurrent and construct validity was determined using linear regression analysis with repeated measures data derived from each stage of the maximal load-incremental.

When testing concurrent validity, the analysis separately regressed VO_2, VE, HR, and BL against ACS RPE-overall using data from the final minute of each of the maximal load-incremental test stages. VO_2, VE, HR, and BL were compared separately with the RPE using correlation analyses accounting for clustering (stages nested within subjects) throughout the wide range of exercise intensities from the graded exercise test. Simple logarithmic regression analyses were used to verify if the nonlinear design of the new ACS pictogram was appropriate. When testing construct validity, the analysis regressed ACS RPE against the Borg Scale RPE by using data from each of the maximal load-incremental test stages.

An analysis of variance (ANOVA) with one-factor repeated measures was performed to determine the existence of possible differences between the stages of pedalling cadences (different intensities) and their respective responses in all physiologic and psychological variables. A post hoc analysis with Bonferroni correction was used in the case of significant differences in the ANOVA model. The level of statistical significance was set at $p < 0.05$.

CHAPTER V:
RESULTS

5. RESULTS

The 30 male subjects of the present study had the following demographic characteristics: age: 22.37 ± 2.31 years old; height: 177.30 ± 7.27 cm; body mass: 72.95 ± 7.78 kg; and body fat percentage: 14.84 ± 3.50%. None of the participants abandoned the study during its course and none of them stopped the test due to any negative clinical symptoms such as chest pain, heart palpitations or nausea. The means (±SD) of selected physiological variables and the Borg and aquatic cycling ratings of perceived exertion during the maximal load incremental aquatic cycling test are presented in Table 1. The stages of pedalling per minute (bpm) showed a high significant positive relationship with the ACS RPE ($r = 0.93$, $p < 0.05$) and with the VO_2max ($r = 0.85$, $p < 0.05$), while ACS RPE and VO_2max also demonstrated a good significant positive relationship ($r = 0.78$, $p < 0.05$).

Their respective values from regression analysis are shown in Figure 5a, while the percentage of the VO_2max increment (Δ%) regarding previous pedalling cadence stages is shown in Table 1. The Δ% was calculated with the standard formula: change (%) = [(value of the pedalling cadence stage – value of the previous pedalling cadence stage) / value of the previous pedalling cadence stage] x 100. The ANOVA indicated significant main effects in stages of pedalling cadences per minute for ACS RPE ($F_{6,48} = 356.41$, $p < 0.05$, and $\eta2 = 0.98$) and for VO_2max ($F_{1.78,21.42} = 227.17$, $p < 0.05$, and $\eta2 = 0.95$).

The stages of pedalling cadences per minute x ACS RPE interaction effect was significant for all the different stages (100, 115, 130, 145, 160, 175, 190 bpm); a similar result was observed for the VO_2max between all cadences, except for 175 and 190 bpm ($p = 0.12$). Table 1 shows the mean value percentages of the VE increment regarding previous pedalling cadence stages with a significant difference between all cadences. Table 1 shows similar results with VO2, except for 175 and 190 bpm ($p = 0.12$). Table 1 also shows significant differences between cadences regarding the HR values, with an exception between the first two stages (i. e., between 100 – 115 bpm and 115 – 130 bpm). Significant differences were observed between all cadences in the AC or the Borg scales RPE scores (Table 1). Finally, Table 1 shows significant BL differences between all verified cadences.

Table 1. Descriptive responses for selected physiological variables and ratings of perceived exertion (mean ± SD) and percentage of increment regarding previous pedalling cadencies stages along the maximal load incremental test.

	Pedalling cadence stages						
Pedalling cadence (bpm)	100	115	130	145	160	175	190
VO$_2$max	1.07	1.39*	1.73*	2.13*	2.60*	3.24*	3.55$^{\&}$
(L/min)	(0.18)	(0.21)	(0.21)	(0.22)	(0.38)	(0.47)	(0.48)
Δ%		29.90	24.46	23.12	22.06	24.61	9.57
VO$_2$	14.26	18.50*	22.95*	28.28*	34.42*	42.98*	46.89$^{\&}$
(ml/kg/min)	(2.66)	(3.35)	(3.36)	(3.03)	(4.54)	(6.85)	(5.64)
Δ%		29.73	24.05	23.22	21.71	24.86	9.10
VE	23.17	30.56*	40.82*	52.20*	68.73*	97.03*	138.57*
(L/min)	(5.11)	(4.70)	(5.50)	(5.51)	(9.79)	(12.92)	(13.12)
Δ%		31.89	33.57	27.88	31.66	41.78	42.81
HR	99.54	105.08	115.77	132.92*	148.85*	162.08*	173.31*
(bpm)	(14.98)	(17.68)	(22.52)	(20.06)	(21.03)	(23.90)	(27.84)
Δ%		5.56	10.17	14.81	11.98	8.9	6.93
BL		1.18		2.68*		11.15*	11.63*
(mM)		(0.43)		(1.03)		(2.22)	(1.63)
Δ%				97.32		88.85	88.37
ACS RPE	1.11	2.22*	3.1*	4.5*	6.22*	7.67*	9.33*
	(0.33)	(0.83)	(0.78)	(0.73)	(0.97)	(0.71)	(0.50)
Δ%		100	39.64	45.16	32.22	23.31	21.64
Borg Scale RPE	7.55	9.33*	11.33*	13.22*	15.22*	17.00*	19.00*
	(0.88)	(0.87)	(1.12)	(1.20)	(0.97)	(0.71)	(0.71)
Δ%		23.58	21.44	16.68	15.13	11.69	11.76

SD: standard deviation. bpm: beats per minute. Δ%: increment percentage regarding value of the previous stage. The Δ% was calculated with the standard formula: change (%) = [(value of the pedalling cadence stage – value of the previous pedalling cadence stage) / value of the previous pedalling cadence stage] x 100. VO$_{2max}$: maximum oxygen consumption. VO$_2$: oxygen uptake taking in account bodyweight; VE: pulmonary ventilation. HR: heart rate. BL: blood lactate. RPE: overall body rating perceived exertion from Borg or Aquatic Cycling scales (ACS). *: Significant difference ($p < 0.05$) regarding value of the previous stage. &: Trend of difference ($p= 0.12$) regarding previous stage.

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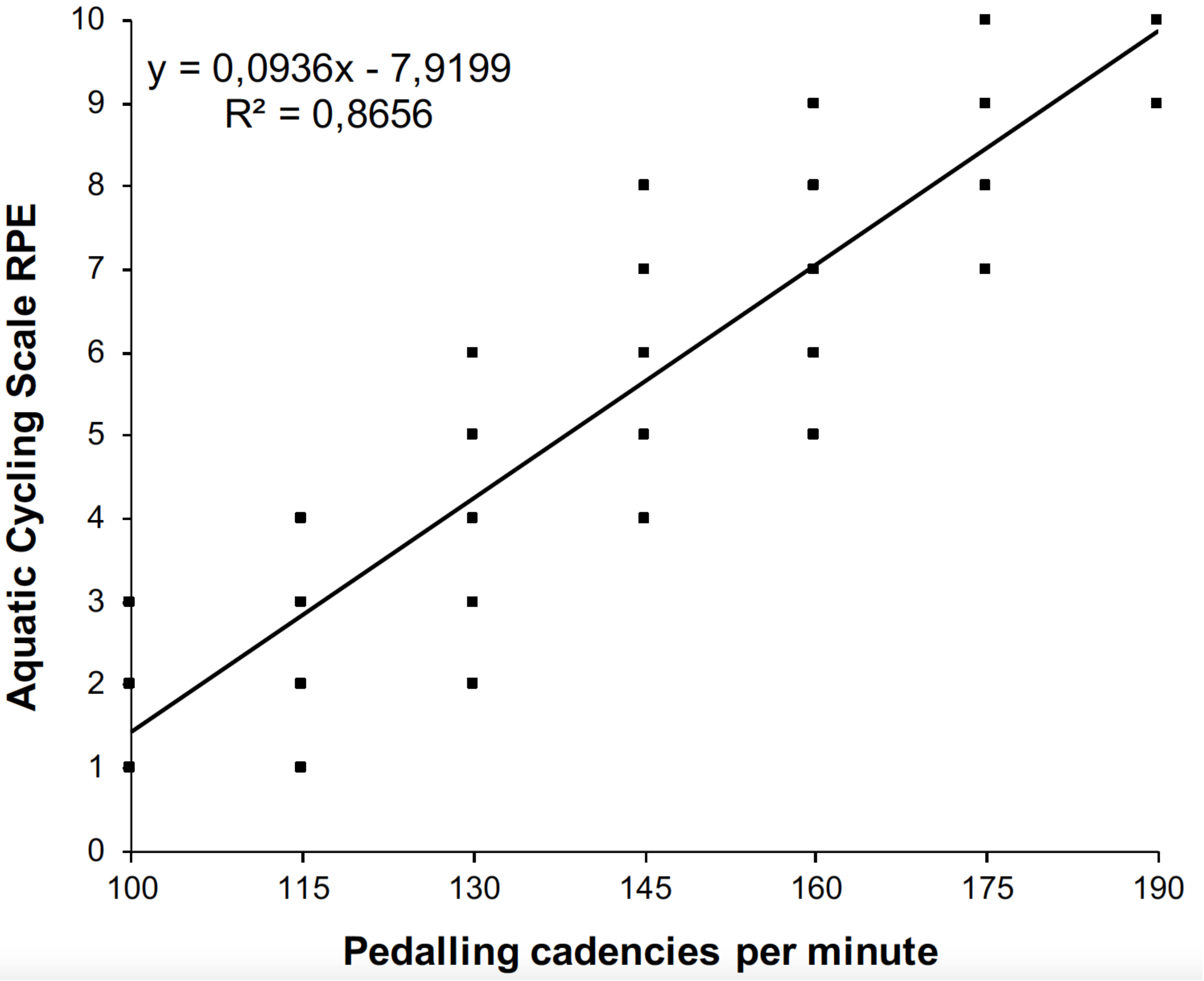
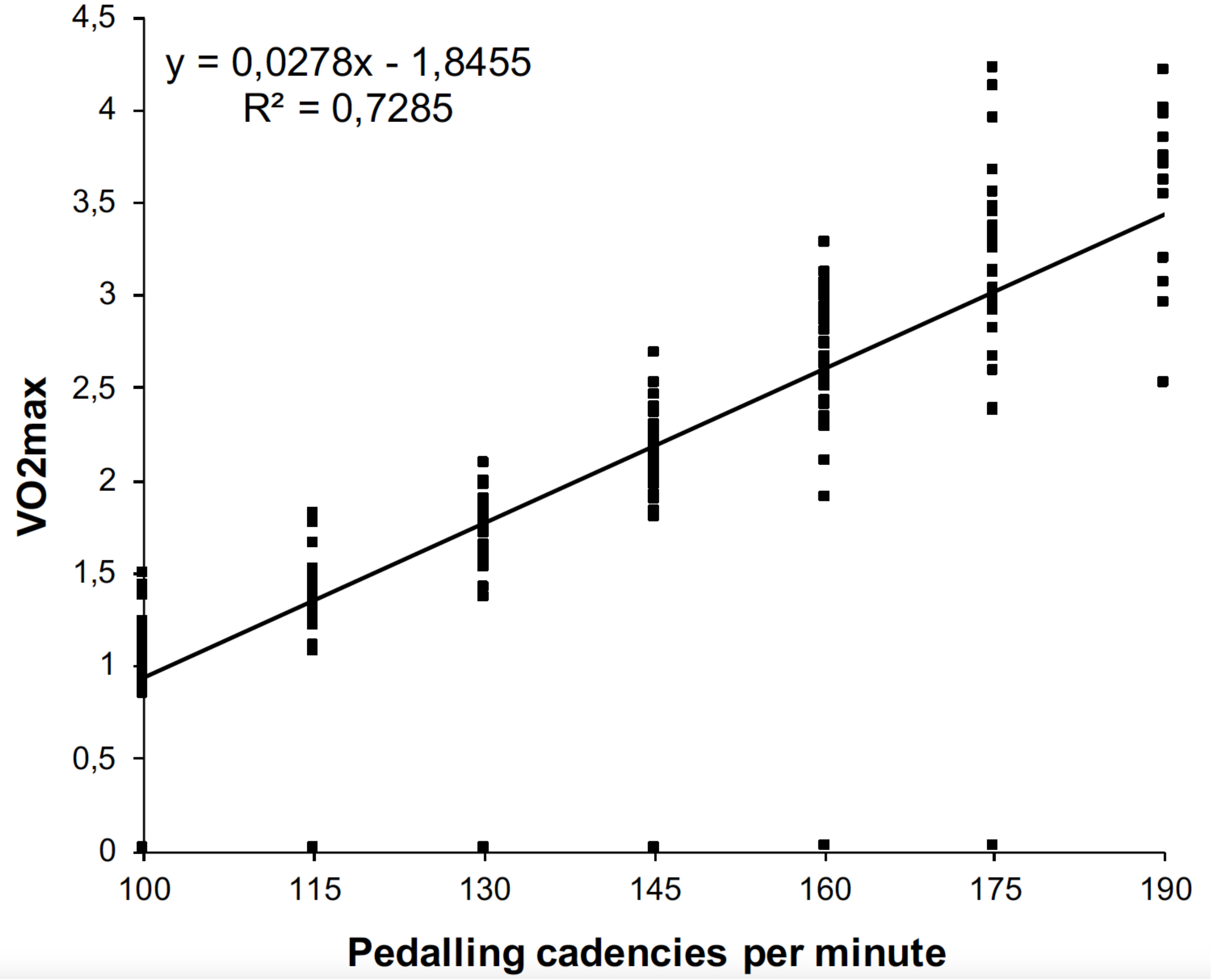
Regarding concurrent validation, correlational analysis indicated ACS RPE values were distributed as positive linear functions of VO_2, VE, HR, and BL. Some data points from physiologic variables appeared to be outliers and they were replaced by a mean value of the close values (Aguinis *et al.*, 2013). Pearson correlation analysis showed a highly significant positive relationship between physiologic variables and the ACS RPE: VO_2 $r = 0.87$; VE $r = 0.86$; HR $r = 0.77$; and BL $r = 0.85$. All correlational functions were statistically significant ($p < 0.05$). Figure 5b shows the values from the regression analysis, and Figure 5c shows the effect plot image of the relationship between the physiologic variables and the ACS RPE along the maximal load incremental test. Figure 5d also shows a significant positive relationship from logarithmic regression analysis between most of the physiologic variables and the ACS RPE.


y = 0,0936x - 7,9199
R² = 0,8656
Aquatic Cycling Scale RPE
0
1
2
3
4
5
6
7
8
9
10
100
115
130
145
160
175
190
Pedalling cadencies per minute


y = 0,0278x - 1,8455
R² = 0,7285
VO2max
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
100
115
130
145
160
175
190
Pedalling cadencies per minute

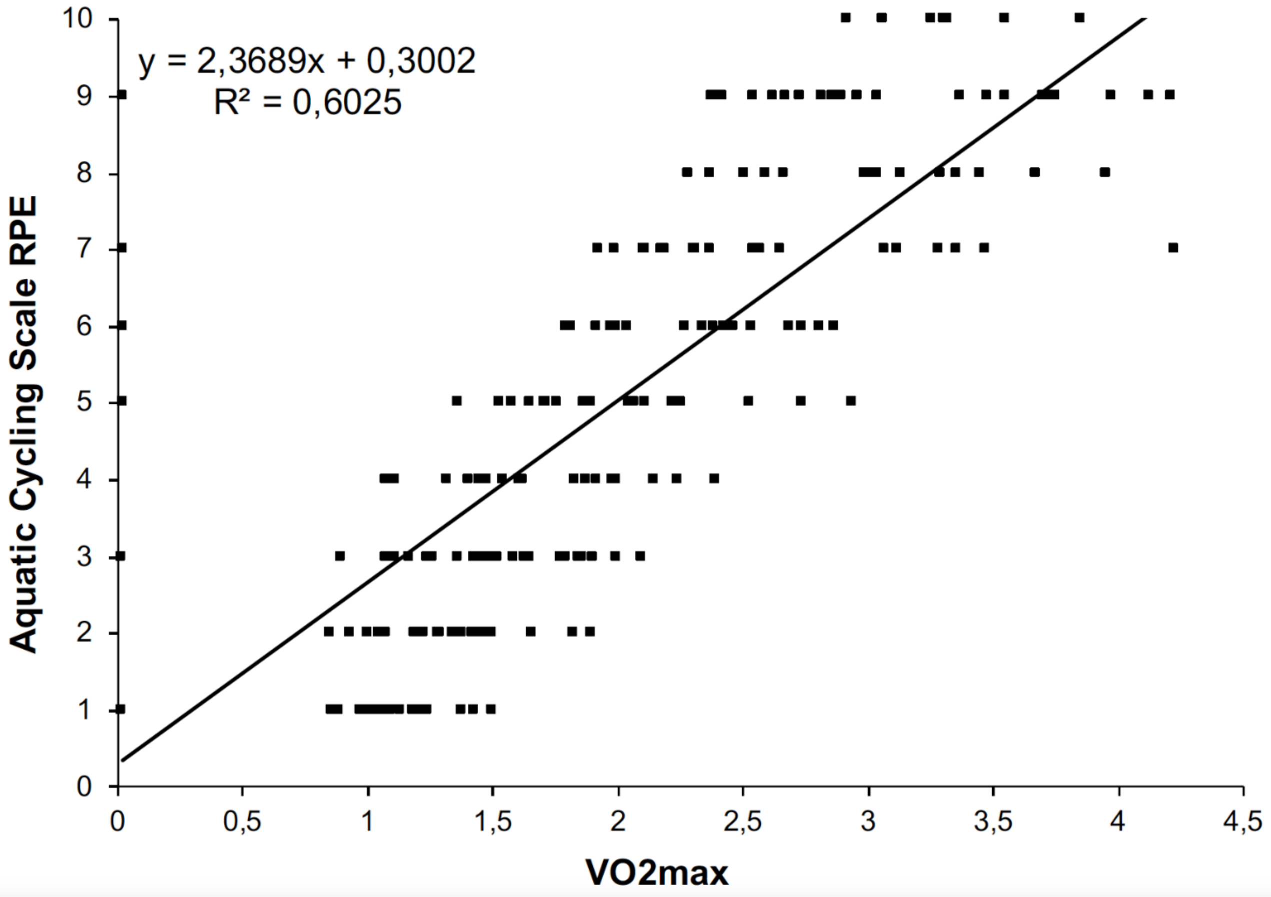
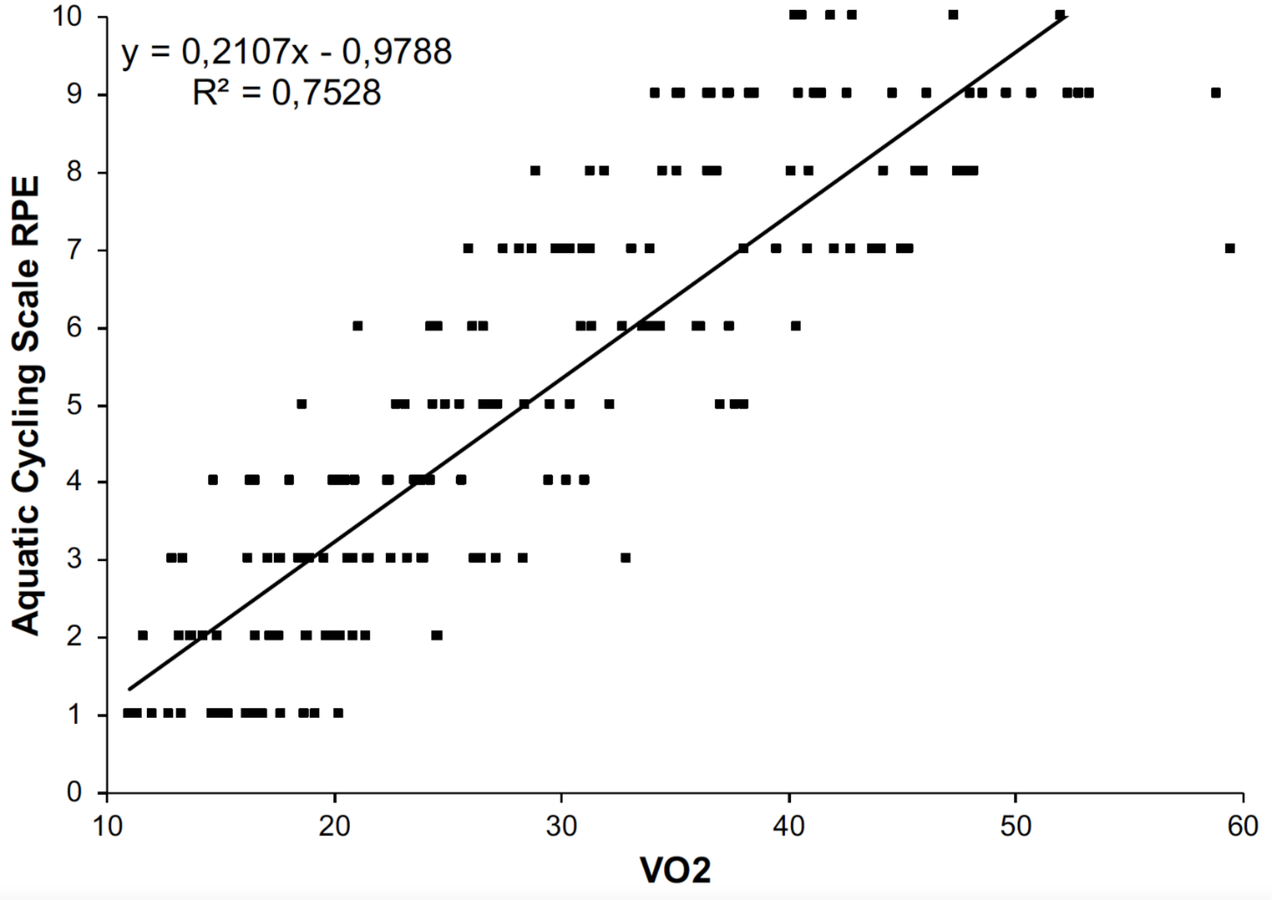
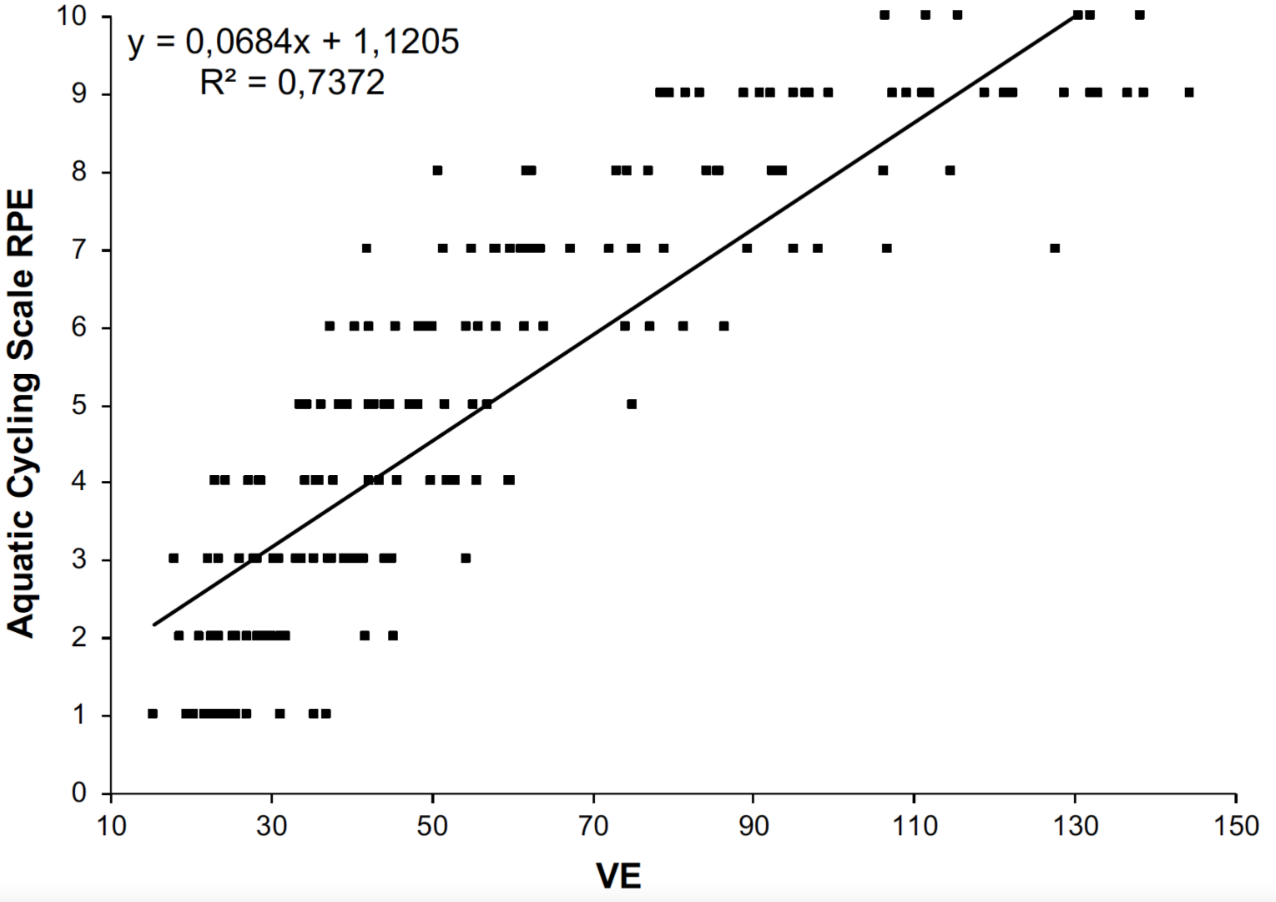
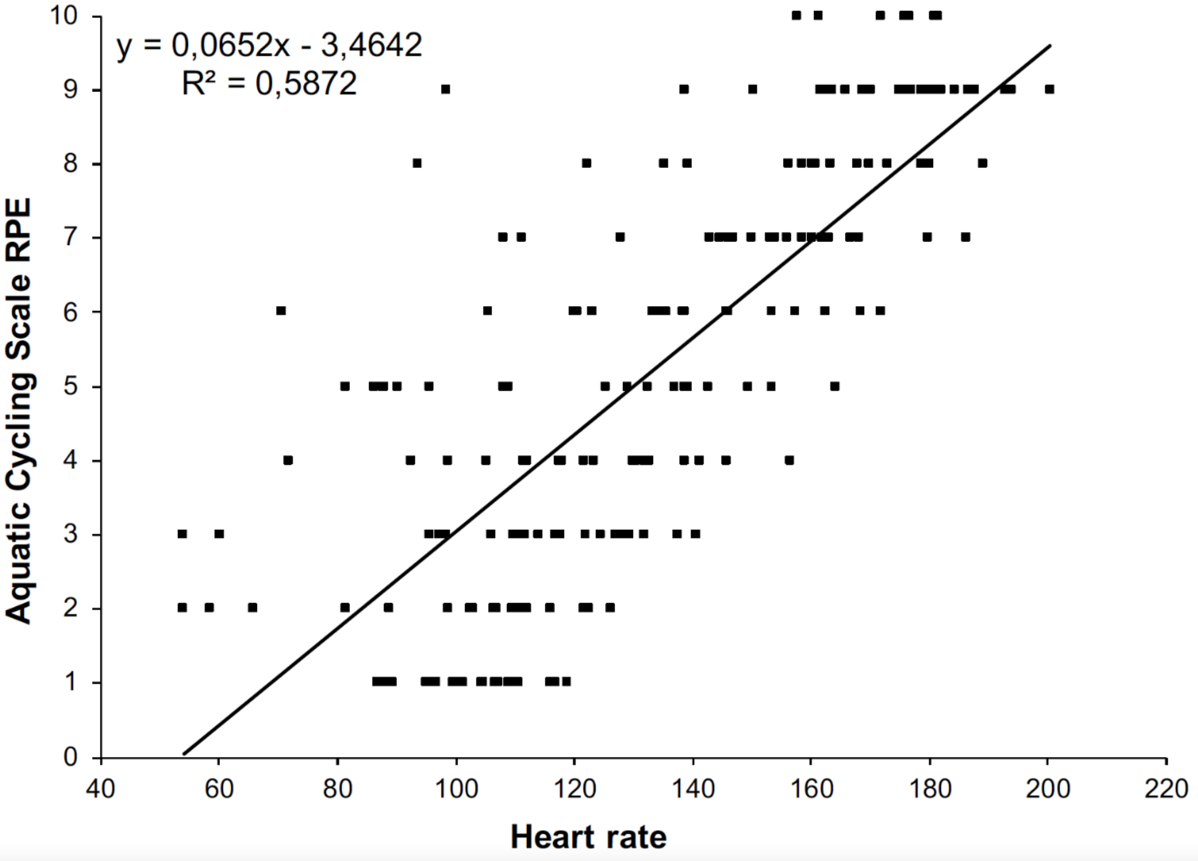


Figure 27a. Simple linear regression analysis between (i) Aquatic Cycling Rating of Perceived Exertion and maximal oxygen uptake (VO_2max) (L/min); VO_2max in each stage of pedalling cadencies per minute (bpm) from the load incremental test, and (ii) Aquatic Cycling Rating of Perceived Exertion and VO_2max along all the maximal load incremental test.


y = 0,2107x - 0,9788
R² = 0,7528
Aquatic Cycling Scale RPE
VO2
0
1
2
3
4
5
6
7
8
9
10
10
20
30
40
50
60


y = 0,0684x + 1,1205
R² = 0,7372
Aquatic Cycling Scale RPE
VE
0
1
2
3
4
5
6
7
8
9
10
10
30
50
70
90
110
130
150



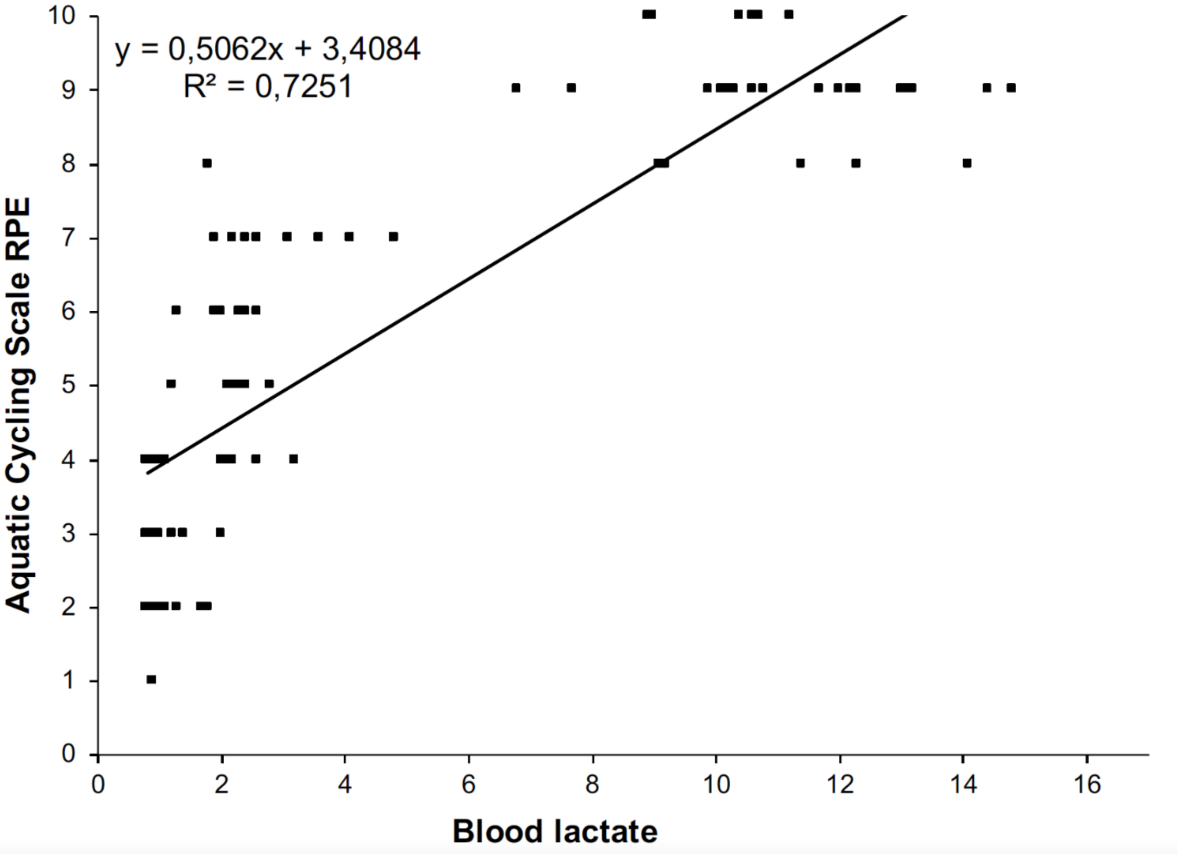


Figure 27b. Simple linear regression analysis between the Aquatic Cycling Rating of Perceived Exertion and some of the different physiological variables along all the maximum load incremental test. VO_2: oxygen uptake taking in account bodyweight (ml/kg/min); VE: pulmonary ventilation (L/min); Heart rate (beats per minute); Blood lactate (mM); Aquatic Cycling Scale RPE: overall body rating perceived exertion from the Aquatic Cycling Scale.

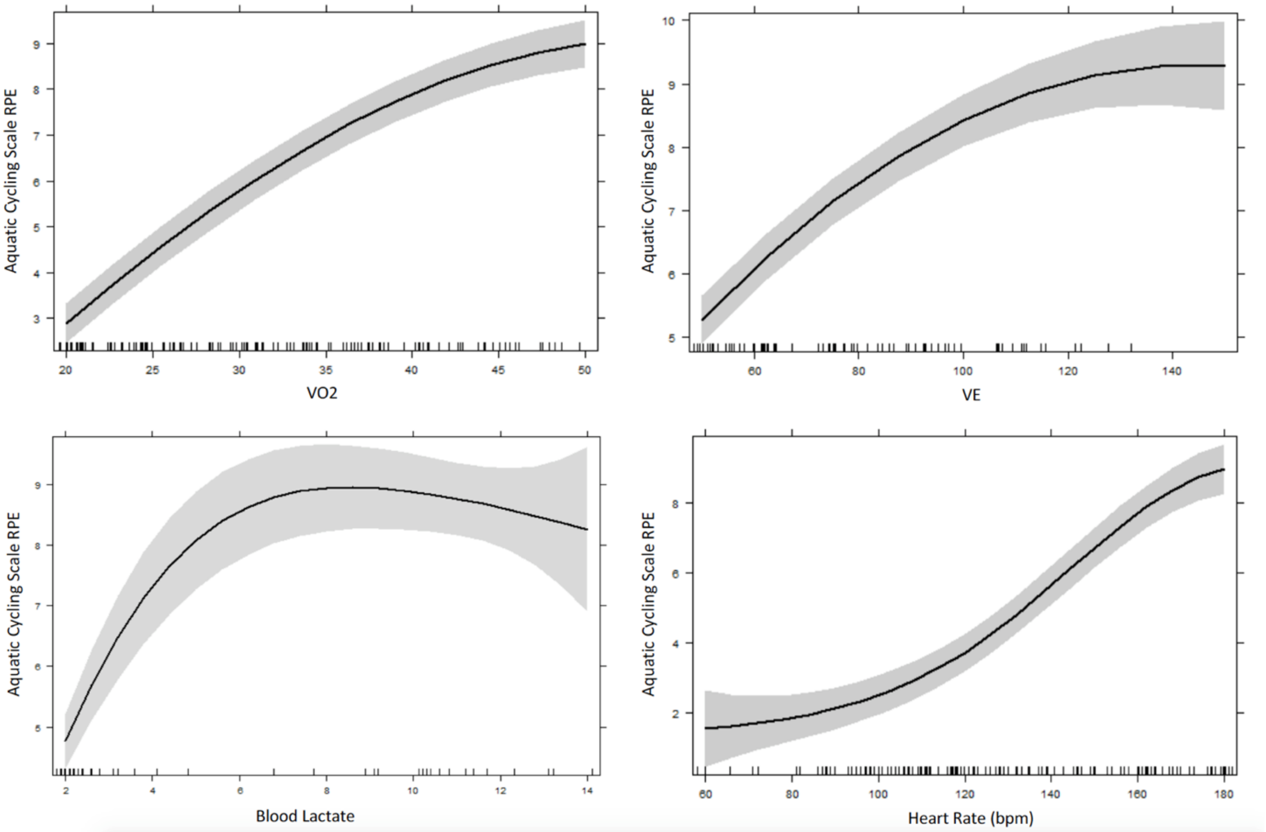
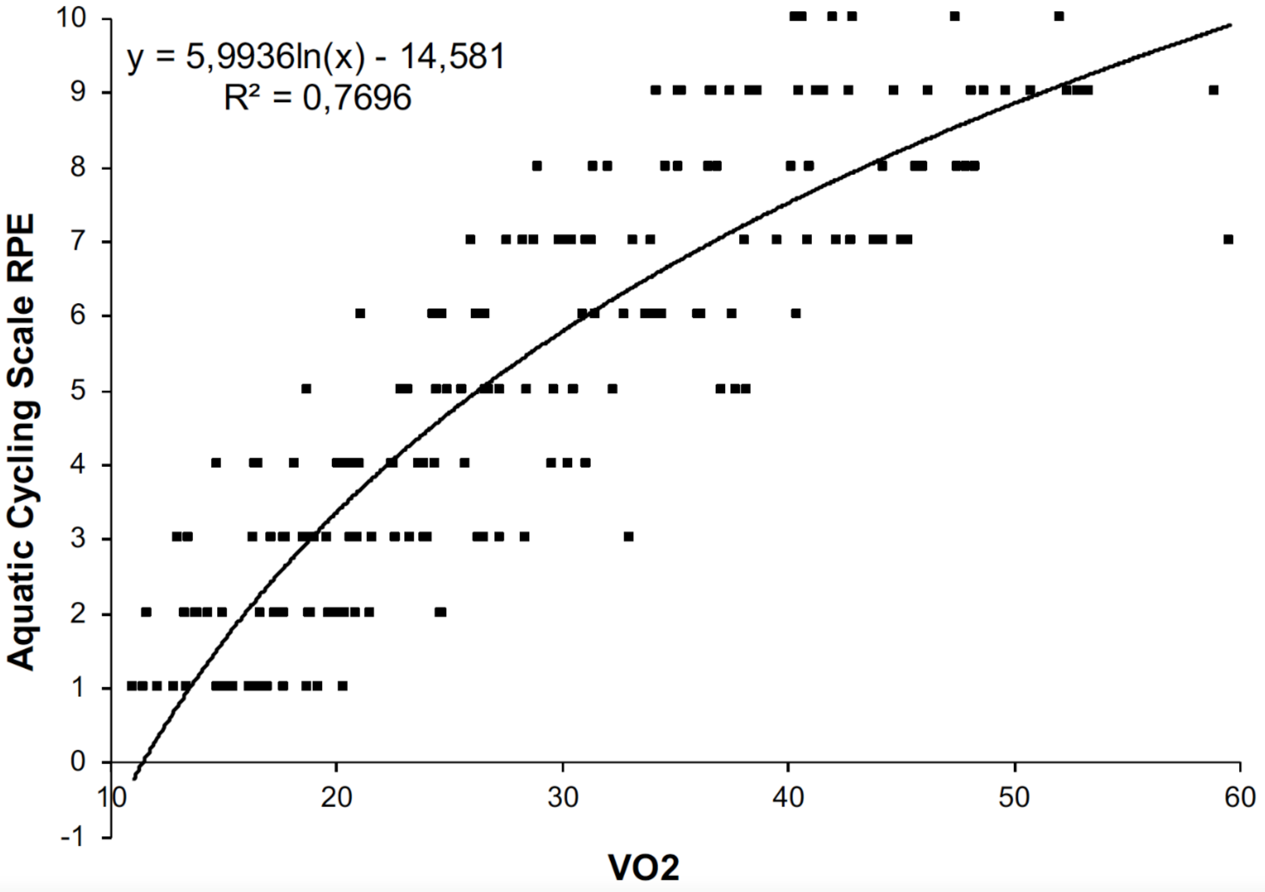
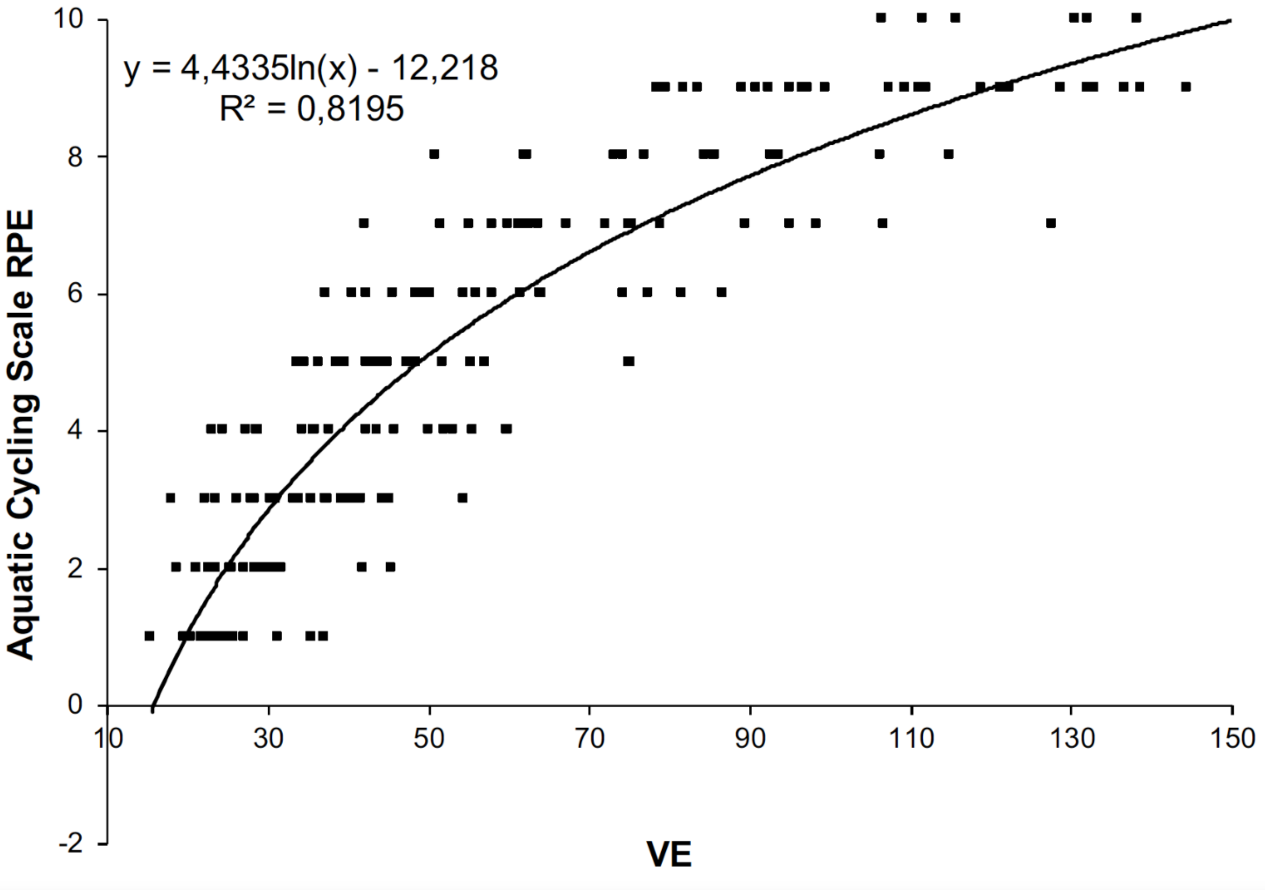


Figure 27c. Effect plot image of the relationship between physiologic variables and the Aquatic Cycling RPE along the load incremental test. VO_2: oxygen uptake taking in account bodyweight (ml/kg/min); VE: pulmonary ventilation (L/min); BL: blood lactate (mM); bpm: beats per minute; RPE: overall body rating perceived exertion from the Aquatic Cycling Scale.


y = 5,9936ln(x) - 14,581
R² = 0,7696
Aquatic Cycling Scale RPE
VO2
10
9
8
7
6
5
4
3
2
1
0
-1
10
20
30
40
50
60


y = 4,4335ln(x) - 12,218
R² = 0,8195
Aquatic Cycling Scale RPE
VE
10
8
6
4
2
0
-2
10
30
50
70
90
110
130
150

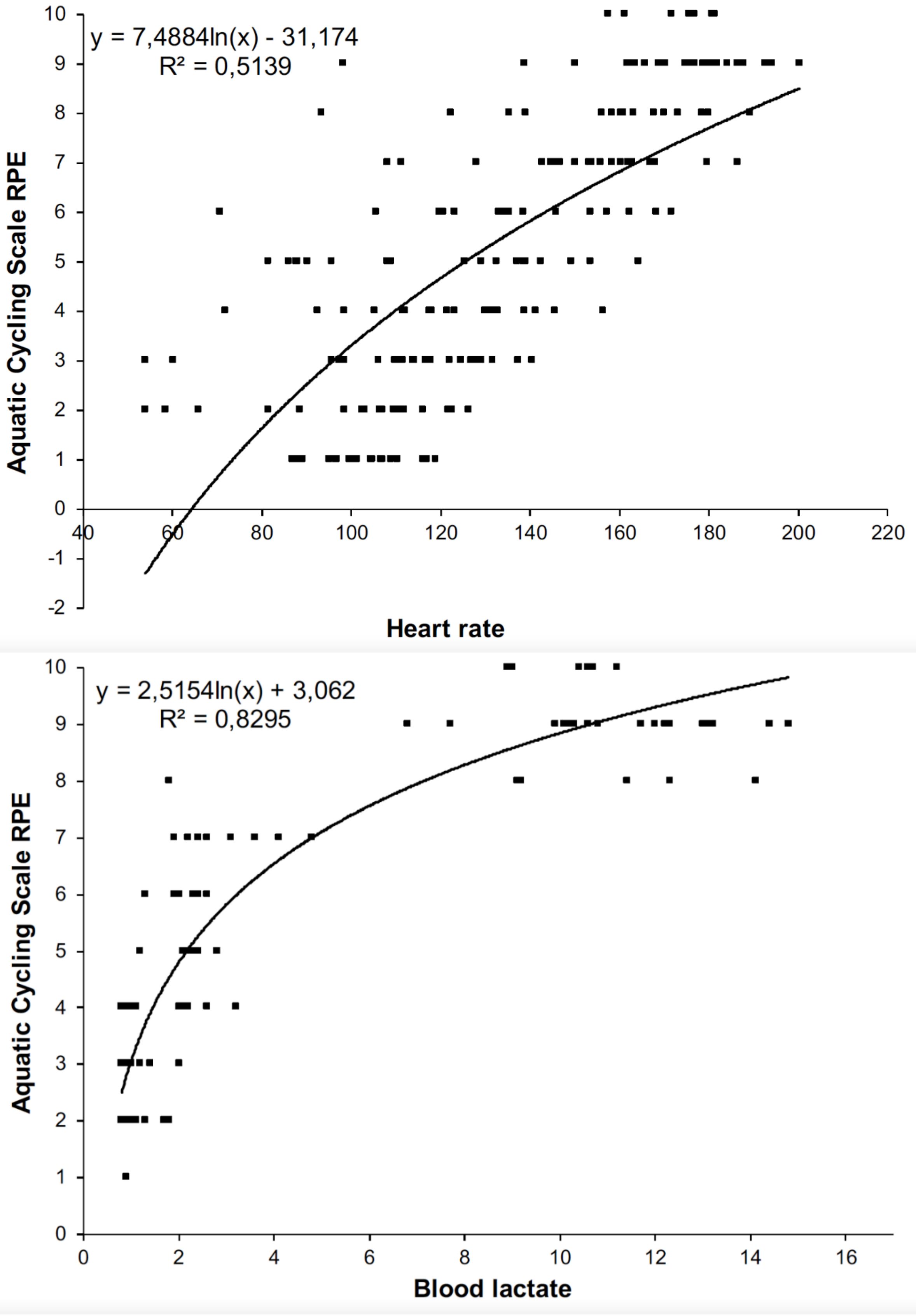


Figure 27d. Simple logarithmic regression analysis between the Aquatic Cycling Rating of Perceived Exertion and some of the different physiological variables along all the maximum load incremental test. VO_2: oxygen uptake taking in account bodyweight (ml/kg/min); VE: pulmonary ventilation (L/min); Heart rate (beats per minute); Blood lactate (mM); Aquatic Cycling Scale RPE: overall body rating perceived exertion from the Aquatic Cycling Scale.

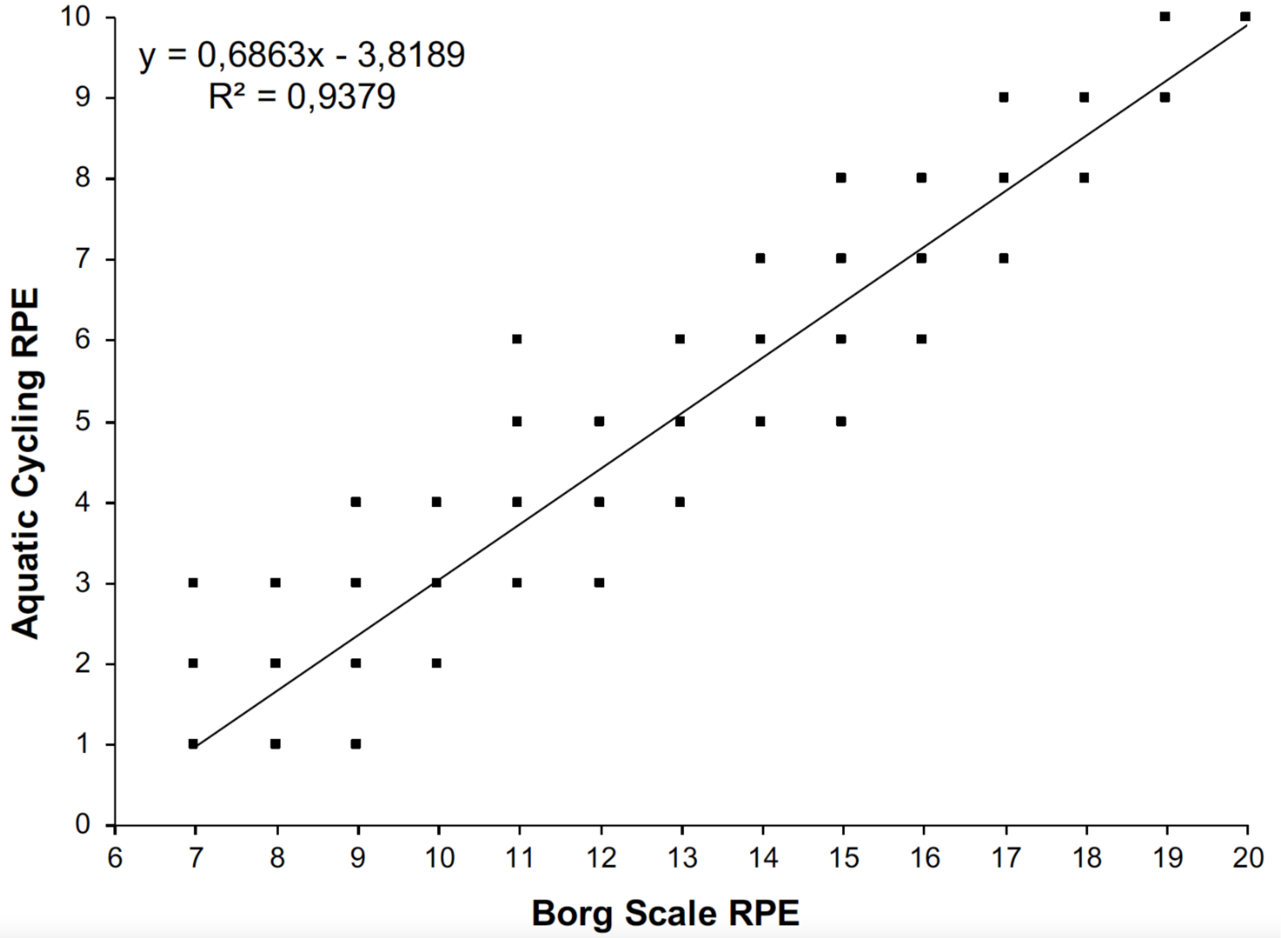


Figure 27e. Simple linear regression analysis between perception scores of the Aquatic Cycling Scale and the Borg Scale along the maximal load incremental test.

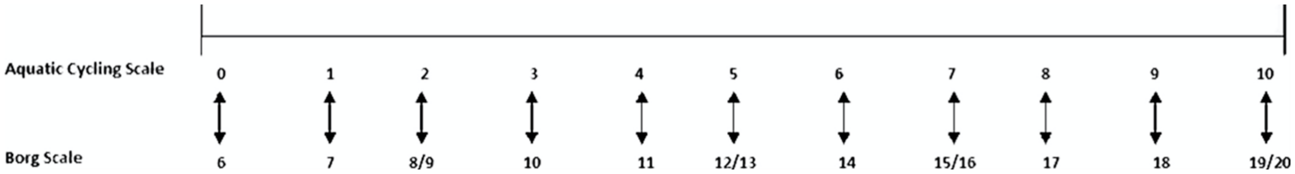


Figure 27f. Ratings of perceived exertion conversion chart between the Aquatic Cycling and Borg RPE scales.

CHAPTER VI:

DISCUSSION

6. DISCUSSION

Some previous studies have shown that due the specific properties of the aquatic medium the physiology responses could be different to this observed in dry land (Garzon *et al.*, 2015). There is substantial amount of scientific literature on the validity of specific RPE scales for different types of exercises (Colado *et al.*, 2018; Nakamura *et al.*, 2009; Robertson *et al.*, 2004), and these studies frequently use the 6-20 category Borg Scale as the gold standard to establish measurement validity (Lagally & Robertson, 2006; Mays *et al.*, 2010). Considering this, the most important finding of the present study was that the ACS is an appropriate tool for monitoring exertion intensity during aquatic cycling by young men, as demonstrated by the concurrent and construct analysis performed.

Validation criteria stipulated that during the load incremental aquatic cycle maximal test, the RPE derived from the ACS would be distributed as a positive linear function of VO_2, VE, HR, and BL responses, and that the RPE derived from the ACS and Borg scales would be positively correlated. All data obtained in the present study supported these concurrent and construct validity criteria. Additionally, it is known that a different pace of movement in water with the same device changes the resistance encountered during exercise, i.e., a higher pace of movement increases exercise intensity (Colado *et al.*, 2013). The same occurred in our study with the increment speed pedalling. As an example of the clear practical transfer of the utility of the ACS as validated in the present study, low-impact aerobic exercises with different levels of exertion intensity are widely recommended and are among the current strategies applied as therapy for weight management and diabetes (Meredith-Jones *et al.*, 2011). Therefore, aquatic cycle activities where this specific scale can be used for monitoring intensity, could improve the safety and efficiency of their implementation.

This significant increment of exercise intensity measured with the perceptual and physiological dependent variables was significantly correlated with an increment of the movement cadence in 15 bpm intervals. Consequently, it could be stated that the ACS can properly identify different intensities during aquatic exercise due to its significant correlation with all the different stages of cadence. An increase of 10 rpm during aquatic cycling pedalling has been considered as adequate stimulus for incrementing physiologic responses (Yazigi *et al.*, 2013), and the present study confirms these physiologic increases for changes at 15 bpm. Moreover, it also shows that the ACS is sensitive enough to determine increments in the perceived exertional signal consequent to these changes during an increment in the aquatic pedalling cadence.

The present study validates a system of perception of effort with immediate applicability for aquatic cycling, overcoming some specific limitations that scales previously validated seem to have had when applied to this specific aquatic activity (Robertson *et al.*, 1996; Robertson *et al.*, 2004). Hence, an important difference between the ACS and previous RPE scales is the use of a specific pictorial with aquatic cycling descriptors and emphasizing it in the facial features associated with the intensity level of the required effort. It has been demonstrated that adequate visual cues (i.e., understandable information for the subject) can, at times, improve understanding of the scores and practicability (Rogers, 2006). Consequently, ACS will be a proper tool for improving the quality of the intensity control during aquatic cycling activities.

These new specific aquatic pictorial descriptors were placed in juxtaposition with numerical classifications in a category scale format, taking into account previous studies which suggested that this could increase the effectiveness of the new scale for better learning results or less mental effort spent (Tabbers *et al.*, 2004). This will facilitate its application for the different practical areas in which the ACS can be used. In addition, previous studies have suggested the need to adapt the pictorial design of the RPE scales to the “reality” of the proposing for this purpose, for example, the modification of the pictogram format in the resting position (Mays *et al.*, 2010). As it has been considered in the present validation in which the pictogram for the resting position (0 RPE score) is a subject not exercising. Moreover, facial expressions, posture and dress are strong visual cues that can influence in the behavioural responses (Howlett *et al.*, 2013). Thus, the new ACS also has taken in account dressing the practitioner of the pictogram with swimwear and to show a typical aquatic bicycle to transmit an accurate impression of an aquatic activity.

However, and much more recurrently for the RPE scales, researchers have always sought a better way to pictorially represent the increase in the intensity of effort during exercise. The development of these scales went from using horizontal representation (Eston *et al.*, 2000) or vertical representation (Groslambert *et al.*, 2001) to others that finally attempted to better represent the physiological reality of exercise by using a type of curvilinear representation (Eston & Parfitt, 2006), usually with fully linearly inclined representations (Robertson *et al.*, 2000; Robertson *et al.*, 2004).

The category rating scale formats that have been developed traditionally to assess RPE are robust enough to evidence both linear and nonlinear response functions. However, sometimes an incremental linear representation could be less accurate visually if we consider that the perceptual relationship with the physiological variables is not always completely linear, where it could appear a possible saturation curve relationship, that is, despite the fact that there is a linear relationship in a large part of the range of values, a saturation at high intensities ends up occurring (Kruel *et al.*, 2013). In this sense, and for aquatic cycling activities, Pinto *et al.* (2016) determined a deflection point at the anaerobic threshold, which was around the value of 8 RPE. Hence, the pictorial representation of the ACS in respect to other previous RPE scales has already included this modification in its design. It can also be observed as shown in Figure 5c, this pictorial design is completely corroborated for ventilatory and lactate variables, while for HR, it has been partially corroborated due to its sigmoid relationship, as it was previously known (Trounson *et al.*, 2017).

The statistically significant values obtained in the logarithmic regression analysis, showed in Figure 5d, also confirm the saturation curve relationship in a value close to 8 RPE for most of the physiological variables: VO_2 r = 0.77; VE r = 0.82; HR r = 0.51; and BL r = 0.83. So, it is corroborated that the nonlinear design of the ACS could be an appropriate representation according to the real physiologic answers during the aquatic cycling activities. In the same way that in our study, it must be also pointed out that other numerous previous results have supported the use of RPE scales to monitor the relative intensity of training during head-out water-based aerobic exercises in people of different ages and physical levels, in which physiologic variables were also employed for the validation, as for example was the case of VO_2 (Alberton *et al.*, 2015; Graef & Kruel, 2006; Pinto *et al.*, 2015; Shono *et al.*, 2000).

6.1. Concurrent Validity

Concurrent validation studies have been extensively used in the development of the OMNI Picture System of Perceived Exertion for distinct ages, genders, equipment, and cardiovascular or neuromuscular exercises (Colado *et al.*, 2012; Colado *et al.*, 2014; Irving *et al.*, 2006; Mays *et al.*, 2010; Nakamura *et al.*, 2009; Robertson *et al.*, 2005; Utter *et al.*, 2002). RPE validation derived from Omni Scales show an excellent correlation with the Borg Scale, which positively suggests that the Omni scales are appropriate alternative for regulating indoor (dry land) exercise training (Robertson *et al.*, 2004). So far, it remains unknown, however, whether this would be the case for aerobic exercise in aquatic environment.

The Aquatic Cycle Scale (ACS) validated in our study reveals itself as a useful tool for the regulation of exercise intensity because it presented strong correlation with the criterion or response variables of performance, in the same way as other previously reviewed studies, for instance, on the OMNI-Kayak Scale (r = 0.91) (Nakamura *et al.*, 2009). Also with physiologic response variables, the strong correlation values obtained in the present study are in line with previous studies, for example, from the Adult OMNI Elliptical Ergometer RPE Scale (VO_{2max} r = 0.94; HR r = 0.96) (Mays *et al.*, 2010), the Adult OMNI Scale RPE for Cycle Ergometer Exercise (VO_2max r = 0.88; HR r = 0.87) (Nakamura *et al.*, 2009).

It is general knowledge that the relationship between the RPE and physiologic variables may be partially explained by the accepted fact that these physiological variables are important sensory cues for exertional perceptions (Nakamura *et al.*, 2009). Linear regression models derived in the present investigation are consistent with previous validation paradigms (Guidetti *et al.*, 2011), most of which used HR (Colado *et al.*, 2018), BL (Irving *et al.*, 2006; Robertson *et al.*, 2003) or VO_2 (Robertson *et al.*, 2005) as criteria measures. The present study found that the ratings of perceived exertion increased concurrently with corresponding increases in metabolic and circulatory responses. The strong positive relationship between aquatic cycling RPE and physiological criterion variables is consistent with previous investigations, which used concurrent paradigms to validate other aquatic RPE indexes (Alberton *et al.*, 2016; Pinto *et al.*, 2015). Thus, the forgoing validity evidence corroborate that the ratings of perceived exertion derived from the ACS are valid indicators of exercise intensities from low to high levels (Mays *et al.*, 2010) during water immersion cycle ergometer exercise.

Barbosa *et al.* (2009) advocated that exercise below the lactate threshold would be feasible in the time domain, without a continuous increase in lactate concentration. When the intensities are above that threshold and below the critical power (higher work rate maintained without a progressive increase in anaerobic metabolism, according to Poole *et al.* (1988), the stabilization of that concentration occurs at higher levels, however the slow component of VO_2 appears, whose amplitude would keep a direct relationship with the exercise intensity (Carter *et al.*, 2002), consequently the VO_2load model estimated for intensities below the lactate threshold underestimates the lactate concentration stabilization point (Lucas *et al.*, 2000). Pringle & Jones (2002) defended that at intensities above the critical power, there would be a progressive increase in the concentration of lactate and VO_2, this exponentially due to the influence of the slow component at intensities below the peak of oxygen consumption. Caputo & Denadai (2008) inferred that that growth could be the result of exponential projection at intensities greater than or equal to the peak of oxygen consumption, which would allow reaching the maximum value at the end of the exercise.

In this study Shono *et al.* (2000) VE was higher than those of the studies using Flowmill by Hotta et al. (1994, 1995). The subjects of the study by Hotta et al. held the handrails on both sides of the flume to exclude the effect of the movement of the arms. In this study, the subjects swung theirs arms as if they were stroking water along with the velocity of the water flow. Therefore, it was supposed that the energy expenditure with the movement of the arms during walking in water increased. In this study, the R2 (0.8195) of the model between VE and ACS makes it possible to obtain this variable, even if indirectly, with a maximum chance of explanation (error) of 18.05%, therefore, the model developed is shown to be also robust, valid and reproducible for this variable.

Such considerations eminently exposed the physiological prerogative to the logarithmic transformation applied to the developed models, which added value to the mathematical requirement inherently common sense. It should be noted that the logarithmic application overlaps the controversy regarding the marker of the limit between exercises below or above the lactate threshold, as being the maximum stable phase of lactate (Pringle & Jones, 2002; Burnley *et al.*, 2006) or the critical power (Poole *et al.*, 1988; Hill *et al.*, 2002).

The above discussion is substantiated by the findings of Derkele *et al.* (2003) and Pringle & Jones (2002), investigating stationary cycling, and Derkele *et al.* (2005), researching swimming, which identified that the critical power would be higher than the maximum stable lactate phase, so the exercise intensity could be represented by different markers, for example: exhaustion time, lactate concentration and VO_2, the which could not be exchanged mutually or easily. For example, the VO_2peak is reached at exhaustion, when the maximum stable lactate phase is low and the critical power is high, as the blood lactate is not stable in the time domain and the slow component of VO_2 is developed, thus the lactate threshold underestimates exercise intensity (Poole *et al.*, 1988; Hill *et al.*, 2002).

Nakamura et al. (2009) evaluated eight male kayakers age = 23.40 ± 4.50 years, weight = 74.50 ± 12.80 kg and height = 175.50 ± 8.70 cm, found R^2 = 0.7921 as an explanation coefficient for the blood lactate concentration and execution speed, which would imply the impossibility of explaining approximately 20.79% of the variability found. Furthermore, its application would require using the relationship between velocity and the OMNI-Kayak RPE to obtain the practitioner's perceived exertion. The ACS obtained for the blood lactate, R^2 = 0.8295, so it was not able to explain, about 17.05% of the existing variability. The difference of 3.74% is possibly not significant in the field of statistics. However, considering the peculiarities of the modalities, in aquatic cycling, the practitioner is immersed (between the waist and xiphoid process), while in Kayak this is not characteristic. Therefore, in the second modality, the effects of hydrostatic pressure on physiological conditions tend to be nullity, this difference support the clinical significance of ACS, especially in training control, in which the effort perceived by the practitioner can be obtained directly.

Costa *et al.* (2013) aimed to verify the response of HR and RPE in water cycling in the depths of the umbilical scar and xiphoid process, for 10 subjects (age: 20.2 ± 2.4 years, height:171.1 ± 7.3 cm, body mass: 67.4 ± 9.2 kg) performed two incremental tests of cadence on a water bicycle, starting at 50 rpm, with increments of 3 rpm at each stage of 1 min until exhaustion. RPE was performed by applying the Borg scale (10 points), considering cardiorespiratory and muscle discomfort. The highest values were measured at the water level in the xiphoid process, but a significant difference (p-value <0.05) was found only for HRmax, umbilical: 184.00± 13.00 bpm and xiphoid: 191.00 ± 10.00 bpm, from the fifth stage.

This result did not diverge from expectations, as bradycardia in water is inversely related to the level of immersion (Barbosa *et al.*, 2009; Kruel *et al.*, 2002) and, consequently, to the increase in hydrostatic pressure, hence the reduction in HR in rest will increase with the depth of immersion, due to the deviation of blood flow to the central region of the body, thus influencing the increase in venous return and, consequently, in the left ventricular end-diastolic volume (Christie *et al.*, 1990). A priori, the significant increase in HR from the fifth stage onwards could suggest a possible weakness in the model developed in the current study. However, such demerit is not substantiated, as what happened in Costa *et al.* (2013) may be a reflex of the practitioner's difficulty in staying on the water bike as the depth increases, given that the buoyant force will require greater effort to maintain the proper position on the water bike, demanding a higher level of energy and possible higher HR values. Therefore, the picture described is characteristic of the modality, which highlights the need for a specific scale of RPE, which will absorb this singularity.

One classic study of aquatic exercise purposed to analyse the relationships between musical cadence and the physiologic adaptations to basic head-out aquatic exercises. Fifteen young and clinically healthy women performed, immersed to the breast, a cardiovascular aquatic exercise called the ‘‘rocking horse.’’ The study design included an intermittent and progressive protocol starting at a 90 bpm rhythm and increasing every 6 minutes, by 15 bpm, up to 195 bpm or exhaustion. The RPE at the maximal HR achieved during each bout (HRmax), the percentage of the maximal theoretical HR estimated (%HRmax), and the blood lactate concentration ([La-]) were evaluated. The musical cadence was also calculated at 4 mmol.L (-1) of blood lactate (R4), the RPE at R4 (RPE@R4), the HR at R4 (HR@R4), and the %HRmax at R4 (%HRmax@R4). Strong relationships were verified between the musical cadence and the RPE (R2:0.85; p <0.01), the HRmax (R2: 0.66; p< 0.01), the %HRmax (R2: 0.61; p<0.01), and the [La-] (R2 = 0.54; p<0.01). The main conclusion is that increasing musical cadence created an increase in the physiologic response. Therefore, instructors must choose musical cadences according to the goals of the session they are conducting to achieve the desired intensity (Barbosa *et al.*, 2010).

The lack of statistical significance between cardiorespiratory and muscular discomforts contradicted Brasil and Di Masi (2005), who postulated that peripheral fatigue would favor higher PSE, as immersion would tend to lead to greater resistance to movement through water. However, the equality between the discomforts reinforces the positive aspect of the model, which will not have its robustness compromised by the practitioner's focus on the perception of respiratory rate or muscle situation.

6.2. Construct Validity

A limited number of studies have examined the construct validity of perceived exertion category scales (Lagally & Robertson, 2006). Some of them have used the Borg (6–20) Scale as a previously validation (i.e. criterion scale) (Mays *et al.*, 2010; Nakamura *et al.*, 2009). These previous investigations reported strong construct validity correlations for the various conditional (i.e. new) RPE scales. For example, the Borg Scale (6–20) showed good correlation with different new scales: (1) r = 0.96 Adult OMNI Elliptical Ergometer RPE Scale (Mays *et al.*, 2010); (2) r = 0.96 Adult OMNI Scale of perceived exertion for walking/running exercise and the Borg Scale (Utter *et al.*, 2004); (3) r = 0.97 Adult OMNI Scale RPE for Cycle Ergometer Exercise and the Borg Scale (Robertson *et al.*, 2004); and (4) r = 0.96 OMNI-

Kayak RPE Scale and the Borg Scale (Nakamura *et al.*, 2009).

Mays (2010) established gender specific validity indicating that the scales can be used for sedentary to recreationally active, college age males and females. Those responses are like previous investigations that examined gender stratified analyses in various exercise modalities (Lagally & Robertson, 2006; Pfeiffer et al., 2002; Robertson et al., 2000; Robertson et al., 2004; Robertson et al., 2003; Utter et al., 2004; Utter et al., 2002). These findings are critical for the establishment of valid metrics for use in males and females for a specific exercise modality. Additionally, the investigation used male pictorial descriptors. Similar correlational values were observed for male and female subjects; thus, the expectation was generated that the pictographic representation should not present distinctions in the understanding of the different groups, perhaps ACS has similar applicability.

This study investigated the validity of differentiated ratings of perceived exertion (dRPE) recorded from the chest (RPE-Chest) and legs (RPE-Legs) during aquatic cycling and aimed to determine a simple and accurate estimate of dRPE to regulate it for practitioners. Twelve active young subjects performed a pedaling task on an immersed ergo cycle using randomly imposed cycling cadences ranging from 50 to 100 rpm in 5- minute steps interspersed by 3-minute active recovery periods. dRPE and cardiorespiratory responses (heart rate, HR; percentage of heart rate peak value, %HRpeak; oxygen uptake, V̇O2; and percentage of peak oxygen uptake, %V̇ O2peak) were measured during the last minute of each level. The data described three-step relationships between dRPE and rpm. RPE-Chest and RPE-Legs increased linearly only for cadences between 60 and 90 rpm ($r=0.81$ and $r=0.88$, respectively; $p<0.001$). At these cadences, significant relationships were also observed between dRPE and all the physiological data (highest Pearson product moment for %V̇ O2peak: 0.81 for RPE-Chest and 0.88 for RPE-Legs, $p<0.0001$). Last, the classic signal dominance from the legs was observed (RPE-Legs > RPE-Chest, $p<0.0001$)

but was reduced compared with data obtained during dryland cycling, suggesting a modulating effect of the aquatic medium. The suggestion was cycling cadence was the better estimator of RPE-Legs, which seemed to be the more appropriate dRPE to regulate the intensity of practitioners in a safe range of pedaling rates (Fontanari et al., 2021).

For a newly developed RPE scale to be considered a valid metric for use in clinical and health-fitness settings, construct validity must also be established. Construct validity is established by a strong positive correlation between a criterion and conditional metric. In the present investigation, the criterion metric was the Borg 6-20 Category Scale with the conditional metric being the newly developed ACS. Construct validation of ACS for use in clinical and aquatic health fitness settings has been demonstrated in previous investigations (Lagally & Robertson, 2006; Robertson et al., 2004; Utter et al., 2004).

In the present study, the construct validity of the Aquatic Cycling Scale was established using the Borg (6–20) Scale (Borg, 1982) as criterion metric. It was hypothesized that the RPE derived from the Aquatic Cycling Scale would be positively correlated with the Borg Scale RPE when perceptual estimates from both metrics were obtained during the same maximal load incremental aquatic cycling test. The validity coefficient between perceptual responses obtained from the two category scales was positive and strong ($r = 0.97$, $p < 0.01$). As a result, the findings supported the research hypothesis, establishing the construct validity of the ACS. The comparatively high level of construct validity presently observed indicates that the ACS measures the same properties of an exertional perception as does the Borg (6–20) Scale when assessments are conducted for adult young men performing an incremental cycling test of maximal load (Robertson *et al.*, 2004).

In Nakamura et al. (2009), the regression analysis showed that the classification of the OMNI–Kayak RPE Scale and the Borg 6–20 Scale was positive, linear and with $R^2 = 0.8100$. While the similar relationship in the current study reached $R^2 = 0.9379$, that is, the estimated model for the ACS was more robust, with a greater correlation (r = 0.9684) with the classic Borg 6–20 scale, this guarantees the reproducibility of the study. In addition, the correlation coefficient can be an indication of the validity of the research (McMurray et al., 2004), in this sense the current study achieved superior results.

The models allow the prediction of physiological responses, so it is possible to follow the evolution of the practitioner in the domain and estimate the RPE according to the stimulus provided. The pragmatic advantage of monitoring the training curve is the possibility of establishing what level of effort the practitioner should achieve. The divergence between the verbalized answer and the estimate would indicate a change in the general physical condition or evolution of the respondent's training curve, which would require an adjustment in the training plan. More clearly, the physiological evolution estimates would be obtained by inverting the model expression, so for VO_2 we would have, considering an RPE y = 5:

$$y = 5{,}9936\ ln(x) - 14{,}581 \therefore 5 = 5{,}9936\ ln(x) - 14{,}581 \therefore x = 26{,}2321\ l/(kg.min)$$

In an analogous manner, other variables can be obtained:

For VE:

$$y = 4{,}4335\ ln(x) - 12{,}218 \therefore 5 = 4{,}4335\ ln(x) - 12{,}218 \therefore x = 48{,}5995\ l/(kg.min)$$

For Heart Rate:

$$y = 7{,}488\ ln(x) - 31{,}174 \therefore 5 = 7{,}488\ ln(x) - 31{,}174 \therefore x = 125{,}2951\ bpm$$

For Blood Lactate:

$$y = 2{,}5154\ ln(x) + 3{,}062 \therefore 5 = 2{,}5154\ ln(x) + 3{,}062 \therefore x = 2{,}1607$$

With all estimates, it is possible to evaluate the real impact of training on the practitioner's objective. This possibility lacks in other scales and other RPE models, especially in the context of aquatic modality.

In this sense, estimating a client’s response highlighting the possibility of comparing the prediction with the report of perceived effort seems to be a practical tool. The suggested mathematical model (figure 27 d), allows the prediction of all the considered physiological variables, therefore being possible to monitor the practitioner in the time domain, accordingly, including generating the perception in the traditional Borg scale for comparison with other modalities that he may come to perform.

Probably, the main advantage of the estimated model resides in the possibility of converting the information. Thus, by using the Aquatic Cycling RPE, the perceptions of VO2max, VO2, VE, Heart Rate, Blood Lactate and Pedaling Cadence are immediately obtained and, despite being estimates, they are statistically reliable. By analogy, it is possible to convert the values to the Borg scale. Pragmatically, the professional who properly monitors his clients will be able to obtain all the variables mentioned using only the ACS, which in the time domain means individual monitoring, allowing to perceive personal evolution, identify non-converging physiological responses, which might be evidence of health impairment and, mainly, to adjust training prescription based on the responses collected. Ultimately, plotting the training curve substantiates the results considering customer observation.

6.3 ORIGINAL FORMAT VS. MODIFIED FORMAT

Perceived exertion has been defined as the ‘‘subjective intensity of effort, strain, discomfort, and/or fatigue that is experienced during physical exercise’’. As a psychophysical estimate of an individual’s subjective level of effort, perceived exertion measures have yielded a considerable amount of research and clinical applicability (Pincivero, Coelho & Campy, 2003).

The present investigation was the first to examine validity of different BORG scale formats developed for ACS (Figure 23 and Figure 22). The original format scale does not have pictorial descriptor placement. Mode specific pictorials can indicate the aerobic threshold between 3 and 4 and the anaerobic threshold at the deflection point, which would be 8 (Pinto et al, 2015). Additionally, a “0” corresponding to the verbal descriptor “extremely easy” was placed at the beginning of the incline and 10 to extremely hard, which was consistent with the original Borg Scale format. These findings indicate that the original model of the Borg Scale applied to an ACS format is a valid tool for determining perceptual responses during varying exercise intensities in healthy males, as shown in the figure (figure 27f).

The Lagally and Robertson (2006) findings establish the construct validity of the OMNI-RES using the Borg RPE scale as the criterion metric. For both men and women, RPE (active muscle and overall body) from the OMNI-RES and Borg scale were positively correlated, indicating that the 2 scales provide similar information regarding perceived exertion.

It should also be noted that Borg modified the original 6-20 category scale at the low response zones (Borg, 1985). The artificial “zero” or starting point, “6”, was changed to “no exertion at all”. In the older version of the scale there was no verbal expression after the first number (Borg, 1971). Ratings of perceived exertion conversion chart between the Aquatic Cycling and Borg RPE scales, the prevailing culture among aquatic fitness professionals regarding the use of the classic Borg scale converges. Possibly the additional advantage is to make use of the commonsense culture of expressing oneself within the perception of 0 (“extremely easy”) levels of exertion and 10 (“extremely hard”), which facilitates the performer's understanding.

CHAPTER VII:

CONCLUSION

7. CONCLUSION

Different paces are used during aquatic cycling activities (i.e., slow to fast pedalling), thus the exercise intensity fluctuate from low to high levels. Validation of the Aquatic Cycle Scale is necessary because it will add an easy monitoring tool for test, workouts or self-regulating of intensity. The main results of this research will be described below and compared to the initial hypotheses laid out.

H1: There will be statistically significant differences in the behaviour of physiological variables and of perception of effort during the development of the protocol.

The VO_2max, VO_2 and VE showed statistically significant differences in all pedalling cadencies from 115bpm. Such behaviour was also observed in the ACS and Borg Scale RPE. Therefore, confirming the proposed hypothesis 1. HR showed statistical significance only in pedalling cadencies from 145bpm and BL only in cadencies 175bpm and 190bpm. The two situations also confirmed the hypothesis outlined, especially when considering the physiological conditions required for the evolution of the two variables.

H2: The perception of the effort derived from the new scale for water cycling will be distributed as a positive linear function with respect to the response of the physiological variables (heart rate, oxygen consumption and lactic acid).

The data corroborate hypothesis 2, since all correlations were significant ($p<0.05$), regardless of the intensity (R^2), thus the ACS was able to explain, even partially, the variations in the physiological variables included in the current study.

H3: The subjective perception of the effort derived from the new scale for water cycling and the Borg Scale 6-20 during the increase in the load in the protocol used may be positively correlated.

The hypothesis was satisfied, given that the aim of this thesis is the concurrent and construct validation of the scale for rating perceived exertion in aquatic cycling. Therefore, RPE-ACS has a positive linear correlation of the RPE-Borg Scale ($r=0.97$; $p<0.05$).

CHAPTER VIII:

PRACTICAL IMPLICATION

8. PRACTICAL IMPLICATION

The findings of this research offer practitioners the following practical applications:

1. The ACS it is feasible and easy to apply in group classes, small groups and individuals. It does not require technological resources, prior preparations, including the environment. It is noteworthy that familiarization is easy, due to the playful and intuitive characteristics of the scale. In this sense, the investment is significantly low; a water resistant bunner seems to be enough.

2. Exercise prescription is commonly based on cardiopulmonary exercise testing, which requires expensive equipment that is dependent on calibration procedures and is generally not available to be performed in aquatic environments. In addition, exercise intensity control through tools such as smartwatch may not be accessible to the general population and digital palpation of superficial arteries has demonstrated poor measurement quality in the aquatic environment. To assign or pointing a note to a particular effort on an increasing scale seems to make it easier.

3. From other perspective, it must be considered that sometimes exercisers are training with partners or in a massive group situation where a fixed pedalling cadence is performed for everyone. In this practical situation, and due to usually the different exercisers can have different physical conditioning levels, they need to change the resistance of the aquatic cycling activity increasing or reducing the drag forces by means of the

modification of the mobile parts of the aquatic bicycle, which permits to have a bigger or lower drag force thus achieving a better adaptation of the exercise for each of the exercisers.

4. In this usual practical case in the aquatic settings worldwide, it is needed also tools that can help to monitoring the quality of the stimulus of the training. Thus, in these specific cases, and taking in account the necessity of easy and cheap procedures that can be employed in any place and for any person, besides to employ heart rate as indicator of level of intensity, is need other tools, as is the case of the RPE scale. With the RPE scale the technicians and the users could have a good estimation of the intensity of the exercise, and in this way, they could do the practice more efficient and safety.

5. In definitive, we think that if all these considerations are analysed from a global point of view, ACS is other type of accurate tool that can help easily to monitor the safety and efficiency of the practical applications of the aquatic cycling activities. As aquatic cycling has become a recent fitness trend in Europe, US, South America and still growing around the world, many public and also private swimming pools offer aquatic cycling to a healthy population, classes with musculoskeletal disorders, cardiac could use the training tools. The opportunity to participate in a modern and popular exercise program.

It is worth mentioning that nowadays, although there are different dynamics in the interventions, in particular the use of choreographies, upper limbs and additional equipment, the use of the RPE scale is not compromised, that is, it is applicable to the modality. In short, it reflects the general effort perceived by the practitioner during the sport.

CHAPTER IX:

LIMITATIONS AND PROPOSALS FOR FUTURE STUDIES

9. LIMITATIONS AND PROPOSALS FOR FUTURE STUDIES

9.1. Limitations

Although the present study was conducted exclusively with young men, previous studies have found that men and women rate their perception of exertion similarly when are examined at the same relative exercise intensity (Lagally & Robertson, 2006). Consequently, it might be assumed that this scale could also be applied to women with a profile of physical fitness and age analogous to that of the values of the subjects of our study.

We suggest that new studies using the AC Scale in other groups, such as: apparently healthy adult women, menopause, elderly, and individuals with joint problems, neurodegenerative diseases, obese and sedentary should be conducted. It must be also highlighted that the RPE obtained in the present study associated to the anaerobic threshold is higher than has been generally noted for data derived from OMNI Scales (0-10) for both weight bearing and non-weight bearing exercise modes. It is known that anaerobic threshold is usually associated with 14 RPE on 6-20 Borg Scale (Purvis & Cukiton, 1981), i.e., 6 RPE on 0-10 Scale (Lagally & Robertson, 2006). However, this RPE value could be a higher (7-8 RPE) to trained subjects, as in our study (Haskvitz *et al.*, 1992).

Moreover, an overall body perception to identify global cardiovascular fatigue was asked to subject in our study, however it is possible that they also experienced a high fatigue from lower limbs working against the high aquatic drag forces in the last stages of the load-incremental test. This aspect maybe could have influenced in their global RPE. So, it should be recorded not only overall body RPE if not also chest and lower limbs RPE in order to have another interpretation of the results obtained in future studies (Alberton *et al.*, 2011; Okura &Tanaka,2001).

9.2. Proposals for Future Studies

Considering the results and the experience gained, in addition to some of limitations set forth, ideas or projects to develop soon are proposed below.

- It would be interesting to apply to tables with different age groups and gender.

- ACS can be recommending for use in aquatic cycling by the professional providers of physical and rehabilitation exercises.

- ACS could contribute em estudos longitudinais e ainda utilizando Borg Scale no grupo controle.

- Apply ACS in multifactorial studies, that is, different groups undergoing the intervention simultaneously and still using Borg Scale in the control group.

- Apply ACS in prospective cohort studies, that is, follow the evolution of PSE in the time domain due to periodic and regularly available stimuli and still using or not the Borg Scale in the control group.

- Evaluate the physiological aspects, training variables and response in ACS under a multivariate approach. In this way, it would be possible to set up the influence of each variable considered against the established group of variables and a dynamic closer to the practitioners' reality, therefore, it would be possible to identify peculiarities in the studied group.

- The development of a structural equation model will conceptually allow the use of any type of variable, including those of a semantic order. Thus, the result of the ACS could be detailed by the impact of each variable used, such as: sleep condition, mood level, perception of life, level of education and understanding of the practice instructions, as well as the domains of social skills, human and technical, which would extend to the adequacy of the RPE the possible results arising from the ACS.

CHAPTER X:

REFERENCE

10. REFERENCE

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CHAPTER XI:

ANNEXS

Annex 1: Informed consent.

Este documento certifica su aceptación en la participación del estudio denominado “Validación de la escala de percepción del esfuerzo para adultos durante el ciclismo acuático”, motivo de elaboración de Tesis Doctoral por parte de Dña. Roxana Brasil Macedo.

Con su firma, usted manifiesta explícitamente que ha entendido la descripción del tipo de ejercicio a realizar y sus posibles complicaciones. Además, usted indica que cualquier duda que haya podido surgir sobre el proceso de evaluación y sus posibles riesgos ha sido respondida con claridad, quedando satisfecho con las explicaciones aportadas.

Las pruebas, tests y cuestionarios realizados para evaluar su condición física permitirán obtener información sobre su estado general de salud.

La prueba específica constará en primer lugar de un estudio cineantropométrico, donde se recopilarán los datos correspondientes a su composición corporal, utilizando para ello los procedimientos característicos de la ISAK (International Society of Advancement in Kineantropometry).

En segundo lugar de un test de carácter máximo en bicicleta acuática con medición de los gases respiratorios y de la frecuencia cardiaca, a través de un analizador de gases y pulsómetro, respectivamente. A su vez, se procederá a la medición del lactato sanguíneo, para ello, se pinchará superficialmente el lóbulo de la oreja y se extraerá una gota de sangre (4 veces como máximo), por un profesional sanitario. Se le pedirá que evalúe su sensación de esfuerzo a lo largo de toda la prueba según das escalas diferentes.

Durante las valoraciones y tras las mismas, podrá experimentar fatiga.

La información obtenida como consecuencia de dicho ejercicio será confidencial y su uso será meramente informativo y científico, salvaguardando su identidad. Para ello será necesario su expreso consentimiento mediante autorización por escrito.

Al firmar el presente documento usted acepta la completa responsabilidad de su propia salud, y reconoce que ha sido informado y ha entendido que esta responsabilidad no es asumida por los responsables de su programa de ejercicio físico. Del mismo modo, admite la creación, utilización y difusión del material fotográfico y de vídeo, que con fines científicos pueda generarse con su participación en el estudio.

En Valencia a __________de________________________de 2012.

D. Dña. Roxana Brasil Macedo.

DNI

Firma

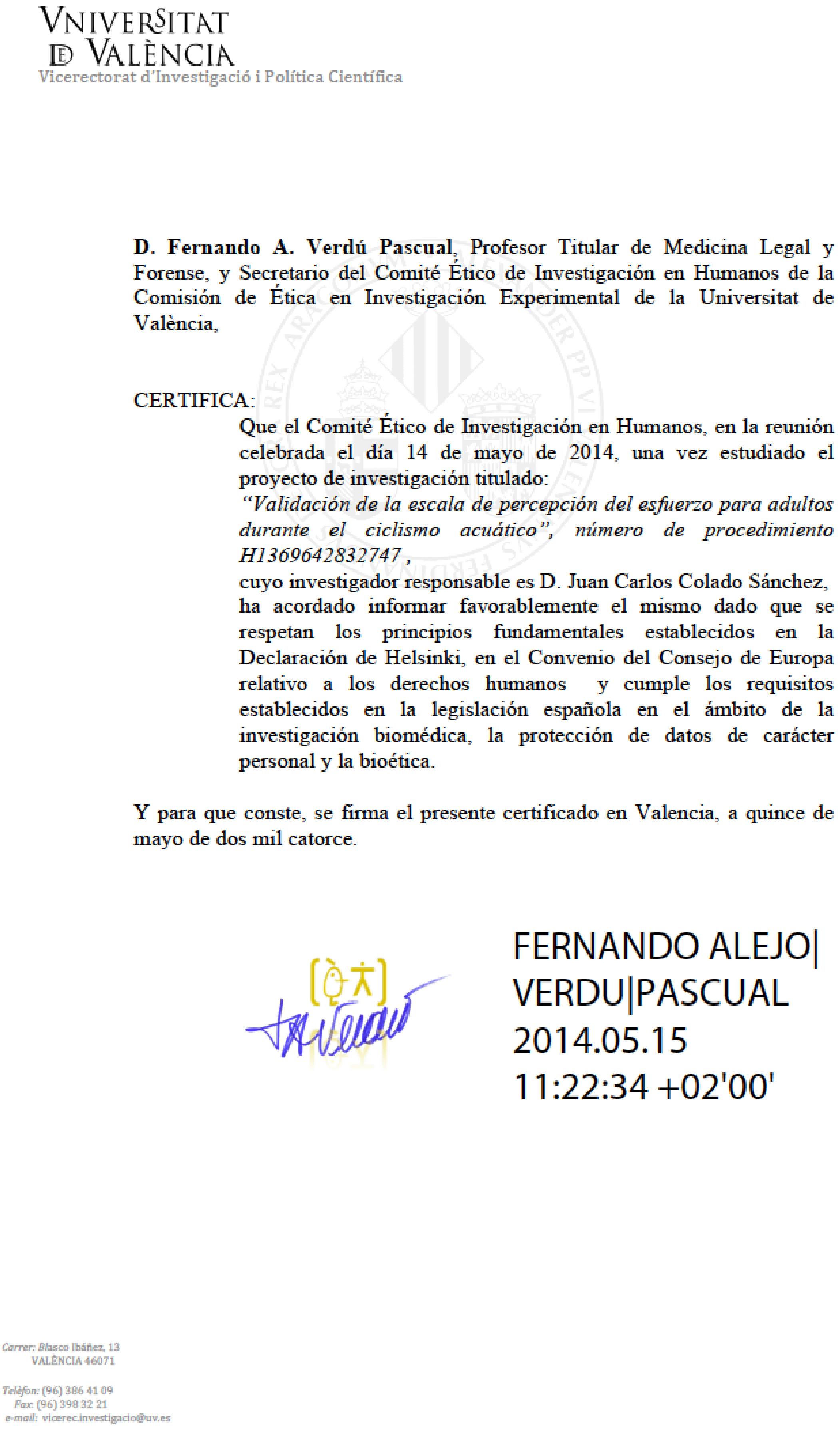
Annex 2: Worksheet for annotation of variables and characterial data of the sample.

Test máximo en bici acuática

Número sujeto:
Nombre y apelidos:
Edad:
Nivel de actividad física:
Fecha de familiarización:
Altura:
Masa:
%Grasa:
Fecha y hora de medición:

Tiempo	Cadencia	Familiarización		Medición		LACTATO
		Borg 6 -20	Omni 0 -10	Borg 6 -20	Omni 0 -10	Reposo:
3 min	100 lpm					
5 min	115 lpm					Aqui:
7 min	130 lpm					
9 min	145 lpm					Aqui:
11 min	160 lpm					
13 min	175 lpm					
15 min	190 lpm					
17min	205 lpm					
Final						Aqui:
Tiempo total test						

Annex 3: Approval of the Ethics Committee of the University of Valencia (Spain).



VNIVERSITAT DE VALÈNCIA
Vicerectorat d'Investigació i Política Científica

D. Fernando A. Verdú Pascual, Profesor Titular de Medicina Legal y Forense, y Secretario del Comité Ético de Investigación en Humanos de la Comisión de Ética en Investigación Experimental de la Universitat de València,

CERTIFICA:

Que el Comité Ético de Investigación en Humanos, en la reunión celebrada el día 14 de mayo de 2014, una vez estudiado el proyecto de investigación titulado:
"Validación de la escala de percepción del esfuerzo para adultos durante el ciclismo acuático", número de procedimiento H1369642832747 ,
cuyo investigador responsable es D. Juan Carlos Colado Sánchez, ha acordado informar favorablemente el mismo dado que se respetan los principios fundamentales establecidos en la Declaración de Helsinki, en el Convenio del Consejo de Europa relativo a los derechos humanos y cumple los requisitos establecidos en la legislación española en el ámbito de la investigación biomédica, la protección de datos de carácter personal y la bioética.

Y para que conste, se firma el presente certificado en Valencia, a quince de mayo de dos mil catorce.

FERNANDO ALEJO|
VERDU|PASCUAL
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