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TESIS DOCTORAL INTERNACIONAL

HIGH INTENSITY INTERVAL TRAINING EFFECTS IN MODERATELY TRAINED ATHLETES: TRIATHLON TRAINING IMPLICATIONS

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Vitoria-Gasteiz, 2020

PROGRAMA DE DOCTORADO ACTIVIDAD FÍSICA Y DEPORTE
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PREFACIO Y AGRADECIMIENTOS

«En serio, Milos, tens que provar de fer un triatló, jo crec que és el teu esport». Mi hermano siempre había creido que el triatlón seria un deporte relevante en mi vida. Sería en el año 2007 cuando estudiaba INEFC en Barcelona cuando intentaba convencerme. Y le hice caso, probé y fue ese deporte el que me condujo 2 años después a mi nueva aventura en Euskal Herria, tierra dónde ha visto a grandes ciclistas y triatletas; una oportunidad perfecta para crecer tanto a nivel deportivo, como académico y laboral. Quizás queda un poco típico, pero el triatlón es mi vida ya sea sufriendo como amateur en la larga distancia, trabajando como directora deportiva de un club de triatlón y por supuesto, siendo el tema central de esta tesis.

Per tant, la primera menció especial d'agraïment anirà per ells, la meva familia. Gràcies papes i Albert per estar sempre allà i encoratjar-me dia darrera dia a fer el que de veritat m'agradés i em fés feliç, per no posar cap trava quan hi han hagut imprevistos i per ajudar-me de totes les maneres possibles a poder fer realitat el meu somni de créixer académica i personalment i poder passar el temps inolvidable que vaig passar a Australia.

Mila esker Koldo, pazientziarekin nire bidelagun izateagatik, elkarrekin bizitako abenturengatik eta azken egunera arte nire erabaki guztietan laguntzeagatik. Beharrezko oinarria izango zara beti.

I will never forget when Gaizka introduced me to David and proposed to work together in a cotutelle PhD. At this point my Aussie adventure began, being one of the best experiences of my life. I do not have enough thanks to my Australian supervisors Dr. David Bentley and Dr. Lynda Norton for their incalculable help in every field and their kilograms of patience. I want to write a special mention to the Norton's family who adopted me as another member of their lovely family. I want to express my infinite gratitude to Flinders University for the assistance provided, to increase my knowledge and my academic experience. As well as, to all University staff for their affection, particularly to the College of Nursing and Health Sciences & Medicine and Public Health staff members. Also, to the Lakers Triathlon Club, I have many great friends and hard training sessions that I will never forget. Special thanks to Nigel and Grant for promoting my research and providing our studies with great triathletes. To all the Lakers who participated in the studies, you are amazing. All of you are culprits in my «Australian addiction».

Mi director de la UPV/EHU, el Dr. Gaizka Mejuto. Sin los principios, capacidad de búsqueda y perseverancia de Gaizka, no hubiese sido posible este trabajo ni hubiese tenido la oportunidad que me presentó de formarme en otro país y adquirir una experiencia que me servirá para muchos aspectos de mi vida, mila esker por estar siempre dispuesto a ayudar fuera cuál fuera el horario, el día o el tema. Del mismo modo, a mi tutor y co-autor de los artículos que conforman la tesis, el Dr. Javier Yanci, por su trabajo constante, la impoluta metodología de trabajo que le caracteriza y su predisposición para facilitarme el camino, claves para poder llevar a cabo y defender esta tesis. Asimismo, agradecer toda la ayuda obtenida desde la Facultad de Ciencias de la Actividad Física y el Deporte de la Universidad del País Vasco (UPV/EHU), tanto durante el máster como el doctorado. Eskerrak UPV/EHU-ko Doktorego Komisioari, burokraziarekin laguntzeagatik eta atzerriko unibertsitateko egonaldirako mugikortasun beka emateagatik.

Així com tot l'equip de professors de l'INEFC Barcelona per guiar-me durant la llicenciatura. Parlant de l'INEFC Barcelona, no puc oblidar-me dels meus amics, gent que coneixes en l'època universitaria i t'acompanyen durant la resta de la vida, convertint-se en part de la teva familia. Força grup 3.

Eskerrik asko ikerketetan parte hartu duten bizkaitar triatleta guztiei, Sopelako lehen urteetako lagun guztiei: Jorge Núñez, Mon, Cris, Javi, Jorge, Izaskun etab. Eta nire Getxotri taldeko triatletei egunero partekatutako uneengatik eta famili handi bat bezala izateagatik. Azkenik, eskerrak Asierri, nire ondoan egoteagatik eta elkarrekin egingo ditugun kilometro guztiengatik.

DECLARACIÓN

Yo, Dña. Milos Mallol Soler, con DNIXXXXXXX declaro ser la autora de la siguiente tesis doctoral conjuntamente elaborada con la ayuda de mis directores de tesis, la Dra. Lynda Norton, por parte de la Flinders University de South Australia y por el Dr. Gaizka Mejuto, por parte de la Universidad del País Vasco/Euskal Herriko Unibertsitatea (UPV/EHU). Mi participación en este proyecto engloba desde el diseño del proyecto de investigación hasta su redacción, pasando por la recogida de datos, organización de instalaciones y participantes, tratamiento de los datos, entre otras funciones.

Al tratarse de una tesis en régimen de cotutela, se llevó a cabo en ambos paises, en Australia dónde realicé una estancia de 12 meses (Noviembre de 2015 - Noviembre de 2016), lugar dónde se diseñaron los estudios, se llevo a cabo la recogida de datos, además de tener la oportunidad de ampliar mi experiencia tanto académica como de investigación, pudiendo presentar oralmente un *abstract* en el Sports Medicine Australia Annual Scientific Conference. En el País Vasco, desde Febrero del 2017 hasta la actualidad, se desarrolló el tratamiento de los datos, el análisis de resultados y la redacción tanto de los artículos como del documento final.

Cada detalle del plan de trabajo se ha ejecutado íntegra y sistemáticamente. Los datos se recogieron con total rigurosidad científica, aportándome una gran experiencia organizativa y de resolución de imprevistos surgidos durante dicha fase, aprendiendo a solventarlos de manera eficaz. Las funciones que desarrollé para la toma de datos pasaron por el reclutamiento y la captación de participantes, la elaboración de documentos informativos, la difusión de las investigaciones a distintos clubs, entidades deportivas y académicas, la solicitud y preparación del material de laboratorio, así como la compra de material deshechable, la realización de los test en laboratorio, el seguimiento y recogida de muestras durante los entrenamientos HIIT, la organización del laboratorio y de los estudiantes becarios ayudantes, la recogida de datos y la elaboración de informes para los participantes. Una vez terminada la recogida de datos, inicié la organización y análisis de los mismos, conjuntamente con una revisión sistemática de la literatura científica previa, abarcando desde aspectos fisiológicos de los triatletas hasta las respuestas de atletas de resistencia frente a un programa HIIT con el fin de cotejarlos con los resultados obtenidos en la presente tesis doctoral.

Esta tesis se presenta en formato de compendio de publicaciones y por tanto se encuentra conformada por los distintos proyectos de investigación divididos en artículos. Gracias al gran trabajo tanto de mis directores como de otros investigadores en fisiología del deporte, los artículos derivados de este proyecto de tesis han sido aceptados y/o publicados en revistas científicas relevantes en nuestra área de conocimiento. Asimismo, durante el tiempo como doctoranda he presentado oralmente dos abstracts en dos congresos internacionales, en el Australian Sports Medicine Annual Scientific Conference (Octubre de 2016) en Melbourne (Australia) y en el European College of Sports Sciences Congress (Julio de 2017) en Essen (Alemania).

En cuanto a la financiación para la realización de la tesis doctoral, la UPV/EHU financió parte de mi estancia en Australia con una dotación enmarcada en la convocatoria de ayudas para la estancia en Universidades extranjeras para personal investigador en formación de la UPV/EHU. Por su parte, Flinders University me concedió una beca para cubrir los gastos de viaje y alojamiento al Australian Sports Medicine Annual Scientific Conference 2016

(2016 Faculty of Medicine, Nursing and Health Sciences Student Conference Travel Grant), así como otra ayuda para gastos anuales de investigación (Research Student Maintenance-RSM). La información de dichas becas se detalla en el apartado de anexos.

Para concluir este apartado, los directores y los co-autores de los artículos derivados de este proyecto, declaran que la presente tesis doctoral, incluyendo cada uno de los artículos publicados que la conforman, no presenta ningún conflicto de intereses.

READING CONSIDERATIONS

This PhD project is submitted on the basis of article compilation. The introduction, chapter 1, reviews what is currently known on the topic, summarising the main triathlete characteristics and the physiological effects of a high intensity interval program on triathletes obtained from the scientific literature. Followed by chapter 2 where the PhD goals and hypothesis are displayed.

The following chapter 3 describes the methodology used in each article and chapter 4 presents the main results and discussion. All references cited in the document are located in chapter 5.

The principal dissertation conclusions are expounded in chapter 6 followed by practical applications to these conclusions (chapter 7), research limitations (chapter 8) and future directions for investigation (chapter 9).

In Chapter 10, appendixes, the reader can find the three published articles indexed in JCR or Scopus journals. The first and the second article were published in the Spanish language, whereas the third publication was in English language. Each article maintains their own citation style and bibliography according to each journal requirements, however, the remaining thesis format has been standardised to provide document unity and homogeneity. The articles followed a similar investigation line, focusing on the physiological characteristics of moderately trained triathletes and their responses to the High-intensity Interval Training (HIIT) stimulus. The first article, «El triatlón y el control de la carga mediante la percepción del esfuerzo» focused on the analysis of the commonly used methods to quantify training load in triathlon, describing the principal physiological and performance parameters involved. This work was published by Archivos de Medicina del Deporte, the official sport medicine journal of Spain.

The second study, «Diferencias entre triatletas masculinos y femeninos en las respuestas fisiológicas de un test máximo incremental y una competición simulada» analyses the physiological and performance differences between gender during a cycle-ergometer maximal incremental test and cycling and running portions of a simulated sprint triathlon in the laboratory. This paper was published by Revista Iberoamericana de Ciencias de la Actividad Física y el Deporte.

The last article, the study «Comparison of Reduced-volume high-intensity interval training and high-volume training on endurance performance in triathletes» observes triathletes physiological and performance responses after 4-weeks of a reduced volume training program supplemented by cycle HIIT sessions. This study was published in the Intenational Journal of Sport Performance and Physiology.

After published articles, other scientific contributions are also included such as information of publications, Ethics commite, grants and scholarships, international meeting participations and other type of publications, parallel research and academical activities and research images.

ABBREVIATIONS

Spanish

AT = Umbral anaeróbico

BL = concentración de lactato en sangre

$Cadmedia20km_{bike}$ = Cadencia media durante los 20 km de ciclismo

$Cadmax20km_{bike}$ = Cadencia máxima alcanzada durante los 20 km de ciclismo

DT = Desviación típica

ETM = Error técnico de medición

FC = Frecuencia Cardíaca

FCmax = Frecuencia cardíaca máxima

$FCmedia20km_{bike}$ = Frecuencia cardíaca media durante los 20 km de ciclismo

$FCmax20km_{bike}$ = Frecuencia cardíaca máxima alcanzada durante los 20 km de ciclismo

$FCmedia_{transición}$ = Frecuencia cardíaca media durante los 3 minutos de transición

$FCmedia5km_{run}$ = Frecuencia cardíaca media durante los 5 km de carrera

$FCmax5km_{run}$ = Frecuencia cardíaca máxima alcanzada durante los 5 km de carrera

LT/VT = Umbral de lactato/Umbral ventilatorio

$PETCO_2$ = Presión parcial de dióxido de carbono exhalado

$PETO_2$ = Presión parcial de oxígeno exhalado

P = Potencia

$Pmedia20km_{bike}$ = Potencia media durante los 20 km de ciclismo

Pmax = Potencia máxima alcanzada

$Pmax20km_{bike}$ = Potencia máxima alcanzada durante los 20 km de ciclismo

PVT1 = Potencia correspondiente al primer umbral ventilatorio

PVT2= Potencia correspondiente al segundo umbral ventilatorio

r = Coeficiente de correlación de Pearson

RPE = Ratio de percepción del esfuerzo

RPEmedia5km$_{run}$ = Percepción del esfuerzo media durante los 5 km de carrera

RPEmedia20km$_{bike}$ = Percepción del esfuerzo media durante los 20 km de ciclismo

RPEmedia$_{transición}$ = Percepción del esfuerzo media durante los 3 minutos de transición

TE = Tamaño del efecto

Ttotal 20km$_{bike}$ + 5km$_{run}$ = Tiempo total en completar el sector de ciclismo sumado al sector de Carrera (sin contar la transición).

T5km$_{run}$ = Tiempo en completar 5 km de carrera

T20km$_{bike}$ = Tiempo en completar 20 km de ciclismo

UPV/EHU = Universidad del País Vasco/ Euskal Herriko Unibertsitatea

Velmedia5km$_{run}$ = Velocidad media durante los 5 km de carrera

Velmedia20km$_{bike}$ = Velocidad media durante los 20 km de ciclismo

Velmax5km$_{run}$ = Velocidad máxima alcanzada durante los 5 km de carrera

Velmax20km$_{bike}$ = Velocidad máxima alcanzada durante los 20 km de ciclismo

VE/VO$_2$ = Equivalente ventilatorio para el oxígeno.

VE/VCO$_2$ = Equivalente ventilatorio para el dióxido de carbono.

VO$_2$max = Consumo máximo de oxígeno

VO$_2$VT1 = Consumo de oxígeno correspondiente al primer umbral ventilatorio

VO$_2$VT2 = Consumo de oxígeno correspondiente al segundo umbral ventilatorio

VT = Umbral ventilatorio

VT1 = Primer umbral ventilatorio

VT2 = segundo umbral ventilatorio.

% Dif. = Porcentaje de diferencia

% VO$_2$maxVT = Porcentaje de consumo máximo de oxígeno registrado en el umbral ventilatorio

%VO$_2$VT1= Porcentaje de consumo máximo de oxígeno en el primer umbral ventilatorio

%VO$_2$VT2= Porcentaje de consumo máxima de oxígeno en el segundo umbral ventilatorio

English

ATP = Adenosine Tri-Phosphate

AU = Arbitrary units

Bike TT = 20 km cycling time trial

BMI = Body mass index

$Cadence_{av}$ = Average cadence

$Cadence_{max}$ = Maximal cadence

CO_2 = Carbon dioxide

CON = Control

CTT = Cycling time trial

d = Cohen effect size

Dif % = Mean difference percentatge

$Distance_{av}$ = Average distance

ES = Effect size

HIIT = High-intensity Interval Training

$HIIT_{bike}$ = High-Intensity Interval Training cycling group

$HIIT_{run}$ = High-Intensity Interval Training running group

HIIT 1 = First HIIT session

HIIT 8 = Last HIIT session

HR= Heart rate

HR_{av} = Average heart rate

HR_{av} Bike TT = Average heart rate during 20 km cycling time trial

HR_{av} RunTT = Average heart rate during 5 km running time trial

$HR_{av\text{-}recovery}$ = Average heart rate during recovery interval

$HR_{av\text{-}work}$ = Average heart rate during work HIIT interval

HR_{max} = Maximal heart rate

$HR_{max\text{-}recovery}$ = Maximal heart rate during recovery interval

$HR_{max\text{-}work}$ = Maximal heart rate during work HIIT interval

O_2 = Oxygen

p = significance

$Pace_{av}$ = Average pace

P_{av} = Average power

P_{av} Bike TT = Average power during 20 km cycling time trial

P_{max} = Maximal power

PO = Power output

POMS = Profile of Mood States

PPO= Peak power output

PVO_2max = Power at maximal volume of oxygen consumption point

PVT1 = Power at first ventilatory threshold

PVT2 = Power at second ventilatory threshold

RPE = rating of perceived exertion

RPE_{av} = Average rating of perceived exertion

RPE_{max} = Maximal rating of perceived exertion

RPE-min = Rating of perceived training load method

RSPE = Rating scale of perceived exertion

RTT = Running time trial

Run TT = 5 km running time trial

SD = Standard desviation

$Speed_{av}$ = Average speed

$Speed_{max}$ = Maximal speed

TT = Time Trial

VO_2 = Oxygen uptake

VO_2max = Maximum oxygen uptake

VT = Ventilatory threshold

wk = Week

y = Year

10 km TT = 10 kilometers of running time trial

$\%vVO_2max$ = Velocity at maximal volume of oxygen consumption percentatge

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CHAPTER 1

Introduction and theoretical framework

Chapter 1. Introduction and theoretical framework

1.1. El triatlón

El triatlón es un deporte de estructura compleja, dadas las disciplinas que lo forman (la natación, el ciclismo y el atletismo), realizándose de manera consecutiva a través de transiciones (1, 2). Los orígenes de este deporte se remontan a Francia en el año 1920, dónde se realizaban los tres deportes de manera esporádica y sin reglamentación (3). Las primeras reglamentaciones aparecieron en 1934, en la localidad de la Rochelle (Francia), dónde se desarrolló la «carrera de los tres deportes» que consistió en atravesar los 200 m que formaban el canal de la localidad a nado, 10 km de bicicleta por el parque Laleu y 1200 m de carrera en el estadio André-Barbeau (3). No obstante, no es hasta el año 1975, en San Diego (EEUU), cuando se origina el triatlón moderno tal y cómo se conoce actualmente. En esta prueba precursora, los participantes encadenaron 800 m de natación, 8 km de bicicleta y 8 km de carrera. Sin embargo, la repercusión mundial del nuevo deporte no llegó hasta 1977 con la celebración del primer Ironman (3,8 km nadando, 180 km en bici y 42,2 km de carrera a pie) en Honolulu (Hawai) (2, 3). A partir de ese momento, la modalidad del triatlón se empezó a reglar por parte de la Unión Internacional de Triatlón/*International Triathlon Union* (ITU) y la Corporación Mundial de Triatlón/*World Triathlon Corporation* (WTC).

Según la ITU (4), los tipos de competición más comunes en los que se compite actualmente son: Super *sprint* (400 m natación, 10 km ciclismo y 2,5 km carrera), *Sprint* (750 m natación, 20 km ciclismo y 5 km corriendo), Olímpico o Estándar (1500 m natación, 40 km ciclismo y 10 km corriendo), *Half* (1.900 m natación, 90 km ciclismo y 21 km corriendo), Doble Olímpico (2.500-3.000 m natación, 80 km ciclismo y 20 km corriendo), ITU-Larga Distancia (4.000 m natación, 120 km ciclismo y 30 km corriendo), Ironman o Larga Distancia (3.800 m natación, 180 km ciclismo y 42,195 km corriendo) y el triatlón cross (1 km natación, 20-30 km ciclismo de montaña y 6-10 km de trail running) (2, 4). Esta variedad de competiciones crea un deporte con participantes dispares. Por una parte, los triatletas profesionales que compiten en la distancia corta de este deporte, lo hacen en las series mundiales y los Juegos Olímpicos, competiciones exclusivamente diseñadas para deportistas de élite. Sin embargo, en larga distancia, las competiciones tienden a agrupar tanto triatletas profesionales como no profesionales, llamados grupos de edad. Las carreras más relevantes en la distancia ironman vienen de la mano de empresas como Ironman y Challenge, aunque los campeonatos tanto regionales, continentales e incluso mundiales siguen siendo organizados por las federaciones deportivas dónde, además de la competición de deportistas élite, también compiten los grupos de edad (5).

1.2. El triatlón desde un punto de vista científico

En los últimos años, la investigación entorno a este deporte ha aumentado considerablemente, abordando el estudio de esta modalidad desde diferentes perspectivas (fisiológica, biomecánica, métodos de entrenamiento, morfológica, psicológica, nutricional, etc.), factores que afectan directa e indirectamente al rendimiento durante la competición (6-20). Un gran número de investigadores han centrado sus trabajos en conocer cuáles son los aspectos fisiológicos más determinantes para una obtención del rendimiento óptimo de los triatletas (21-37). Diversos estudios analizaron la influencia de variables fisiológicas como la acumulación de lactato (10, 13, 22, 37), el consumo de oxígeno (10, 23, 28, 38, 39), la frecuencia cardíaca (8, 9, 21, 25, 30, 40), la potencia, la velocidad, la economía de carrera y de pedaleo asociadas a los umbrales (8, 9, 11, 13, 20, 27, 39, 41-43), la termorregulación e hidratación en distintos momentos de competición (36, 44, 45), la ingesta de nutrientes para una constante recarga de sustratos energéticos (14, 35, 46, 47) y otros factores fisiológicos.

Anteriores investigaciones exponen que el sector de la carrera a pie parece ser decisivo en la mayoría de las distancias, cobrando mayor importancia cuanto más distancia de carrera se debe completar (27, 31, 48-50). Por esta razón, varios estudios han realizado una observación específica de las respuestas fisiológicas durante este sector, concretamente sobre la economía de carrera y el coste energético que supone la realización del parcial ciclista previo (13, 26), así como los efectos de la variabilidad típica del tramo ciclista en distintas competiciones sobre el parcial de carrera (11-13, 16, 19, 21, 27, 40, 51) y los efectos en este sector tanto de las disciplinas previas de natación y ciclismo (9, 12, 17, 26, 27, 41, 43, 52). Otra vertiente fisiológica altamente analizada en el triatlón ha sido la respuesta que genera el organismo del triatleta frente a una competición o a un programa de entrenamiento, siendo los procesos de inflamación, estrés oxidativo y daño muscular los más estudiados (37, 53-56).

Como todo deporte de resistencia en el cuál se realizan movimientos de manera repetida en un período de tiempo prolongado, también en el triatlón, resulta esencial analizar la modalidad desde la perspectiva de la biomecánica, tanto para la mejora del rendimiento como para evitar posibles lesiones causadas por la repetición sistemática del gesto deportivo (57-62). A nivel biomecánico, la afectación del sector ciclista sobre el sector de carrera es uno de los temas ampliamente estudiados (8, 19, 63). Previas investigaciones analizaron distintas variables biomecánicas como por ejemplo, la repercusión de la posición de la cala o la zona de apoyo del pie durante el pedaleo en el posterior sector de carrera (16, 19), la ergonomía del cuadro de la bicicleta (8), el tipo de intensidad y la distancia a la que se desarrolla el sector ciclista o el análisis de como los distintos puntos de apoyo durante el pedaleo influyen en otras variables biomecánicas de la subsecuente carrera de un triatlón, como pueden ser la oscilación vertical, la posición corporal, las adaptaciones cinemáticas o las moficaciones mecánicas de la carrera (13, 16-19, 27, 40, 51). Por otro lado, varios autores compararon la biomecánica de la carrera tanto de manera aislada, es decir, sin la realización de ninguna actividad previa, con la carrera de un triatlón, realizada posteriormente a un parcial ciclista, concluyendo que no existían diferencias en la oscilación vertical de la cadera y el tobillo, el ángulo formado por el tronco o las fases de vuelo y contacto (13). Sin embargo, otros estudios si observaron disminución en la amplitud de zancada y la posición corporal, tendiendo a inclinarse hacia delante en la carrera realizada después del sector ciclista (13), posición atribuida a una fatiga muscular local, que consecuentemente puede provocar una disminución de la economía de carrera (27). Por último, algunos estudios también han analizado los efectos del uso de neopreno en la biomecánica del nado (64, 65).

Además del análisis científico desde un punto de vista fisiológico y biomecánico, otros estudios centraron sus investigaciones sobre otras vertientes científicas, como por ejemplo, los aspectos técnico-tácticos durante un triatlón. Se han analizado los efectos del drafting durante la natación en los subsiguientes parciales (42), los efectos del uso del neopreno (28, 64, 66) o el empleo de distintos tipos de cadencia durante el ciclismo y sus efectos en la carrera a pie (11, 17). Desde un punto de vista nutricional se han analizado la ingesta de carbohidratos idónea para distintos formatos de competiciones, así como el tipo de suplemento a ingerir para la mejora del rendimiento

(46, 47, 67). Los estudios sobre los factores psicológicos también son recurrentes en la literatura científica relacionada con el triatlón, en los que se analiza desde el perfil psicológico de los triatletas (68), la preparación mental para el día de competición (69), hasta las posibles predicciones del rendimiento en un ironman teniendo en cuenta la motivación, la confianza y la seguridad en cada uno de los sectores o la motivación y la ansiedad previas a la competición (70).

1.3. Parámetros fisiológicos y de rendimiento más relevantes en la cuantificación de la carga en el triatlón

Previamente al inicio de un proceso de investigación, resulta necesario realizar una descripción exhaustiva de los parámetros más relevantes que serán analizados. El triatlón al ser un deporte enmarcado exclusivamente en los deportes de resistencia, presenta una amplia relación con variables fisiológicas como el consumo máximo de oxígeno (VO_2max), el umbral ventilatorio/lactato (VT/LT), la potencia crítica (CP), la capacidad anaeróbica (AC), la frecuencia cardíaca (FC) y la economía /eficiencia (21, 71-73). Asimismo, existen unos parámetros kinéticos que según Millet et al. son determiantes en el rendimiento del triatlón juntamente con las variables fisiológicas tradicionales nombradas anteriormente. Estas variables son: el ratio de oxidación de los carbohidratos, el ratio de almacenamiento de calor, el ratio de la utilización de la capacidad anaeróbica y el ratio de acumulación de metabolitos (72). Por lo tanto, la complejidad del triatlón no recae en el simple hecho de que sea una disciplina deportiva compuesta por tres deportes, sino también, que su rendimiento depende de varios factores fisiológicos que pueden priorizarse dependiendo de la distancia de competición, fisiología del triatleta, el clima y el perfil de la competición (25, 31). A consecuencia, resulta esencial realizar una cuantificación de la carga a la que el triatleta es sometido, ya sea durante el entrenamiento, en competición o incluso en test de laboratorio (71, 74). Tradicionalmente, se monitoriza la carga en dos vertientes: la externa y la interna. La carga externa es definida cómo el trabajo completado por el atleta, independientemente de sus respuestas fisiológicas al ejercicio (71). Este tipo de carga se contabiliza con distancia (km), tiempo (segundos, minutos, horas), ritmo (km/h, min/km, min/100m), potencia (W) y aceleración (m/s). Por el contrario, la carga interna se refiere al estrés tanto fisiológico como psicológico al cuál es sometido el atleta, clave para determinar la carga de entrenamiento. Variables cómo FC, concentración de lactato, VO_2max, TRIMP, biomarcadores, percepción del esfuerzo etc. se definen como parámetros intrínsecos. Una combinación entre los parámetros fisiológicos, es decir, la carga interna, y la externa es fundamental para la cuantificación de la carga del entrenamiento en triatlón (71).

1.4. La percepción del esfuerzo cómo método de cuantificación de la carga complementario en triatletas

A nivel práctico, resulta compleja la medición de la mayoría de los parámetros que conforman la carga interna durante el entrenamiento o en competición (71, 75). En los últimos años se ha extendido notablemente el uso del pulsómetro en triatletas de todos los niveles. Sin embargo, cuando se inició la presente investigación, su uso se encontraba limitado y un relevante número de triatletas no profesionales no disponían de métodos para el control de la carga interna en su proceso de entrenamiento (74). Por esta razón, el artículo 1 se centró en el análisis de otro tipo de método de cuantificación de la carga interna del entrenamiento, de forma subjetiva, la percepción del esfuerzo. Este método, se basa en la percepción del propio deportista, y es controlada por el entrenador o fisiólogo (76). Diseñado por Gunnar Borg en 1982, se basa en una escala de puntuación dónde a cada valor le corresponde una sensación de esfuerzo percibida (RPE) (77). La escala inicial se basó en valores del 6 al 20 que presentaron una estrecha correlación entre las categorías de la escala y la FC del sujeto durante el esfuerzo; cuando el sujeto, con una edad comprendida entre los 30 y 50 años, percibía un esfuerzo del 12 en la escala, su FC se encontraba alrededor de 120 pulsaciones/min (78). No obstante, posteriormente se concluyó que en el ámbito de la actividad física y el deporte, existía una gran variabilidad dependiendo de la experiencia deportiva previa, el tipo de ejercicio, la familiarización con la RPE y las adaptaciones fisiológicas asimiladas a consecuencia del entrenamiento deportivo (76). La escala original fue reducida a 10 categorías con el objetivo de facilitar su uso durante el entrenamiento y obtener una correlación positiva con la concentración de lactato en sangre y la concentración de lactato muscular (79). Previamente, otros autores validaron el uso del método RPE cómo método complementario de control de la carga en distintos momentos durante competiciones o simulaciones en laboratorio de triatlón (21, 80-83) pero pocos lo emplearon para el control diario del entrenamiento (74, 84).

1.5. El sexo del triatleta como elemento diferenciador de rendimiento

En triatlón, a pesar de ser un deporte ampliamente analizado y descrito en la literatura científica, especialmente en el último lustro, pocos estudios se han centrado en las demandas específicas en competición de las triatletas femeninas (85). Las distancias son las mismas tanto para hombres como mujeres (4). De hecho, dependiendo de la carrera, hombres y mujeres compiten simúltaneamente. Sin embargo, las clasificaciones se dividen por sexo y categoría (4). Posiblemente esta diferenciación de categorías se debe a que existe un aspecto altamente relevante para el rendimiento en los deportes de resistencia: las características fisiológicas propias de sus atletas (29, 86-88). En muchas modalidades deportivas se ha observado que existen diferencias entre hombres y mujeres en las características fisiológicas (88-91). En este sentido, diversos autores se han centrado en analizar el perfil fisiológico de los deportistas de resistencia dependiendo de la edad y el sexo (29, 86-88), concluyendo que el sexo puedo ser un factor diferenciador en el rendimiento en deportes de resistencia. Sin embargo, en comparación con otras modalidades deportivas, para nuestro conocimiento pocos trabajos se han centrado en analizar las diferencias entre triatletas masculinos y femeninos, comparando los resultados obtenidos en una prueba máxima incremental, en pruebas sub-máximas en laboratorio, o valorando el rendimiento obtenido en competición (92-94). Concretamente, se han observado diferencias en el rendimiento de triatletas de élite masculinos y femeninos durante test máximos y sub-máximos en el laboratorio, obteniendo valores mayores de consumo máximo de oxígeno y de potencia máxima de los deportistas masculinos. Estas diferencias pueden ser debidas a aspectos tanto antropométricos, como morfológicos y/o fisiológicos (86, 92, 95). Uno de los pocos estudios publicados al respecto (94), analizó las diferencias entre sexos en triatletas no profesionales teniendo en cuenta el tiempo empleado y la potencia en cada sector durante una competición de triatlón de distancia corta (1 km natación, 30 km ciclismo y 9 km corriendo). Este trabajo describe también la asociación entre los resultados obtenidos en competición y los resultados obtenidos en un test máximo incremental para cada una de las modalidades (94). Se concluyó además que podría existir una asociación entre el rendimiento total del triatlón y el volumen máximo de oxígeno relativo obtenido en el test incremental de nado, la velocidad al umbral ventilatorio durante el test de carrera y la fuerza absoluta de una flexión de pierna en el caso de las triatletas femeninas, mientras que el grupo masculino sólo la velocidad correspondiente al umbral ventilatorio presentó asociación con el rendimiento final del triatlón (94). Estos resultados ponen de manifiesto la importancia de la diferenciación tanto de los objetivos de los entrenamientos, como de la estrategia de competición a seguir dependiendo del sexo del triatleta. Debido a la escasa investigación al respecto, existe la necesidad de un análisis más exhaustivo sobre las diferencias entre triatletas masculinos y femeninos y sus características fisiológicas con el fin de tener una información más precisa.

1.6. El entrenamiento de alta intensidad en deportes de resistencia

Los profesionales del entrenamiento deportivo se encuentran en una búsqueda continua de los métodos que podrían ser idóneos para la mejora del rendimiento y lograr los objetivos planteados para sus deportistas. En los últimos años, el método de entrenamiento de intervalos a alta intensidad o high intensity interval traininig (HIIT) se ha ido implementando y testando en multitud de deportes, desde colectivos (96-103) hasta individuales (104-113), concluyendo en un gran número de investigaciones que mediante el HIIT se producen mejoras tanto en el rendimiento deportivo como en la capacidad cardiovascular de los deportistas, acompañado de un consecuente ahorro de tiempo de entrenamiento (114-116). El HIIT es un método de entrenamiento estructurado en repeticiones, con una duración entre los 10 s y los 5 min y realizado a altas intensidades (próximas al máximo o supra-máximo), separadas de períodos de recuperación a intensidades bajas (107, 108, 111, 117, 118). Las respuestas fisiológicas que se persiguen con la aplicación de este método son, por un lado a nivel musculo-esquelético (mejora de la función y capacidad mitocondrial, la densidad capilar, la respuesta molecular y producir un mayor estrés celular, entre otras), y por otro a nivel cardiovascular (aumento del volumen sistólico, gasto cardíaco y del volumen sanguíneo, así como del consumo máximo de oxígeno) (116).

Debido a la multitud de tipos de HIIT que se pueden encontrar, ya sea por la duración de la intervención, por la intensidad del esfuerzo, por la duración de los intervalos o por la intensidad o duración de los períodos de recuperación (107, 112, 119), un importante número de estudios se ha centrado en conocer cuál es la mejor estructura de un programa HIIT para cada tipo de atleta y deporte (101, 110, 112, 115, 119-123). En el ámbito de los deportes de resistencia, un relevante número de autores han centrado sus investigaciones en la búsqueda de los efectos de este método de entrenamiento con el uso de distintas duraciones tanto del estímulo, de la recuperación y del programa de intervención (105, 107, 112, 119, 123, 124). Por un lado, se ha concluido que la aplicación de un programa HIIT produce un aumento significativo del VO_2max (96, 110, 111, 125). Por ejemplo, Hottenrott et al. (2012) observaron mejoras significativas en corredores recreacionales de media maratón después de 12 semanas de HIIT a una intensidad cercana al VO_2max, aunque los corredores recreacionales no mostraron cambios en el rendimiento de una competición de media maratón (106). Resultados similares fueron obtenidos por Gormley et al. (126) y Helgerud et al. (127) con hombres moderadamente entrenados en deportes de resistencia, observando la eficacia del método HIIT para la mejora del VO_2max. Por su parte, Etxebarria et al. (112) concluyeron que 3 semanas de un programa de HIIT utilizando intervalos de trabajo tanto cortos como largos produjeron mejoras de un 7% en el VO_2max de triatletas masculinos moderadamente entrenados. Otras investigaciones en atletas observaron cambios en otras variables como la velocidad correspondiente al VO_2max, la velocidad correspondiente al umbral de lactato, la economía de carrera, y el % VO_2 correspondiente al OBLA, tras realizar 8 y 10 semanas de un programa HIIT (128, 129). En la misma línea, Gojanovic et al. (118) observaron incrementos tanto en los valores de VO_2max, la velocidad correspondiente al

VO_2max, las frecuencias cardíacas (FC) sub-máximas y mejoras en el rendimiento de un test de 2 millas después de la aplicación de un programa HIIT de 4 semanas en el que los corredores entrenados realizaban los intervalos al 100% de su velocidad asociada al VO_2max (vVO_2max) (118). Por otro lado, distintos estudios se han centrado en los efectos del HIIT en variables relacionadas con el ciclismo (104, 105, 108). El entrenamiento de 3 semanas de HIIT a intensidades próximas a los ritmos de competición, alrededor de 85% de la potencia pico, complementado por intervalos supra-máximos al 175% de la potencia máxima obtenida en los test de laboratorio, parecen favorecer el incremento del rendimiento de un test de una hora contra el reloj en ciclistas de nivel provincial (105). Por su parte, Lindsay et al. (108) observaron incrementos en la potencia sostenida y una mayor resistencia a la fatiga en un test de 40 km en ciclistas competitivos al realizar 4 semanas de un programa de entrenamiento en el que el volumen de entrenamiento fue reducido un 15% y suplementado por sesiones HIIT al 80% de la potencia pico. Billat (122) y Laursen (115) en sus correspondientes revisiones sistemáticas sobre los efectos del HIIT en ciclistas tanto profesionales como amateurs, concluyeron que se trata de un método que ayuda a la mejora de la potencia aeróbica pico, aumenta el tiempo de la aparición de fatiga, incrementa el umbral ventilatorio, la acumulación de lactato y la actividad de las enzimas oxidativas (115, 122).

Sin embargo, no todos los estudios muestran efectos positivos tras la aplicación del HIIT. Contrariamente a los resultados expuestos anteriormente, Enoksen et al. (128) no obtuvieron diferencias significativas entre un grupo de corredores bien entrenados de media distancia que siguieron un plan de entrenamiento tradicional con alto volumen de trabajo a baja intensidad, comparado con otro grupo de corredores de características similares que realizaron un programa de bajo volumen y alta intensidad durante 10 semanas. Estos autores concluyeron que ambos grupos presentaron un incremento relevante del VO_2max , la vLT y la economía de carrera (128). De forma similar, Acebedo et al. (129) observaron que los corredores de larga distancia participantes en el estudio, a pesar de que eran capaces de rendir a un %VO_2 correspondiente al OBLA durante más tiempo después de un programa HIIT, no presentaron mejoras significativas ni en VO_2max ni en el VT (129). Debido a los resultados contradictorios, parece necesario realizar más estudios que se centren en el análisis de los efectos que tiene el HIIT en comparación con otros métodos de entrenamiento, así como observar su validez en períodos en los que los entrenadores planifican una reducción del volumen de entrenamiento, ya sea en semanas pre-competición o de tapering o porque se produce algún tipo de lesión.

1.7. El entrenamiento de alta intensidad en deportistas no profesionales

La mayoría de estudios sobre los efectos del HIIT han sido realizados con deportistas de élite o altamente entrenados (100, 104, 120, 130-133), sin embargo, existe un número inferior de investigaciones centradas en los efectos del HIIT concretamente en triatletas recreacionales o no profesionales. La aplicación de un programa HIIT de manera específica en triatletas no profesionales fue abordada por distintos autores (110, 112, 117, 134). Etxebarria et al. (112) concluyó que un total de seis sesiones HIIT en ciclismo, durante 3 semanas, provocaba mejoras en el rendimiento en una prueba de una hora de duración de ciclismo simulando una competición de triatlón y en el rendimiento de los consiguientes 5 km de carrera, obteniendo un efecto de transferencia del ciclismo a la carrera (112). Asimismo, se observó una mejora en la capacidad de mantener el tiempo en un test de esprines repetidos, aspecto indispensable en triatlón como consecuencia de los cambios que se producen a causa del desnivel durante la competición o en los cambios de ritmo en el pelotón (112). Estos autores, concluyeron que el empleo de intervalos HIIT tanto cortos (de 10 a 40 s), como largos (5 min) incrementa la capacidad de ejecución en un test de esprines repetidos, así como mejora en diferentes variables fisiológicas y de rendimiento durante 1 h de ciclismo simulado. Sin embargo, solo el grupo HIIT de intervalos largos aumentó el rendimiento durante los 5 km de carrera (112). Por otro lado, García-Pinillos et al. (117) combinaron un plan de entrenamiento tradicional con altos volúmenes de entrenamientos en los deportes de natación y ciclismo con un plan de entrenamiento HIIT para el entrenamiento de la carrera, obteniendo mejoras en el rendimiento de un triatlón sprint simulado y en un test de salto vertical. Estos cambios se relacionaron con una mejora neuromuscular que generó una mayor potencia muscular y una mejora de la economía de trabajo durante el triatlón (117). Por su parte, Jakeman et al. (134) analizaron el efecto de 6 sesiones HIIT de 10 min compuestas por esprines de 6 s durante 2 semanas en triatletas sub-élite, obteniendo durante un test de 10 km contra el reloj, una demora del tiempo a la hora de alcanzar los 4mmol.L^{-1} o punto OBLA después de la aplicación del programa y un 10% de reducción en el tiempo en completar esa distancia. Además, los triatletas aumentaron la potencia pico durante las sesiones de HIIT (134).

1.8. El entrenamiento HIIT en las modalidades de carrera y ciclismo

En varias ocaciones, los entrenamientos de carrera, ya sea en atletas o en triatletas llegan a generar un estrés excesivo y un índice lesional mayor, debido al componente excéntrico de los movimientos propios de esta modalidad (135-137). Previos autores investigaron si el entrenamiento de una modalidad deportiva, menos exigente a nivel músculo-esquelético y diferente a la que se compite, producía beneficios en el rendimiento del deporte principal. Por ejemplo, se observó que el ciclismo causaba alguna transferencia en el rendimiento durante la carrera (57). En el caso del triatlón, al ser un deporte de tres disciplinas, este tipo de entrenamiento cruzado adquiere mayor importancia, al poder mantener o mejorar una modalidad con el entrenamiento de otra y con el menor estrés fisiológico posible (57). Etxebarria et al. (112) concluyó que 3 semanas de intervención complementadas con entrenamientos HIIT en la modalidad de ciclismo mejoraban el rendimiento en 5 km de carrera realizados después de 1 h de ciclismo a intensidad variable, simulando un triatlón. De la misma forma, Pizza et al. (138) observaron que 6 semanas de entrenamiento intensificado de ciclismo mejoraba el rendimiento en una carrera de 5 km, sin cambios significativos en biomarcadores como la testosterona, la testosterona libre, la creatin kinasa y el cortisol, en atletas bien entrenados (138). Sin embargo, parece que el grado de beneficio de este método de entrenamiento varía atendiendo al nivel del atleta, siendo los atletas altamente entrenados y de élite los que requieren entrenamientos con gran especificidad, mientras que los atletas sub-élite o moderadamente entrenados podrían encontrar mayores beneficios en el entrenamiento cruzado o cross training (57, 59).

CHAPTER 2

Objectives and Hypothesis

Chapter 2. Objectives and hypothesis

The aims and objectives of this thesis are:

- **Objective 1:** To examine the commonly used methods to quantify training load in triathlon training, describing the principal physiological and performance parameters involved.
    - **Hypothesis 1:** The rating of perception exertion might be a complement to other physiological and performance variables during a laboratory test or training session in triathletes.
- **Objective 2:** To analyze performance differences between male and female moderately trained triathletes during a cycle ergometer maximal incremental test, and a simulated 20 km cycling time trial plus 5 km run.
    - **Hypothesis 2:** We hypothesied that in non-professional level, male triathletes would obtain greater performance during a cycle ergometer maximal incremental test and 20 km cycling plus 5 km running tests than their female counterparts.
- **Objetive 3:** To analyse posible associations between maximal incremental test results and simulated test performance in moderately trained triathletes.
    - **Hypothesis 3:** A correlation between physiological values registered in laboratory tests and performance variables during a simulated competition might exist.

- **Objetive 4:** To examine changes in fitness and physiological variables in moderately trained triathletes after a 4-week reduced volume training period supplemented with a supervised HIIT training program.

    - **Hypothesis 4:** HIIT may help to improve endurance performance. Two HIIT sessions per week might help to mantain athletes peformance during a 4-week reduced volume program.

CHAPTER 3

METHODOLOGY

Chapter 3. Methodology

As an article compilation thesis, the reader can find two different types of methodologies. Firstly, scientific literature analysis to elaborate our first article of the thesis and two original researches for articles 2 and 3.

Article 1. Review. El Triatlón y el control de la carga mediante la percepción del esfuerzo.

Design and experimental approach

A literature search was conducted on September, 2014. The following databases were searched: PubMed, SPORTDiscus,MEDLINE, and CINAHL (Cumulative Index to Nursing and Allied Health Literature). Databases were searched from inception to September 2014, with language limitation to Català, English and Spanish. Abstracts and citations from scientific conferences were excluded.

Literature Search

In each database, the title, abstract, and keywords search fields were searched. The following keywords, combined with Boolean operators (AND and OR), were used: RPE; RPE + method; perceived + exertion; Borg + scale; triathlon; endurance + sports; training load; cycling; running and swimming. No additional filters or search limitations were used.

Inclusion criteria

Studies were eligible for further analysis if the following inclusion criteria were met: a/researches were randomized control trials; b/

participants were triathletes or endurance athletes with/without previous competition experience; c/RPE was used as a quantification or control method during training or competition. Studies were excluded if a/ the research is a case study; b/review articles c/ participants were active triathletes or endurance athletes with previous training experience and familiarised with RPE scale ; d/ RPE method was utilised as a unique method of training load, without other method validation; e/ participants age was lower than 18 years-old and higher than 60 years-old f/ they were related to animal studies.

Quality assessment

To evaluate the level of evidence and observe the quality assessment of the research Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence tool was utilized (139). Two independent observers reviewed the studies and then individually decided whether inclusion was appropriate. In the event of a disagreement, a third observer was consulted to determine the inclusion in the analysis. The level of evidence was defined as strong («consistent findings among multiple high-quality randomised controlled trials (RCTs)»); moderate («consistent findings among multiple low-quality RCTs and/or non-randomised controlled trials (CCTs) and/or one high-quality RCT»); limited («one low-quality RCT and/or CCTs, conflicting evidence»); conflicting, («inconsistent findings among multiple trials (RCTs and /or CCTs)»); no evidence («no RCTs or CCTs»). The Oxford Centre of Evidence-based Medicine—Levels of Evidence was employed to determine the level of evidence according to the kind of study and question scope, considering that the highest level of evidence «1» pertaining to a systematic review, and lowest level of evidence system «5» being expert opinion (139).

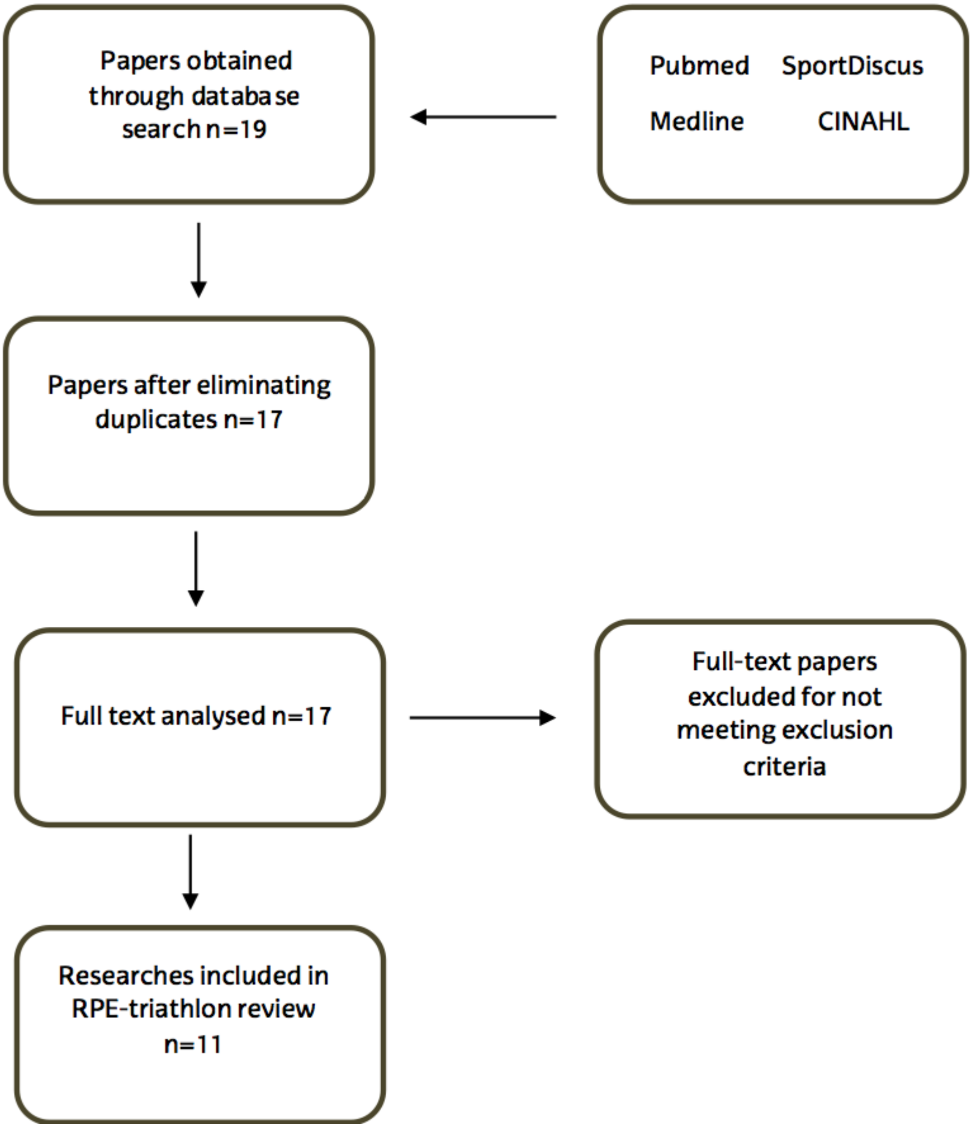

Figure 1. PRISMA 2009 flow adapted diagram.

Articles 2 and 3. Diferencias en las respuestas fisiológicas entre triatletas masculinos y femeninos and Comparison of reduced volume-high-intensity interval training compared to high volume training on endurance performance in triathletes

Participants

Both included a group of 16 moderately trained triathletes (8 females and 8 males; age = 40 ± 12 y; height = 172.4 ±1 0.8 cm; body mass = 73.0 ±1 2.1 kg; body mass index = 24.4 ± 2.4 kg·m−2) competing in triathlon, cycling, or running events were recruited from a number of South Australia clubs. However, two of them withdrew from the research project. Participants were informed of the study protocols and experimental procedures and provided written informed consent. The study was approved by the Southern Adelaide Clinical Human Research Ethics Committee (HREC code 334.16), adhered to the Declaration of Helsinki guidelines (2013).

Table 1. Participants characteristics (N=16).

	Intervention (HIIT) group	Control (CON) group
Age (yrs)	42.9 ± 12.1	37.2 ± 13.3
Gender	4 female + 4 male	4 female + 4 male
Height (cm)	171.0 ± 10.9	174.3 ± 9.7
Body mass (kg)	70.8 ± 9.7	76.0 ± 15.2
BMI ($kg.m^{-2}$)	23.8 ± 1.7	24.7 ± 2.0

Abbrevations: BMI = body mass index; CON, control; HIIT, high-intensity interval training

Table 2. Participants anthropometric characteristics divided by genre. Parte superior All- Men-Women- Dif.(%)- d

	All	Men	Women	Dif. (%)	d
Age (yr)	40,4 ± 12,5	47,7 ± 14,3	35,x ± 8,1	-26,6	-1,6
Anthropometric characteristics					
Height (cm)	172,4 ± 10,1	179,9 ± 8,6	166,8 ± 7,2**	-7,3	-1,8
Weight (kg)	73,0 ± 12,1	77,8 ± 5,8	69,4 ± 14,6	-10,7	-0,6
BMI ($kg.m^{-2}$)	24,4 ± 2,5	24,0 ± 1,3	24,7 ± 3,2	2,8	0,2
Biceps skinfold (mm)	6,9 ± 3,5	4,6 ± 2,0	8,6 ± 3,4*	87,0	1,2
Triceps skinfold (mm)	12,2 ± 5,3	8,3 ± 3,1	15,5 ± 4,4**	86,6	1,6
Subscapular skinfold (mm)	15,0 ± 6,8	12,7 ± 3,6	16,7 ± 8,3	31,5	0,5
Waist perimeter (cm)	80,3 ± 8,5	85,2 ± 6,1	76,7 ± 8,5	-9,9	-1,0
Hip perimeter (cm)	97,6 ± 4,4	96,8 ± 3,6	98,2 ± 5,1	1,4	0,3

Abbreviations: BMI = body mass index, Dif (%) = mean differences, d = Cohen effect size *P ‹ .05, **P ‹ .01, significant differences with men group.

The inclusion and exclusion criteria

Participants could take part in the experiment if the following inclusion criteria were met: a) subjects were competitive athletes currently training or competing in any triathlon distance on a regular basis (with a minimum 2 y of experience in competition) and completed a sprint triathlon distance between 1 hour 15 minutes and 1 hour 45 minutes,. The exclusion criteria were: triathletes with no competition experience in the previous 1 month, triathletes with less than 2 years competitive experience in their sport, or who had an injury that prevented them from participating in training or testing.

Procesures and testing protocols

In both studies for articles 2 and 3, all participants completed physiological testing at Flinders University's exercise physiology laboratory. The testing involved standard anthropometric measures (height and body mass) followed by an incremental exercise test to exhaustion to determine VO_2max on a cycle ergometer (Wattbike, Nottingham, United Kingdom). The test procedure was composed of 10 minutes usual warm-up and an incremental test where the initial load was set at 80 or 100 W, depending on the gender (female or male). Each stage lasted 1 minute, and the load was increased by 20 W until exhaustion (140). Parameters recorded were: ventilatory variables (TrueOne 2400 -ParvoMedics, Sandy, UT) , power output (PO) (Wattbike software, Nottingham, United Kingdom), heart rate (HR) (Polar RS400, Kempele, Finland) and rating of perceived exertion (RPE) using the Borg scale from 0 to 10 (79) in every stage, as well as, HR maximum and peak power output (PPO). After test, the first ventilatory threshold (PVT1) for each participant was identified as the PO at which ventilatory equivalent for oxygen and the end-tidal O_2 pressure started to increase without a corresponding increase in the postapneic end-tidal CO_2 pressure. For its part, the second ventilatory threshold was set up as the PO (PVT2) when a decrease in end-tidal CO_2 pressure was observed together with an increase in ventilator equivalent of CO_2 output. Eventually, a simulated triathlon performance time trial was performed in 3 parts: the first one, a 20-km cycling time trial (CTT) on a cycle ergometer (Wattbike); followed by a 3-minute transition where participants changed from cycling to running shoes and a 5-km running time trial (RTT) on the treadmill (TMX58, Trackmaster, Newton, KS) simulating an identical sprint triathlon distance for cycling and running (4). Triathletes completed the simulation triathlon flat out, changing gear on the bike and velocity on the treadmill when they needed. Parameters recorded were HR continuously and RPE every 10 minutes during the cycling and running; Average and maximum power, and overall cycling time were determined for the 20-km cycling, and average and maximum speed recorded every 10 minutes for the 5-km run. Laboratory testing was repeated within 2 days following the 4-week HIIT intervention period.

The third study (Article 3) included an intervention with subjects distributed to either a HIIT group who reduced their training volume (minutes) by an average of 43% ($P < .01$, $d = -2.7$) and added supervised HIIT cycling sessions in the laboratory twice a week during 4-week intervention. Or to the control group who maintained their training volume (−3%, $P > .05$, $d = -0.1$) over the intervention. An overall training load was calculated using the rating of perceived training load method (RPE-min) for each participant (74). You should explain how this was calculated.

Tabla 3. Comparison of usual weekly and intervention training time for both the HIIT group and CON group.

	Intervention (HIIT) group				Control (CON) group			
	Usual week	Intervention week	Dif. (%)	d	Usual week	Intervention week	Dif. (%)	d
Training volume (min)	648.3 ± 178.7	365.4 ± 105.9**	-43.6	-2.7	509.5 ± 195.6	492.8 ± 201.9	-3.3	-.1
RPE-min (AU)	2163.8 ± 910.6	1654.4 ± 779.7*	-23.5	-.7	2859.8 ± 1442.8	2259.8 ± 1193.8	-21.0	-.5

Abbrevations: CON, control group; d, Cohen effect size value; Dif., mean differences; HIIT = High-Intensity Interval Training; RPE, rating of perceived exertion. * $P < 0.05$, ** $P < 0.01$ significant differences with usual week.

Subjects randomly assigned to the HIIT group attended supervised HIIT sessions on a cycle ergometer twice a week during 4-week intervention program. Prior to the intervention, individual training zones at 95% and 115% of power obtained at VO_{2max} (PVO_{2max}) were calculated for each triathlete based on their pre-testing results. The session structure included a 10-minute warm-up where participants selected power and cadence, followed by 6 repetitions of 2 minutes at 95% of PVO_{2max} including a recovery period between repetitions of 2 minutes; 4 repetitions of 1 minutes at 115% of PVO_{2max} including 1minute and 30 seconds of recovery between repetitions, followed by 5-minute cooldown. All HIIT sessions were conducted above the individual's anaerobic threshold (AT). In every session the following parameters were registered: average and maximum HR (HR_{av} and HR_{max}), RPE, average power (P_{av}), and PO during each repetition and recovery session were recorded. Participants were provided with a HR monitor (RS400; Polar, Kempele, Finland) to record all session times and HR. They were asked to reduce their training volume from their individualized training programs focusing on RPE-min method (RPE average of the session x duration of the session). The athletes were asked to record time, distance, and HR data from the monitors, the type of activity, and RPE from all training sessions in a diary for the 4-week period, this was reviewed by the researchers weekly to ensure program compliance. Participants randomized to the control group followed their usual training program without volume reductions. HR monitors were provided in order to register type of activity, time, distance, HR, and RPE data for each training session performed during the 4-week period. Likewise, the control group diaries were reviewed by the researchers each week to ensure protocol.

Statistical Analysys

Article 2. Diferencias en las respuestas fisiológicas entre triatletas masculinos y femeninos

Results are presented as mean (SD). A t test for paired samples was used to analyze the differences between the usual week and intervention week training volume and RPE-min independently for each group (HIIT and CON). A t test for independent samples was used to analyze the differences in training load (RPE-min, AU) between groups (HIIT and CON) during intervention weeks (weeks 1– 4).The between-group (HIIT and CON) comparison from pretest to posttest in aerobic capacity and simulated triathlon test variables was calculated by a 2-way mixed analysis of variance (group x time). In addition, a t test for paired samples was used to analyze the differences between the pretest and posttest independently for each group (HIIT and CON). To allow a better interpretation of the results, practical signifi cance between the pretest and posttest independently for each group was assessed by calculating Cohen's effect size. Effect sizes (d) of above 0.8, between 0.8 and 0.5, between 0.5 and 0.2, and lower than 0.2 were considered as large, moderate, small, and trivial, respectively. The statistical significance was set at $P < .05$.

Article 3. Comparison of reduced volume-High-Intensity Interval Training compared to high volume training on endurance performance in triathletes

Results are presented as mean (SD). A t test for independent samples was used to analyze the differences in anthropometry, maximal incremental test and simulated competition. To allow a better interpretation of the results, practical significance between the pretest and posttest independently for each group was assessed by calculating Cohen's effect size. Effect sizes (d) of above 0.8, between 0.8 and 0.5, between 0.5 and 0.2, and lower than 0.2 were considered as large, moderate, small, and trivial, respectively. The correlation between maximal incremental test and the simulated competition was analysed using Pearson R Index. In both articles the statistical significance was set at $p < .05$ and data analysis was performed using the Statistical Package for Social Sciences (version 21.0 for Windows; SPSS Inc, Chicago.

CHAPTER 4

DISCUSSION

Chapter 4. Discussion

The first article of this dissertation presents a scientific literature review on the Rate of Perceived Exertion (RPE) applied to triathlon and was published in the highest Spanish ranked Sport Medicine Journal. Until the last search performed for the review, dating to March 2014, only 7 papers used and/or analysed RPE to quantify the internal load in triathlon. Both, training as well as in racing or simulating conditions. The principal purpose of RPE method is to complement the traditional load quantification methods, such as, HR, lactate concentration, power or speed at VT (31, 72, 74). Hausswirth et al. (2000) observed that greater RPE values were associated with an increase in muscle fatigue after different types of running, including running after a triathlon (141). Moreover, previous authors tested RPE as a marker of effort compared with traditional load quantifiers in an Ironman race, recording RPE during the three sections of competition and during transitions (83). During this type of triathlon, the rating of perceived exertion modulated the race pace.

After swim to bike and bike to run transitions, RPE was re-set to face the new sports demand and decreased due to the switch of muscle group from one sport to another (80, 83). Additionally, RPE was utilised as a performance indicator when the triathletes swam with or without neoprene during an olympic distance triathlon and when compression stockings were or not wore in a half ironman (81, 82). Research by Teuma et al. (2004) was the only study located before September 2014 where RPE was used as a complement method to control load during triathlon training sessions. They concluded that RPE was highly associated with HR (84).

In order to open the scope of the review, four articles were included where participants carried out one of triathlon's sports, i.e. swimming, cycling or running and met the inclusion criteria described in the Methodology section, (see Chapter 3). Baden et al. (2004) concluded that teleoanticipatory mechanisms regulated the RPE values depending on running distance or running duration by the adjustment of attentional focus, comparing associative and dissociative thoughts (142). Similarly, Standley et al. (2007) concluded that associative thoughts during a cycle ergometer test evoked higher RPE values than dissociative thoughts (143). For swimming, Wallace et al. (2009) showed that during swimming training sessions, coaches perceived higher RPE values than athletes for high intensity exercise, whereas, at low intensities coach perceived a lower RPE than swimmers. This review, concluded that the RPE load quantification method was used more in competition than in the day to day training activity of triathletes (75).

The second study investigated physiological and mechanical differences between genders in triathlon. This original research, showed that no significant differences were found between male and female triathletes during maximal incremental testing (Table 2 page 43 of «*Diferencias entre triatletas masculinos y femeninos en las respuestas fisiológicas de un test máximo incremental y una competición simulada*»; annexe 10.1.2). However, pratical differences for VO_{2max}, P_{max}, PVT1, PVT2 and VO_2VT2 were observed between groups, such that men obtained greater values. Similar results were previously obtained by a number of other researchers (26, 93-95). Millet et al. (2004) observed significant differences between genders (for VO_{2max} (19.5% y 17.9%), PPO (24.3% y 23.9%) and $\%VO_2VT$ (3,5% y 4,1%) and categories (junior and senior, respectively) (26). Similarly, Schabort et al. (2000) obtained a difference of 26.8% for VO_{2max} (93) whereas Sleivert et al. (1993) showed a 15% difference (94). Additionally, Sleivert et al.

(1993) concluded that an 8.1% change in %VO_2VT and 37.3% change in PVT were calculated between groups during an maximal incremental cyclergometer test, with male triathletes obtaining higher values (94). These differences might be explained due to a greater muscle mass concentration in males than females. Furthermore, it could be related to a smaller relative lipid accumulation shown by males (90, 93).This idea is also presented by Lepers et al. (2013) where female athletes presented a larger lipid accumulation than males (13% and 5%, respectively) (86). Moreover, cardiovascular differences, such as a lower haemoglobin concentrations in female athletes (-5-10%) could be a precursor of dissimilarities between genders (86, 90, 144).

Male triathletes registered superior results for time, $speed_{av}$, P_{av} and P_{max} during a simulated triathlon 20 km cycle section than female. However, neither significant nor practical differences were found during 5 km run. These results coincide with those obtained by Lepers et al. (2013). They aimed to analyse the difference between genders and the results showed a 10-14% greater performance in men for the cycling section but no differences for the of 5 km run (86). Our data, in contrast, indicate the difference in the 20 km cycle section was 10% higher, and 7% greater for the run section, for males. Therefore, our results showed that the main differences between groups were in the 20 km cycle and not in the 5 km run. This idea is concordance with the investigations of Millet et al. (2004), where they concluded that specific cycling training might be relevant in performance enhancement in female triathletes during a simulated triathlon race or a triathlon in comparison to men (26). The explanation for this phenomenom of 5 km running difference between genders, could be explained by the context in which the experiment was conducted; simulation conditions, distance and triathletes level. In our research, athletes performed a 20 km cycling followed by 5 km running flat out. In their study, Millet et al. (2004) the running section was developed at submaximal intensities over 7 minutes (26). Additionally, in their research sample, comparing triathletes aerobic and morphological characteristics, they recruited highly trained triathletes and the present sample were recreational triathletes. The VO_2max of subjects in Millet's (2004) study ranged between 74.3 ± 4.4 and 61.0 ± 5.0 for senior male and female triathletes, respectively (26); whereas in our research the VO_2max values were 44.9 ± 6.3 for male and 40.5 ± 2,4 for female triathletes.

Another interesting finding was the fact that female triathletes showed a practical greater HR_{av} compared with males during transition (112 ± 11 bpm vs 123 ± 24 bpm) , while males employed less time to complete the simulation triathlon than the female group (60.3min ± 2.3min vs 64.7 ± 4.6).

Regarding the association between maximal incremental test and simulated triathlon, triathletes who obtained a higher VO_2max value during the incremental test were associated with a lower time to complete the 20 km cycle and a superior P_{av} ($r = -0,543$, $p < 0,05$). Additionally, a greater VO_2VT2 during the maximal incremental test was associated with a lower HR_{av} during transition. These results suggest that a higher cardiovascular capacity might benefit cycle performance in a simulated triathlon and greater recovery during transition. This might result in the athlete running with lower energetic expenditure and better oxygen transportation capacity. The authors mentioned above, Millet et al. (2004), suggested the same concept in their research where the triathletes who obtained greater values in VO_2max and PPO in the cycling section showed an association with the three triathlon disciplines (26).

Furthermore, in our case, male triathletes who showed a superior value of VO_2VT2 during the maximal incremental test obtained a greater P_{max} during 20 km cycling. Whereas, female triathletes with a higher VO_2max were associated with a greater average speed during the 5 km run, and higher values in VO_2VT2 were associated with superior average speed during the 20 km cycling.

Additionally, females obtained a higher PVT2 value, performed 20 km cycling using a minor Cad_{av}. Sleivert et al. (1993) also observed a positive association between VO_2max and time to complete 9 km running in female triathletes during a short triathlon, whereas male triathletes showed an association between speed at VT and time to complete the whole triathlon (94). Thus, based on our results, these evoked that the maximal incremental test improvement might be associated to a simulated triathlon test depending of the gender.

The third publication of the current dissertation focused on the influence of 1 and 2 min intervals of cycle HIIT sets as a supplement during reduced weekly training volume in moderately trained triathletes. It has been vastly demonstrated that the training time spent at or near VO_2max is essential to effectively improve the aerobic capacity (114, 145, 146). The novel view in this article was that VO_2max showed a 6.7% improvement coinciding with the majority of the scientific literature on this topic. Although, the weekly training time was reduced by 43% and supplemented by two short-duration HIIT sessions in the overall training program. For example, Etxebarria et al. (2014) obtained enhancements of 7.3% and 7.5% for short and long HIIT efforts, respectively. These HIIT bouts consisted of 9 to 11 repetitions of 10-, 20-, and 40-s efforts for short sets, and 6 to 8 repetitions of 5-min efforts for long sets, completing a number of 6-HIIT session intervention program (112).

Other authors showed more moderate improvements. For instance, Gojanovic et al. (2015) reported a gain of 3.5 % in the VO_2max after a 4-week HIIT training with 4-5 bouts of 60 % time to exhaustion at 100% velocity at VO_2max (118). However, one pioneer study from Acevedo and Goldfarb (1989) determined that an 8-week intensive intensity program did not improve VO_2max in long distance runners using the system of sets at 90-95 % HR_{max} limiting the recovery where the next repetition started when subject HR reached 120 bpm (129). The unprecedented point of the current article is that previous authors used the HIIT as a training complement, without volume and load reductions, whereas our program carefully monitored, registered and followed up the HIIT effects when weekly volume training was considerably reduced.

Despite of VO_2max, the location of ventilatory threshold (VT) resulted in a useful aerobic condition indicator (57, 115, 140, 147-149). In our investigation, results showed the HIIT group improved significantly at both time points. Namely, triathletes could maintain greater average power levels during a maximal cycle ergometer test after four weeks of HIIT training at similar intensities and reducing the training volume by 4.7 hours average per week. Laursen et al. (2002) obtained an improvement of 6 % in PVT_1 and 7% in PVT_2 in highly trained cyclists (104). The main difference, however, relies on the reduction of the volume by 2 hours per week.

Referring to simulated triathlon test following a 43% reduction in training duration with a 23 % reduction in training load (RPE-min), HIIT participants maintained values for cycling time, P_{av}, HR_{av} and running times, therefore, the performance remained unchanged. Preceding literature observed improvements in running time performance after a cycling HIIT program with no total training volume reduction (112, 150). Etxebarria et al. reported that the change of 5 km running times after four weeks of long sets HIIT sessions was small (from 21.25 ± 2.47 min to 20.21 ± 2.31min). Similarly, Mutton et al. (1993) showed decreases of 1.7min in 5000 m and 18-21 seconds in 1609 m TT using either running only or running plus cycle training (150). Likewise, Mikesell et al. (1984) and Murphy et al. (1987) obtained equal improvements in running performance when comparing both groups (109, 151). In cycling TT performances, Lindsay et al. (1996)

demonstrated a decrease of 3.5% for completion of a 40 km TT in professional cyclists after 4-weeks of a HIIT program replacing 15% of the total weekly training volume by HIIT sessions (108). Interestingly, reducing the volume and tailoring the intensities of HIIT, could be of great help for athletes and coaches in order to improve the quality of the training, and reduce the harmful factors associated with higher volumes of exercise such as injury risk and chronic fatigue.

CHAPTER 5

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Chapter 5. References

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CHAPTER 6

CONCLUSIONS

Chapter 6. Conclusions

Acording to our research our conclusions are as follows:

- The RPE is an ecological, useful and attainable load quantification method for all triathletes, considering that minimal equipment is involved. The Borg scale is a helpful tool provided that a long familiarisation period is provided. However, its use is necessary as a complement to other physiological methods which are able to be reliably quantifiable such as HR.
- Male and female moderately trained triathletes showed practical differences for VO_2max, power at both ventilatory thresholds and $V0_2$ at 2nd ventilatory threshold after a cycle ergometer maximal test. Although, only 20 km cycling during the simulated race presented significant differences between sexes which may generate differences to the overall simulated triathlon time.
- A superior VO_2max during the maximal test may be related to a faster time to complete a 20 km simulated cycle section, as well as, a greater power average. Additionally, a higher VO_2VT2 value may be associated with a lower HR average during the transition section. Distinguishing the results by gender, higher values obtained in the maximal test may be associated to superior performances on a 20 km cycle for males, and may be related to a superior performance on a 5 km run for females.
- The supplement of two cycle HIIT session-week during specific reduced volume periods such as periodisation, tapering or off-season, may help to achieve or maintain high levels of

physiological and fitness variables such as VO_2max, power at 1st and 2nd ventilatory thresholds, while the performance is maintained. However, it is clear that to achieve improvements on cycling and running in moderately trained triathletes specific threshold volume training is required rather than volume reduced programs supplemented by HIIT.

CHAPTER 7

Practical applications

Chapter 7. Practical applications

We believe that our research work adds interesting practical applications for scientists, coaches and practitioners.

- As a practical application, it might be necessary that triathletes had a larger triathlon experience in order to interpret the perceptions received from training and/or competition. Additionally, this method must be validated before use, in order to confirm association with athletes physiological characteristics.
- Moderately trained triathletes presented physiological differences between gender during cyclergometer maximal incremental test and the cycle portion of 20 km in a simulated race. For this reason, considering the triathlete gender when developing training individualization might be relevant to achieve a greater performance.
- A specific training to improve the aerobic capacity might involve a performance enhancement during the 20 km of cycle section in a triathlon, specifically in male triathletes. On the other hand, female triathletes seemed to show a greater 5 km running performance when their aerobic capacity was increased.
- 2 HIITbike sessions during 4 weeks where volume training is reduced, such as, tapering, off-season or injury period, appears to maintain cycling and running performance, acting as cross transfer method. Therefore, cycling training could

help to maintain running performance. However, the use of traditional high volume and threshold volume training is essential in moderately trained triathletes in order to improve cycling or running performances.

CHAPTER 8

LIMITATIONS

Chapter 8. Limitations

No research work is without limitations and factors that can interfere in the scientific process. This is especially delicate when working with human groups. We identified and tried to overcome the following with the ultimate goal of respect the scientific methods.

- The sample size. The research structures required that participants were able to attend twice a week to the university in order to perform the supervised HIIT sessions over the duration of at least one month. As the subjects were non-professional, they had to balance work and family with study participation, and various participants dropped out during the data collection.
- The simulated race was performed in the laboratory in order to analyse the maximum number of variables. The researchers tried to reconstruct the environment as similar as possible to the race, however there were some aspects that could not exactly be recreated.
- Due to a lack of time, just one maximal test on the pre and post test were performed by each participant. However, it had been interesting to perform one maximal test of each discipline (swim, cycle and run) to each triathlete.

For the review article, as a pilot study of this dissertation and the first contact with scientific writing and research, the methodology and the article writing showed a slightly lack of experience. Nevertheless, it was helpful to indentify methodological errors and set the base for the research skills.

CHAPTER 9

FUTURE DIRECTIONS

Chapter 9. Future directions

There is a long way until the scientific community can give a satisfactory answer to the multiple questions that have arisen at the end of this research. In order to keep on lighting this path, we strongly believe that the following investigations should lead the continuation of our work:

- To investigate differences between male and female triathletes depending on the age, level and experience in triathlon, the race distance, hours of training or other factors related with the athlete's performance.
- To increase the sample of the study in order to distinguish thoroughly the association between physiological and morphological variables such as VO_2max, muscle fibre types and recruitment, oxidative stress produced by a triathlon race, and the triathlon performance.
- To focus on female triathletes physiological and biomechanical variables in order to increase the race performance.
- To determine the optimal HIIT structure, compare effects of distinct program sessions and interval durations and intensities, as well as, to observe different HIIT characteristics depending of the age, gender, level, experience of the participants. and triathlon distance.
- To analyse the effects of HIIT on the three disciplines of triathlon. Specifically, in swimming which is the least studied discipline.

- To look for associations between laboratory variables from the three sports disciplines and performance variables obtained from different distances of a triathlon competition or simulated competition.
- To extend the work on biomarkers such as inflamation, oxidative stress and muscle damage caused by HIIT training, dependant of triathlete characteristics. This is currently under research by the author of the present doctoral thesis.

CHAPTER 10

APPENDIXES

10.1. TRABAJOS PUBLICADOS

10.1.1. Artículo 1: «El triatlón y el control de la carga mediante la percepción del esfuerzo»

Revisión

El Triatlón y el control de la carga mediante la percepción del esfuerzo

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Resumen

El triatlón moderno se ha convertido en uno de los deportes de resistencia más practicado en los últimos años en el mundo entero. Además, por un lado, presenta unas características históricas aparte de unas demandas biológicas específicas que lo hacen distinto de otros deportes. Así mismo, el hecho de haberse popularizado tanto en las últimas décadas ha generado una constante en los procesos de investigación sobre diferentes áreas: los mejores materiales para su práctica, el mantenimiento de la forma durante un período prolongado en el tiempo, las transiciones entre modalidades durante la pruebas, el aumento de competiciones y la búsqueda de los mejores métodos de entrenamiento. Sin embargo, no todos los practicantes pueden permitirse tener a su disposición los mismos medios de control del entrenamiento que los triatletas de élite. Por lo tanto, es de gran interés, para triatletas y entrenadores, determinar un método válido, fiable y de fácil utilización que se pudiera aplicar en distintos grupos de personas. Por ello, es de especial interés conocer los principales métodos de control de la carga de entrenamiento y competición en deportes de resistencia, especialmente los aplicados al triatlón. Por tanto, nuestro trabajo tuvo por objeto analizar la percepción del esfuerzo (RPE), metodología basada en las propias percepciones de cada deportista. Previamente a ello, realizamos un análisis exhaustivo de la literatura científica publicada hasta el momento para nuestro conocimiento, con relación a los diferentes métodos de control de la carga de entrenamiento y competición, así como la evaluación de su fiabilidad en triatlón.

Key words:
Resistencia.
Entrenamiento. Fisiología.
Cuantificación. RPE.

Triathlon and control the load by perceived exertion

Summary

The modern triathlon has become one of the most popular endurance sports Worldwide. Anyway shows specific historical characteristics and on the other hand, biological demands that make it a different sport. Due to its popularity during the last decades, new research methods have been applied to its different modalities and in different aspects. In order to maximize the performance and get the peak performance as prolonged as possible, these investigations have developed new materials for practitioners and improve new training methods, the transitions among modalities during competitions, the training and competitions load control, the big amount of competitions and the best training's techniques among others. However, not all triathletes have the access to the same training monitoring control as elite triathletes do. Therefore, it could be of great interest for athletes and coaches to develop a valid, reliable and easy managing tool in order to control the training load in as many individuals as possible with reliable accuracy, validity. Thus, it would be relevant to know the main methods of training load and competition load in endurance disciplines sports especially focus on triathlon. Therefore, in the present research work, we will analyze the current concept of triathlon sport and its main methods to set the training work load, internal and external. Thus, we will focus on those methods based on athlete's own perceived exertion effort (RPE), but previously we will analyze whether current scientific literature (for author's knowledge) describes those training and competition load methods and their reliability in triathlon.

Palabras clave:
Endurance. Training.
Physiology.
Quantification. RPE.

Introducción

Desde su inicio moderno hasta la actualidad, el triatlón ha ido modificándose y creando nuevas distancias de competición. En 1975 recibe por primera vez la denominación de triatlón, en San Diego (EEUU), dónde los participantes debieron encadenar 800 m de natación, 8 km de bicicleta y 8 km de carrera. Sin embargo, la primera prueba con repercusión a nivel internacional no aparece hasta 1977 en el archipiélago de Hawai (Honolulu) con la celebración del primer Ironman[1]. En la actualidad existen diferentes modalidades de triatlón: a partir de la creación de los Ironman (3.800 m nado-180 km ciclismo-42,195 km carrera a pie) se empieza a reglar por parte de la Unión Internacional de Triatlón/*International Triathlon Union* (ITU) y la Corporación Mundial de Triatlón/*World Triathlon Corporation* (WTC) las distancias y las modalidades. Según la ITU[2], los tipos de competición más comunes en los que se compiten son:

- Super *sprint:* 400 m nadando, 10 km en bici y 2,5 km corriendo aunque las distancias pueden variar;
- *Sprint:* 750 m nadando, 20 km en bici y 5 km corriendo;
- Olímpico: 1500 m nadando, 40 km en bici y 10 km corriendo;
- *Half:* 1900 m nadando, 90 km en bici y 21 km corriendo;
- Doble Olímpico: 2500-3000 m nadando, 80 km en bici y 20 km corriendo;
- ITU-Larga Distancia: 4000 m nadando, 120 km en bici y 30 km corriendo;
- Ironman o Larga Distancia: 3800 m nadando, 180 km en bici y 42,195 km corriendo.

La variedad de pruebas crea un deporte con participantes muy heterogéneos, con condiciones físicas y objetivos deportivos muy distintos. Pese a dicha heterogeneidad, existe un objetivo común entre todos los triatletas: La cuantificación de la carga en el entrenamiento.

Cuantificación de la carga en triatlón

Los métodos para cuantificar la carga en el triatlón se centran en la monitorización de medidas externas tales como la distancia recorrida, el tiempo de entrenamiento o el ritmo[3]. Habitualmente dichos métodos se suelen complementar mediante la cuantificación "tradicional" de las características fisiológicas consideradas internas (la potencia aeróbica, el umbral anaeróbico (AT), la frecuencia cardíaca (FC), el umbral del lactato/ventilatorio (LT/VT), el consumo máximo de oxígeno (VO_2max) y/o la economía/eficiencia. Es interesante destacar que solo los factores de VO_2max y LT/VT han sido investigados extensivamente en triatletas[4].

Aun así, los fisiólogos del ejercicio que trabajan con triatletas tienen que enfrentarse habitualmente con diferentes modos de ejercicio, según el objetivo de la sesión; variaciones inter-individuales en el historial de entrenamiento en natación, ciclismo y carrera, que a su vez afectan a las adaptaciones al entrenamiento de los atletas y a los perfiles de entrenamiento; géneros diferentes y como se ha apuntado anteriormente, a triatlones con diferentes distancias[4].

Por esta razón, consideramos interesante revisar otros métodos de cuantificación de naturaleza subjetiva, es decir, aquellos que se centran en las percepciones y sensaciones del propio atleta para ejercer un control de la carga de entrenamiento. Dentro de estos métodos encontramos los diarios, los cuestionarios retrospectivos[5-7], los niveles de ansiedad y estados de ánimo (POMS)[8] y finalmente la percepción del esfuerzo (RPE).

El método del control de la carga mediante RPE, es uno de los métodos más utilizados[5,6]. En la RPE el deportista da un valor a la sensación de esfuerzo que percibe sobre el entrenamiento realizado[9], atendiendo a una escala de puntuación. En 1987, su creador Gunnar Borg la define como "un indicador importante del grado y la individualidad del esfuerzo físico"[10]. Una de las más utilizadas es la *Rating Scale of Perceived Exertion* (RSPE) propuesta por Borg, que contiene categorías del 6 al 20[6]. Con su creación se pretende aumentar la linealidad del volumen de oxígeno y la frecuencia cardíaca con la carga de trabajo. Asimismo, resulta muy interesante la interpretación directa de la tabla durante el trabajo. Existe una estrecha correlación entre las categorías de la escala con la FC del sujeto durante la prueba; es decir que un 6 en la escala corresponde a 60 pulsaciones/min del sujeto y un 20 en la escala a 200 pulsaciones/minuto, siempre y cuando el sujeto tenga una edad comprendida entre 30 y 50 años. Sin embargo, se percibe una gran variabilidad dependiendo de la edad, del tipo de ejercicio, del entorno de trabajo y de la ansiedad del sujeto, entre otros factores. Finalmente, remarcar una desventaja sobre dicha escala: las respuestas no son comparables entre individuos, ya que cada sujeto tiene una adaptación y por lo tanto una percepción distinta a otro frente una misma carga de trabajo (Tabla 1).

En posteriores trabajos, Borg modifica la escala reduciéndola a una de 10 puntos, ya que, según sus estudios, es más sencilla de utilizar, más adecuada para sujetos que poseen escasa familiarización con la fatiga del entrenamiento y los métodos de control de la carga[6]. Otra característica que aumenta su funcionalidad es el hecho de ser más visual, ya que a cada categoría le corresponde una expresión y sus valores se correlacionan. Si una respuesta es 4, la intensidad de 2 será la mitad de la intensidad de 4. Finalmente, en otro estudio de 1981, se obtiene una correlación más estrecha entre la concentración de lactato en sangre, la concentración de lactato muscular del sujeto y las categorías de la nueva escala a determinadas cargas de trabajo[11] (Tabla 2).

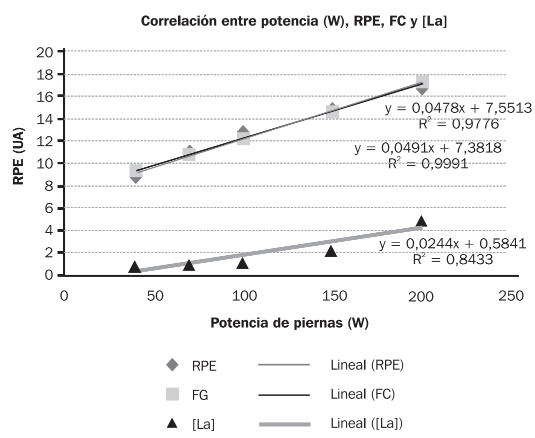
Tabla 1. Adaptación de Escala de RPE 15 categorías (Borg,1982).

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very Hard
18	
19	Very, very hard
20	

Tabla 2. Adaptación de la Escala de RPE 10 categorías (Borg, 1982).

0	Nothing all	
0.5	Very, ver weak	(just noticeable)
1	Very weak	
2	Weak	(light)
3	Moderate	
4	Somewhat strong	
5	Strong	(heavy)
6		
7	Very Strong	
8		
9		
10	Very, very strong	(almost max)
	Maximal	

Figura 1. Adaptación gráfica del estudio potencia de pierna y RPE (Borg, 1987).



RPE: Percepción del esfuerzo; UA: Unidad arbitraria; W: Watios; FC: Frecuencia cardíaca; La: Concentración de lactato.

Borg[10] estudia la correlación entre la RPE, la FC y la concentración de lactato en sangre (BL) durante un ejercicio de pierna y otro de brazo. En esta revisión, nos centramos en los datos obtenidos del trabajo de pierna, ya que tanto en la carrera como en el ciclismo en triatlón hay mayores demandas de los miembros inferiores que de los superiores (la natación ocupa menos tiempo que las otras dos modalidades juntas) (Figura 1). La percepción del esfuerzo obtiene valores más elevados en el ejercicio de brazo que en el ejercicio de pierna a la misma intensidad de trabajo. Un comportamiento idéntico se da con las siguientes variables fisiológicas: FC, BL, potencia, presión arterial sistólica y diastólica, captación de oxígeno e intercambio respiratorio.

Durante un ejercicio equilibrado, con cargas incrementales, la curva del RPE predice combinaciones simples de FC y BL (Figura 1); es decir

Tabla 3. Adaptación del estudio RPE, FC y [La] durante un ejercicio de piernas y brazos (W) (Borg, 1987).

W	RPE	FC	[La]
40	8,88	94	0,99
70	11,13	108	1,1
100	12,88	123	1,31
150	14,88	146	2,3
200	16,75	173	5,03

que existe una correlación entre dichos factores, principalmente entre la RPE y la FC (Tabla 3). Como consecuencia, la RPE puede resultar un buen método para el control del entrenamiento en triatlón.

Actualmente existe otra escala, la propuesta por Hawley y Burke[12], la cual está compuesta por cuatro niveles.

Debido a que estos métodos subjetivos de cuantificación de la carga, concretamente el RPE, son fáciles de utilizar, han sido validados, requieren poco material, su utilización requiere un bajo coste económico y tienen una gran correlación con la FC[5,13-15], pueden resultar una interesante alternativa a otros métodos tradicionales. Igualmente con la validez ecológica que proporciona, hace que el método RPE pueda ser muy interesante para una gran parte de triatletas que no compiten a nivel profesional, ya que no disponen de la totalidad de recursos para el control del entrenamiento.

Por lo tanto, el objetivo de este trabajo es realizar una revisión bibliográfica de los principales métodos de control de la carga a través de la percepción del esfuerzo en el triatlón.

Percepción del esfuerzo y triatlón

Hemos encontrado siete estudios hasta Septiembre de 2014 que utilizan la percepción del esfuerzo por parte del triatleta para medir las sensaciones de esfuerzo durante una prueba o un simulacro de prueba, pero su función principal en los estudios es como método de cuantificación complementario a los métodos tradicionales[8,16-20].

Con el fin de complementar dicha información, se ha revisado en la literatura, artículos en los que la percepción del esfuerzo fuera uno de los métodos principales y que el contexto fuera uno de los tres deportes que conforman el triatlón (natación, ciclismo y atletismo)[5,13,21,22]. Sin embargo, se ha incluido en dicha revisión un estudio realizado dentro de los deportes colectivos, concretamente el balonmano, en el cuál se valida el método RPE en el control de la intensidad de entrenamiento[15] (objetivo concreto de esta revisión).

En contra de lo esperado, el uso del RPE en el mundo del triatlón está más relacionado al rendimiento en competición que al control de la intensidad de entrenamiento para poblaciones de deportistas de todos los niveles. Dentro de los estudios de triatlón se observó la utilización del RPE como comparador del esfuerzo entre los sectores que conforman un triatlón con los deportes que conforman dichos sectores, pero de manera aislada; por ejemplo, se compara el RPE entre la carrera durante un triatlón y una carrera aislada de las mismas características[8,17].

Tabla 4. Resumen de los artículos más relevantes publicados en la literatura científica en cuanto a triatlón y percepción subjetiva del esfuerzo (RPE).

Artículo	n	Modalidad deportiva	Método	RPE	Conclusión
Kerr *et al.,* 1998	5	Triatlón Olímpico	Cálculo temperatura central, temperatura corporal y temperatura de la piel en triatlones con o sin neopreno	Marcador del nivel de fatiga que perciben los sujetos	La utilización de traje de neopreno en triatlones olímpicos en aguas cálidas no afecta a la termorregulación de los triatletas. No existen diferencias significativas en la RPE con o sin neopreno.
Hausswirth *et al.,* 2000	7	Triatlón Olímpico	Recogida de respuestas musculares, fisiológicas y RPE en: - Carrera triatlón olímpico (45') - Últimos 45' sesión carrera (2h15') - Carrera aislada de 45' Todas misma velocidad	Marcador de fatiga muscular	RPE registrada durante las contracciones isométricas es un buen buen índice para acercarse al nivel de la fatiga durante ejercicios prolongados.
Barrios *et al.,* 2004	9	Triatlón Olímpico	Registro de 15 sesiones de natación	Control de la intensidad en el entrenamiento	La percepción del esfuerzo esfuerzo es un método complementario para el control de las cargas de entrenamiento.
Parry *et al.,* 2011	12	Triatlón Ironman	Recogida de datos sobre estado de ánimo y RPE antes, durante y después del Ironman de Austria 2008	Indicador del esfuerzo y la fatiga en las transiciones durante la competición	El RPE y la FC aumentan durante ironman. - En transiciones disminuyen ambos, la FC se recupera enseguida y el RPE tarda en volver a valores iniciales a causa del cambio de grupos musculares. - Tener consciencia de la percepción del esfuerzo ayuda a modular el ritmo de carrera.
Taylor *et al.,* 2013	8	Triatlón *sprint*	Registro respuestas fisiológicas, RPE y ritmo de carrera en un triatlón *sprint* y en una carrera aislada de 5 km	Comparador del esfuerzo en distintos sectores de un triatlón e indicador de esfuerzo durante las transiciones	La fatiga acumulada en el triatlón no dista de la RPE que se obtiene en la carrera aislada. Después de cada transición la RPE se compensa, baja los valores, para afrontar el siguiente segmento.
Etxebarria *et al.,* 2013	9	Triatlón Olímpico	Test incremental submáximo de carrera aislada, después de 1h ciclismo constante y después de 1h ciclismo variable	Comparador del esfuerzo en distintos sectores de un triatlón	Existe más demanda fisiológica y RPE más alta en carreras con ciclismo previo, que en carrera aislada. Son menores las demandas y la RPE en la carreras con sector ciclista constante que en la variable.
Del Coso *et al.,* 2014	36	Medio Ironman	Recogida pre y post competición a triatletas con o sin medias compresivas de: - Potencia de salto - Concentraciones mioglobina y creatina quinasa en sangre - RPE junto con dolor muscular	Indicador de la fatiga muscular	No existen diferencias significativas en ninguna de las variables entre los sujetos con medias compresoras y los que no usaron.
Baden *et al.,* 2004	22 + 40	Atletismo	Registro durante carreras de 8 y 10 millas + 2 carreras de 10 min n tapiz rodante a la velocidad que pueda el sujeto	Indicador del esfuerzo relacionado con la teleanticipación	El RPE fue más alto en las carreras más cortas, a causa de la teleanticipación.
Stanley *et al.,* 2007	13	Cicloergómetro	Cicloergómetro. Test submáximo al 75% del VO_2max	Indicador del esfuerzo relacionado con el tipo de pensamientos	Los pensamientos asociativos conllevan un RPE más alto que los disociativos.
Faulkner *et al.,* 2008	9	Atletismo	Test hasta la extenuación y recogida de datos en una carrera de 7 millas y una media maratón	Comparador del esfuerzo en distintas distancias de competición en atletismo	El RPE es mayor en carreras cortas y tiene valores más altos que en carreras más largas, también van a más velocidad. Debido a la *"pacing estrategy".*
Wallace *et al.,* 2009	12	Natación	Entrenamientos de natación trabajando la eficiencia y la capacidad aeróbica	Control de la intensidad en el entrenamiento	A altas intensidades los entrenadores tienen una percepción del esfuerzo mayor y a bajas intensidades menor.

FC: Frecuencia Cardíaca; VO_2máx: Volumen Máximo de Oxígeno.

Asimismo, la RPE también es útil como indicador de fatiga justo en las transiciones durante una competición, es decir, en los últimos tramos de un sector, la entrada a boxes y los primeros tramos del nuevo sector[8,16]. El método RPE como indicador de fatiga a nivel muscular durante la competición es otra de sus utilizaciones[18,19]. En el estudio de Hausswirth *et al.,* la RPE recogida durante contracciones isométricas resulta un buen indicador de aproximación al nivel de fatiga muscular durante un ejercicio prolongado. Es importante recalcar que en todas estas utilizaciones, la RPE no es el único método que se emplea durante la investigación, sino que actúa complementándose con otros métodos fisiológicos, tradicionales.

Resaltar el estudio de Barrios *et al.* [14], en el cual se lleva a cabo una valoración del esfuerzo percibido en el control del entrenamiento de triatlón, concluyendo que es un método complementario para el control del entrenamiento ya que se observa una alta correspondencia con la FC. Siguiendo esta línea de validación del método RPE, otros autores, anteriormente nombrados, realizan el mismo ejercicio en deportes como la natación, el atletismo y el balonmano llegando a la misma conclusión[5,13,15], sin embargo todos los autores aseguran que es necesario un tiempo de familiarización, por parte de los deportistas, con la escala de Borg para obtener unos resultados aceptables.

Finalmente, señalar otros tres empleos de la percepción del esfuerzo: como medidor del esfuerzo en la simulación de un triatlón olímpico en el cuál se quiere investigar si aumenta la fatiga por calor en aguas cálidas si se nada el sector de natación con o sin neopreno; relacionado con la teleanticipación en dos carreras de atletismo de distinta distancia[21] y finalmente en un estudio de ciclismo relacionado con los pensamientos asociativos y disociativos[22].

Conclusiones y aplicaciones prácticas

El triatlón es un deporte que se basa en la mejora de los siguientes parámetros: Consumo máximo de oxígeno, potencia crítica, umbral del lactato y economía y eficiencia.

Para la mejora del rendimiento en triatlón, la RPE parece ser una herramienta útil, fiable y asequible (validez ecológica) para todo tipo de triatletas, ya que el instrumental es mínimo. La escala de Borg en estas condiciones, puede ser de gran ayuda, siempre y cuando haya un período prolongado de familiarización por parte del deportista.

Como aplicación práctica, la RPE debe respetar los siguientes principios: el sujeto debe poseer una experiencia mínima en el mundo del triatlón, para saber interpretar las percepciones que recibe durante el entrenamiento y confirmar que el método tiene una fuerte correspondencia con los valores fisiológicos del deportista, es decir, validarlo antes de usarlo.

No obstante creemos que son necesarias investigaciones dentro del mundo del triatlón en las que un control exhaustivo de las cargas internas y externas del entrenamiento puedan ayudar a comprobar la fiabilidad y validez de esta herramienta. Así como aumentar el número de investigaciones durante el entrenamiento, ya que la mayoría de estudios analizan el control y el rendimiento en competición.

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10.1.2. Artículo 2: «Diferencias entre triatletas masculinos y femeninos en las respuestas fisiológicas de un test máximo incremental y una competición simulada»

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DIFERENCIAS EN LAS RESPUESTAS FISIOLÓGICAS ENTRE TRIATLETAS MASCULINOS Y FEMENINOS

PHYSIOLOGICAL RESPONSES DIFFERENCES BETWEEN MALE AND FEMALE TRIATHLETES

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RESUMEN

Los objetivos de este estudio fueron analizar las diferencias entre triatletas masculinos y femeninos amateurs en el rendimiento en un test incremental máximo y en una competición simulada y describir si existe asociación entre el rendimiento en el test máximo incremental y la prueba simulada de competición. Un total de catorce triatletas recreacionales, 8 mujeres

(35,0 ± 8,1 años; 166,8 ± 7,2 cm; 69,4 ± 14,6 kg; 24,7 ± 3,2 kg·m^{-2}) y 6 hombres (47,7 ± 14,3 años; 179,9 ± 8,6 cm; 77,8 ± 5,8 kg; 24,0 ± 1,3 kg·m^{-2}) realizaron un test incremental máximo y una competición simulada (20 km bici y 5 km carrera a pie). A pesar de que no se observaron diferencias significativas entre el grupo masculino y femenino en el test máximo incremental, a efectos prácticos, el grupo masculino obtuvo valores mayores para VO_2max, Pmax, PVT1, PVT2 y VO_2VT2 (p > 0,05, ES = -0,8 a -1.9, alto). Con respecto a la competición simulada, si bien no se obtuvi-eron diferencias en función de sexo en los 5 km de carrera, el grupo femenino obtuvo valores significativamente inferiores para las variables velocidad (media y máxima) (p < 0,05 y p < 0,01, ES = -1,3 – -4,1, alto) y potencia (media y máxima)(p < 0,01, ES = -2.4 – -2.8, alto) durante los 20 km de ciclismo, así como un tiempo de ejecución del sector ciclista significativamente mayor que el grupo masculino (p < 0,01, ES = 1,6, alto). Por otro lado, un mejor rendimiento durante el test máximo incremental se asoció a un mejor rendimiento durante los 20 km de ciclismo en el grupo masculino (r = 0,848, p < 0,05), mientras que en el grupo fe-menino se asoció tanto a los 20 km en bici como a los 5 km corriendo (r = -0,714 a -0,822, p < 0,05). Los resultados obtenidos en el estudio ponen de manifiesto que los triatletas masculinos tienen un mejor rendimiento en un test incremental máximo y en el sector de ciclismo en una competición simulada y que la asociación entre el rendimiento en un test incremental y el rendimiento en los sectores de la prueba simulada depende del sexo.

Palabras clave: rendimiento, consumo máximo de oxígeno, potencia, umbral ven-tilatorio, ciclismo, carrera.

ABSTRACT

The current study focused on the differences between male and female non-professional triathletes during a maximal incremental test on the cycle ergometer, as well as, the cycle and run portion of a simulated sprint triathlon. In addition, this research analysed the during association between cycle ergometer maximal incremental test and simulated race variables.

Fourteen recreational triathletes, 8 female (35.0 ± 8.1 years; 166.8 ± 7.2 cm; 69.4 ± 14.6 kg; 24.7 ± 3.2 kg·m^{-2}) and 6 male (47.7 ± 14.3 years; 179.9 ± 8.6 cm; 77.8 ± 5.8 kg; 24.0 ± 1.3 kg·m^{-2}) performed a maximal incremental test and a simulated sprint triathlon race (20 km cycle and 5 km run. No significant differences were found during maximal testing between groups, however, males obtained higher VO_2max, Pmax, PVT1, PVT2 and VO_2VT2 (p > 0.05, ES = -0.8 to -1.9, large values than females. No differences between gender were observed during 5 km running during the simulated triathlon. Average and maximal speed (p < 0.05 y p < 0.01, ES = -1.3 – -4.1, large and average and maximal power (p < 0.01, ES = -2.4 – -2.8, large during the 20-km cycling were significantly lower in the female group, whereas, time to complete the 20 km (p < 0.01, ES = 1.6, large was significantly longer than the male triathletes.

Male triathletes who obtained greater values during the maximal test, presented a superior 20 km cycling performance. Females who presented larger values during the maximal test accomplished superior performances during both cycling and running simulated tests. These results suggest that recreational male triathletes may present a greater performance during maximal cycle ergometer test and during 20 km cycling simulation than female and the association between a maximal incremental test and simulated triathlon performances might depend on the triathlete's gender.

Key words: Performance, maximal oxygen consumption, power, ventilatory threshold, cycling, running.

INTRODUCCIÓN

El triatlón es una modalidad deportiva compleja compuesta por tres sub disciplinas: la natación, el ciclismo y la carrera a pie. En la actualidad, existen competiciones con una importante diferencia en cuanto a las distancias a realizar en cada prueba. Mientras que en el caso del triatlón de corta distancia (pruebas sprint) los deportistas deben de realizar 750 m nadando, 20 km en bici y 5 km de carrera a pie (1), cuya duración aproximada puede rondar entre los 50-60 min, en el caso de las pruebas de larga distancia (pruebas Ironman) los deportistas deben de recorrer hasta 3,8 km nadando, 180 km en bici y 42 km de carrera a pie (1), pudiendo llegar la duración de las pruebas hasta 17 h. En el caso de los triatletas de élite, suele ser común que se especialicen en una sola distancia o modalidad, mientras que los triatletas recreacionales suelen competir en formatos de distinta distancia en una misma temporada. Este aspecto puede dificultar el proceso de entrenamiento en triatletas de categoría amateur presentando diferentes respuestas fisiológicas, y por lo tanto una disparidad de requerimientos fisiológicos a entrenar, dependiendo de la distancia de la competición. Posiblemente por estas diferencias en la especialización de la competición, muchos autores se han centrado durante los últimos años en analizar cuáles son los factores determinantes del rendimiento no solo en triatletas de élite (2, 3) sino también en triatletas amateurs (4, 5).

A pesar de que el triatlón es un deporte en auge y practicado por más de 30.000 personas en España, únicamente el 19.6 % de las licencias son de mujeres (6). Esta disparidad en la práctica en función del sexo también se ve reflejada en la literatura científica ya que la gran mayoría de estudios se han centrado en el análisis del rendimiento en triatletas masculinos (5, 7-11). Aunque existe una importante cantidad de trabajos científicos que han estudiado las diferencias en el rendimiento físico debidas al sexo en otros deportes de resistencia (12-18), en el caso del triatlón, este tipo de estudios son mucho más escasos (2-4, 19). Concretamente en triatletas de élite, se han descrito diferencias entre triatletas masculinos y femeninos en el rendimiento en test máximos y submáximos en condiciones de laboratorio, obteniendo los hombres mejores valores de consumo de oxigeno máximo (VO_2max) y potencia máxima que las mujeres (3, 19). Estas diferencias parecen ser debidas a aspectos tanto antropométricos, como por ejemplo la menor acumulación de masa grasa, como a aspectos fisiológicos relacionados, por ejemplo con mayores niveles de concentración de hemoglobina y mayor cantidad de fibras musculares en el caso de los hombres (19). Sin embargo, hasta el momento, únicamente una investigación se ha centrado en el análisis de estas diferencias atendiendo al sexo en triatletas recreacionales (4). Los resultados de este estudio mostraron similitudes entre triatletas masculinos y femeninos para el VO_2max, la potencia máxima y el porcentaje del VO_2max obtenido en el umbral ventilatorio durante un test máximo. Por otro lado, a pesar de que Stevenson et al. (2013) analizaron las diferencias en función del sexo en el rendimiento en triatlones de distintas distancias en triatletas no profesionales, que nosotros conozcamos, no se han publicado estudios que se centren en las diferencias entre ambos sexos en una prueba simulada.

Por otro lado, en la literatura científica existen estudios centrados en analizar la posible relación entre los test tanto máximos como submáximos desarrollados en el laboratorio con el rendimiento deportivo en competición (17, 18, 20). Concretamente en triatletas de nivel nacional, parece existir una es-trecha relación entre variables fisiológicas y el rendimiento final de un triatlón de distancia estándar (2, 3). Millet et al. (2004) observaron que la potencia pico obtenida durante un test en cicloergómetro y el gasto energético durante una carrera en tapiz realizada después del sector ciclista, eran variables asociadas con el rendimiento final de un triatlón en triatletas femeninas profesionales (2) Sin embargo, en el caso de triatletas masculinos, observaron que el umbral ventilatorio estaba asociado al rendimiento competitivo (2). En la misma línea, Schabort et al. (2000) observaron que la acumulación de lactato correspondiente a la potencia relativa de 4 $W \cdot kg^{-1}$ durante un test en cicloergómetro, juntamente con la velocidad pico alcanzada en el tapiz rodante durante un test máximo de carrera, eran las mejores variables indicadoras del rendimiento de triatletas de nivel nacional en un triatlón olímpico o estándar (3). A pesar de que los estudios mencionados anteriormente han analizado algunas asociaciones entre el rendimiento en test de laboratorio y competición o pruebas simuladas, únicamente hemos encontrado un estudio donde se analiza la asociación existente entre el rendimiento en test máximos incrementales de laboratorio y pruebas de competición o simuladas de competición. Dicho estudio, concluye que el rendimiento durante un triatlón de una distancia de 1 km de natación, 30 km de ciclismo y 9 km de carrera a pie puede estar relacionado con diferentes variables fisiológicas como el VO_2max absoluto y relativo, el % VO_2max en el VT y la potencia o velocidad correspondiente al VT. Estos autores exponen que estas asociaciones dependen del nivel y del sexo del triatleta (4). Teniendo en cuenta la escasez de estudios publicados en la literatura que analizan este aspecto, parece necesario realizar más estudios científicos que permitan acercarse a un mayor nivel de evidencia sobre las asociaciones entre test máximos incrementales y el rendimiento en triatlón.

OBJETIVOS

Por lo tanto, los objetivos de este estudio fueron, por un lado, analizar las diferencias entre triatletas masculinos y femeninos amateurs en el rendimiento en un test incremental máximo y en una competición simulada (20 km bici y 5 km carrera a pie), y por otro lado, analizar si existe asociación entre el rendimiento en el test máximo incremental y la prueba simulada de competición.

MATERIAL Y MÉTODO

Participantes

Catorce triatletas recreacionales (40,4 ± 12,5 años; 172,4 ± 10,1 cm; 73,0 ± 12,1 kg; 24,4 ± 2,5 kg·m^{-2}) tomaron parte en el estudio. Del total de partici-pantes, ocho eran mujeres (35,0 ± 8,1 años; 166,8 ± 7,2 cm; 69,4 ± 14,6 kg; 24,7 ± 3,2 kg·m^{-2}) y 6 hombres (47,7 ± 14,3 años; 179,9 ± 8,6 cm; 77,8 ± 5,8 kg; 24,0 ± 1,3 kg·m^{-2}). Todos los participantes competían asiduamente a nivel regional (Sur de Australia) y entrenaban activamente en triatlón, ciclismo y/o carreras de distancias medias y largas. Los criterios de inclusión considerados para la participación en el estudio fueron que los triatletas estuvieran entrenando de manera estructurada para una competición en alguna de las distancias que conforman el triatlón, que poseyeran una experiencia mínima de dos años en competiciones de triatlón, que hubiesen finalizado un triatlón sprint en un tiempo comprendido entre 75 y 105 min en los 6 meses anteriores a la investigación y que no presentaran ningún tipo de lesión que impidiera la participación en el estudio. Antes de iniciar la investigación a todos los participantes se les informó sobre los protocolos y test que se realizarían en el estudio y todos ellos firmaron un consentimiento informado. El estudio fue revisado y aprobado por el Southern Adelaide Clinical Human Research Ethics Committee (HREC, código 334.16) de la Universidad de Flinders (Adelaida, South Australia), el cuál seguía los principios éticos establecidos en la Declaración de Helsinki (2013).

Procedimiento

Las mediciones se realizaron en el laboratorio de fisiología de la Universidad de Flinders (Adelaida, South Australia). En una única sesión, los participantes acudieron al laboratorio y se midieron las variables antropométricas en primer lugar. Seguidamente, realizaron un test incremental, progresivo y maximal hasta la extenuación volímica en el cicloergómetro. Después de descansar 60 min en el mismo laboratorio, los triatletas realizaron un test simulado de competición realizando 20 km en cicloergómetro, tres min de transición y 5 km de carrera a pie en un tapiz rodante siguiendo el protocolo establecido por Etxebarria et al. (2014). La temperatura media del laboratorio fue de 15,8 ± 2,8 °C y la humedad relativa del 63,4 ± 7,4%. Antes del test incremental, los triatletas realizaron un calentamiento que consistió en 10 minutos eligiendo la potencia, cadencia y velocidad del cicloergómetro según sus preferencias y hábitos de entrenamiento.

Una vez pasados 50 minutos desde la finalización del test máximo incremental, los participantes realizaban un segundo calentamiento a modo de activación durante 10 minutos, en los cuáles podían elegir tanto la potencia, cadencia y velocidad que prefirieran. A todos los participantes, se les indicó que no realizaran ejercicio intenso y no tomaran cafeína ni bebidas alcohólicas 24 h antes de la sesión de test. Asimismo, durante los test y los descansos podían consumir su bebida isotónica habitual y agua. Antes de empezar los test en cicloergómetro, se sustituyeron los pedales del cicloergómetro por los aquellos que cada atleta utilizaba en su propia bicicleta y se ajustaron las medidas biomecánicas (manillar, altura y retroceso del sillín), para intentar reproducir la postura y el pedaleo habitual durante los entrenamientos y las competiciones.

Mediciones

Antropometría: Se midió la altura de los participantes con un tallímetro (Seca 220, Hamburgo, Alemania) y la masa corporal mediante una báscula (Seca 813, Hamburgo, Alemania). Seguidamente, siguiendo el protocolo de la Internation-al Society for the Advancement of Kinanthropometry (ISAK), se realizaron tres mediciones de los pliegues tricipital, subescapular y bicipital con un plicómetro (Harpenden Baty, West Sussex, Reino Unido). Para el análisis estadístico posterior, se tomó el valor de la mediana de los tres valores obtenidos en cada pliegue. El error técnico de medición (ETM) entre las tres repeticiones fue calculado atendiendo al procedimiento descrito por Gore et al. (1996), obteniéndose valores inferiores al 5% (21). Finalmente se midieron los perímetros de cintura y de cadera de cada participantes con una cinta antropométrica (Seca 201, Hamburgo, Alemania) siguiendo el protocolo establecido por Norton et al. (1996) (22).

Test incremental máximo en cicloergómetro: En este estudio se utilizó el protocolo establecido por Bentley et al. (2007) para triatletas y realizado en un cicloergómetro (Wattbike Trainer, Nottingham, Reino Unido). El test incremental daba comienzo pedaleando a una potencia de 80 W para las triatletas femeninas y 100 W para los triatletas masculinos (23). Posteriormente, se incrementaba la potencia en 20 W cada minuto hasta la extenuación. El test se daba por terminado cuando el sujeto era incapaz de mantener la potencia asignada al intervalo o cuando comunicaba a los investigadores la incapacidad de continuar (24). La potencia (P) se registró en cada intervalo usando un software específico Wattbike (Nottingham, Reino Unido. La frecuencia cardíaca (FC se registró constantemente durante todo el test mediante un pulsómetro (Polar RS400, Kempele, Finlandia). Durante toda la prueba se registró el intercambio gaseoso mediante un analizador de gases (TrueOne2400, ParvoMedics, Utah, EEUU). Teniendo en cuenta el método propuesto para el cálculo de umbrales ventilatorios expuesto por Chicharro et al. (2000) y por Bentley et al. (2005), el primer umbral ventilatorio (VT1) se consideró en el momento en que la ratio de ventilación-volumen de oxígeno (VE/VO_2 y la presión del flujo final de oxígeno ($PETO_2$) comenzaban a incrementar sin el correspondiente incremento de la presión de flujo final de dióxido de carbono ($PETCO_2$ y el segundo umbral ventilatorio (VT2) se consideró al producirse una disminución del $PETCO_2$ conjuntamente con un incremento de la ratio de ventilación-volumen del dióxido de carbono (VE/VCO_2) (24, 25)

Prueba simulada de competición: Los triatletas realizaron en el laboratorio una simulación de competición utilizando un protocolo adaptado de Etxebarria et al., (5) (2014) con el objetivo de analizar el rendimiento en los sectores de ciclismo, transición y carrera. La simulación de la competición fue la siguiente: a) 20 km de ciclismo contrarreloj en un cicloergómetro (Wattbike Trainer, Nottingham, Reino Unido), b) una transición de 3 min en la que los triatletas se cambiaron las zapatillas de ciclismo por las de carrera a pie y c) 5 km corriendo en un tapiz rodante (Trackmaster TMX58, Kansas, EEUU) (26). A todos los participantes se les indicó que deberían completar cada segmento en el menor tiempo posible, teniendo la opción de modificar la resistencia del cicloergómetro y la velocidad de la cinta tantas veces como necesitaran. La FC fue registrada de manera continua durante toda la prueba con el pulsómetro antes mencionado. En el sector de ciclismo, la P (W), la velocidad ($km \cdot h^{-1}$), las cadencias medias y máximas (rpm) y el tiempo (min) empleado en realizar los 20 km fueron obtenidas mediante el software del cicloergómetro. En el sector de carrera, se obtuvo el tiempo total (min), la velocidad máxima y la velocidad media ($km.h^{-1}$) alcanzada por cada triatleta durante los 5 km mediante el software del tapiz rodante. Tanto en el sector de ciclismo como en el de carrera se registró la percepción subjetiva del esfuerzo (RPE) mediante la escala de Borg adaptada (27), compuesta por 10 categorías fácilmente identificables durante el esfuerzo y mostrándola visualmente al participante cada 10 minutos durante toda la simulación.

Análisis estadístico

Los resultados se presentan como media ± desviación típica (DT) de la media. Para calcular las diferencias entre el grupo masculino y femenino en las distintas variables analizadas (antropometría, test incremental máximo y prueba de competición simulada) se utilizó una prueba t para muestras independientes. Además, se calculó el porcentaje de diferencia (Dif. %) y el tamaño del efecto (TE) (28) para conocer las diferencias a efectos prácticos entre los grupos. Tamaños del efecto (TE) menores a 0,2, entre 0,2-0,5, entre 0,5-0,8 o mayores de 0,8 fueron considerados trivial, bajo, moderado o alto, respectivamente (28) Las asociaciones entre las variables del test incremental máximo y la prueba simulada de competición se calcularon mediante la correlación de Pearson (r). Para la interpretación de las magnitudes de las correlaciones se utilizó la siguiente escala: menor que 0,1, trivial; de 0,1 a 0,3, baja; de 0,3 a 0,5, moderada; de 0,5 hasta 0,7, alta; 0,7-0,9, muy alta; mayor que 0,9, casi perfecta (29). El análisis de los datos se realizó mediante el paquete estadístico Statistical Package for Social Science (SPSS® Inc, versión 23.0 para Windows, Chicago, IL, EEUU). El nivel de significación se estableció en $p < 0,05$. En los casos en los que a pesar de que las diferencias fueran no significativas pero los TE fueran altos, (TE > 0,8) se consideraron diferencias a efectos prácticos.

RESULTADOS

Con respecto a las características antropométricas de los triatletas participantes en el estudio (Tabla 1), los resultados mostraron una mayor altura para el grupo masculino en comparación con el grupo femenino ($p < 0,01$, Dif. (%) = -7,3%, ES = -1,8, alto). Sin embargo, en el grupo de triatletas femenino se observaron significativamente mayores valores en el pliegue del bíceps y del tríceps en comparación con el grupo de triatletas masculino ($p < 0,05$ o $p < 0,01$, Dif. (%) = 86,6 - 87,0%, ES = 1.2-1.6, alto).

Tabla 1. Características antropométricas de todos los participantes del estudio y divididos por sexo (hombres y mujeres).

	Todos	Hombres	Mujeres	Dif. (%)	ES
Edad (años)	40,4 ± 12,5	47,7 ± 14,3	35,x ± 8,1	-26,6	-1,6
Características Antropométricas					
Altura (cm)	172,4 ± 10,1	179,9 ± 8,6	166,8 ± 7,2**	-7,3	-1,8
Masa (kg)	73,0 ± 12,1	77,8 ± 5,8	69,4 ± 14,6	-10,7	-0,6
IMC ($kg.m^{-2}$)	24,4 ± 2,5	24,0 ± 1,3	24,7 ± 3,2	2,8	0,2
Pliegue bíceps (mm)	6,9 ± 3,5	4,6 ± 2,0	8,6 ± 3,4*	87,0	1,2
Pliegue tríceps (mm)	12,2 ± 5,3	8,3 ± 3,1	15,5 ± 4,4**	86,6	1,6
Pliegue subescapular (mm)	15,0 ± 6,8	12,7 ± 3,6	16,7 ± 8,3	31,5	0,5
Perímetro cintura (cm)	80,3 ± 8,5	85,2 ± 6,1	76,7 ± 8,5	-9,9	-1,0
Perímetro cadera (cm)	97,6 ± 4,4	96,8 ± 3,6	98,2 ± 5,1	1,4	0,3

IMC = Índice de masa corporal; Dif. (%) = diferencia de medias en porcentaje; ES = tamaño del efecto.* $p < 0,05$ o ** $p < 0,01$ diferencias significativas con el grupo masculino.

Con respecto a los resultados obtenidos en el test máximo incremental llevado a cabo en cicloergómetro (Tabla 2), a pesar de que no se observaron diferencias significativas entre el grupo masculino y femenino para las variables máximas (VO_2max, FCmax y Pmax) y tampoco en la potencia y consumo de oxígeno en VT1 y VT2, a efectos prácticos, el grupo masculino obtuvo valores mayores para VO_2max, Pmax, PVT1, PVT2 y VO_2VT2 ($p > 0,05$, Dif. (%) = -6.2 a -18.9 %, ES = -0,8 a -1.9, alto)

Los resultados obtenidos por todos los participantes y por el grupo masculino y femenino correspondientes al test de simulación de competición se muestran en la Tabla 3. Durante los 20 km del sector de bicicleta, los triatletas masculinos consiguieron realizar los 20 km en un menor tiempo, alcanzar una mayor Velmax, realizarlo a una mayor Velmedia y generar una mayor Pmax y Pmedia ($p < 0,01$ ó $p < 0,05$, Dif. (%) = -30,4 a 9,9%, ES = -4,1 a 1,6, alto). No se obtuvieron diferencias significativas entre el grupo masculino y femenino, para los valores relacionados con la cadencia, la FC y el RPE ($p > 0,05$, Dif. (%) = -6,7 a 4,2, ES

= -0,9 a 0,2 bajo a alto). En el sector de la transición del ciclismo a la carrera, no se observaron diferencias significativas ni a efectos prácticos en las variables analizadas salvo en la FCmedia, donde el grupo femenino mostró un valor mayor que el grupo masculino (p > 0,05, Dif. (%) = 10,2%, ES = 1,1, alto). En el sector de carrera a pie (5 km), a pesar de que no se obtuvieron diferencias significativas entre ambos grupos, a efectos prácticos, el grupo de hombres fue capaz de alcanzar una mayor Velmax a lo largo de los 5 km (p > 0,05, Dif. (%) = -6,4%, ES = -1,1, alto). Finalmente, con respecto al tiempo total de la simulación de 20 km ciclismo, y 5 km de carrera a pie, a efectos prácticos, los triatletas masculinos emplearon menor tiempo para completar la prueba en comparación con el grupo de triatletas femenino, a pesar de que las diferencias no fueron significativas (p > 0,05, Dif. (%) = 7,2%, ES = 1,9, alto).

Tabla 2. Resultados obtenidos por todos los participantes, por el grupo de hombres y por el de mujeres en el test incremental máximo realizado en cicloergómetro.

	Todos	Hombres	Mujeres	Dif. (%)	ES
Máximos					
VO_2max (ml.kg^{-1}.min^{-1})	42,4 ± 4,8	44,9 ± 6,3	40,5 ± 2,4	-9,8	-1,9
FCmax (lpm)	172 ± 11	173 ± 12	172 ± 10	-0,1	0,0
Pmax (W)	256 ± 51	277 ± 54	241 ± 45	-12,7	-0,8
VT1					
PVT1 (W)	151 ± 31	167 ± 32	139 ± 25	-16,9	-0,9
VO_2VT1 (%)	68 ± 8,8	70,3 ± 10,6	66,3 ± 7,4	-5,8	-0,6
VT2					
PVT2 (W)	209 ±42	235 ± 41	190 ± 34	-18,9	-1,1
VO_2VT2 (%)	86,1 ± 6,2	89,3 ± 7,1	83,8 ± 4,4	-6,2	-1,3

VO_2max = consumo máximo de oxigeno; FCmax = frecuencia cardíaca máxima alcanzada; Pmax = potencia máxima alcanzada; VT1 = primer umbral ventilatorio, VT2 = segundo umbral ventilatorio; PVT1 = potencia correspondiente al primer umbral ventilatorio; PVT2 = potencia correspondiente al segundo umbral ventilatorio; VO_2VT1 = porcentaje de volumen de oxígeno máximo en el primer umbral ventilatorio; VO_2VT2 = porcentaje de volumen de oxígeno máximo en el segundo umbral ventilatorio, Dif. (%) = diferencia de medias en porcentaje; ES = tamaño del efecto.

Con respecto a la asociación entre los resultados obtenidos en el test incremental y el test simulado de competición para el total de la muestra, se observó una correlación negativa entre el VO_2max obtenido en el test incremental y el T20kmbike (r = -0,543, p < 0,05) (Figura 1A) y positiva con la Pmedia20kmbike (r = 0,608, p < 0,05) (Figura 1B) obtenidas durante el test de competición simulada.

También se observó una correlación negativa entre el VO_2VT2 y la FCmedia-transición (r= -0,676, p < 0,05) (Figura 1C) y entre el VO_2VT1 y el RPEmedia5k-mrun (r = -0,557 p < 0,05) (Figura 1D).

Tabla 3. Resultados obtenidos por todos los participantes, por el grupo de hombres y por el grupo de mujeres en el test de triatlón simulado (20 km de ciclismo, transición y 5 km de carrera a pie).

	Todos	Hombres	Mujeres	Dif. (%)	ES
Sector ciclismo					
$T20km_{bike}$ (min)	33,8 ± 2,3	32,0 ± 1,2	35,2 ± 2,0**	9,9	1,6
$Velmedia20km_{bike}$ (km/h)	35,3 ± 2,3	36,7 ±2,2	34 ± 1,9*	-6,6	-1,3
$Velmax20km_{bike}$ (km/h)	37,4 ± 2,4	39,5 ± 2,0	35,7 ± 0,9**	-9,5	-4,1
$Pmedia20km_{bike}$ (W)	182 ± 41	213 ±40	159 ± 22**	-25,2	-2,4
$Pmax20km_{bike}$ (W)	260 ± 62	311 ± 46	217 ± 34**	-30,4	-2,8
$Cadmedia20km_{bike}$ (rpm)	95 ± 7	98 ±4	92 ± 7	-6,7	-0,9
$Cadmax20km_{bike}$ (rpm)	106 ± 9	108 ± 8	103 ± 10	-4,9	-0,5
$FCmedia20km_{bike}$ (lpm)	157 ± 14	156 ± 16	157 ± 13	0,8	0,1
$FCmax20km_{bike}$ (lpm)	165 ± 12	165 ± 16	165 ± 10	-0,4	-0,1
$RPEmedia20km_{bike}$ (UA)	6 ± 2	6 ± 1	6 ± 2	4,2	0,2
Transición ciclismo - carrera a pie					
$FCmedia_{transición}$ (lpm)	118 ± 19	112 ± 11	123 ± 24	10,2	1,1
$RPEmedio_{transición}$ (UA)	3 ± 1	3 ± 1	3 ± 2	17,2	0,4
Sector carrera a pie					
$T5km_{run}$ (min)	29 ± 2,6	28,3 ± 2	29,5 ± 3	4,2	0,6
$Velmedia5km_{run}$ (km/h)	10,6 ± 1,0	11 ± 0,8	10,4 ± 1	-5,9	-0,8
$Velmax5k_{run}$ (km/h)	12 1,3	12.5 ± 0.7	11,7 ± 1,6	-6,4	-1,1
$FCmedia5km_{run}$ (lpm)	162 ± 11	161 ± 9	163 ± 13	1,1	0,2
$FCmax5km_{run}$ (lpm)	175 ± 8	176 ± 10	174 ± 8	-0,7	-0,1
$RPEmedia5km_{run}$	6 ± 2	6 ± 2	7 ± 2	16,9	0,5
$Ttotal20\ km_{bike} + 5km_{run}$ (min)	62,8 ± 4,3	60,3 ± 2,3	64,7 ± 4,6	7,2	1,9

Variables de ciclismo 20km: T20kmbike = Tiempo empleado para completar los 20 km; Velmedia20kmbike y Velmax 20kmbike = velocidad media y máxima; Pmedia20kmbikey Pmax20kmbike = Potencia media y máxima; Cadmedia20kmbike y Cadmax20kmbike = cadencia media y máxima; FCmedia20kmbike y FCmax20kmbike = Frecuencia cardíaca media y máxima; RPEmedia20kmbike= Percepción del esfuerzo media del tramo de ciclismo. Variables durante los 3 minutos de transición: FCmediatransición y RPEmediotransición= Frecuencia cardíaca media y percepción del esfuerzo medio. Variables de carrera 5km: T5kmrun = Tiempo empleado para completar los 5 km a pie; Velmedia5kmrun y Velmax5krun= velocidad media y velocidad máxima; FCmedia5kmrun y FCmax5kmrun = Frecuencia cardíaca media y máxima; RPEmedia5kmrun = Percepción del esfuerzo del tramo de carrera. Ttotal20kmbike+ 5kmrun = Tiempo total en completar el sector de ciclismo seguido de la carrera a pie.

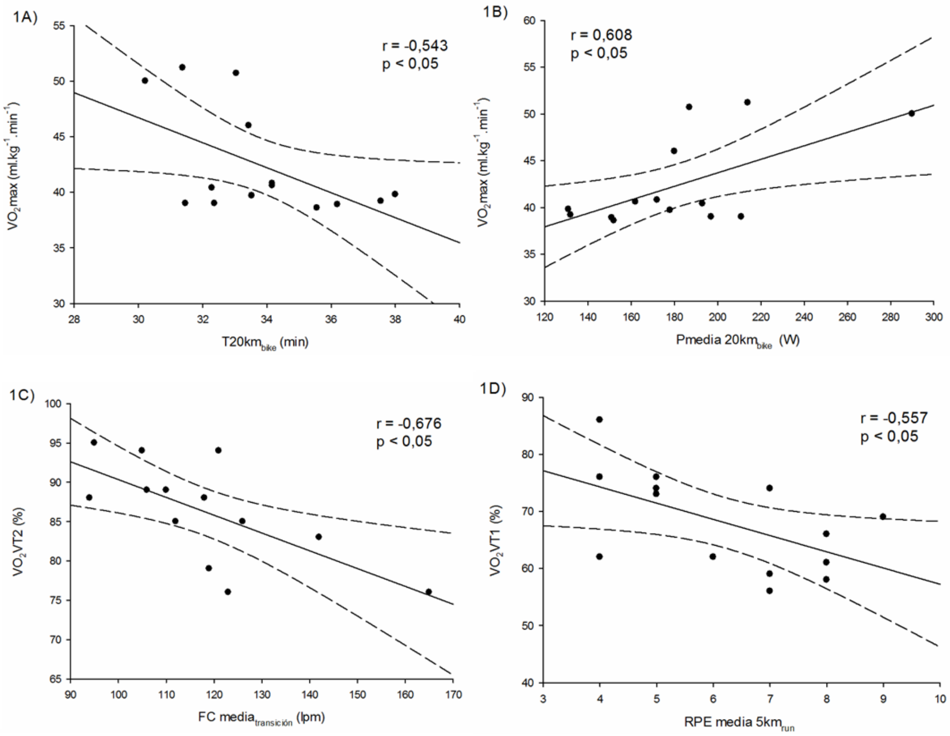

Figura 1. Correlaciones entre VO_2max y el T20kmbike (1A), entre el VO_2max y la Pmedia20kmbike (1B), entre el VO_2VT2 y la FCmediatransición(1C) y entre el VO_2VT1 y la RPE media5kmrun (1D) en el total de los participantes.
VO_2max = consumo máximo de oxigeno; T20kmbike = Tiempo empleado para completar; Pmedia20kmbike= Potencia media; VO_2VT2 = porcentaje de volumen de oxígeno máximo en el segundo umbral ventilatorio; FCmediatransición= Frecuencia cardíaca media; VO2VT1 = porcentaje de volumen de oxígeno máximo en el primer umbral ventilatorio; RPEmedia5kmrun = Percepción del esfuerzo del tramo de carrera. $^*p < 0,05$, $^{**} p < 0,01$, correlación significativa.

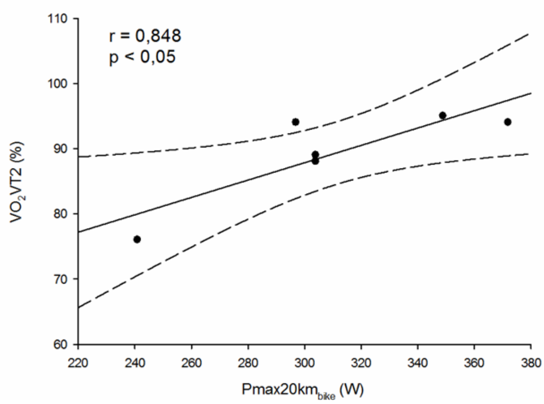

Figura 2. Correlaciones entre el VO_2VT2 y la Pmax20kmbike para el grupo masculino de triatletas.
VO2VT2 = porcentaje de volumen de oxígeno máximo en el segundo umbral ventilatorio; Pmax20kmbike= Potencia máxima. $^*p < 0,05$, $^{**} p < 0,01$ correlación significativa.

Con respecto a las asociaciones entre los resultados obtenidos en el test incremental y el test simulado de competición para el grupo de triatletas masculino, únicamente se observó una correlación significativa y positiva entre el VO_2VT2 y la Pmax 20kmbike durante el sector ciclista ($r = 0,848$, $p < 0,05$) (Figura 2).

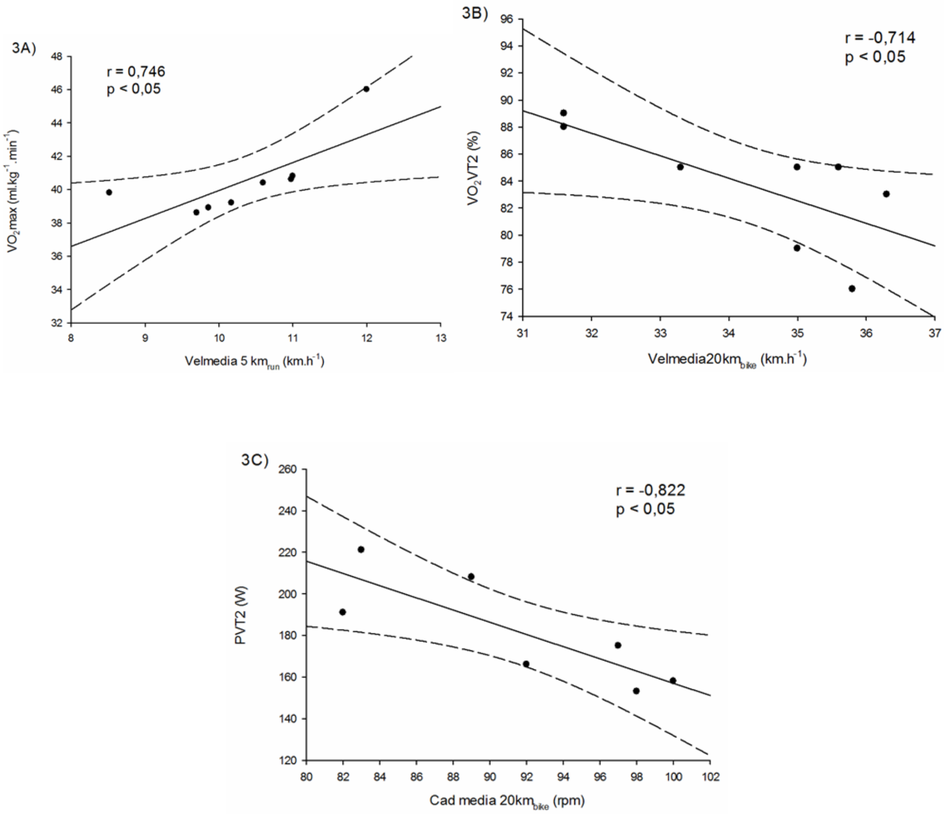

Figura 3. Correlaciones entre el VO_2max y la Velmedia5kmrun (3A), entre el VO2VT2 y el T20kmbike (3B) y entre la PVT2 y la Cadmedia20kmbike (3C) para el grupo femenino de trialtletas

VO_2max = consumo máximo de oxigeno; Velmedia5kmrun = velocidad media; VO_2VT2 = porcentaje de volumen de oxígeno máximo en el segundo umbral ventilatorio; T20kmbike = Tiempo empleado para completar los 20 km en bicicleta; PVT2 = potencia correspondiente al segundo umbral ventilatorio; Cadmedia20kmbike = cadencia media obtenida durante los 20 km de ciclismo. *$p < 0,05$, ** $p < 0,01$, correlación significativa.

Finalmente, con respecto al grupo femenino, se observó una correlación positiva entre el VO_2max y la Vmedia5kmrun ($r = 0,746$, $p < 0,05$) (Figura 3A), una correlación negativa entre el VO_2VT2 y la Velmedia20kmbike ($r = -0,714$, $p < 0,05$) (Figura 3B) y entre la PVT2 y la Cadmedia20kmbike ($r = -0,822$, $p < 0,05$) (Figura 3C).

DISCUSIÓN

El objetivo principal del presente estudio fue analizar las diferencias entre triatletas masculinos y femeninos en el rendimiento en un test máximo incremental y en una prueba de competición simulada (20 km sector ciclismo, transición y 5 km sector carrera). Además, otro de los objetivos del estudio fue analizar la asociación entre el rendimiento en el test incremental y el test simulado de competición. A pesar de que las diferencias en el rendimiento fisiológico atendiendo al sexo han sido analizadas en triatlón (2-4, 30) que nosotros conozcamos, esta investigación es la primera que analiza las diferencias entre triatletas masculinos y femeninos de nivel amateur. De la misma forma, a pesar de que la asociación entre pruebas incrementales y test simulados de competición ha sido analizadas en triatletas de élite (2, 3), no hemos encontrado ningún estudio al respecto en triatletas amateurs.

En la literatura científica se ha expuesto que el sexo puede ser un elemento diferenciador en el rendimiento mostrado por deportistas de distintas modalidades de resistencia (esquiadores de fondo, ciclista, atletas de maratón) en pruebas de laboratorio que miden la capacidad cardiovascular (12, 31, 32). La mayor parte de investigaciones apuntan a que en deportistas de resistencia, los hombres obtienen mayores niveles de VO_2max que las mujeres (12, 31, 32). Los resultados obtenidos en el presente estudio en el test máximo incremental en el cicloergómetro, mostraron que, a pesar de que las diferencias no fueron significativas, a efectos prácticos, el grupo masculino presentó valores mayores que el grupo femenino no solo en el VO_2max, sino también en la Pmax, PVT1, PVT2 y VO_2VT2 ($p > 0,05$, Dif. (%) = -6.2 a -18.9%, ES = -0,8 a -1.9, alto). Estos resultados concuerdan con resultados obtenidos en anteriores estudios en otras modalidades de resistencia (12, 31, 32). (12), durante un test incremental en el cicloergómetro, observando diferencias significativas entre ambos sexos en ciclistas competitivos de nivel regional y nacional en variables cómo la potencia aeróbica máxima (27.5%), la potencia generada en el umbral de lactato (40.4%), la potencia en OBLA (34.4%) o el VO_2max (20.2%) (12). En la misma línea, Sandbakk et al. (2012) (31) observaron que la velocidad pico (17%), la potencia pico (62%) y el VO_2max (59%) presentaban diferencias significativas en función del sexo en esquiadores de fondo (31). Por su parte, Maughan et al. (1983) (32) observaron que los corredores de maratón masculinos registraban un VO_2max más alto que las corredoras femeninas en maratonianos no profesionales (14,9%) durante un test máximo realizado sobre tapiz rodante (32). Referente al triatlón, previos estudios han analizados las variables fisiológicas entre hombres y mujeres triatletas (2-4). Millet et al. (2004) (2) apreciaron diferencias entre ambos sexos para el VO_2max (19,5% y 17,9%), para la potencia pico (24.3% y 23.9%) y para el % VO_2max en el VT (3,5% y 4,1%) en categorías junior y senior, respectivamente. De manera similar, Schabort et al. (2000) (3) observaron diferencias del 26.8% y del 12,3% para las variables VO_2max durante un test incremental en el cicloergómetro. Finalmente, Sleivert et al. (1993) (4) obtuvieron diferencias para la variable VO_2max (15.0%), %VO_2max en el VT (8.1%) y potencia en el VT (37.3%) durante un test máximo incremental en el cicloergómetro, siendo los valores más elevados en el caso de los hombres. Estas diferencias entre sexos pueden explicarse debido a una mayor concentración de masa muscular, una mayor fuerza muscular y una menor acumulación de masa grasa relativa por parte de los triatletas masculinos (3, 33). En la misma línea, Lepers et al. (2013) hallaron que una menor acumulación relativa de masa grasa (un 5% en el caso de triatletas masculinos y un 13% en féminas), juntamente con una mayor concentración de hemoglobina (alrededor de un 5-10% más en los triatletas masculinos), entre otros factores, podrían ser los motivos de las diferencias encontradas en el rendimiento cardiovascular entre ambos sexos (19, 33, 34).

Además del análisis de las diferencias en función de sexo en el rendimiento en una prueba incremental máxima, aspecto que ha sido abordado ampliamente en la literatura científica (2-4, 12, 31, 32, 35, 36), desde un punto de vista más práctico, puede resultar especialmente relevante conocer si estas diferencias también se dan en pruebas más similares a la competición. A pesar de la importancia que podría tener conocer estas diferencias, no hemos encontrado ninguna evidencia sobre el estudio de las diferencias entre sexos durante una prueba de triatlón simulada en triatletas amateurs. Los resultados obtenidos en nuestro estudio muestran que los triatletas masculinos consiguieron realizar los 20 km del sector de ciclismo en un menor tiempo, alcanzaron una mayor velocidad media y máxima y consiguieron generar una mayor potencia tanto media como máxima comparado con las triatletas femeninas. Durante la transición, el grupo de mujeres mostró un valor mayor de FCmedia en comparación con el grupo masculino (TE = 1,1), mostrando una menor capacidad de recuperación una vez finalizado el sector ciclista. Contrariamente, en el sector de carrera a pie, no se obtuvieron diferencias significativas entre ambos grupos. Teniendo en cuenta la simulación completa (20 km sector ciclista + 5 km sector carrera), a pesar de que las diferencias no fueron significativas, a efectos prácticos, los resultados indicaron que los triatletas masculinos emplearon menor tiempo para completar la prueba en comparación con el grupo de triatletas femenino (Ver Tabla 3). Estos resultados coinciden con los obtenidos en otros estudios en competición. Según el estudio realizado por Lepers et al. (2013), la diferencia media del rendimiento general en un triatlón entre hombres y mujeres se sitúa en torno a un 10-14% (19), valor similar al obtenido en la diferencia entre hombres y mujeres en el tiempo empleado en el sector 20 km ciclismo (10%) y en el sector 20 km ciclismo + 5 km carrera a pie (7%). No obstante, parece ser que las diferencias dependen del sector analizado (19, 36). Lepers et al. (2013) expone que el sector de natación (no analizado en este estudio) es el sector en el que menos diferencias se observan entre hombres y mujeres y sin embargo en los sectores de ciclismo y carrera de un Ironman las diferencias fueron del 12-16% y del 13,3% respectivamente (19). Los resultados obtenidos en nuestro estudio exponen que las diferencias entre ambos grupos en la prueba simulada se dan en el sector de ciclismo, pero no en el de carrera. Millet et al. (2004) en la misma línea que los resultados obtenidos en nuestro estudio, concluyen que en triatletas femeninas tanto profesionales como amateurs, así como de categoría senior o junior, puede ser especialmente relevante el entrenamiento específico del sector ciclista para la mejora del rendimiento de un triatlón o prueba simulada (2). En el presente estudio, el hecho de no observarse diferencias significativas en el sector de carrera entre ambos grupos podría estar relacionado con las condiciones en las que se desarrolló la prueba, la distancia recorrida y el nivel de los triatletas. Teniendo en cuenta que se encontraron diferencias entre hombres y mujeres triatletas en el sector de carrera en competición, (2, 19), podría ser interesante realizar estudios que confirmen si estas diferencias en el sector de carrera a pie en pruebas simuladas dependen de la distancia recorrida.

Por otro lado, anteriores estudios han analizado la asociación existente entre el rendimiento en test incrementales y el rendimiento en competición o pruebas simuladas de competición (2-4, 36). Se ha observado que un mejor ren-dimiento en un test incremental puede estar asociado al rendimiento deportivo en competición (2, 3, 19). En el presente trabajo, teniendo en cuenta el total de participantes, se obtuvo que los deportistas con un valor superior de VO_2max estaba asociado a un menor tiempo y una mayor Pmedia en la prueba de 20 km de ciclismo. Asimismo, se observó que los triatletas con un mayor VO_2VT2 durante el test máximo en cicloergómetro tenían una menor FCmedia durante la transición de la simulación. Dichos resultados ponen de manifiesto que una mejor capacidad cardiovascular puede ser beneficiosa para el rendimiento en una simulación de triatlón durante el sector de ciclismo y permite una mejor recuperación durante la transición, y por lo tanto empezar el sector de carrera a pie con menos desgaste energético (2).

Además de las asociaciones para todos los participantes, una de las novedades de este estudio es el análisis de las asociaciones entre una prueba máxima incremental y una prueba simulada en el laboratorio en función del sexo. Mientras que el grupo masculino mostró solamente una relación entre el VO_2VT2 y la Pmax 20kmbike, en el grupo femenino se observó que las triatletas con un valor superior de VO_2max eran capaces de mantener una mayor Velmedia durante los 5 km de carrera a pie ($r = 0,746$, $p < 0,05$), y que las participantes que obtenían una mayor PVT2 durante el test máximo en cicloergómetro, utilizaban una Cadmedia20kmbike menor. Contrariamente a los resultados obtenidos en el presente estudio, Sleivert et al. (1993) no observaron relaciones entre las variables fisiológicas obtenidas de un test máximo en cicloergómetro con el rendimiento del sector ciclista en un triatlón corto (1 km natación, 30 km ciclismo, 9 km carrera) en triatletas recreacionales. Sin embargo, el tiempo empleado para el sector de carrera sí que presentaba relaciones significativas con el VO_2max y la velocidad en el VT en el grupo femenino. Por su parte, en los triatletas masculinos se observó una relación entre el tiempo en completar el triatlón y la velocidad en el VT durante el test máximo sobre el tapiz rodante al igual que en estudios precedentes (4). Los resultados obtenidos en el presente estudio muestran que a pesar de que en triatletas masculinos tener una mejor capacidad cardiovascular puede influir en el rendimiento en el sector ciclista y no en la carrera a pie, en el caso de las triatletas una mejora del rendimiento en un test incremental puede estar asociado a un mejor rendimiento en la prueba de 5 km en carrera a pie. La mejora del rendimiento en un test incremental podría estar asociada al rendimiento en una prueba simulada de forma diferenciada según el sexo de los triatletas.

CONCLUSIONES

Los resultados obtenidos en el presente estudio en el test máximo incremental muestran que a pesar de que las diferencias entre triatletas masculinos y femeninos no fueron significativas, a efectos prácticos el grupo masculino presentó valores absolutos superiores para VO_2max, Pmax, PVT1, VT2 y en el VO_2VT2. En la prueba simulada de competición, no se obtuvieron diferencias en el sector 5 km carrera a pie entre triatletas masculinos y femeninos, manifestándose dichas diferencias en el sector de 20 km en ciclismo. Este aspecto pone de manifiesto que las diferencias en el tiempo total empleado en la competición simulada podrían ser debidas específicamente a uno de los sectores de la prueba, el ciclismo.

Respecto a la asociación entre el rendimiento en el test incremental y la prueba simulada, los resultados de este estudio ponen de manifiesto que un valor de VO_2max superior puede estar asociado con un menor tiempo y una potencia media superior durante los 20 km de ciclismo. Además, un valor de VO_2VT2 mayor se relaciona con una menor FCmedia durante la transición. Además, diferenciando la muestra en función del sexo, los resultados obtenidos muestran que un mejor rendimiento en el test incremental está asociado un mejor rendimiento en el sector 20 km ciclismo para los triatletas y con el sector 5 km carrera a pie en el caso de las triatletas. Estos resultados apuntan a que la mejora del rendimiento en un test incremental puede estar asociado al rendimiento en una prueba simulada de forma distinta en triatletas masculinos que en femeninos.

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10.1.3. Artículo 3: «Comparison of Reduced-volume high-intensity interval training and high-volume training on endurance performance in triathlon»

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Human Kinetics
ORIGINAL INVESTIGATION

Comparison of Reduced-Volume High-Intensity Interval Training and High-Volume Training on Endurance Performance in Triathletes

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Purpose: To investigate changes in physiological and performance variables in triathletes following a 4-wk period of reduced training volume and increased training intensity. ***Methods:*** Sixteen moderately trained triathletes were randomly allocated to 2 groups: a control (CON) group, which followed their usual training, or a high-intensity interval training (HIIT) group, which completed 2 HIIT sessions per week during 4 wk of reduced training volume ***Results:*** Maximal oxygen consumption (VO_2max) increased significantly in the HIIT group ($P = .03$, $d = 0.5$) but remained unchanged in the CON group. Cycling power at first and second ventilatory thresholds increased significantly in the HIIT subjects ($P = .03$, $d = 1.0$) and was unchanged in the CON participants ($P = .57$). During the simulated triathlon test, pretest–posttest cycling times and average power were unchanged in both groups ($P > .05$). No significant interactive effects between groups were observed for running time ($P = .50$). ***Conclusion:*** After a 4-wk HIIT program, VO_2max and power at first and second ventilatory thresholds were found to have increased significantly while cycling and running performance were unchanged, despite an overall reduction in training time. In the present study, performance was only shown to improve with usual (high-volume) training. Summarizing, in order to improve running or cycling performances, high-volume training programs are highly recommended.

Keywords: intermittent training, VO_2max, ventilatory thresholds, time trial

As athletes strive to improve physical fitness and performance, there is greater pressure to push the boundaries of exercise training. This often manifests itself as increased training volume, especially training time, but also, for example, incorporation of cross-training and specificity of training such as transition drills for triathletes.[1] Eventually, there comes a point where athletes cannot train longer because higher volumes of training are associated with health problems such as compromised immunity and overuse injuries.[2] There is also the constant problem of finding enough time for physical training yet also ensuring periods for optimal recovery and physiological adaptation.[3] Therefore, a common objective of coaches and scientists is to find more efficient ways to optimize performance outcomes for athletes while minimizing the risk of overtraining and injury.

Recently, the effects of short periods of intensified, or high-intensity interval training (HIIT), in athletes have become popular and underpinned by research studies showing it to be an effective method of training,[1,4,5] although not in all studies.[6] HIIT is a training method structured as repeated bouts (repetitions) of vigorous-intensity exercise of between 10 seconds and 5 minutes duration, separated by lower-intensity recovery periods.[7] Previous authors have examined both short-duration sets (from 10 to 60 s at maximal and supramaximal intensities) and long-duration sets (from 2 to 5 min at submaximal intensities),[1,2,5,8] while durations between 1 and 2 minutes at maximal intensities need further investigation. It is common for athletes to incorporate HIIT performed at intensities greater than the anaerobic threshold for training sessions of 20 to 40 minutes total duration.[1,9] Typical endurance training incorporates a significant number of hours (elevated training volume) of subthreshold-intensity exercise to observe physiological and biochemical adaptations to enhance aerobic performance.[10] However, it is unclear whether HIIT training may be able to achieve larger improvements in aerobic capacity (maximal oxygen consumption [VO_2max]) or endurance performance by building on work and recovery sets at or close to maximum intensities.[7,11] A number of researchers have concluded that HIIT shows a greater increase in VO_2max when compared with continuous endurance training in running.[12–14] However, Hottenrott et al[12] did not observe any significant differences in half marathon performance following either HIIT or lower-intensity endurance training. Therefore, there is still some controversy surrounding the efficacy of HIIT for endurance performance improvement in athletes.

Besides VO_2max, several studies have considered a number of physiological variables obtained from laboratory tests on endurance athletes. Peak aerobic power output (PO), time to fatigue at different supramaximal intensities, ventilatory threshold (VT), lactate accumulation, and oxidative enzymes activity are common physiological variables, which frequently show significant enhancements on highly trained and recreational cyclist,[9] whereas running economy, running speed associated with onset of blood lactate accumulation, peak treadmill speed together with VT, and capillarization and oxidative enzyme activity were usually increased in different levels of runners after HIIT sessions.[9,15] Most of these researches also collected performance variables such as time to complete, rating of perceived exertion (RPE), maximum and average heart rate (HR) during running or cycling time trial (CTT) or race simulation.[6,9,16–19] Referring to triathlon, Etxebarria et al[1] observed a moderate increase in VO_2max values with a significant improvement in maximal aerobic power and maximal repeat sprint ability during a 1-hour variable power

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cycling, simulating the cycling section of a triathlon race where the pace is varied, after 3 weeks of HIIT program. Likewise, 5-km run ability improved significantly following 6 sessions of cycle HIIT sessions.[1] Despite this article observing specific performance variables, no previous researches were found that focused on the effect of HIIT program in triathletes' performances during a competition or simulated competition. Millet et al[2] suggested that cycle high-intensity training combined with cross-training might improve running performance. In addition, Mutton et al[20] found a period of HIIT in either running or running–cycling group showed similar changes in VO_2max, standardized HR, and blood lactate responses, and in 5000- and 1609-m time-trial performances. The enormous training volume that runners perform is associated with an increased risk of injuries.[2,20] There are limited studies investigating the effects on triathlon performances when replacing part of running volume by HIIT cycling.

Therefore, the aim of this study was to investigate changes in fitness and performance variables in triathletes following a 4-week period of reduced training volume and increased training intensity. Previous literature supplemented athletes training programs with long and short intervals, whereas in the current study, the subjects training program volume was reduced significantly and replaced by twice a week HIIT cycle sessions from 1- to 2-minute duration in order to observe the effect on physiological markers and cycling and running performance on triathletes.

Methods

Participants

A group of 16 moderately trained triathletes (8 females and 8 males; age = 40 [12] y; height = 172.4 [10.8] cm; body mass = 73.0 [12.1] kg; body mass index = 24.4 [2.4] kg·m^{-2}) competing in triathlon, cycling, or running events were recruited from a number of community clubs. The inclusion criteria required to participate in the study were that subjects were competitive athletes currently training or competing in any triathlon distance on a regular basis (with a minimum 2 y of experience in competition) and completed a sprint triathlon distance between 1 hour 15 minutes and 1 hour 45 minutes. The exclusion criteria were: (1) adults with no competition experience in the previous 1 month, (2) adults with less than 2 years competitive experience in their sport, and (3) adults who had an injury that prevented them from participating in training or testing. A number of 16 participants consented and completed preintervention testing. However, 14 participants completed the study including postintervention testing (Table 1). One athlete withdrew from the study due to a viral illness and another due to work and training constraints. One athlete did not complete the last 5-km running time trial (RTT) during posttesting due to acute calf pain during the treadmill run. Participants were informed of the study protocols and experimental procedures and provided written informed consent. The study was approved by the Southern Adelaide Clinical Human Research Ethics Committee (HREC code 334.16), and it adhered to the Declaration of Helsinki guidelines (2013).

Table 1 Participants Characteristics (N = 16)

	Intervention (HIIT) group	CON group
Age, y	42.9 (12.1)	37.2 (13.3)
Gender	4 women + 4 men	4 women + 4 men
Height, cm	171.0 (10.9)	174.3 (9.7)
Body mass, kg	70.8 (9.7)	76.0 (15.2)
BMI, kg·m^{-2}	23.8 (1.7)	24.7 (2.0)

Abbreviations: BMI, body mass index; CON, control; HIIT, high-intensity interval training.

Procedures

Participants allocated to the HIIT group reduced their training volume (minutes) by an average of 43% ($P < .01$, $d = -2.7$) and replaced this with supervised HIIT cycling sessions in the laboratory. However, the control (CON) group maintained their training volume (−3%, $P > .05$, $d = -0.1$) over the 4-week intervention (Table 2). An overall training load was calculated using the rating of perceived training load (RPE-min) method.[2,11] The RPE-min value was the average RPE score for the session[8] multiplied by the duration of the session (minutes) in order to obtain the self-reported session training load (AU).[21]

Testing Protocols

Prior to the 4-week intervention period, all participants completed physiological testing at Flinders University's exercise physiology laboratory. The testing involved standard anthropometric measures (height and body mass) followed by an incremental exercise test to exhaustion to determine VO_2max on a cycle ergometer (Wattbike, Nottingham, United Kingdom). The cycle ergometer was fitted with the triathlete's own pedals, and the dimensions of the bike were adjusted to achieve the athlete's usual bike position. The test procedure was as follows: (1) 10 minutes for athletes to perform their usual warm-up and (2) an incremental test where the initial load was set at 80 or 100 W, depending on the gender (female or male). Each stage lasted 1 minute, and the load was increased by 20 W until exhaustion. PO was obtained in each stage, HR and RPE recorded in the final 15 seconds of every stage, and HR maximum and peak power output (PPO) were determined as previously described.[22] Expired gases were analyzed by TrueOne 2400 (ParvoMedics, Sandy, UT), and HR was recorded using Polar RS400 (Polar, Kempele, Finland) series HR monitor until test completion. Power (average and maximum) were recorded by the Wattbike software (Wattbike, Nottingham, United Kingdom). The Borg scale (from 0 to 10) was employed in order to monitor the RPE and ensure the athlete performed the correct intensity and recorded at the end of each stage. The first ventilatory threshold (PVT_1) for each participant was established as the PO at which ventilator equivalent for oxygen and the end-tidal O_2 pressure started to increase without a corresponding increase in the postapneic end-tidal CO_2 pressure. The second ventilatory threshold was identified as the PO (PVT_2) when a decrease in end-tidal CO_2 pressure was observed together with an increase in ventilator equivalent of carbon dioxide output.[22,23] In addition, a simulated triathlon performance (3) Time trial run was conducted and consisted of 3 parts: (1) 20-km CTT on a cycle ergometer (Wattbike); (2) 1 to 2 minutes transition where participants changed from cycling to running shoes; and (3) 5-km RTT on the treadmill (TMX58, Trackmaster, Newton, KS) to simulate an identical sprint triathlon distance for cycling and running.[24] Subjects were asked to complete the simulation triathlon flat out, changing PO on the bike and velocity on the treadmill as many times as they needed. HR was recorded continuously, and RPE was recorded every 10 minutes during the cycling and running. Average and maximum power, and time to completion were recorded for the 20-km cycling, and

Table 2 Comparison of Usual Weekly and Intervention Training Time for Both the HIIT and CON Groups

	Intervention (HIIT) group				CON group			
	Usual week	Intervention week	Dif., %	*d*	Usual week	Intervention week	Dif., %	*d*
Training volume, min	648.3 (178.7)	365.4 (105.9)**	–43.6	–2.7	509.5 (195.6)	492.8 (201.9)	–3.3	–0.1
RPE-min, arbitrary units	2163.8 (910.6)	1654.4 (779.7)*	–23.5	–0.7	2859.8 (1442.8)	2259.8 (1193.8)	–21.0	–0.5

Abbreviations: CON, control; *d*, Cohen effect size; Dif., mean differences; HIIT, high-intensity interval training; RPE, rating of perceived exertion.
*$P < .05$, **$P < .01$, significant differences with usual week.

average and maximum speed were recorded every 10 minutes for the 5-km run. All laboratory testing was repeated within 2 days following the 4-week HIIT intervention period.

Training Intervention

Participants who were randomly allocated to the HIIT intervention attended supervised HIIT sessions on a cycle ergometer twice a week. Individual training zones at 95% and 115% of power obtained at VO_2max (PVO_2max) were determined for each participant based on their preintervention testing. The session structure was similar for all HIIT training sessions: a 10-minute warm-up where participants determined the preferred power and cadence, followed by 6 × 2 minutes at 95% of PVO_2max; 4 × 1 minutes at 115% of PVO_2max, followed by 5-minute cooldown. All HIIT sessions were performed beyond individual anaerobic threshold. The recovery periods for the 1- and 2-minute interval sets were 1 minute 30 seconds and 2 minutes, respectively, where athletes continuing to pedal at a low intensity of choice. Average HR (HR_{av}) and HR maximum, RPE, average power (P_{av}), and PO during each repetition and recovery session were recorded. Participants were provided with a HR monitor (RS400; Polar, Kempele, Finland) to record session time and HR. They were instructed to reduce their training volume from their individualized training program focusing on session RPE. The RPE was recorded, and RPE-min (RPE average of the session × duration of the session) was calculated by researchers in each session.[21] The athletes were instructed to record all training in the 4-week period, and this was reviewed by the researchers weekly to ensure program compliance. Participants reported time, distance, and HR data from the monitors, type of activity, and RPE in their training diaries.

Participants randomized to the CON group performed their usual training program without volume reductions. HR monitors were provided to the CON group participants who were asked to record type of activity, time, distance, HR, and RPE data for each training session performed during the 4-week period. This was reviewed by the researchers each week to ensure protocol compliance.

Statistical Analysis

Results are presented as mean (SD). A *t* test for paired samples was used to analyze the differences between the usual week and intervention week training volume and RPE-min independently for each group (HIIT and CON). A *t* test for independent samples was used to analyze the differences in training load (RPE-min, AU) between groups (HIIT and CON) during intervention weeks (weeks 1–4).The between-group (HIIT and CON) comparison from pretest to posttest in aerobic capacity and simulated triathlon test variables was calculated by a 2-way mixed analysis of variance (group × time). In addition, a *t* test for paired samples was used to analyze the differences between the pretest and posttest independently for each group (HIIT and CON). To allow a better interpretation of the results, practical significance between the pretest and posttest independently for each group was assessed by calculating Cohen's effect size. Effect sizes (*d*) of above 0.8, between 0.8 and 0.5, between 0.5 and 0.2, and lower than 0.2 were considered as large, moderate, small, and trivial, respectively.[25] The statistical significance was set at $P < .05$. Data analysis was performed using the Statistical Package for Social Sciences (version 21.0 for Windows; SPSS Inc, Chicago, IL).

Results

Weekly Training Load

Table 3 shows the RPE-weighted training loads on a week-by-week basis for the 2 groups. There were no significant differences in weighted training loads between the groups across all weeks of the intervention phase.

Aerobic Capacity

Differences in HIIT and CON groups for pretest and posttest in VO_2max, PVT_1, PVT_2, and PPO during cycle ergometer maximal are shown in Table 4. The VO_2max increased significantly in the HIIT group ($P < .05$, $d = 0.5$) but remained stable in the CON group for the maximal cycle ergometer tests. Furthermore, the greater VO_2max increase in HIIT group produced a significant interaction between groups ($F_{1,12} = 4.72$, $P = .05$; Table 4). Both groups significantly increased PVT_1 following the intervention phase. However, only the HIIT participants showed an improvement at the PVT_2. There was a significant interaction for PVT_2 between the 2 groups ($F_{1,12} = 6.32$ $P = .03$). There were no differences between groups in PPO although the HIIT participants significantly increased there PPO following the 4-week intervention.

Simulated Triathlon Test

The HIIT group maintained cycling time from 33.3 (2.1) minutes to 32.9 (2.3) minutes ($P = .23$, $d = 0.18$); P_{av} from 193 (46) W to 192 (34) W ($P = .98$, $d = 0.02$) running time from 28.8 (1.9) minutes to 28.4 (1.8) minutes ($P = .59$, $d = 0.22$); and RPE_{av} in both sports (from 6 [2] to 7 [1], $P = .86$, $d = 0.50$ in CTT and from 6 [2] to 6 [1], $P = .55$, $d = 0.50$ in RTT) preintervention–postintervention testing (Figures 1 and 2). In addition, the HR_{av} in bike and running tests were similar (163 [7] beats per minute [bpm] and 161 [8] bpm, $P = .19$, $d = 0.27$) for cycling and (164 [7] bpm and 164 [8] bpm, $P > .99$, $d = 0.0$) for running preintervention and postintervention tests, respectively (Figures 1 and 2). The CON group showed a significant decrease in running performance time (29.4 [4.0] min to 27.1 [2.7] min, $P = .04$, $d = 0.53$) while the cycling time and HR_{av} did not significantly change (34.5 [2.6] min to 33.7 [3.2] min, $P = .11$, $d = 0.27$ and 148 [16] bpm to 147 [16] bpm, $P = .5$, $d = 0.06$,

Table 3 Training Contents Distribution and Differences in Training Load (RPE-min, AU) Between Groups During Intervention Weeks

	Total training sessions		Total swimming sessions		Total cycling sessions		Total running sessions		Training load (RPE-min)			
	HIIT group	CON group	HIIT group	CON group	HIIT group	CON group	HIIT group	CON group	HIIT group	CON group	Dif., %	*d*
Week 1	6	8	1	2	3	3	2	3	1347.7 (715)	2055.7 (1184.5)	52.5	0.6
Week 2	7	8	2	2	3	3	2	3	1886.2 (748.6)	2416.3 (1536.8)	28.1	0.3
Week 3	6	7	2	2	3	3	1	3	1609.7 (933.2)	2042 (1086.8)	26.9	0.4
Week 4	7	8	2	2	3	3	2	3	1773.9 (937.2)	2525.3 (1274.3)	42.4	0.6

Abbreviations: CON, control; *d*, Cohen effect size; Dif., mean differences; HIIT, high-intensity interval training; RPE, rating of perceived exertion.

Table 4 Differences in Intervention (HIIT) and CON Groups for Pretest and Posttest in VO_2max, PVT_1, PVT_2, and PPO During Cycle Ergometer Maximal

	Intervention (HIIT) group				CON group				
	Pre	Post	Dif., %	*d*	Pre	Post	Dif., %	*d*	*P* (between groups)
VO_2max, mL·kg^{-1}·min^{-1}	42.4 (5.2)	45.2 (6.0)*	6.7	0.5	43.1 (4.5)	42.8 (3.9)	–0.8	–0.1	.05***
PVT_1, W	148.3 (31.7)	174.9 (26.1)**	18.0	1.0	154.0 (31.6)	179.7 (27.4)**	16.7	0.9	.91
PVT_2, W	195.8 (43.7)	227.5 (32.1)**	16.2	1.0	227.3 (36.2)	236.5 (39.7)	4.0	0.2	.03***
PPO, W	242.3 (52.0)	278.6 (58.0)*	15.0	0.6	275.2 (45.8)	290.0 (52.8)	5.4	0.3	.24

Abbreviations: CON, control; *d*, Cohen effect size; Dif., mean differences; HIIT, high-intensity interval training; PPO, peak power output; PVT_1 and PVT_2, power at first and second ventilatory thresholds; VO_2max, maximal oxygen consumption.
**P* < .05, ***P* < .01, significant differences with pre. ****P* < .05, significant interaction between groups.

respectively). Also, the HR_{av} in the running test remained unchanged (159 [16] bpm to 161 [13] bpm, $P = .28$, $d = 0.14$). However, P_{av} was increased from 170 (31) W to 183 (40) W ($P = .07$, $d = 0.59$). There were no significant interactive effects obtained between groups ($F_{1,12} = .50$, $P = .49$; Figures 1 and 2). No significant changes were observed in this group for RPE_{av} in CTT (from 6 [1] to 6 [1], $P = .42$, $d = 0.0$) or RTT (from 6 [2] to 7 [2], $P = .25$, $d = 0.50$).

Discussion

Our objective was to investigate how 1- and 2-minute intervals of cycle HIIT sets influence these variables on moderately trained triathletes who reduced their weekly training volume. Maximum aerobic capacity is a strong physiological indicator associated with endurance performance.[2,9,18,22,26] Endurance athletes, such as cyclists, runners, and triathletes, typically have a high VO_2max and an elevated VT.[2,27] Therefore, the improvement of both variables in endurance sports is a fundamental objective of training. Previous researchers concluded that HIIT helped the enhancement of anaerobic and aerobic metabolism response to the energy demand, increasing energy status in the muscle and improving ATP availability in recreational active athletes[9] In addition, a recruitment of fast fibers which aid to increase oxidative capacity of muscle, the improvement of capillarization and oxidative enzyme activity, and plasma volume indicated an enhancement of aerobic metabolism capacity.[9,15] Otherwise, highly trained athletes endurance performance might improve due to the increase of skeletal muscle buffering capacity. However, central and peripheral adaptations to HIIT needs further investigation, such as neuromuscular and endocrinological adaptations, expression on cation pumps skeletal muscle, expression on fiber type, and myoglobin levels.[9]

It has been concluded that the time trained at or near VO_2max is essential to effectively improve the aerobic capacity.[28–30] After 4 weeks of HIIT training, VO_2max significantly increased by 6.7%, despite an overall reduction in training volume and training load. This was in agreement with previous researchers who observed an increase in aerobic capacity after a HIIT training program.[1,8] Etxebarria et al[1] observed a 7.3% and 7.5% increase for short (10-, 20-, and 40-s efforts) and long HIIT (5-min efforts), respectively, after 3 weeks performing a either short or long cycling HIIT twice a week. Similarly, Gojanovic et al[8] found a positive change after 4 weeks of running HIIT twice a week using intervals between 3 and 4 minutes 45 seconds at VO_2max for duration equal to 60% of time to exhaustion. VO_2max improved 3.5% in a CON group that performed the sessions on a treadmill and 1.9% for a group that used a lower-body positive pressure treadmill. However, Acevedo and Goldfarb[6] concluded that 8 weeks of HIIT did not enhance VO_2max in competitive long-distance runners. The novel finding in the current study was that VO_2max presented similar improvements to previous research despite the weekly training time being reduced by 43% with the addition of 2 short-duration HIIT sessions in the overall training program.

A range of studies have investigated the optimum duration, intensity, and recovery stimulus to achieve a greater improvement in aerobic capacity. Some authors have used short intervals (from

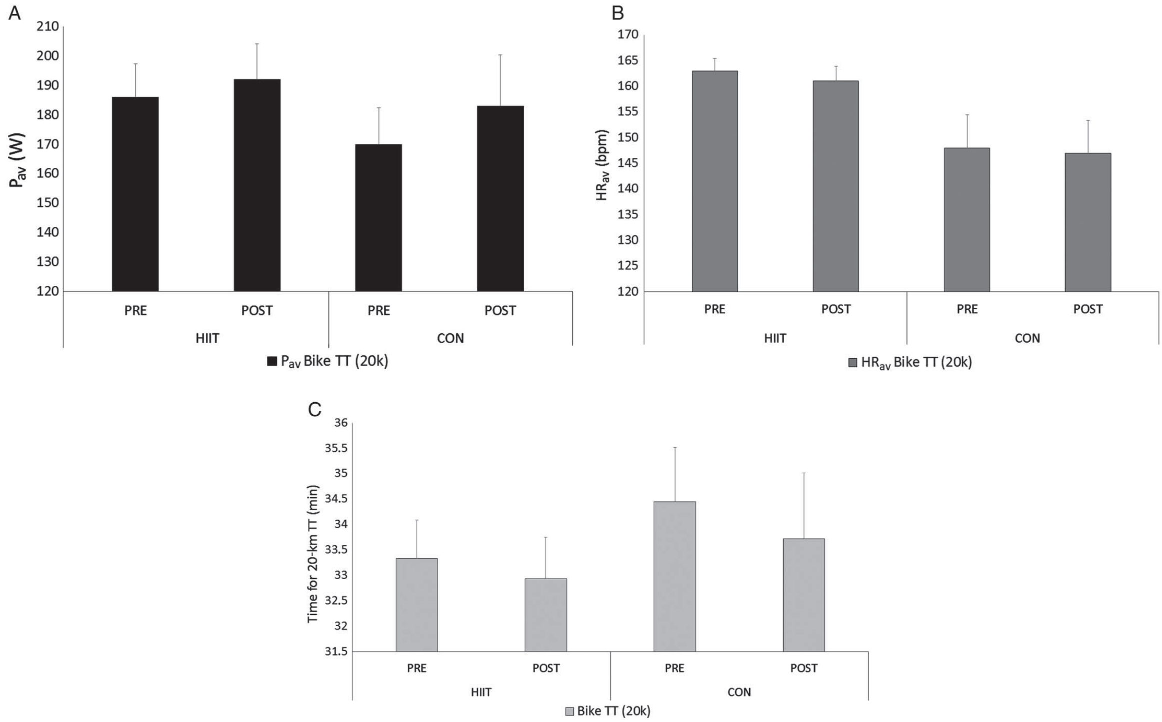

Figure 1 — Differences between intervention (HIIT) and CON groups during for pretest and posttest on P_{av}. (A), HR_{av} (B), and time for 20-km cycling TT (C). bpm indicates beats per minute; CON, control; HIIT, high-intensity interval training; HR_{av}, average heart rate in cycling test; P_{av}, average power; TT, time trial.

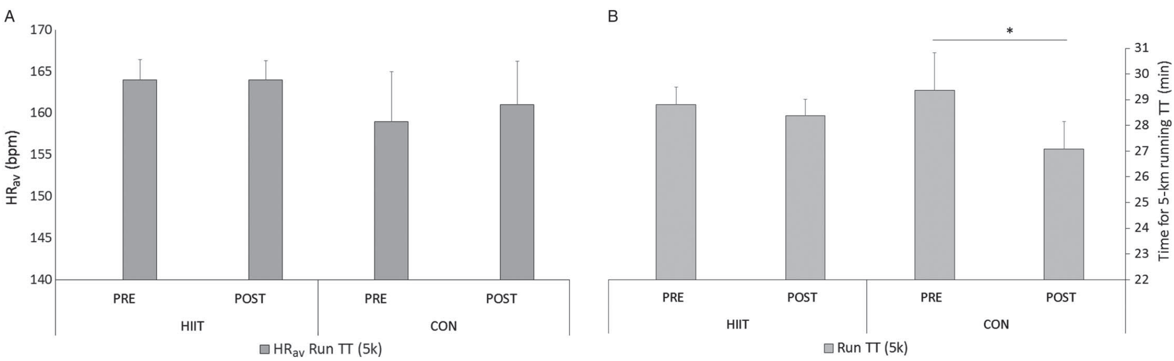

Figure 2 — Differences between intervention (HIIT) and CON groups for (A) HR_{av} running and (B) time for 5-km running time trial. bpm indicates beats per minute; CON, control; HIIT, high-intensity interval training; HR_{av}, average heart rate in running test. *$P < .05$, significant difference between tests.

15 to 30 s),[1,8,16] whereas in Etxebarria et al[1] and Mallol et al,[31] 5-minute intervals were employed during their respective intervention training programs. All studies concluded that there is an improvement in aerobic capacity using HIIT as a complement to usual training protocols, without total volume and load reduction.[1,8,30] Mallol et al[31] showed that a triathlete amateur group that performed 4 weeks of running HIIT twice a week decreased their maximal speed during a maximal run test on the treadmill. However, Mallol et al observed that HR and average velocity during a cycle-ergometer TT test were considerably lower, probably due to a residual fatigue from the intensified training period. Accordingly, in the current study, we tried to use shorter efforts at higher intensity in order to observe the athlete's responses to 1- and 2-minute duration intervals.

Other important indicators of an athlete's aerobic conditioning are the VT (VT_1 and VT_2). In our investigation, we focused on power at these points in order to observe if 4 weeks of HIIT could improve the aerobic capacity. The results showed that the HIIT group improved significantly at both time points. Namely, athletes could maintain greater P_{av} levels during a maximal cycle ergometer test after 4 weeks of HIIT training at similar intensities. These findings were in agreement with Laursen et al[5] who observed improvement of 6% in PVT_1 and 7% in PVT_2. However, the highly trained cyclists in Laursen's study[5] reduced their normal training program by 2 hours, whereas the participants in this study reduced their training volume by and average of 4.7 hours per week. The percentage of VO_2 at which the VT occurred remained unchanged from an average of 70.3% to 71% ($P = .84$) for VT_1 and from 84% to 85.6% ($P = .58$) for VT_2. The CON group showed improvements in aerobic threshold at VT_1 as expected because of the high volume of endurance training they completed.

High-intensity interval training participants maintained their performance in the simulated triathlon test following a 43% reduction in training duration with a 23% reduction in training load (RPE-min). All variables measured: cycling time, P_{av}, HR_{av}, and running times remained unchanged. Previous literature observed improvements in running performance (time) after a cycling HIIT program with no total training volume reduction.[1,20] Etxebarria et al[1] concluded that the change of 5-km running times after 4 weeks of long sets HIIT sessions was small (4.9% [4.7%]), decreasing the total time (from 21.25 [2.47] min to 20.21 [2.31] min). Likewise, Mutton et al[20] observed decreases in 5000- and 1609-m TT (1.7 min and 18–21 s, respectively) and VO_2max improvements in runners using either running only or running plus cycle training. Similarly, Mikesell and Dudley[19] and Murphy[32] observed equal improvements in running performance when comparing both training groups. Other investigators have shown improvements in cycling TT performances following cycling HIIT programs, without significant volume reduction in training volume.[17,18] Lindsay et al[17] observed a decrease of 3.5% for completion of a 40-km TT in professional cyclists after 4 weeks of HIIT program. All participants had a moderate/base-intensity background before approximately 15% of the total weekly training volume was replaced by HIIT training.

In the current investigation, the CON group improved running performance after 4 weeks of high volume and low-moderate intensity. This shows that to improve running performance, rather than simply maintenance over a 4-week period, high-volume training emerges as the superior approach over HIIT, even though the high-intensity training resulted in enhancements of VO_2max and ventilatory thresholds. Even so, the HIIT group maintained time, power, HR, and speed variables in running and cycling performances (simulated triathlon) despite the reduction in training load. HIIT group performances remained unchanged maybe due to other factors which were not measured in the current research, such as running economy, fatigue accumulated after HIIT sessions, motivation, and psychological variables. These findings suggest that the use of this method of training during specific volume reduced periods such as periodization, and off-season, might help to achieve and/or maintain high physiological and fitness levels, such as VO_2max and power at ventilator thresholds while the performance is maintained.

Practical Applications

The use of cycling HIIT training sessions over 4 weeks appears to maintain cycling and running performances during tapering, between seasons, or during a period of training modification such as injury which requires a reduction of volume and/or sport mode modification. Furthermore, this method improved VO_2max, PVT_1, and PVT_2 in the volume reduction periods. In addition, cycling HIIT using a cross-training methodology may be a useful adjunct for maintaining running performance in triathletes, using different mechanisms which can be targeted by different intensities, sport modality, and volume training stress. Nevertheless, it is clear that improvements in running and cycling performance in moderately trained triathletes require a threshold volume of training to be achieved rather than via reduced volume in combination with a HIIT stimulus.

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10. 2. UBICACIÓN DE LOS ARTÍCULOS

10.2.1. Índice de calidad de las revistas

A continuación se adjuntan las características de las revistas en las que se han publicado los trabajos de esta tesis doctoral.

Tabla 4. Índice de calidad de las revistas.

Journal	ISSN	Country	Category	IF	Quartile
AMD	02128799	Spain	Sports science	NA	4
IJSPP	1555-0265	USA	Sport science	3.042	1
RICCAFD	2255-0461	Spain	Sport science	NA	

ISSN = International Standard Serial Number; AMD = Archivos de Medicina del Deporte IJSPP = The International Journal of Sports Physiology and Performance ; RICCAFD = Revista Iberoamericana de Ciencias de la Actividad Física y el Deporte; IF = Journal impact factor.

10.2.2. Grado de Cumplimiento con la Normativa correspondiente a Tesis por compendio de contribuciones

De acuerdo con la Normativa de la Escuela de Máster y Doctorado de la Universidad del País Vasco- Euskal Herriko Unibertsitatea para la presentación de Tesis por compendio de contribuciones, en su capítulo XI. el trabajo debe constar de un mínimo de tres publicaciones, las cuáles deberán ser artículos publicados en revistas que aparezcan en la última relación publicada por el Journal of citation reports (SCI y/o SSCI), o SCOPUS, o en las bases de datos especificadas. Al menos una de las publicaciones deberá situarse en el primer o el segundo cuartil de su categoría. Asismismo, en el caso e co-autoridad de un artículo, el doctorando deberá aparecer como primer o segundo autor.

Todas la publicaciones deberán haber sido aceptadas en las revistas correspondientes, a fecha posterior a la primera matricula de la tesis doctoral.

Tabla 5. Características de las revistas dónde se encuentran las publicaciones.

Journal	Indexación	Impacto
ADM	Scopus/Latindex	
RICCAFD	Latindex	
IJSPP	JCR	3.042

10.3. COMITÉ DE ÉTICA

10.3.1. Comité de ética para la recolecta de datos de los estudios originales

Government of South Australia
SA Health

General research application

1. Please delete ALL instructions after completing each section.
2. Please submit this application via Online Forms.
3. A hard copy of the application is not required by the Ethics office.
4. Please refer to the Submission Guidelines for more information.

Multi and single site applications where SAC HREC is the lead site

Please refer to the submission guide for more information.

1. Go to Online Forms and complete the NEAF form
   - If this is for a single site application, only sections 1 and 2 are required.
2. Fill out this template and upload to Online Forms via the *Documents* tab with all the application documents required.
3. Generate a submission code and email the submission code, study title, principal investigator's name, telephone number and email address to Research.ethics@health.sa.gov.au. If the office does not have this code, your application cannot be processed.
4. An SSA (Site Specific Assessment) form will also need to be created for all SA Health sites the research is being conducted. Through the already created NEAF, create a SSA form via the SSA tab. When you are ready to submit, generate a submission code and email to the Research Governance Officer for review.

Application checklist – please make sure your application is submitted with all required documentation or it will be returned for resubmission**.**

√	Chief investigator and Co investigators have signed off on the application Please provide any email sign off with the application DO NOT send separately.
√	Letter of endorsement from the head of department(s)
√	Indemnity approval is to be provided with the Site Specific Assessment form.
NA	Aboriginal community approval (if relevant)
NA	Project approvals from other HRECs that have reviewed this application
NA	CTN notification form / Clinical Trial Agreement for a sponsored trial to the Research Governance Officer.
√	PIS/CF: with or without third party consent / have appropriate logos and headers / Genetic/pharmacogenetic PIS/CF (if relevant)
NA	Proof the trial is registered on the Australian Register of Therapeutic Goods (ARTG) (if relevant)
√	I have signed and dated the Statement of Compliance
√	I have submitted the application via online forms and emailed the submission code, study title, principal investigator's name, telephone number and email address to

	Research.ethics@health.sa.gov.au
√	I have added the footer details with the version number and date.

Government of South Australia
SA Health

Flinders UNIVERSITY

General research application form

Project Title:	Effects of high intensity training (HIT) and reduced training volume on running and cycling performance in well trained competitive athletes.
Investigator Details:	
Chief Investigator	
Name:	Dr Lynda Norton
Qualifications:	PhD, MPH, RN Grad Dip Intensive Care
Department/address:	Social Health Sciences, S266 Sturt South, Flinders University, Bedford Park, 5042 SA
Contact details: phone and email	8201 5830 lynda.norton@flinders.edu.au
The Chief Investigator is to provide either a signature or an email to confirm they are part of the study with this application. Please do not send separately.	Signature:
Co-investigators	
Name:	Ms Milos Mallol Soler
Qualifications:	
Department/address:	Social Health Sciences, Sturt South, Flinders University, Bedford Park, 5042 SA
Contact telephone number:	8201 5773 mall0078@flinders.edu.au
Co-investigator agreement All co investigators are to provide either a signature or an email to confirm they are part of the study.	Signature:
Contact Person	If other than an investigator
Name:	Dr Lynda Norton
Position:	CI

Department/address:	Social Health Sciences, Sturt South, Flinders University, Bedford Park, 5042 SA
Contact telephone number:	As above
Email address:	As above
Are you requesting a waiver of consent?	NO
Genetic Analysis Will there be any genetic (DNA/RNA) analyses?	NO .
Are any blood or blood products being used in this study? I.e. red blood cells, fresh frozen plasma, cryoprecipitate, platelets, albumin, intravenous immunoglobulin, factor viii, prothrombinex, blood warmers, blood infusion devices, cell salvage devices/protocols – intraoperative and post-operative	YES (Finger tips blood samples)
Financial interest Does the principal investigator have a financial interest in this study?	NO
Is this study commercially sponsored*? A commercial sponsor is the organisation or company that will be invoiced for the SAC HREC review of this application. **Details for invoicing:** Sponsor or coordinating company: ABN: Australian postal address and contact person: Sponsor protocol number for this study:	NO
Is this study funded by a grant? Is this study investigator driven? Is this study part of a cooperative trial group?	NO YES NO

Where is this research being done in Australia? Please list all sites where this research is being conducted and ethics approval is being sought:

- *Exercise Physiology, Lab Sturt Campus, Flinders University*

SA public health sites: NA

Interstate public health sites: NA

Letter of endorsement from the head of department(s)

The head of department has provided an email endorsing the research. Submitted to on-lineforms

Project Details

Clearly describe the study and justify why it should be done using the headings supplied.

Research objectives

1. Background:

High-intensity interval training (HIT) describes physical exercise that is characterized by brief, intermittent bursts of vigorous activity, interspersed by periods of rest or low-intensity activity. HIT can serve as an effective alternate to traditional endurance training, inducing similar or even superior changes in a range of physiological and performance measures. Less is known regarding the effects of low-volume HIT, but growing evidence suggests this type of training stimulates physiological remodelling comparable with moderate-intensity continuous training despite a substantially lower time commitment and reduced total exercise volume.

Previous studies on HIT in athletes have added HIT to the athlete's traditional training load. To examine the effects of low-volume HIT in athletes is problematic, as athletes dislike reducing their overall training load during a competitive season. This study will investigate the effect of low volume HIT in well-trained athletes over a period of 4-weeks. Additionally, we will compare the effects between groups who continue usual volume training and a group who reduce their training load by half. Capitalising on the typical reduction in training load seen in athletes in the off-season.
Specifically, the question is: how are fitness and performance measures affected by a HIT intervention with a reduced volume of training

2. Rationale:

By altering the volume of training undertaken by groups of well trained athletes and substituting a HIT component to one of these groups we will be able to determine the physiological effects on fitness and cycling performance induced by the training changes.

During the period of reduced training one group of athletes will perform HIT in place of their usual mixed training. Another group will reduce their training load by half for 4 weeks while a control group will continue their usual raining load.

3. Objectives:

The aim of this research is to observe the physiological changes in running and cycling performance after a 4-week period of reduced training versus a low-volume HIT or a usual training load.

Hypothesis

The hypothesis is that HIT during a detraining phase of the season will result in less decay of the peak physiological performance measures than moderate intensity activity when matched for overall energy expenditure.

Proposed Methods

1. **Study design**:

This is a randomised control trial with subjects randomised to one of three trial arms:
Intervention 1 will run over four weeks with participants attending 3 supervised high intensity training sessions each week and participating in a reduced training load on alternate days.
Intervention 2 will be conducted concurrently; participants will follow an individually designed training program that is half their usual training load (in METs).
Control group
A control group will continue their usual training program over the same four week period.

All participants will undergo performance and fitness testing before and immediately following the training period.

2. **Study Duration**: 7 months

3. **Participant Selection** (number and details of recruitment): Thirty experienced athletes will be recruited from triathlon, cycling and running clubs in Adelaide. Interested athletes will be emailed an information sheet and training questionnaire to determine their eligibility. Athletes who meet the inclusion criteria will be invited to the exercise physiology laboratory for

4. Inclusion criteria:

(a) experienced competitive athletes with $\geq$2 years regular training/competition experience.
(b) be $\geq$ 18 and < 60 yrs of age.
(c) be willing to participate in either of the training programs, or as controls.
(d) undergo a pre-exercise screening evaluation according to the nationally accepted professional standard Sports Medicine Australia (SMA) pre-exercise screening system (SMA, 2012).

5. Exclusion criteria:

Subjects will be excluded from the study if: (a) they have been competing or training regularly for <2 years or (b) they have been sent for medical clearance, based on the SMA screening guidelines, and clearance to participate is not provided.

6. Withdrawal criteria: Participants are informed that the study is entirely voluntary and they have the right to withdraw from the study at any time without giving a reason. If they decide not to participate in the study, or if they withdraw from the study, they may do so freely; their relationship with the university will not be affected in any way.

7. Statistical analysis (including justification of sample size, if relevant):

Differences between groups will be determined by Repeated Measures Analysis of Variance.
We calculated the sample size required to detect a small effect size change of 0.2 using an alpha of 0.05; a power of 0.8 and using a repeated measures ANOVA. In athletes at the end of a competitive season we would expect a small change in aerobic fitness over a 4-week period with a 50% reduction in training load.
The results indicated 8 participants per group were required to be confident a 0.2 effect size could be detected.
The total sample size of 10 per group is to accommodate dropouts.

Use of human tissue samples

Procedures involving the participant

1. Concurrent treatment: NA

2. Invasive procedures: NA

3. Procedures involving x-rays or ionizing radiation: NA

4. Facilities for dealing with contingencies*:*

The researchers are qualified and experienced exercise scientists with many years of experience leading physical activity / training sessions. They both have current first aid and CPR qualifications and at least one of the researchers will be on-site during all fitness testing and HIT sessions. The exercise physiology laboratory has phones with the university emergency numbers and SA emergency numbers and first aid equipment.

Assessment of Participants

1. **Clinical Assessment**:

Pre-exercise screening will be conducted for all participants prior to enrolment in the study. Screening involves a series of health related questions and physiological tests to determine whether the participant requires medical clearance before upgrading an exercise program. It has been endorsed by a number of national health professional associations including Sports Physicians and the Exercise and Sports Science Australia. It has also been adopted by many universities and professional organisations as part of pre-exercise screening standards. Briefly, via questionnaire, screening identifies people with either signs or symptoms of, or established, disease who are advised to seek medical clearance before commencing or upgrading physical activity.

Pre-exercise screening

Participants are asked a number of questions relating to their general health such as known medical conditions, signs or symptoms of disease, current medications, and any other risk factors they may have (Appendix 5 Pre-exercise screening). Subjects will be interviewed in a private and confidential environment by the researchers who are trained in obtaining health information.

2. **Laboratory Assessment**:

*Anthropometric measurement*s

The following anthropometric measurements will be taken: height, weight, waist and hip girths as well as measures of biceps, triceps and subscsapular skinfolds. Trained anthropometrists will measure all subjects. Measurements will follow the International Society for Advancement of Kinanthropometry guidelines as described in Anthropometrica (Norton and Olds 1996).

Time trial

A stationary cycle test will be used to determine the subject's physiological performance during a 20-minute time trial (TT). In the TT the participant will try to cover the greatest distance possible in a fixed 20 minute time period. This provides an externally valid model for examining how an initial work rate is chosen and maintained by an athlete during self-selected exercise. Participants' heart rate is monitored continuously throughout the test using the Polar® RS400 series heart rate monitor. The intensity chosen for the test follows standard procedures for time trial cycling tests. Researchers will document heart rate, rating of perceived exertion, power output (Watts), speed and cadence (Appendix X Data collection sheet).

Maximal oxygen uptake test

All participants will undertake a graded exercise test on a treadmill. Ventilation, oxygen and carbon dioxide concentrations will be measured directly during the test via a Parvo® metabolic cart (Appendix X VO_{2max} report). Following an appropriate warm-up, the workrate (treadmill speed) is progressively increased every minute until the participant can no longer continue [volitional fatigue]. The test lasts approximately 10-15 minutes.

3. Other. Finger tip Blood samples collect on HIT session

On the first and last HIT session (week 1 and week 4) participants will provide a finger tip blood samples before and after HIT training session. After training blood samples will be taken immediately, 15 min, 30 min and 45 min after exercise. The samples will be analised by ichroma to measure the followed variables: Cortisol, CRP, CK-MB, myoglobin and ferritin. The objective of these analyses is observe stress and inflammation responses, muscle damage and iron deficiency (anaemia).

4. **Monitoring adverse effects** (e.g. emotional, psychological and physical): During testing and training sessions participants will wear heart rate monitors and researchers will continually monitor heart rates and subject well-being. Facilities to allow participants to lie down are available in the exercise physiology laboratory.

5. Significant adverse effects should be reported to the FCREC.

Research relating specifically to the Aboriginal community:

NA

Researcher indemnity/participant injury compensation

Researcher indemnity and participant compensation has been verified by both Flinders University – Steve Semmler and SA Health

Registration of Clinical Trials (Drug or Device)

NA

Administrative Aspects

1. No commercial sponsor

2. No funding

3. Clinical data sheets: Appendices Pre-exercise screening, Data collection sheet, VO_{2max} report.

4. Maintenance of records: Data will be stored on computer and in hard copy in a central registry at Flinders University, room S266 and will have identifying information removed. The computer access to the central registry will be password protected. Discs, data backups and hard copies kept by the central registry will be stored in a locked filing cabinet in room S266 in a secured area of the university for a period of 7 years.
5. Special facilities required and use of hospital facilities: Performance and fitness testing and HIT sessions will be conducted in the Exercise Physiology laboratory (G119) on the Sturt campus of Flinders University.

Ethical Considerations

1. Benefits anticipated from study.
Please refer to the National Statement 1.6 for guidance.

Participants will be given a written results sheet at the end of each testing session and these will be explained to the participant face-to-face at the time. Participants will gain increased knowledge and awareness of a range of exercise parameters relevant to their training. The HIT group will undertake 4-weeks of HIT cycle sessions in a safe, monitored environment.

Given that "lack of time" is the number 1 reason for sub optimal levels of physical activity in the general population, data that adds to the body of knowledge on HIT may assist in developing safe activities that are higher in intensity but take less time to complete for the broader community.

2. Risks of any harm - including physical disturbance, discomfort, anxiety or pain.
Please refer to the National Statement (NS) 1.6 and 2.1 for guidance.

This study involves testing participants to maximal levels of exertion. Increases in adverse effects may generally include muscle and joint soreness and tiredness. There is also a potential for more serious events such as dizziness, chest pain, or life-threatening events. Life-threatening events are extremely rare and estimated at approximately 1 in every 600,000 hours of vigorous exercise (Norton et, al 2008).

However, in order to minimise this risk and satisfy the project aims the following will be performed:
1. All participants will undergo pre-exercise screening following Sports Medicine Australia's Pre-exercise Screening criteria (SMA 2012)
2. Selection will be on the basis they are currently training or competing at vigorous levels of intensity on a regular basis (with a minimum 2 years of experience in competition)
3. The age requirement has been limited to a maximum of 60 years
4. The testing involves subjecting the participants to exercise intensity at levels they regularly perform as part of their training and competition. During training weeks there is the possibility that subjects could get injured. However, the HIT will be supervised on all occasions and conducted on stationary bicycle ergometers in the laboratory.

3. Research involving dependent relationships – *this includes patients of the researcher, staff, students, children, mentally ill, intellectually impaired.*
NA

4. Separation of research and clinical responsibilities.

NA, the researchers do not hold any clinical responsibilities.

5. Treatment of control groups.

Participants in the control group will undergo performance and fitness testing at the same time periods as the intervention participants. They will continue their usual athletic training regime over the 4-week period

6. Use of placebo.
NA

7. Source of payment for normal participants.
NA

8. Protection of privacy and preservation of confidentiality.
Please refer to NS 1.11 and 3.5.13 / 3.5.14 for guidance.

Data collection will comply with both Commonwealth and State legislation regarding the privacy and confidentiality of information obtained from participants. The data will be collected, analysed and stored in accordance with the Information Privacy Principles of the Privacy Act, 1988, the Privacy Amendment (Private Sector) Act 2000.

Data will be stored on computer and in hard copy in a central registry at Flinders University, room S266 and will have identifying information removed. The computer accesses to the central registry will be password protected. Discs, data backups and hard copies kept by the central registry will be stored in a locked filing cabinet in room S266 in a secured area of the university for a period of 7 years.

9. Restriction of use of data.
Please refer to NS 3.2.11 for guidance.

Staff involved in the research will be allowed access to the data. Conditions for accessing data include permission from the Chief Investigator(s) and agreement to maintain participant confidentiality. Research publications resulting from this study will use aggregated data and will not identify individual subjects

10. Any other particular ethical consideration

Recruitment of participants

Method and nature of advertising. Please provide copy of advertisement and state where the adverts will appear e.g. website, notice boards etc.

Flyers will be placed on notice boards at triathlon, running and cycling clubs that conduct regular competitions (Appendix 1 Study flyer).

How will the study be promoted or advertised?

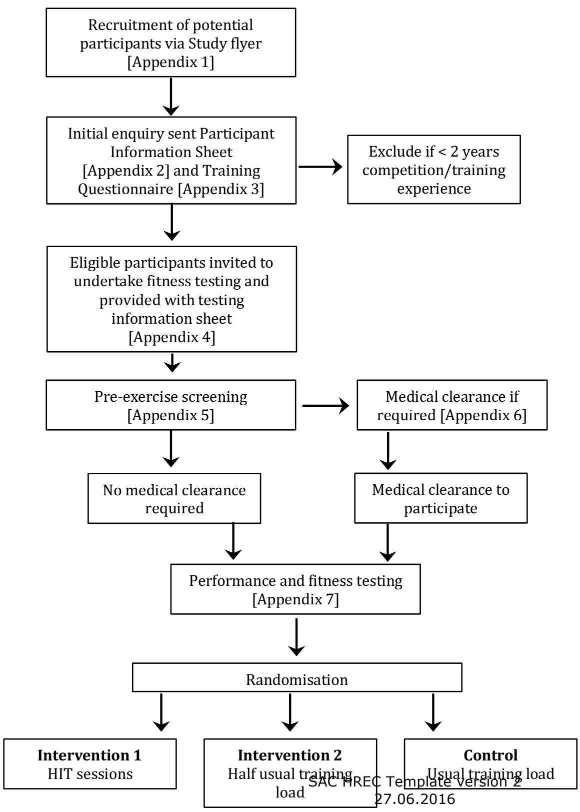
If sufficient numbers are not recruited through the flyers a media story will be developed in conjunction with the Flinders University Marketing and Communications Office and promoted on the Flinders University website.

Consent Process:

Dr Lynda Norton and Ms Milos Mallol will be obtaining consent

Participants will be recruited from a number of community athletics groups (cycling, running and triathlon clubs). Interested individuals will be provided with an information sheet (Appendix 2 Participant Information Sheet) and an activity questionnaire (Appendix 3 Training questionnaire). On completion of the training questionnaire those participants who meet the inclusion criteria (> 2years experience competing /training in their sport) who continue to express an interest in the study will be invited to attend the exercise physiology laboratory and provided with written information describing the performance and fitness testing (Appendix 4 Testing information).

A flow chart illustrating the participant information and consent process is shown below.



A copy of the signed consent form is to be filed in the participant's medical record

Statement of compliance with NH&MRC National Statement on Ethical Conduct in Human Research (2007) & the Australian Code for the Responsible Conduct of Research (2007)

By submitting this application the applicant(s) will comply with both of the above documents. All researchers are expected to be familiar with their responsibilities under each document. The application must include a statement that the project complies with the above documents.

STATEMENT: ***I hereby declare that the*** *Effects of high intensity training (HIT) and reduced training volume on running and cycling performance in well trained competitive athletes* ***trial complies with the above documents.***

Signed*:__*

Print name*:__Lynda Norton*

Dated*:_10.02.2016*

10.3.2. Hoja de información a los participantes y consentimiento informado

Participant Information Sheet/Consent Form

Non-Interventional Study - *Adult providing own consent*

Flinders University Sturt Campus

Title	Effects of high intensity training (HIT) and reduced training volume on running and cycling performance in well trained competitive athletes.
Short Title	Effects of HIT on running and cycling performance
Coordinating Principal Investigator/ Principal Investigator	Dr Lynda Norton
Associate Investigator(s)	Milos Mallol (PhD student)
Location	Sturt Campus Flinders University

Part 1 What does my participation involve?

1 Introduction

You are invited to take part in this research project, which is called *Effects of high intensity training (HIT) and reduced training volume on running and cycling performance in well trained competitive athletes.* This is because you are an athlete with more than 2 years of training and competition experience. The research project is aiming to investigate the effects of a reduced volume of training supplemented with high intensity training on running and cycling performance in well trained athletes.

This Participant Information Sheet/Consent Form tells you about the research project. It explains the tests and research involved. Knowing what is involved will help you decide if you want to take part in the research.

Please read this information carefully. Ask questions about anything that you don't understand or want to know more about. Before deciding whether or not to take part, you might want to talk about it with a relative, or friend

Participation in this research is voluntary. If you don't wish to take part, you don't have to.
If you decide you want to take part in the research project, you will be asked to sign the consent section. By signing it you are telling us that you:
• Understand what you have read
• Consent to take part in the research project
• Consent to the tests and research that are described
• Consent to the use of your personal and health information as described.

You will be given a copy of this Participant Information and Consent Form to keep.

2 What is the purpose of this research?

The aims of this project are to

1) Observe changes in running and cycling performance after four weeks of HIT cycling with a reduction in training volume.
2) Compare running and cycling performance between participants using (1) traditional training, (2) training that has been reduced by half and (3) training reduced by half and supplemented with cycle HIT.

HIT has been shown to maintain physiological performance in athletes. However, there are few studies showing the use of HIT during the off-season when training volume typically decreases in athletes.
This study will provide information on changes in running and cycling performance associated with typical off-season training and following a period of HIT.

The results of this research will be used by the researcher *Milos Mallol* to obtain a *Doctor of Philosophy* degree.

This research has been initiated by PhD student, Milos Mallol under the guidance of Dr Lynda Norton and Dr David Bentley.

3 What does participation in this research involve?

All experienced athletes who request an information form are eligible to participate in the study and you will be asked to sign a consent form prior to participating. You will complete an initial questionnaire on your athletic experience and your typical training week. These will be completed and returned via email. Approximately 30 participants will be enrolled in the study.

If you consent to participate in the study, you will be randomised to one of three 4-week training programs. You will also be asked to participate in two physiological testing sessions at the Flinders University Exercise Physiology laboratory. These will be conducted before and immediately after the 4-week training program. The laboratory tests include anthropometry (height, weight, waist and hip girths, skinfold measurement for body fat determination), a 20 minute cycle time trial, and a maximal aerobic treadmill test. You will also complete a training diary during the 4-week intervention.

There are no costs associated with participating in this research project, nor will you be paid.

4 What do I have to do?

You will be asked to follow a 4-week training program. This may involve you continuing your usual training program, reducing your training volume by half or reducing your training program by half and supplementing it with supervised HIT conducted at Flinders University. You will be asked to undertake physiological testing on two separate occasions before and after the 4-week training program.
Additionally, you might be in High Intensity training group, in this case, you will provide a finger tip blood samples before and after the first and the last HIT session (in two HIT sessions).

5 Other relevant information about the research project

The testing and training will be undertaken during the downtime from competitive training.

6 Do I have to take part in this research project?

Participation in any research project is voluntary. If you do not wish to take part, you do not have to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage.

If you do decide to take part, you will be given this Participant Information and Consent Form to sign and you will be given a copy to keep.
Your decision whether to take part or not to take part, or to take part and then withdraw, will not affect your relationship with Flinders University.

8 What are the possible benefits of taking part?

We cannot guarantee or promise that you will receive any benefits from this research, however the sharing of your experiences will improve your knowledge in Exercise Physiology and in athletic performance.

9 What are the possible risks and disadvantages of taking part?

This type of testing is designed for people who are trained and who have regular experience in pushing themselves hard in training or in competition.
Overall, the risk associated with this investigation is no different to the risk you face whenever you cycle and run to maximal levels. The testing involves maximal-level exertion, this means there is always some risk that you may feel nauseous or light-headed. There is also an extremely small chance of other more significant adverse effects such as collapse or even sudden death. This is why you will be required to fill in a pre-exercise screening questionnaire and sign a consent form for the testing stating that you understand there are risks associated with maximal exertion and that you understand and accept these risks as part of the study process.

10 What will happen to my test samples?

We will measure your anthropometric measures and your physiology results (heart rate, power output, distance covered in the time trial and results of gas analysis) on two occasions during the research project.
All data collected will be coded with a participant ID number and any identifying information such as your name will be removed. All data will be stored in a password-protected computer in a locked office on the university campus. No one except the study investigators will have access to the data.

11 Can I have other treatments during this research project?

Whilst you are participating in this research project, you may continue to take any medications or treatments you have been taking. You should tell the investigators about any changes to these during your participation in the research project.

12 What if I withdraw from this research project?

If you decide to withdraw from this research project, please notify a member of the research team before you withdraw. Your participation in this study is entirely voluntary and you have the right to withdraw from the study at any time without giving a reason. You may answer 'no comment' or refuse to answer any questions. If you decide not to participate in this study, or if you withdraw from the study, you may do so freely, your relationship with the university will not be affected in any way.

If you do withdraw your consent during the research project, the researchers and relevant study staff will not collect additional personal information from you, although personal information already collected will be retained to ensure that the results of the research project can be measured properly and to comply with law.

13 What happens when the research project ends?

Outcomes from the project will be summarised and given to you by the investigator if you would like to see them.

Part 2 How is the research project being conducted?

16 What will happen to information about me?

By signing the consent form you consent to the study investigator and relevant research staff collecting and using personal information about you for the research project. Any information obtained in connection with this research project that can identify you will remain confidential. The questionnaires and test results will initially be identified using your participant ID. When being entered into an electronic database your participant ID will be replaced with a study number and all identifiable information will be removed. We will also record your date of birth and sex to assist in anthropometric analysis of the data. All copies of the questionnaires and test results will be stored in a locked filing cabinet in a secure office at Flinders University for 5 years and will then be destroyed. Your information will only be used for the purpose of this research project and it will only be disclosed with your permission, except as required by law.
It is anticipated that the results of this research project will be published and/or presented in a variety of forums. In any publication and/or presentation, information will be provided in such a way that you cannot be identified.
In accordance with relevant Australian and/or South Australian privacy and other relevant laws, you have the right to request access to the information collected and stored by the research team about you. You also have the right to request that any information with which you disagree be corrected. Please contact the research team member named at the end of this document if you would like to access your information.
Any information obtained for the purpose of this research project that can identify you will be treated as confidential and securely stored. It will be disclosed only with your permission, or as required by law.

17 Complaints and compensation

If you suffer any injuries or complications as a result of this research project, you should contact the study team as soon as possible and you will be assisted with arranging appropriate treatment. If you are eligible for Medicare, you can receive any medical treatment required to treat the injury or complication, free of charge, as a public patient in any Australian public hospital.

18 Who is organising and funding the research?

Milos Mallol is conducting this research project under the supervision of Dr Lynda Norton and Dr David Bentley

19 Who has reviewed the research project?

All research in Australia involving humans is reviewed by an independent group of people called a Human Research Ethics Committee (HREC). The Southern Adelaide Clinical Human Research Ethics Committee has approved the ethical aspects of this research project
This project will be carried out according to the *National Statement on Ethical Conduct in Human Research (2007)*. This statement has been developed to protect the interests of people who agree to participate in human research studies.

20 Further information and who to contact

The person you may need to contact will depend on the nature of your query.
If you want any further information concerning this project or if you have any medical problems which may be related to your involvement in the project (for example, any side effects), you can contact the principal investigator on mall0078@flinders.edu.au or any of the following people:

Study contact person

Name	Milos Mallol
Position	Principal Investigator
Telephone	0401808986
Email	mall0078@flinders.edu.au

For matters relating to research at the site at which you are participating, the details of the local site complaints person are:

Complaints contact person

Name	Paula Davies
Position	Manager, Office of Research Ethics Officer
Telephone	8204 6061
Email	Health.SALHNOfficeforResearch@sa.gov.au

If you have any complaints about any aspect of the project, the way it is being conducted or any questions about being a research participant in general, then you may contact:

Reviewing HREC approving this research and HREC Executive Officer details

Reviewing HREC name	Southern Adelaide Clinical
HREC Executive Officer	Damian Creaser
Telephone	8204 6285
Email	Health.SALHNOfficeforResearch@sa.gov.au

Local HREC Office contact (Single Site -Research Governance Officer)

Name	Dawn Jennifer
Position	Research Governance Officer
Telephone	8204 6139
Email	Health.SALHNOfficeforResearch@sa.gov.au

Consent Form

Title	Effects of high intensity training (HIT) and reduced training volume on running and cycling performance in well trained competitive athletes.
Short Title	HIT on running and cycling performance
Coordinating Principal Investigator/ Principal Investigator	Dr Lynda Norton
Associate Investigator(s)	Milos Mallol (PhD student)
Location	Sturt Campus Flinders University

Declaration by Participant

I have read the Participant Information Sheet or someone has read it to me in a language that I understand.

I understand the purposes, procedures and risks of the research described in the project.

I have had an opportunity to ask questions and I am satisfied with the answers I have received.

I freely agree to participate in this research project as described and understand that I am free to withdraw at any time during the project without affecting my future health care.

I understand that I will be given a signed copy of this document to keep.

Name of Participant (please print) ______________________________

Signature ______________________ Date ______________________

Name of Witness* to
Participant's Signature (please print) ______________________________

Signature ______________________ Date ______________________

* Witness is not to be the investigator, a member of the study team or their delegate. In the event that an interpreter is used, the interpreter may not act as a witness to the consent process. Witness must be 18 years or older.

Declaration by Senior Researcher†

I have given a verbal explanation of the research project, its procedures and risks and I believe that the participant has understood that explanation.

Name of Senior Researcher†
(please print) ______________________________

Signature ______________________ Date ______________________

† A senior member of the research team must provide the explanation of, and information concerning, the research project.

Note: All parties signing the consent section must date their own signature

10.3.3. Flyer del estudio

Appendix 1: Sporting club flyer

4-week High Intensity Training Intervention Study

Are you between the ages of 18 and 50?

Do you regularly compete in athletic competitions?

Have you participated in regular training over the last two years?

Flinders University is conducting a research project looking at the effects of a 4-week High Intensity Training program in experienced female endurance athletes.

We are looking for participants to undertake a supervised 4-week training program in September-October 2016.

An individualised 4-week training program including:

- Supervised training sessions
- Fitness and performance checks before and after the program to show your progress
- An activity diary to help monitor your progress

REQUIREMENTS:

- participants must be between the ages of 18 and 50;
- attend 2 training sessions per week for 4 weeks:
- be available for testing before and after the project; and
- have been competing for more than 2 years.

For more information email

Milos Mallol on mall0078@flinders.edu.au
Or Dr Lynda Norton on Lynda.norton@flinders.edu.au

10.3.4. Cuestionario inicial para los participantes

Participant Questionnaire

Effects of high intensity training (HIT) on running and cycling performance in well trained competitive athletes.

Participant name:

Date of Birth:

Email:

Phone:

1. How long have you been training and competing regularly?

<2 years	2-4 years	4-6 years
6-8 years	8-10 years	>10 years

2. What kind of events do you participate in?

Sprint	Olympic	Half Ironman	Ironman
Marathon	Half Marathon	Combination	

Other endurance sport:

3. How much time do you spend training and in an average week?

10.3.5. Diario de entrenamiento de la semana previa al pre test

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Typical training week

Please, fill out the training table for your current weeks training sessions. If you record your training data in a computer program like Garmin connect or Polar you can include a table from this application.

Rating of Perceived Exertion

Perceived exertion is a load quantifying method where the athlete is who perceives himself the effort that he is doing during a training session.
Each athlete is different, so the same training session would produce different responses in each person.

RPE scale (from 0 to 10 points) is the instrument used to grade the effort levels.

rating	description
0	NOTHING AT ALL
0.5	VERY, VERY LIGHT
1	VERY LIGHT
2	FAIRLY LIGHT
3	MODERATE
4	SOMEWHAT HARD
5	HARD
6	
7	VERY HARD
8	
9	
10	VERY VERY HARD (MAXIMAL)

Session training examples

Swimming

Warm up 1000 meters with different technique exercise, It is easy for me, so I am feeling like a level 2 (Very light).

The aim part is a 7x 400 meters with different intensities in each interval, I am training at different intensities (moderate, max effort, hard) but the overall, I have felt around level 5.

During warm-down I have felt level 3.

My RPE swimming session is (2+5+3)/3 = 3.3= 3 moderate.

Cycling

The route was Glenelg-Cross Rd- Freeway- Mount Lofty- Greenhill Road-Anzac Hwy-Glenelg.
The first part I have gone warming up, so it has been very easy/light, so my score is 1.
The Freeway and mount lofty's up have been hard but then Greenhill's down has been moderate. My overall of the main part has been level 4

Between Anzac Hwy to Glenelg road I have performed the warm down, my felt has been 3.

My RPE cycling session is (1+4+3)/3 = 2.6 = 3 moderate

Running

Warm up 2k, I have run light I score with a 3.
Then I have done a fartlek 3x 1k Tempo + 200m steady + 400m Threshold + 200m recovery. At the first interval has been had but the second and the thirds one have been really hard. My feeling in the main part has been between 6 and 7. Actually, I have felt 7 in the most part of the training, so my score is 7
Then I have run 2k easy, 4 point in RPE scale

My RPE running session is (2+7+4)/3= 4.6 = 5 hard

Week 1

Guidelines to fill your typical week

- You have one table for each sport. You don't need to fill all gaps, for example if you usually perform 3 swim sessions, 2 bike sessions and 3 run sessions, you should fill 3 columns on swimming, 2 on bike and 3 on running table.
- Type or kind of training week: You should insert one of your usual load week (no tapering, recovery or starting season week). See below one example
- HR on swimming trainings and Watts on cycling trainings only if you get tools to measure it.

Type of activity	**Swimming (pool)**	
Date & time	20/04/16	
Total session time	1h	
Total distance	2800m	
Work intensity	Endurance extensive, Threshold, max effort *	
	Average	Maximum
Heart Rate * *If you can measure	130	150
Rating of Perceived Exertion	4	7

Type of activity	**Cycling hills (Mt Osmond & Belair)**	
Date & time	22/04/16	
Total session time	2h30'	
Total distance	65	
Work intensity	60% VO2max, 80% VO2max*	
	Average	Maximum
Speed	28	46
Watts* *If you can measure	160	220
Heart Rate	143	170
Rating of Perceived Exertion	6	8

(*) It's not necessary that use this concepts, you can insert your personal intensities classification (A1, A2, A3 or endurance extensive, intensive, speed or 70% of HR)

SWIMMING

Type of activity								
Date & time								
Total session time								
Total distance								
Work intensity								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Heart Rate * ***If you can measure**								
Rating of Perceived Exertion								

Type of activity								
Date & time								
Total session time								
Total distance								
Work intensity								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Heart Rate * ***If you can measure**								
Rating of Perceived Exertion								

CYCLING

Type of activity								
Date & time								
Total session time								
Total distance								
Work intensity								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed								
Watts* *If you can measure								
Heart Rate								
Rating of Perceived Exertion								

Type of activity								
Date & time								
Total session time								
Total distance								
Work intensity								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed								
Watts* *If you can measure								
Heart Rate								
Rating of Perceived Exertion								

RUNNING

Type of activity								
Date & time								
Total session time								
Total distance								
Work intensity								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed								
Watts* ***If you can measure**								
Heart Rate								
Rating of Perceived Exertion								

Type of activity								
Date & time								
Total session time								
Total distance								
Work intensity								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed								
Watts* ***If you can measure**								
Heart Rate								
Rating of Perceived Exertion								

10.3.6. Descripción de los test a realizar en el laboratorio

Appendix 5: Fitness testing information sheet

We would like to invite you to participate in 4-week High Intensity Training Intervention Study.

Every participant in the 4-week HIT must complete pre-exercise screening. The screening follows professional guidelines developed by Sports Medicine Australia. It involves a series of questions and tests to determine whether you need to see a GP before altering your training program.

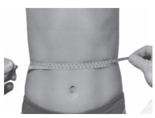
The screening session takes about 2 hours, 2h 30minutes and involves a range of measurements of health and fitness. The measures include height, weight, skin folds and body girths, a 10-kilometre time trial (running) and a maximal aerobic fitness test.

Pre-exercise screening questions
When you first arrive for screening you will be asked a number of questions relating to your work/study, lifestyle habits, signs or symptoms of health problems, medications that you are taking, and any known disease or risk factors you may have. You don't have to answer the questions if you don't want to, although they are all important in helping us make recommendations about your training program. Your screening questionnaire will be kept in a locked filing cabinet in the research laboratory and will only be accessible to senior staff involved in the study. Additionally, we will keep identifying information like your name and address separate from the screening questionnaire.

Body girths and skinfolds
We will measure your waist and hip girths; these will be used to calculate your waist-hip ratio (WHR). Additionally, we will measure some skinfolds used to calculate your fat body composition.

Height and weight
Height is measured in bare feet and your weight in light clothing.


hip measurement


waist measurement


bicep skinfold measurement

Maximal oxygen uptake test
You will undertake a graded exercise test on a treadmill. Following an appropriate warm-up, the work-rate (treadmill speed) will be progressively increased every minute until you can no longer continue, that is you are exhausted. Your oxygen uptake will be measured using the open circuit method, this means that you will be connected to a one-way mouthpiece and respiratory valve and your expired air will be analysed using our metabolic cart. The test

lasts approximately 10-15 minutes and is used to determine your maximal aerobic fitness through Ventilation rates, heart rate and perceived of exertion.

A printed report showing all of your results will be provided immediately following the testing.

Time trial tests
A 10 kilometer time trial run test will be used to determine your aerobic fitness and run performance. The field test lasts about 40-70 minutes. Researchers will document your heart rate, rating of perceived exertion, speed and aerobic fitness. At the final of the test, lactate will be analyzed by fingertip blood sample.

Remember

Please avoid intense exercise in the 24 hours before the test

As you are performing a high intensity exercise bout it is advisable that you refrain from eating a large quantity of food or water before the test.

Wear comfortable clothes and shoes to exercise in. We will be taking skinfold measurements so shorts and loose fitting t-shirts are recommended (sports bra/bikini top would be appropriate for women).

We recommend that you bring a snack to have after the test.

If you suffer from asthma bring your reliever medication (for example, Salbutamol/Ventolin).

Where: The Exercise Physiology Research Laboratory at Flinders University , G119 between the Sturt gym and the tennis courts on the attached map. Pay as you go parking is available in car park 13.

When:

Who to contact: Milos Mallol: (08) 8201 5773 mall0078@flinders.edu.au

Lynda Norton: (08) 8201 5830 / 0403 431 917 or email: lynda.norton@flinders.edu.au

10.3.7. Herramienta de valoración: Pre-exercise screening

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ADULT PRE-EXERCISE SCREENING TOOL

This screening tool does not provide advice on a particular matter, nor does it substitute for advice from an appropriately qualified medical professional. No warranty of safety should result from its use. The screening system in no way guarantees against injury or death. No responsibility or liability whatsoever can be accepted by Exercise and Sports Science Australia, Fitness Australia or Sports Medicine Australia for any loss, damage or injury that may arise from any person acting on any statement or information contained in this tool.

Name: ______________________________

Date of Birth: ______________ Male ☐ Female ☐ Date: ______________

STAGE 1 (COMPULSORY)

AIM: to identify those individuals with a known disease, or signs or symptoms of disease, who may be at a higher risk of an adverse event during physical activity/exercise. This stage is self administered and self evaluated.

Please circle response

1.	Has your doctor ever told you that you have a heart condition or have you ever suffered a stroke?	Yes	No
2.	Do you ever experience unexplained pains in your chest at rest or during physical activity/exercise?	Yes	No
3.	Do you ever feel faint or have spells of dizziness during physical activity/exercise that causes you to lose balance?	Yes	No
4.	Have you had an asthma attack requiring immediate medical attention at any time over the last 12 months?	Yes	No
5.	If you have diabetes (type I or type II) have you had trouble controlling your blood glucose in the last 3 months?	Yes	No
6.	Do you have any diagnosed muscle, bone or joint problems that you have been told could be made worse by participating in physical activity/exercise?	Yes	No
7.	Do you have any other medical condition(s) that may make it dangerous for you to participate in physical activity/exercise?	Yes	No

IF YOU ANSWERED 'YES' to any of the 7 questions, please seek guidance from your GP or appropriate allied health professional prior to undertaking physical activity/exercise

IF YOU ANSWERED 'NO' to all of the 7 questions, and you have no other concerns about your health, you may proceed to undertake light-moderate intensity physical activity/exercise

I believe that to the best of my knowledge, all of the information I have supplied within this tool is correct.

Signature ______________________ Date ______________

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ADULT PRE-EXERCISE SCREENING TOOL

STAGE 2 (OPTIONAL)

Name: ____________________

Date of Birth: ____________________ Date: ____________________

AIM: To identify those individuals with risk factors or other conditions to assist with appropriate exercise prescription. This stage is to be administered by a qualified exercise professional.

Question		RISK FACTORS
1. Age ______ Gender ______	≥ 45yrs Males or ≥ 55yrs Females +1 risk factor	
2. Family history of heart disease (eg: stroke, heart attack) Relative / Age / Relative / Age ☐ Father ___ ☐ Mother ___ ☐ Brother ___ ☐ Sister ___ ☐ Son ___ ☐ Daughter ___	If male < 55yrs = +1 risk factor If female < 65yrs = +1 risk factor Maximum of 1 risk factor for this question	
3. Do you smoke cigarettes on a daily or weekly basis or have you quit smoking in the last 6 months? Yes No If currently smoking, how many per day or week? ______	If yes, (smoke regularly or given up within the past 6 months) = +1 risk factor	
4. Describe your current physical activity/exercise levels: Sedentary ☐ Light ☐ Moderate ☐ Vigorous ☐ Frequency (sessions per week): ___ ___ ___ Duration (minutes per week): ___ ___ ___	If physical activity level < 150 min/ week = +1 risk factor If physical activity level ≥ 150 min/ week = -1 risk factor (vigorous physical activity/ exercise weighted x 2)	
5. Please state your height (cm) ______ weight (kg) ______	BMI = ______________ BMI ≥ 30 kg/m² = +1 risk factor	
6. Have you been told that you have high blood pressure? Yes No	If yes, = +1 risk factor	
7. Have you been told that you have high cholesterol? Yes No	If yes, = +1 risk factor	
8. Have you been told that you have high blood sugar? Yes No	If yes, = +1 risk factor	

Note: Refer over page for risk stratification.

STAGE 2 Total Risk Factors = ______

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9.	Have you spent time in hospital (including day admission) for any medical condition/illness/injury during the last 12 months? Yes No	If yes, provide details
10.	Are you currently taking a prescribed medication(s) for any medical conditions(s)? Yes No	If yes, what is the medical condition(s)?
11.	Are you pregnant or have you given birth within the last 12 months? Yes No	If yes, provide details. I am ______ months pregnant or postnatal (circle).
12.	Do you have any muscle, bone or joint pain or soreness that is made worse by particular types of activity? Yes No	If yes, provide details

STAGE 3 (OPTIONAL)

AIM: To obtain pre-exercise baseline measurements of other recognised cardiovascular and metabolic risk factors. This stage is to be administered by a qualified exercise professional. (Measures 1, 2 & 3 – minimum qualification, Certificate III in Fitness; Measures 4 and 5 minimum level, Exercise Physiologist*).

	RESULTS		RISK FACTORS
1. BMI (kg/m²)		BMI ≥ 30 kg/m² = +1 risk factor	
2. Waist girth (cm)		Waist > 94 cm for men and > 80 cm for women = +1 risk factor	
3. Resting BP (mmHg)		SBP ≥140 mmHg or DBP ≥90 mmHg = +1 risk factor	
4. Fasting lipid profile*			
Total cholesterol		Total cholesterol ≥ 5.20 mmol/L = +1 risk factor	
HDL		HDL cholesterol >1.55 mmol/L = -1 risk factor HDL cholesterol < 1.00 mmol/L = +1 risk factor	
Triglycerides		Triglycerides ≥ 1.70 mmol/L = +1 risk factor	
LDL		LDL cholesterol ≥ 3.40 mmol/L = +1 risk factor	
5 Fasting blood glucose*		Fasting glucose ≥ 5.50 mmol = +1 risk factor	
		STAGE 3 Total Risk Factors =	

RISK STRATIFICATION

Total stage 2
or
Total stage 3
Plus stage 2 (Q1 - Q4)

≥ 2 RISK FACTORS – MODERATE RISK CLIENTS
Individuals at moderate risk may participate in aerobic physical activity/exercise at a light or moderate intensity (Refer to the exercise intensity table on page 2)

< 2 RISK FACTORS – LOW RISK CLIENTS
Individuals at low risk may participate in aerobic physical activity/exercise up to a vigorous or high intensity (Refer to the exercise intensity table on page 2)

Note: If stage 3 is completed, identified risk factors from stage 2 (Q1-4) and stage 3 should be combined to indicate risk. If there are extreme or multiple risk factors, the exercise professional should use professional judgement to decide whether further medical advice is required.

10.3.8. Ejemplo de un diario de entrenamiento

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Training Diary

Please, fill out the training table for each week of your training sessions. If you record your training data in a computer program like Garmin connect or Polar you can include a table from this application.

Rating of Perceived Exertion
Perceived exertion is a load quantifying method where the athlete is who perceives himself the effort that he is doing during a training session.
Each athlete is different, so the same training session would produce different responses in each person.

RPE scale (from 0 to 10 points) is the instrument used to grade the effort levels.

rating	description
0	NOTHING AT ALL
0.5	VERY, VERY LIGHT
1	VERY LIGHT
2	FAIRLY LIGHT
3	MODERATE
4	SOMEWHAT HARD
5	HARD
6	
7	VERY HARD
8	
9	
10	VERY VERY HARD (MAXIMAL)

SESSION TRAINING EXAMPLES

Swimming

Warm up 1000 meters with different technique exercise, It is easy for me, so I am feeling like a level 1 (Very light).

The aim part is a 7x 400 meters with different intensities in each interval so,
- The first interval is easy, level 2
- 2, 3 and 4 intervals have been hard because I have swum the first in my group level 5
- 5 interval, the pace was harder, but I have swum behind another swimmer so I have maintained the level 5
- 6 and 7 interval were recovery, so I have felt that the effort was moderate, level 3.

In general, I have graded with 1, 2,5,5 and 3 points, so the average is (1+2+5+5+3)/5= 3,2.

My RPE swimming session is (1+2+5+5+3)/5= 3,2 ≈ 3

Cycling

The route was Glenelg-Cross Rd- Freeway- Mount Lofty- Greenhill Road-Anzac Hwy-Glenelg.
The first part I have gone warming up, so it has been very easy/light, so my score is 1.
During freeway I am doing a time trial, I try to do my best time in the up, it has been very hard, I almost have to stop. My score in this part is 9
The up until Mt. Lofty I have ridden slower but I was really tired, normally I up easy but today it has been hard like a 6 in the scale.

During Greenhill's down I could recovery and in general the down has been easy, 2

Between Anzac Hwy to Glenelg I have improved the speed but I haven't felt hard effort, my score is 3

My RPE cycling session is (1+9+6+2+3)/5= 4.

Running

Warm up 2k, I have run light I score with a 2. Then I have done a fartlek 3x 1k Tempo + 200m steady + 400m Threshold + 200m recovery.
In the first lap RPE score has been 7
Second lap has been 8
And the last lap, I have been very tired and I have to stop, so my score has been 10.
Then I have run 2k easy, 3 point in RPE scale

My RPE running session is (2+7+8+10+3)/5= 6.

Week 1

SWIMMING

Type of activity	Swimming (pool)		Swimming (pool)					
Date & time	13/7/16		15/7/16					
Total session time	1.5hr		1.5hr					
Total distance	3.2km		3.1km					
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Heart Rate * *If you can measure								
Rating of Perceived Exertion	4	9	5	8				

Type of activity								
Date & time								
Total session time								
Total distance								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Heart Rate * *If you can measure								
Rating of Perceived Exertion								

CYCLING

Type of activity	Cycling (flat)		Cycling (TT)		Cycling (hills and flat)			
Date & time	11/7/16		14/7/16		16/7/16			
Total session time	40min		2hr		3.5hr			
Total distance	16km		52km		85km			
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed	24.8	37.7	26	36.6	24.2	48.5km		
Watts* *If you can measure								
Heart Rate	120	152	123	168	125	170		
Rating of Perceived Exertion	3	5	6	10	5	9		

Type of activity								
Date & time								
Total session time								
Total distance								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed								
Watts* *If you can measure								
Heart Rate								
Rating of Perceived Exertion								

RUNNING

Type of activity	Running (continuous)		Running (fartlek)		Running (trails)			
Date & time	12/7/16		14/7/16		17/7/16			
Total session time	37min		1hr10min		1hr35min			
Total distance	7km		12.5km		14.5km			
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed	5:24pace	4:30pace	5:28pace	4:30pace	6:37pace	5:50pace		
Watts* *If you can measure								
Heart Rate	165bpm	190bpm	164bpm	188bpm	162bpm	182bpm		
Rating of Perceived Exertion	5	8	6	9	5	8		

Type of activity								
Date & time								
Total session time								
Total distance								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed								
Watts* *If you can measure								
Heart Rate								
Rating of Perceived Exertion								

Week 2

SWIMMING

Type of activity	Swimming (pool)		Swimming (pool)					
Date & time	20/7/16		22/7/16					
Total session time	1hr		1hr					
Total distance	3km		3km					
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Heart Rate * *If you can measure								
Rating of Perceived Exertion	5	8	5	8				

Type of activity								
Date & time								
Total session time								
Total distance								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Heart Rate * *If you can measure								
Rating of Perceived Exertion								

CYCLING

Type of activity	hills		TT		TT			
Date & time	19/07/16		21/07/16		23/07/16			
Total session time	3hr		1hr10mins		2hr20mins			
Total distance	68.5km		30km					
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed	22.9km	59.1	25.6km/hr	34.4km/hr	27km/hr	40.8km/hr		
Watts* *If you can measure								
Heart Rate	130	165	125	144	135	160		
Rating of Perceived Exertion	7	10	5	8	6	9		

Type of activity								
Date & time								
Total session time								
Total distance								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed								
Watts* *If you can measure								
Heart Rate								
Rating of Perceived Exertion								

RUNNING

Type of activity	fartlek		Hard run		Hard run		interval	
Date & time	19/07/16		21/07/16		23/07/16		24/07/16	
Total session time	1hr 15mins		25min		43min		1hr (including rests)	
Total distance	13km		5km		8km		9km	
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed	5:44min/km	5:00km	4:55km	4:30/km	5:15km	4:30km	4:45km	4:30km
Watts* *If you can measure								
Heart Rate	162	173	166	182	166	185	158	186
Rating of Perceived Exertion	5	8	8	10	6	10	8	10

Type of activity								
Date & time								
Total session time								
Total distance								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed								
Watts* *If you can measure								
Heart Rate								
Rating of Perceived Exertion								

Week 3

SWIMMING

Type of activity	**Swimming (pool)**		**Swimming (pool)**					
Date & time	27/7/16		29/7/16					
Total session time	1hr		1.5hr					
Total distance	2700m		4km					
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Heart Rate * ***If you can measure**								
Rating of Perceived Exertion	5	8	6	9				

Type of activity								
Date & time								
Total session time								
Total distance								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Heart Rate * ***If you can measure**								
Rating of Perceived Exertion								

CYCLING

Type of activity	Flats and small hills		TT		Easy ride			
Date & time	26/7/16		28/7/16		30/7/16			
Total session time	1.5hr		1hr50min		4hr6min			
Total distance	37km		52km		96km			
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed	24.5km/hr	41.8km/hr	28.6km/hr	42.5km/hr	23.4km/hr	55.7km/hr		
Watts* *If you can measure								
Heart Rate	134	171	137	168	133bpm	171bpm		
Rating of Perceived Exertion	6	9	6	9	6	10		

Type of activity								
Date & time								
Total session time								
Total distance								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed								
Watts* *If you can measure								
Heart Rate								
Rating of Perceived Exertion								

RUNNING

Type of activity	fartlek		fartlek		Trail run			
Date & time	26/7/26		28/7/17		31/07/2016			
Total session time	1hr10min		57min		1hr11min			
Total distance	13km		10km		12.5km			
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed	5:29	4:02	5:39	4:30	5:42	4:20		
Watts* *If you can measure								
Heart Rate	161	181	151	162	160	185		
Rating of Perceived Exertion	6	9	5	8	7	10		

Type of activity								
Date & time								
Total session time								
Total distance								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed								
Watts* *If you can measure								
Heart Rate								
Rating of Perceived Exertion								

Week 4

SWIMMING

Type of activity	**Swim (pool)**		**Swim (pool)**					
Date & time	03/08/2016		05/08/2016					
Total session time	1.5hr		1hr					
Total distance	3.85km		2.5km					
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Heart Rate * ***If you can measure**								
Rating of Perceived Exertion	6	9	6	9				

Type of activity								
Date & time								
Total session time								
Total distance								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Heart Rate * ***If you can measure**								
Rating of Perceived Exertion								

CYCLING

Type of activity	Cycling (hill repeats)		Cycling (TT brick)		Cycling (hills)			
Date & time	02/08/2016		04/08/2016		06/08/2016			
Total session time	1hr34min		1hr9min		3hr24min			
Total distance	39km		31km		72km			
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed	24.6km/hr	43.8km/hr	26.9km/hr	31.5km/hr	21.3km/hr	60km/hr		
Watts* *If you can measure								
Heart Rate	132	176	128	147	126	165		
Rating of Perceived Exertion	6	9	6	9	7	9		

Type of activity								
Date & time								
Total session time								
Total distance								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed								
Watts* *If you can measure								
Heart Rate								
Rating of Perceived Exertion								

RUNNING

Type of activity	Running (fartlek)		Running (brick session)		Running (continuous)			
Date & time	02/08/2016		04/08/2016		06/08/2016			
Total session time	1hr10min		37min		1hr38min			
Total distance	13km		8km		18km			
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed	5:24	4:05	5:00	4:00	5:28/km	4:20/km		
Watts* *If you can measure								
Heart Rate	158	175	143	178	157	183		
Rating of Perceived Exertion	6	9	7	10	7	10		

Type of activity								
Date & time								
Total session time								
Total distance								
	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Speed								
Watts* *If you can measure								
Heart Rate								

10.3.9. Plantilla recogida de datos sesión HIIT en el laboratorio

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HIT SESSION TABLE

Name	
Date	
Hour	
Session number	

	Warm up	***Main Part 1****	***Main Part 2 *****	***Recovery***
Time				
Distance				
W avg				
W max				
Speed avg				
Speed max				
Cadence avg				
Cadence max				
HR avg				
HR max				

* Main part 1 is 6x2’ @ 95% VO_2max with 2’ active recovery

** Main part 2 is 4x1’ @ 115% VO_2max with 1’30’’ active recovery

10.4. BECAS Y AYUDAS

10.4.1. Ayuda para la estancia en universidades extranjeras de personal investigador en formación de la UPV/EHU, y para la estancia en la UPV/EHU de personal investigador en formación procedente de universidades extranjeras, para la elaboración de tesis doctorales en régimen de cotutela

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NAZIOARTEKO BIKAINTASUN CAMPUSA
CAMPUS DE EXCELENCIA INTERNACIONAL

RESOLUCIÓN DE 26 DE JUNIO DE 2015, DE LA VICERRECTORA DE ESTUDIOS DE POSGRADO Y RELACIONES INTERNACIONALES, POR LA QUE SE CONCEDEN AYUDAS PARA LA ESTANCIA EN UNIVERSIDADES EXTRANJERAS DE PERSONAL INVESTIGADOR EN FORMACIÓN DE LA UPV/EHU, Y PARA LA ESTANCIA EN LA UPV/EHU DE PERSONAL INVESTIGADOR EN FORMACIÓN PROCEDENTE DE UNIVERSIDADES EXTRANJERAS, PARA LA ELABORACIÓN DE TESIS DOCTORALES EN RÉGIMEN DE COTUTELA.

El Consejo de Gobierno de la Universidad, celebrado el 5 de febrero de 2015, aprobó la convocatoria de ayudas para la estancia en universidades extranjeras de personal investigador en formación de la UPV/EHU, y para la estancia en la UPV/EHU de personal investigador en formación procedente de universidades extranjeras, para la elaboración de Tesis Doctorales en régimen de Cotutela, según establece la convocatoria en la medida en que exista disponibilidad presupuestaria, se podrán realizar convocatorias mediando únicamente la preceptiva aprobación de la Comisión de Postgrado de la UPV/EHU.

La Comisión de Posgrado de la UPV/EHU en sesión celebrada el 25 de febrero de 2015, acordó aprobar y publicar la convocatoria de ayudas para la estancia en universidades extranjeras de personal investigador en formación de la UPV/EHU, y para la estancia en la UPV/EHU de personal investigador en formación procedente de universidades extranjeras, para la elaboración de Tesis Doctorales en régimen de Cotutela. En dicha convocatoria se estableció hasta el 17 de marzo de 2015 el plazo para presentar las correspondientes solicitudes de ayuda.

Siendo la Comisión Mixta, compuesta por dos miembros de la Comisión de Posgrado de la UPV/EHU y un miembro de la Escuela de Máster y Doctorado, la competente para valorar las solicitudes y emitir el informe de adjudicación o denegación y su posterior aprobación por la Comisión de Posgrado.

A la vista de los datos anteriores, el Vicerrectorado de Estudios de Posgrado y Relaciones Internacionales,

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RESUELVE:

Primero.- Distribuir el presupuesto destinado para estas ayudas entre las solicitudes estimadas, una vez valorados los diferentes méritos presentados por los candidatos y las candidatas. Los importes señalados son los concedidos de acuerdo con las bases de la convocatoria:

		ESTANCIA		IMPORTE A CONCEDER		IMPORTE
Nº	DNI/ PASAPORTE	FECHAS	MESES	VIAJE	ESTANCIA	TOTAL
1	74940799Z	Del 1/09/2014 al 1/09/2016	9	300,00 €	7.200,00 €	7.500,00 €
2	40451993F	Del 1/11/2015 al 1/07/2016	9	1.200,00 €	7.200,00 €	8.400,00 €
3	G42862746	Del 22/06/2015 al 30/04/2016	9	1.200,00 €	7.200,00 €	8.400,00 €
4	78875659B	Del 1/04/2015 al 31/12/2015	9	200,00 €	7.200,00 €	7.400,00 €
5	16084880Z	Del 29/04/2015 al 31/01/2016	9	200,00 €	7.200,00 €	7.400,00 €

Segundo.- Las solicitudes desestimadas son las detalladas a continuación:

Nº	DNI/ PASAPORTE	MOTIVO DE DENEGACIÓN
1	CC35505648	1
2	400043706	2
3	AN681643	3

1.- Solicitud presentada fuera de plazo
2.- No realizar la Tesis Doctoral en Régimen de Cotutela
3.-Haber realizado la estancia con anterioridad a la apertura de la convocatoria

Tercero.- Para que la ayuda se haga efectiva será necesario, como indica la base 9.6 de la convocatoria, que los beneficiarios y beneficiarias realicen el viaje dentro de los 2 meses siguientes a la publicación de la resolución, perdiendo todos los derechos el beneficiario o beneficiaria en caso contrario, salvo autorización expresa de la Comisión de Posgrado de la UPV/EHU.

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Cuarto.- De acuerdo con la base 9ª de la convocatoria y para hacer efectivo el pago de los importes adjudicados, los beneficiarios y las beneficiarias de estas ayudas están obligados y obligadas a presentar en la Sección de Máster y Doctorado, los siguientes documentos:

a) El convenio especifico de Cotutela entre la UPV/EHU y la Universidad extranjera, o bien, la aprobación del citado Convenio por parte de la Comisión de Posgrado de la UPV/EHU y por parte de la Comisión encargada de la aprobación perteneciente a la otra Universidad.

b) Declaración jurada de no estar sujeto a incompatibilidad en la percepción de la ayuda (documento 2).

c) Declaración individualizada de aceptación de la ayuda y de las condiciones de disfrute y obligaciones previstas en la convocatoria (documento 3).

d) Datos bancarios: entidad, sucursal y nº de cuenta en la que debe realizarse el ingreso, así como el BIC/SWIFF (documento 4).

Quinto.- El pago del importe de la ayuda se realizará en dos plazos, el primero en el momento de la incorporación a la Universidad extranjera o en la UPV/EHU y el segundo a los tres meses de haberse incorporado a la labor investigadora.

Sexto.- Así mismo, será necesario que el Director o Directora de la Tesis donde realice la estancia certifique la fecha de incorporación a la labor investigadora (cumplimentando el documento A) y la fecha de finalización de la estancia (cumplimentando el documento B), así como el informe sobre las actividades realizadas por el alumno o la alumna (documento 6). Estos documentos estarán disponibles en la Web descrita en la base 5.3 de la convocatoria.

Séptimo.- La adjudicación de la ayuda supone para los adjudicatarios la aceptación de las condiciones y obligaciones establecidas en la convocatoria objeto de esta resolución.

Octavo.- El incumplimiento de cualquiera de las obligaciones dará lugar a la revocación de la ayudas concedida.

Contra la presente resolución, cabe interponer los siguientes recursos:

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a) Potestativamente, el **recurso de reposición** que autoriza el artículo 116.1 de la Ley 30/1992, de 26 de noviembre, en el plazo de 1 mes a contar desde el día siguiente al de la recepción de la notificación ante el Rector de la UPV/EHU, el cual se entenderá desestimado por silencio administrativo negativo, una vez transcurrido 1 mes desde su interposición sin notificarse la resolución expresa del mismo.

b) Directamente, **recurso contencioso administrativo** ante los Juzgados de lo Contencioso Administrativo de Bilbao en el plazo de 2 meses, a contar desde el día siguiente al de la recepción de la notificación de la resolución, de conformidad con lo dispuesto en el artº 6.4 de la Ley Orgánica 6/2001, de 21 de diciembre, de Universidades y en los artículos 8.3 y 14.1, regla primera, de la vigente Ley Reguladora de la Jurisdicción Contencioso Administrativa, de 13 de julio de 1998.

Leioa, 26 de junio de 2015

EL RECTOR,
LA VICERRECTORA DE ESTUDIOS DE POSGRADO Y RELACIONES INTERNACIONALES
P.D. (Resolución de 30/01/2013) (BOPV 13/02/2013)

Miren Nekane Balluerka Lasa

10.4.2. Faculty of Medicine, Nursing and Health Sciences Student Conference Travel Grant

Gmail

milos mallol <milosmallol@gmail.com>

Milos Mallol Soler - Outcome Notification - 2016 Faculty of Medicine, Nursing and Health Sciences Student Conference Travel Grant

Health Research <health.research@flinders.edu.au> 1 September 2016 at 04:28
To: "mall0078@flinders.edu.au" <mall0078@flinders.edu.au>
Cc: Kay Govin <kay.govin@flinders.edu.au>, Lee-Ann Thomas <leeann.thomas@flinders.edu.au>, Lynda Norton <lynda.norton@flinders.edu.au>, David Bentley <david.bentley@flinders.edu.au>

Dear Milos,

2016 Faculty of Medicine, Nursing and Health Sciences Student Conference Travel Grant

I am pleased to advise you that the Faculty Research Committee has approved your application for support to attend:

The 2016 Sports Medicine Australia (SMA) Conference held in Melbourne, Victoria, Australia from the 12th - 15th October 2016.

An amount of up to $500.00 was approved subject to copies of the tax invoices / receipts being presented to this office (health.research@flinders.edu.au) within 2 months of the conference date in order to claim reimbursement.

Would you also provide us, at the time when you forward copies of the Tax Invoices / Receipts, your banking details so we may arrange reimbursement via Electronic Funds Transfer (EFT) directly into your bank account:

Name of Bank:

Account Name:

BSB:

Account #:

Kind regards,

Lee-Ann

Research Administration and Finance Officer

Faculty of Medicine, Nursing and Health Sciences

Room 5.13, Health Sciences Building

Flinders University

GPO Box 2100, Adelaide SA 5001

P: + 61 8 8201 5892 | E: leeann.thomas@flinders.edu.au | W: http://www.flinders.edu.au

10.4.3. Faculty of Medicine, Nursing and Health Sciences Research Student Maintenance (RSM)

Gmail milos mallol <milosmallol@gmail.com>

2016 RSM allocation

health.research@flinders.edu.au <health.research@flinders.edu.au> 18 August 2016 at 07:17
Reply-To: health.research@flinders.edu.au
To: mall0078@flinders.edu.au
Cc: nort0095@flinders.edu.au

Dear Milos,

An allocation for Research Student Maintenance (RSM) has been made as follows:
Student: Milos Mallol Soler
Account No: 01.700.41038
Amount: $2000

Would you please note that the funds must be spent or committed by 1st December. No transactions may be processed to this account number during December.

Unspent RSM funds do not automatically roll over to the next calendar year without a written request from the Supervisor to the Research Administrator (health.research@flinders.edu.au) prior to the end of the current calendar year.

The funds may be expended at the discretion of the supervisor on chemicals, subject payment, minor equipment, photocopying, microfilms, reagents, slides, tapes, disks, computer ink, software, transcription, survey questionnaires, stationery, travel within Australia to University for Research Week, field travel within Australia, provided that such expenditure relates to the student's research project.
The funds may not be used for conference travel, workshops, training courses, publishing or costs associated with thesis production.
Students wanting to buy Reference/Text books need to contact the Research Administrator. Any books bought will remain the property of the University but may be used by the student for the length of their candidature.
Further information is available on the application form, available at: https://www.flinders.edu.au/mnhs/courses/scholarships.cfm

Claiming reimbursement – forms available at: http://www.flinders.edu.au/finance/forms.cfm
- Students use: Payment Requisition form
- Employees use: Employee Reimbursement form

Receipts for expenditure must accompany the above reimbursement form and are to be presented to the School Accounts Clerk for reimbursement prior to the end of December.

The supervisor has a responsibility to ensure that the expenditure is in the best interests of the student. It should be noted that the allocation may not be used under any circumstances to finance travel by a supervisor.

Kind regards,
Lee-Ann Thomas
Faculty Research Administration Unit
Faculty of Medicine, Nursing and Health Sciences
Room 5.13, Health Sciences Building
Flinders University
Phone: +61 8 8201 5892

10.5. OTRAS PUBLICACIONES CIENTÍFICAS RELACIONADAS CON LA TESIS

10.5.1. Effects of 4 Weeks High-Intensity Training on Running and Cycling Performance in Well-Trained Triathletes

SPORTS AND EXERCISE MEDICINE

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Research

Effects of 4 Weeks High-Intensity Training on Running and Cycling Performance in Well-Trained Triathletes

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ABSTRACT

Introduction: The aim of this study was to investigate the effect of a 4 week high-intensity interval training (HIT) program on running and cycling performance. HIT is a training method which can be used to improve physical fitness in less time, and reduced training volume, than traditional endurance training. HIT allows athletes to accumulate time at higher training intensities, which is difficult to achieve when training in a continuous method.
Methods: Twelve well-trained triathletes completed 4 traditional training weeks as a control period. They were then randomly assigned to a bike or run HIT program completing 2 HIT sessions each week. A 20-minute cycling time trial and maximal aerobic power test on the treadmill were measured before and after the HIT program.
Results: Both bike and run HIT group achieved an increase of 6.7 and 2.1% in velocity at 2 mM and a decrease of 6.4 and 8.4% in the HR variable at 2 mM, respectively. Velocity peak decreased 1.9% in the run HIT group and 1.8% for HR at 4 mM. Velocity peak decreased ~2% in the bike group and maintained HR maximum while there was a small reduction in the run group. For cycle time trial, the bike HIT group demonstrated a significant improvement in average velocity (8.8%), whereas, velocity was slightly lower in the run training group (-3.5%).
Conclusion: A 4-week bike HIT program improved running performance in moderate to well-trained triathletes. However, in our study, the cycle performance was not enhanced by a 4-week HIT running program, this may be due to the accumulated fatigue for the run group subjects.

KEYWORDS: High intensity training; Cross training; Blood lactate; Performance; Triathlon.

ABBREVIATIONS: HIT: High-intensity interval training; AT: Anaerobic Threshold; IEC: Institutional Ethics Committee; WMA: World Medical Association; BMI: Body Mass Index; ISAK: International Society for the Advancement of Kinanthropometry; LT: Lactate Threshold; RPE: Rating of Perceived Exertion.

INTRODUCTION

The optimal training recipe for improvement in performance in each of the modes of swimming, cycling or running is one of the most important elements of competitive triathlon. Therefore the search for new training methods to achieve improved triathlon performance is of paramount significance for coaches and scientists. The running component of elite triathlon largely dictates overall race performance.[1-4] Thus, improving running performance is viewed as the most important triathlon modality to achieve a satisfactory final race outcome especially in elite

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athletes.[1] Therefore, training for many athletes should focus on optimizing running performance.

Maximal oxygen uptake (VO_{2max}) and other submaximal physiological parameters are often viewed as key performance indicators in triathletes and other endurance athletes.[5] Recently the effects of high-intensity interval training (HIT) on VO_{2max}, anaerobic threshold (AT), running and cycling performances in endurance running and triathlon have been investigated, concluding that interval training consisting of multiple 5 min bouts at high intensity (85% of maximum heart rate (HR_{max}) was more likely to benefit 5 km running performance.[6,7] Short and long intervals at supramaximal and submaximal exercise intensities respectively, improved cycling physiology and performance.[6,7] Lindsay et al[8] concluded that, in competitive cyclists, a 4-week program of HIT increased peak sustained power output and fatigue resistance by ~5% and significantly improved 40 km time trial performance. In contrast, Acevedo and Goldfarb found no improvement in VO_{2max} in competitive long distance runners after 8 weeks of HIT.[9] However, 10 km race performance and time to fatigue did improve indicating that improvements in performance can be dependent of other variables in elite athletes.[9]

Some authors have defined cross-training as a) the participation in an alternative training mode exclusive to the one normally used in competition b) combining an alternative training mode with task-specific training c) cross transfer of training effects from one sport to the other one.[1,10] Several investigations have focused on cross-training transfer between swimming and running.[11-15] Millet et al[1] found that swimming training did not provide additional beneficial adaptations for the other disciplines in triathlon. They concluded that swimming training was highly specific, there were no significant relationships between training amounts in cycling or running and performance in swimming. Hence, performance improvement in swimming would be due specifically to improved swim technique and propulsive efficiency in swimming.[1] However, they were able to show that improvement in running performance may be as a result of training in cycling, which had a significant effect on running performance (τ_1=42: r=0.56: p<0.001). Additionally, performance in triathlon was related to the running training amounts (τ_1=52; fatigue function: τ_2=4: r=0.52; p<0.001).[1] Others have shown that training in cycling may help reduce over-use injuries, maintain aerobic condition and/or minimize stress during high training periods.[1,16,17] But few investigations have examined the impact of HIT training on cycling or running performance in triathletes.[7] Similarly, there is limited evidence of the impact of HIT in cycling and it is effects on running performance.

For these reasons, the purpose of this study was to observe the performance and physiological outcomes in incremental running and cycle time trial performance in triathletes during 4 weeks of HIT of either cycling or running. It was hypothesized that cycling HIT would enhance running performance in well trained triathletes.[1]

MATERIALS AND METHODS

Participants

Twelve male well-trained triathletes with a minimum of 2 years triathlon experience were invited to participate in the study. Their physical characteristics were (mean±SD); age, 34.0±5 yr; height, 178.8±3.2 cm; mass, 74.1±5.3 kg, body mass index (BMI) 23.3±1.6 kg·cm^{-2}, VO_{2max} 60.6±4.7 mL·kg^{-1}·min^{-1} (Table 1). The inclusion criteria was that they were training between 6-10 h a week to compete in a half ironman. Prior to commencement of the study the subjects completed a pre-questionnaire in order to establish background information on training patterns and medical history. The participants were divided into 2 HIT groups: bike HIT completed 2 sessions of HIT cycling per week and run HIT completed 2 sessions of HIT running per week.

Variables	Means±SD
Age (years)	34±5
Body height (cm)	178.8±3.21
Body mass (kg)	74.1±5.3
BMI (kg·cm^{-2})	23.29±1.55
VO_{2max} (mL·kg^{-1}·min^{-1})	60.55±4.72

BMI: Body mass index; VO_{2max}: Maximum rate of oxygen consumption

Table 1: Anthropometric measures of study participants.

The Institutional Ethics Committee (IEC) *Comité De Ética en la Investigación con Seres Humanos (CEISH) de la Universidad del País Vasco (UPV/EHU)* approved on February 11th 2015, the study following the guidelines of the World Medical Association (WMA) declaration of Helsinki-Ethical principles for medical research involving human subjects. Participants were informed about the study protocols and experimental procedures, and provided written informed consent.

Testing Protocol

The participants were familiarized to the laboratory procedures before any testing. They were tested on 2 occasions (1) before the HIT period and (2) following 4 weeks of HIT. The subjects completed a maximal incremental treadmill test for determination of the lactate threshold, VO_{2max} and a 20 min cycle time trial at each testing period.

Anthropometric measurements were also taken including: height (cm) and body mass (kg), using International Society for the Advancement of Kinanthropometry (ISAK) criteria. After a 10 min warm-up on the treadmill (Trackmaster, USA), a maximal test was performed. This consisted of 3 min stages with 30 seconds recovery. The 1st stage started at 8 km/h and the velocity increased 2 km/h until exhaustion. The time in the stage and the speed at exhaustion was recorded. To simulate the energetic cost of outdoor running conditions, the treadmill was set at 1% gradient.[7,18]

Heart rate (HR) was measured with a thoracic belt and

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wrist receiver (Polar RS400, Finland) during the test.

After each 3 min stage and during the 30 s recovery, blood Lactate concentration (BLa) was measured (Lactate Pro Analyser, Arkray, Japan). Two measures of the lactate threshold (LT) were calculated using the D-max method graph to observe the performance outcomes.[19,20] In this study, LTs were classified by 2 mM zone as lactate threshold 1 (LT_1) low intensity and >4 mM lactate threshold 2 (LT_2) as high intensity. Seiler identified the first low-intensity training zone (LITz) as a stable BLa at ~2 mM. The high-intensity training zone (HITz) was above maximum lactate steady-state intensity, greater than or equal to 4 mM.[21] Finally, the zone between 2 and 4 mM was the threshold training (ThT). In this research, LITz was used as the training intensity area on traditional training weeks and HITz and LITz on HIT training weeks.

Therefore, the speed and the HR at LT_2, the velocity peak (maximum) and HR maximum achieved were observed to determine the changes on running performance.

During recovery, participants provided a value for rating of perceived exertion (RPE) using the Borg Scale 6-20.[22]

Additionally, 48 h after the VO_{2max} test the participants completed a 20 min cycling time trial (TT). Each athlete used their competition cycle mounted on a cycle roller training device (Bkool, model Bkool one; Madrid, Spain). The subject's bike was fitted with a power meter in the hub of the rear wheel (Powertap, model Powertap G3 Alloy Wheels; Madison, WI, USA) for recording average power (W). HR was recorded with a HR and power monitor (Garmin Forerunner 910XT). Average HR, velocity and cadence were measured during the TT.[23]

Training Intervention

Before the 1st laboratory test session, participants completed 4 low intensity training weeks (control) in which they trained 9 sessions per week (3 swimming, 3 cycling and 3 running). The subjects performed during 4 control weeks 26.28 km (~12 h) swimming, 19.83 h cycling and 10.42 h running. Participants exercised at less than 70% of the maximum heart rate (MHR), and trained below LT_1 (<2 mM) measured during the pre-test, accumulating 7.5 h of training per week. The 4 week control sessions were designed in order to familiarize and obtain a similar start point for all subjects before the pre-test.

After the pre-test, participants were randomly assigned into one of 2 HIT groups. Both groups completed the same swimming sessions, however, the HIT cycle group completed 2 HIT cycling sessions per week and the HIT run group performed 2 sessions of HIT running per week. Each HIT session was 7×5 min at 85% of MHR and HITz (>4 mM). Running intensities were extrapolated using D-max graph and cycling intensities using 20 minutes TT test as published by Allen and Coggan.[23] All intensities were corroborated using exercise intensity categories (subjective and objective measures) Norton et al.[24] Besides the 2 HIT sessions every week, another seven (3 swim, 1 or 2 run and 1 or 2 cycle) training sessions in each group were aerobic extensive, lower than 70% of MHR and LITz (<2 mM), identical intensity than control weeks. During HIT training weeks, all subjects performed ~12 h swimming (25.95 km). Additionally, the bike HIT group completed 4.2 h bike HIT, 13.4 h cycling and 18.2 h running and the run HIT group completed 10.8 h cycling, 4.2 h run HIT and 6.1 h running.

During 8 training weeks (4 control weeks and 4 HIT weeks), each triathlete recorded their total HR data for all their training sessions (less swimming sessions), using a range of HR monitors (Polar Electro, models RCX5 and RC3, Finland and Garmin Forerunner, models 910XT and 920XT, Olathe, Kansas, USA) and the RPE for each session.

STATISTICAL ANALYSIS

The statistical analysis was performed with SPSS Statistics 20. To evaluate whether data were normally distributed the Shapiro-Wilk was used. In the case of normal distribution, for a pre- and post-test group comparison the student's *t*-test for paired samples was applied.

To determine possible interaction effects between groups a 2 factor analysis of variance (ANOVA) with repeated measures on the 2nd factor was calculated. Independent post-hoc *t*-test was applied for an inter-group comparison. The level of significance was set at $p \leq 0.05$.

RESULTS

HR and Velocity at LT_1 on a Maximal Treadmill Test

For each group, the velocity at 2 mM on the treadmill increased while HR at this point decreased in both groups, however, no significant differences were observed between pre- and post-test for these variables at 2 mM (LT_1).

Running velocity at LT_1 improved (11.9±1.7 *vs.* 12.7±1.5 km/h) in the cycle group and in the run group (11.56±1.0 *vs.* 11.8±1.5 km/h). Additionally, HR at LT_1 was reduced (157±18 *vs.*147±11 bpm) in the cycle group and the run groups (154±9 *vs.* 141±16 bpm) (Table 2).

Velocity and HR at LT_2 on a Maximal Treadmill Test

At the post-test, velocity ($F=6.93$, $p=0.025$) and HR ($F=9.01$, $p=0.013$) at 4 mM, on treadmill showed significant differences between groups, being lower in run group than cycle group at post-test. However, no significant differences were found between tests (Figure 1, graphs B and C). Cycle group showed a greater improvement on velocity and HR at LT_2 compared with the run group which diminished both variables (Table 2) (Velocity: 14.4±1.47 to 14.13±0.94; HR: 166±10 to 163±8) at this

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	HIT BIKE			HIT RUN		
	Pre	Post	*p*-value (intra-group)	Pre	Post	*p*-value (intra-group)
V 2 mM	11.9±1.72	12.7±1.54	0.46	11.56±1.01	11.8±1.49	0.69
V 4 mM	14.85±1.48	15.62±1.01	0.28	14.4±1.47	14.13±0.94	0.50
HR 2 mM	157±18	147±11	0.77	154±9	141±16	0.66
HR 4 mM	173±13	175±5	0.77	166±10	163±8	0.29
V peak	19.00±1.09	18.67±1.03	0.36	18.00±1.26	17.33±1.03	0.36
HR peak	187±5	187±8	0.70	180±9	177±11	0.26

V: Velocity; HR: Heart rate.

Table 2: Mean±SD aerobic capacity, aerobic power and heart rate during the incremental exercise test in the Bike HIT and Run HIT groups pre- and post- the intervention program.

point on post-test than pre-test in run group, without significance differences.

However, no significant differences were observed between pre- and post-test for either group, in variables such as, velocity and HR at 4 mM.

Velocity and HR_{peak} (Maximal) on a Maximal Treadmill Test

Velocity peak in running tended to be lower in both groups, presenting significant differences at the post-test (F=5.0, p=0.049), from 19.0±1.1 to 18.7±1.0; 18.0±1.3 to 17.3±1.0 for bike and run group, respectively (Figure 1, graph D).

However, no significant differences were recorded for velocity or HR peak during the incremental running test between pre- and post-tests for each group (Table 2). The HR_{peak} was similar in the bike HIT group but was slightly lower in the run group after 4 weeks of HIT (Table 2).

HR, Velocity and Cadence Average on 20 Minutes Cycling Time Trial

The HR average during the 20 min TT cycle showed significant differences between groups at post-test (F=5.42, p=0.042). In both groups HR average decreased, but in the run group this was greater (Figure 1, graph A). No significant differences between

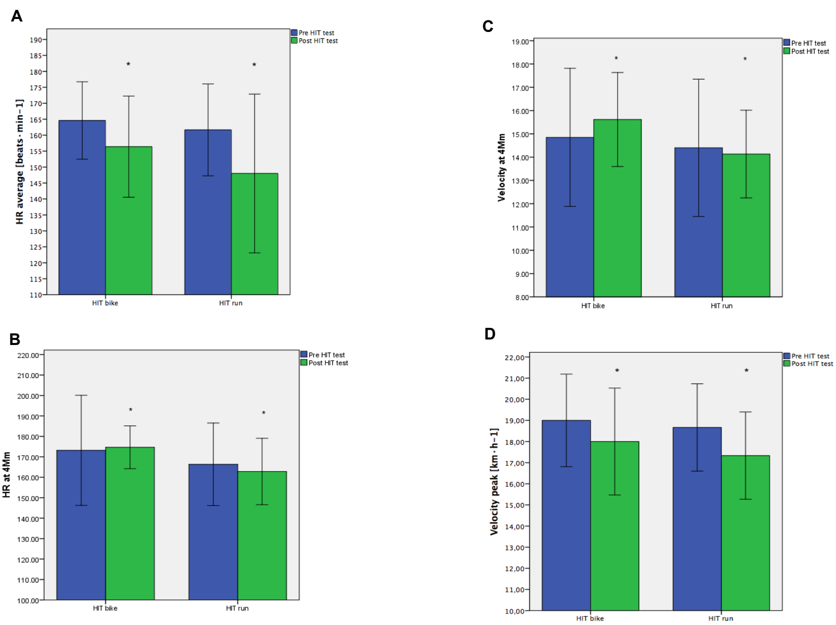

Figure 1: Mean±SD for Effects of 4 HIT weeks on HR average cycle (Panel A), HR at 4 Mmol (Panel B), Velocity at 4 Mmol (Panel C) and run velocity peak (Panel D) on treadmill running in moderate-well trained triathletes. *=p<0.05 group interaction.

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	HIT BIKE			HIT RUN		
	Pre	Post	*p*-value	Pre	Post	*p*-Value
V *av.* TT	42.0±2.14	48.97±1.62	0.72	41.80±0.94	41.05±0.94	-
HR *av.* TT	164±6	162±7	0.48	156±8	148±12	0.15
Cad *av.* TT	95.5±4.93	98.8±8.70	0.37	90.33±9.02	98.3±0.58	0.53

av.: Average; V: Velocity; HR: Heart rate; Cad: Cadence; TT: Time trial.

Table 3: Mean±SD for velocity, cadence and heart rate during the cycle time trial in the HIT Bike and Run groups pre and post the intervention program.

tests were found for velocity, cadence or HR averages during the cycle TT (Table 3).

During the time trial cycle, the bike group demonstrated an improvement in average velocity, whereas, velocity was slightly lower in the run HIT training group. The mean cadence during the cycle time trial was higher in both groups from 95.5-90.3 during bike and run pre-HIT test to 98.8-98.3 on post-HIT test (Table 3).

DISCUSSION

The purpose of this study was to examine the effects of a short period (4 weeks) of HIT in either cycling or running on incremental running and cycle time trial performance in well-trained triathletes. The results of the study demonstrated that 4 weeks of HIT cycling (7×5 min at 85% HR_{max}) induced a slight to moderate improvement in velocity and HR at 2 and 4 mM, and in HR_{peak} during an incremental treadmill test, however, these changes were not significantly different. These results are in line with previous studies, showing that cycling can result in a cross training effect on running and can be used as an alternative to increasing performance in running.[6,7,17]

Both groups enhanced velocity at the 2 mM LT or LT_1 (6.72% for bike group and 2.08% for run group) and decreased HR at LT_1 (Table 2) associated with a cardiovascular adaptation to endurance training.[25] These results were in agreement with several authors who observed that HR after endurance training was also significantly lower during submaximal exercise.[7,12,17] Therefore, it is highly likely that the use of 8×5 min at 85% HR_{max} HIT training might improve running performance at submaximal intensities.

The cycle group participants showed a greater physiological efficiency during post-test to generate more energy, improving HR, and they were more psychologically efficient, enhancing the velocity at high intensities such as LT_2. Nevertheless, we observed that in the run HIT group, velocity and HR at 4 mM were lower on the post-test compared with pre-test. These findings contrasted with other research results which showed an improvement for velocity at lactate threshold from 14.6±1.0 km/h on the pre-test to 15.2±0.8 km/h on the post-test after 10-weeks of high intensity-low volume training program on well-trained male middle-distance runners.[26]

In the case of the HR for the run group, the average HR during the cycle time trial was considerably lower (8.4%) potentially due to residual fatigue from the intensified training. In accordance with this suggestion we hypothesise that the HIT approach induced significant residual and accumulated fatigue which lead to the inferior post training responses. Some authors investigated the manifestation and mechanism of fatigue and overreach after an intensified training weeks using neural, metabolic, immune function, mechanical and cognitive parameters.[27-29] Le Meur et al[27] observed a 4.4±1.1% decrease in velocity average on performance of highly trained triathletes due to overreach after an intensified training protocol. Additionally, they demonstrated a decrease in HR at submaximal and maximal intensities. In this study, the run group subjects presented a considerable HR decrease in cycle TT test. Furthermore, Hanson et al[28] reported a 5.4% decrement in overreached cyclists and Lehmann et al[29] showed an 8% decrease during an incremental exercise test in middle and long distance runners. Therefore, in some athletes, elevated training intensity in running may be counter-productive.[30] However, this requires further investigation. Also the velocity average during the cycle TT were lower (5.1%), HR_{peak}, during maximal test in the treadmill, also decreased for the run group while Bike group maintained it. Whereas, the decrease of peak running velocity during the incremental test in the running group (-1.7%) was impressive, there was a significant difference between groups in the post-test for this variable (Figure 1, graph D). It is proposed that the subjects who completed the HIT running sustained a residual and accumulated fatigue resulting from glycogen depletion or other neurological related fatigue. Some authors explained similar occurrences (HR_{max} and performance decreases) when they investigated fatigue, overreaching and overtraining.[31,32]

The subjects who completed the HIT cycling enhanced 16.6% for velocity, 3.5% for cadence but showed a reduction -1.2% for HR average. The change in velocity with Bike HIT was similar to Lindsay et al[8] research that showed during a 40 km time trial the velocity average augmented 3.5% after 2 HIT weeks. However, in the same study, absolute HR values during time trial were higher on post-HIT test than pre-test (from 89.5±3.2% HR_{peak} on pre-test to 91.6±3.1% on post-test).[8] In our study, average HR in the Bike group showed a decrease of 6.4% at post-test. In the Lindsay et al[8] study, subjects were competitive cyclists but our study participants were triathletes with different sports backgrounds and level of performance. This may explain some of the conflicting adaptations. Nevertheless, our

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results were in agreement with several authors mentioned above, who observed that HR after running training was also significantly lower during submaximal exercise.[7,12,17] Future studies should look to examine further the relative benefits of HIT cycle training on performance in triathletes when running training loads are manipulated.

The run HIT group presented a decrease of 1.8% for average velocity and 5.1% for average HR. Average cadence was higher post-test (8.8%). These outcomes were dissimilar to Millet et al[1] who concluded that running was the discipline which provides the largest transfer to the other triathlon disciplines. It was highly likely that there was no transfer between running training to cycling performance due to the fatigued state and lack of experience of the run triathlete group.

CONCLUSIONS

Implementing intensified training using individual HIT sessions in running and cycling improves running performance at low intensities in moderate to well-trained triathletes. Whereas, training using a similar HIT training method in cycling enhances running performance at high intensities (4 mM) in moderate to well-trained triathletes. Additionally, 4 weeks of cycling HIT training improved cycling performance, whereas, a similar period of running HIT training did not improve cycling performance due to a possible fatigue accumulation. However, an important factor influencing adaptation to HIT is prior aerobic conditioning and training experience of the triathletes. It is possible that using HIT may evoke inferior performance responses due to cumulative fatigue, for this reason, it is necessary to investigate further cross training transfer using the HIT approach in athletes of different experience and training status.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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10.5.2. Artículo pendiente de publicación

Dadas las excepcionales circunstancias a consecuencia del Covid-19, tanto los informes de los revisores externos para contemplar la mención internacional de este trabajo, los procesos administrativos internos por parte de las Universidades y la revisión de artículos de las revistas científicas, los plazos habituales han sufrido retrasos y no ha sido posible incluir el artículo que se adjunta a continuación como parte de la tesis doctoral; al ser la versión final del documento editada a principios del mes de mayo. Por ello, incluimos a continuación la carta de aceptación del artículo por parte de la revista *Journal of Sport Science & Medicine* (IF:1.774; con Indexación Internacional en JCR) y la última versión aceptada por la revista. Este artículo original representa la última parte del trabajo realizado y el colofón a la tesis doctoral presentada.

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TITLE: "PHYSIOLOGICAL RESPONSE DIFFERENCES BETWEEN RUN AND CYCLE HIGH INTENSITY INTERVAL TRAINING PROGRAM IN RECREATIONAL MIDDLE AGE FEMALE RUNNERS"

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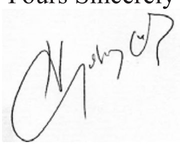
Dear Javier Yanci,

I am glad to inform you that your manuscript is accepted for publication in the Journal of Sports Science and Medicine and it will be published in September 2020 Issue of JSSM. The manuscript will now be edited for style and format.

Please do not hesitate to contact me if you have any questions.

Thank you for giving the JSSM the opportunity to publish your work

Yours Sincerely



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PHYSIOLOGICAL RESPONSE DIFFERENCES BETWEEN RUN AND CYCLE HIGH INTENSITY INTERVAL TRAINING PROGRAM IN RECREATIONAL MIDDLE AGE FEMALE RUNNERS

HIIT IN MIDDLE AGE RECREATIONAL FEMALE RUNNERS

ABSTRACT

Purpose: The aim of this investigation was to compare the changes in endurance running performance and physiological variables after a four-week period of high intensity interval training (HIIT) in either running or cycling in female athletes. **Methods:** Fourteen recreational female runners (age = 42 ± 10 yr, height = 1.67 ± 0.06 m, body mass = 61.6 ± 10.4 kg, body mass index (BMI) = 22.2 ± 3.4 kg.m^{-2}) were randomly allocated to one of two HIIT training groups: running ($HIIT_{run}$) or cycling ($HIIT_{bike}$). Each group performed two HIIT sessions per week for 4 weeks, which consisted of 6 x 2 min at 95% of maximal heart rate (HR_{max}) and 4 x 1 min all out efforts. **Results:** Maximal oxygen consumption (VO_{2max}) in treadmill running increased significantly after the $HIIT_{run}$ ($p < 0.01$, ES = 0.6) but remained unchanged in $HIIT_{bike}$. However, $HIIT_{bike}$ improved average velocity in a 10 km running time trial (TT_{run}) ($p < 0.05$, ES = -0.4), whereas, no changes were found for the $HIIT_{run}$ group. Analysing the first and last HIIT sessions, for $HIIT_{run}$ only the average rate of perceived exertion (RPE_{av}) increased significantly, whereas, performance variables such as average heart rate (HR_{av}) and average pace ($pace_{av}$) remained unchanged. $HIIT_{bike}$ enhanced significantly the average speed of HIIT sets ($speed_{av}$) and the peak power output (PPO) of the session, as well as, the RPE_{av} and delayed onset muscle soreness immediately after HIIT session ($DOMS_{post}$) were increased significantly. **Conclusion:** A regime of HIIT in cycling may evoke increases in female recreational runners' power, which may be related with improvements in a 10 km TT_{run} independent of changes in aerobic capacity. This may be advantageous in order to avoid overuse running related injuries.

Keywords: gender, intermittent training, muscle damage, aerobic capacity, endurance.

INTRODUCTION

High intensity interval training (HIIT) has been widely studied in athletic and non-athletic populations, demonstrating considerable positive benefits, such as, improved training time efficiency relative to increases in aerobic and anaerobic capacity or maintenance of endurance performance during low-volume training periods (Billat et al., 2001; García-Pinillos et al., 2017; Gunnarsson and Bangsbo, 2012; Lindsay et al., 1996). HIIT comes in many different forms and aims to improve distinct sport performances (Laursen and Jenkins, 2002). A number of authors have investigated the optimal HIIT stimulus for improvements in endurance performance such as the intensity and duration of sessions (Etxebarria et al., 2014; Gunnarsson and Bangsbo, 2012; Laursen and Jenkins, 2002; Stepto et al., 1999). Despite the fact that HIIT appears to enhance a number of physiological variables, such as, maximal oxygen consumption (VO_2max), peak power output (PPO), time to exhaustion at maximal velocity, first and second ventilatory threshold and vertical jumping performance (García-Pinillos et al., 2017; Helgerud et al., 2007; Laursen et al., 2002; Laursen and Jenkins, 2002; Mallol et al., 2018) the majority of research examining the effects of HIIT has been conducted with male athletes (Billat et al., 1999; Laursen et al., 2002; Lindsay et al., 1996) or with mixed male and female athletes sample (Farley et al., 2016; Koral et al., 2018; Mallol et al., 2016; Menz et al., 2015) while a group of exclusively female participants is less frequently studied. Some studies have reported less beneficial outcomes to HIIT training in females compared to males and hypothesized this may be due to a greater disposition to aerobic metabolism in females compared to males (Gibala et al., 2014; Gratas-Delamarche et al., 1994). Previous authors supported that gender might be a differentiating element in endurance performance, such as cross-country skiing, cycling and marathon running (Gibala et al., 2014; Gratas-Delamarche et al., 1994). Other studies have concluded that VO_2max, maximal aerobic power, power at lactate threshold (LT), power at onset blood lactate accumulation (OBLA) and peak of speed levels showed significant differences between genders. Such that the male subjects obtained greater values (Hopker et al., 2010; Reaburn et al., 2011; Sandbakk et al., 2012). Additionally, anthropometric and morphological variables such as lipid accumulation may also be an influential factor (Reaburn et al., 2011).

The limited studies on female athletes have shown greater improvements in aerobic and anaerobic capacity after a HIIT program compared with continuous training in female soccer players (Rowan et al., 2012). The authors emphasised the time saving benefits obtained from HIIT sessions, helping to focus on teamwork and sport specific skills (Rowan et al., 2012). Kinnunen et al. (Kinnunen et al., 2017) found that a HIIT program applied in pre-season helped to enhance the maximal and explosive strength capacity, improving neuromuscular performance in female ice-hockey players. Recently, Mallol et al. (Mallol et al., 2018) observed short supramaximal sets of HIIT enhanced maximal VO_{2max} values and submaximal power [W] at the first and second ventilatory threshold capacity. However, no performance improvements were observed during a triathlon race simulation (Mallol et al., 2018). The context of the study was in relation to maintenance of fitness during periods of reduced training. There is minimal research examining the effects of HIIT in females. Therefore, further research is needed to achieve a greater understanding of this training method in females.

Previous researchers concluded that an intensified period of training in running results in a higher level of cumulative fatigue, greater muscle damage and potential injury in runners (Burt et al., 2012; Del Coso et al., 2013). An intensified training program, high volume and/or intensity, presents a demanding stimulus requiring careful planning and monitoring. Running can lead to higher levels of muscle damage and cumulative fatigue owing to eccentric muscle contractions which is evidenced by higher biochemical and perceptual markers of muscle damage and soreness such as creatine kinase (CK) (Burt et al., 2012; Cipryan, 2017; Keane et al., 2015; Quinn and Manley, 2012). In particular, muscle damage is typically observed in the periods after HIIT sessions. Elevated levels of CK, myoglobin and lactate dehydrogenase were induced by 15 s, 30 s and 60 s HIIT running protocols (Cipryan, 2017). Moreover, the muscular eccentric component of down-hill running training involved higher CK values and greater exercise induced inflammatory responses in female runners (Köhne et al., 2016). In female sports teams such as soccer, rugby and netball, female athletes presented an increased level of muscle damage after high intensity sprint training (Le Meur et al., 2011). Intensified HIIT in cycling, which is a more concentric based activity than running, may not result in the same cumulative level of soreness. Therefore, the current study focused on the comparing the residual effects of HIIT in cycling and running modalities. Additionally, Burt et al. (Burt et al., 2012) have presented data showing that different levels of exercise-induce muscle damage were evident following running and cycling exercises. However, as a general form of training HIIT in cycling might nonetheless induce performance changes similar to those shown following running HIIT programs (Burt et al., 2012; Millet et al., 2002) but this has not been extensively investigated. Several studies in well trained runners have observed positive effects on running performance when a part of their run training volume was replaced by cycle training sessions (Etxebarria et al., 2014; Tanaka, 1994; White et al., 2003). Overall, relatively few investigations have been conducted with female athletes in order to examine how CK, as a biomarker of muscle damage, is affected by an intensified running training program. There is also limited research showing how exercise induced CK varies between running and cycling HIIT modes after a period of HIIT in running or cycling.

Therefore, the current investigation focused on examining the difference in physiological responses, performance outcomes and muscle damage, as acute effects, occurring between run and cycle HIIT modes in female athletes.

MATERIALS AND METHODS

Participants

A group of fourteen recreational middle-aged female athletes (age = 42 ± 10 yr, height = 1.67 ± 0.06 m, body mass = 61.6 ± 10.4 kg, body mass index (BMI) = 22.2 ± 3.4 $kg.m^{-2}$) were recruited from a number of community clubs and institutions. Participants were randomly distributed in two groups: a running HIIT group ($HIIT_{run}$, n = 7, age = 41 ± 7 yr, height = 1.64 ± 0.07 m, body mass = 60.7 ± 9.3 kg, BMI = 22.6 ± 2.3 $kg.m^{-2}$) who completed two run HIIT sessions per week, and a cycling HIIT group ($HIIT_{bike}$, n = 7, age = 43 ± 13 yr; height = 1.70 ± 0.03 m; body mass = 62.5 ± 12.1 kg; BMI = 21.8 ± 4.5 $kg.m^{-2}$) who performed an identical HIIT session protocol on the cycle ergometer. The inclusion criteria were: participants were habitual and active runners, ≥ two running sessions per week, and were able to run 10 km in < 70 min. Participants were excluded if they had no running training in the previous one month, or had an injury that prevented them from participating in training or testing.

Participants were informed of the protocols and experimental procedures and signed a formal written consent. The study followed the guidelines established by the Declaration of Helsinki (2013) and was approved by the Human Research Ethics Committee (HREC code 334.16).

Procedures

The study examined the physiological and performance benefits, as well as, the muscle damage generated by four weeks of HIIT using running or cycling in female runners. Participants attended Flinders University Exercise Physiology Laboratory twice weekly at the same time of day, to perform the HIIT sessions. To determine differences between the HIIT programs, participants were divided into two groups: $HIIT_{run}$ who performed supervised running HIIT sessions on an outdoor grass running track and $HIIT_{bike}$ who performed supervised cycling ergometer HIIT sessions in the laboratory. All participants performed identical testing procedures before and after the four-week intervention period. Each subject undertook the initial and final tests (laboratory testing and 10 km running time trial) at approximately the same time of day and were asked to follow a similar protocol for test preparation. The environmental conditions in the laboratory were maintained between 20-22ºC and 55-65% humidity.

Laboratory incremental running test

Each participant completed a ‘fast’ incremental exercise test to exhaustion using treadmill running in the week prior to and a week after the training intervention. The test procedure included: (a) 10 minutes of their usual warm-up intensity on the treadmill (b) an incremental running test where the initial stage was set at 8 $km.h^{-1}$. Each stage lasted one min and the speed was increased by 1 $km.h^{-1}$ until exhaustion (Noakes et al., 1990).

Expired gases were analysed by TrueOne2400 (ParvoMedics, Utah, USA), to determine maximal oxygen consumption (VO_{2max}) on a treadmill, the gas was analysed every 5 seconds but the 2 highest consecutive values over 30s was used. Before the warm up, blood lactate concentration was obtained from a fingertip sample and analysed using a portable lactate analyser (Lactate Pro, Arkray, KDK Corporation, Kyoto, Japan). Heart rate (HR), maximal speed achieved during the last stage completed ($speed_{max}$) and rating of perceived exertion (RPE) were recorded in the final 15 s of every stage. HR was recorded using Polar RS400 series (Kempele, Finland) HR monitor until test completion. The Borg Scale (from 0 to 10) (Borg, 1982) was employed to monitor the RPE at the end of each stage. Participants were previously familiarised to the perceived exertion method and the 10- point Borg Scale.

Running time trial (TT)

After a 60 min break from the incremental running test the participants completed a 10 km TT individually on a 400 m grass running track. Distance was previously measured and marked on the track by the researchers, participants were asked to complete 25 laps. Average and maximum speed ($speed_{av}$ and $speed_{max}$), and HR (HR_{av} and HR_{max}) were recorded (Garmin Forerunner 910XT Olathe, Kansas, USA). RPE average (RPE_{av}) was calculated from values obtained every 2 km throughout the trial. Instantaneous pace and HR were recorded every 2 km. Immediately after the test, lactate concentration was measured from a fingertip sample (Lactate Pro, Arkray, KDK Corporation, Kyoto, Japan).

Training intervention

Participants randomly allocated to the HIIT groups ($HIIT_{run}$ and $HIIT_{bike}$) attended supervised training sessions twice a week. The session structure was similar for all HIIT training: a 10 min warm-up where participants determined their warm-up intensity from the maximal test, followed by 6 x 2 min at 95% of maximal heart rate (HR_{max}) and 4 x 1 min all out (Bogdanis et al., 1996) followed by a 5 min cool-down. The recovery periods for the 1 and 2 min interval sets were 1 min 30 s and 2 min, respectively, with athletes continuing active recovery at a low intensity. $HIIT_{run}$ performed the training outdoors around the same track as used for the 10 km TT. Individual training intensity at 95% of HR_{max} and maximal intensity for the $HIIT_{run}$ group were determined for each participant based on their pre-intervention testing. The $HITT_{bike}$ sessions were performed using a cycle ergometer (Wattbike, Nottingham, UK). The $HIIT_{bike}$ intensity were extrapolated from the treadmill test based on Millet et al. (Millet et al., 2009) review were researchers concluded that HR_{max} obtained from a maximal cycle ergometer test is about 5% (between 6-10 bpm) lower than HR_{max} recorded in a maximal treadmill test. The intensity was also corroborated with RPE values (Basset and Boulay, 2000; Norton et al., 2010) which showed a similar pattern for HR during cycling interval training (Green et al., 2006). Participants could change the cycle resistance as they needed as long as they achieved the stipulated HR. In order to recognise their usual training load, they were asked to complete a 1-week training diary before the intervention to ensure that no significant differences existed between participants. During intervention weeks participants recorded their individual training sessions outside of the HIIT program. Every session was documented in a personal training diary which included the running training duration, distance and RPE_{av} allowing for the session RPE-min to be calculated (Table 1).

Table 1 about here

Acute response to HIIT

The physiological responses to the first (1st) and last HIIT (8th) session in each mode ($HIIT_{run}$ and $HIIT_{bike}$) were measured. Blood lactate (Lactate Pro Analyser, Arkray, Japan) and CK concentrations (Reflotron Plus system, Rotkreuz, Switzerland) were measured before and immediately after the training session from fingertip blood samples. Participants came back to the laboratory 24 h after the HIIT sessions in order to measure CK_{24h} (Quinn and Manley, 2012). Delayed onset muscle soreness (DOMS) was recorded using a CR-10 scale (Lau et al., 2015) before, after and 24 h after session. During each $HIIT_{run}$ session the average and peak HR, HR during recovery intervals, pace, distance covered and average/maximal RPE values were recorded (Borg, 1982). During the $HIIT_{bike}$ average and maximal HR, recovery HR intervals and average and maximal RPE values (Borg, 1982) were recorded. Speed, power and cadence average, maximal power and cadence were also recorded for the $HIIT_{bike}$ group.

Statistical Analyses

Results are presented as mean ± SD. A t-test for independent samples was used to analyze the differences between $HIIT_{run}$ and $HIIT_{bike}$ at baseline (pre-test). The between-group ($HIIT_{run}$ vs $HIIT_{bike}$) comparison from pre-test to post-test or 1st and 8th HIIT sessions for data obtained in the laboratory tests and 10 km TT was calculated using a 2-way mixed ANOVA (group x time). In addition, a t-test for paired samples was used to analyze the differences between the pre-test and post-test independently for each group ($HIIT_{run}$ or $HIIT_{bike}$). Cohen's effect size (Cohen, 1988) was calculated to assess a practical significance between the pre-test and post-test in each group. Effect sizes (ES) of above 0.8, between 0.8 and 0.5, between 0.5 and 0.2, and lower than 0.2 were considered as large, moderate, small, and trivial, respectively (Cohen, 1988). Data analysis was performed using the Statistical Package for Social Sciences (SPSS Inc, version 24.0 for Windows, Chicago, IL, USA). The statistical significance was set at $p < 0.05$. Despite the fact that in some cases, a variable showed a p value > 0.05, whereas, ES was greater than 0.5 (moderate), was considered practical difference.

RESULTS

No significant differences were found pre-intervention between $HIIT_{run}$ and $HIIT_{bike}$ for VO_{2max}, HR_{max} and $Speed_{max}$ in the incremental treadmill test or any variable obtained during the 10 km TT. After 4-weeks of the HIIT intervention, $HIIT_{run}$ improved VO_{2max} significantly ($p < 0.01$, ES = 0.6, moderate), and decreased HR_{max} ($p = 0.09$, ES = - 0.5, moderate) whereas the $Speed_{max}$ values were maintained ($p = 0.11$, ES = 0.3, small). In the $HIIT_{bike}$, no changes were observed after 4-weeks for VO_{2max}, HR_{max} and $Speed_{max}$ (p = 0.16 to 0.26, ES = -0.2 to 0.3, trivial to small) (Table 2). According to the two-way mixed ANOVA analysis (group x time), only VO_{2max} showed a statistically significant difference. The $HIIT_{run}$ group enhanced the VO_{2max} result in post-test ($p = 0.01$) while the $HIIT_{bike}$ group showed no change.

Table 2 about here

After 4-weeks of the intervention, neither $HIIT_{run}$ nor $HIIT_{bike}$ changed either the time to complete the 10 km TT (p = 0.06 to 0.84), ES = 0.1 to -0.2, trivial to small), or average heart rate (HR_{av}) (p = 0.14 to 0.58, ES = -0.2 to -0.3, small) (Table 3). $HIIT_{run}$ resulted in a highe lactate concentration at the end of the test ($Lactate_{post}$) (p = 0.18 to 0.05, ES = 3.6, very large). There was a significant increase in the average and maximum rating of perceived exertion (RPE_{av}) ($p = 0.04$, ES = 1.7, large) and RPE_{max} ($p = 0.04$, ES = 1.6, large), whereas, HR_{av} did not change significantly ($p > 0.05$, ES = -0.2, trivial) (Table 3). In the $HIIT_{bike}$ group the average pace decreased significantly ($p = 0.02$, ES = -0.3 small) and the maximal rate of perceived exertion (RPE_{max}) increased during the 10 km TT post-test (p = 0.04, ES = 0.9, large) (Table 3). There were no group x time differences.

Table 3 about here

Table 3 and Figure 1 show the results for the 1st and 8th HIIT sessions. $HIIT_{run}$ demonstrated a significant increase for RPE_{av} (p = 0.03, ES = 0.8, moderate) and an increase in lactate concentration values immediately after the session ($Lactate_{post}$) (p = 0.14, ES = 0.6, moderate) (Table 4) and creatine-kinase (CK) concentration before session (CK_{pre}) (p = 0.15, ES = 1.0, large) (Figure 1). No significant differences were observed for the remaining variables. The $HIIT_{bike}$ group showed a significant improvement in $Speed_{av}$, P_{av}, and P_{max} (p = 0.01 to 0.03, ES = 0.6 to 0.7, moderate), while increases in RPE_{av} and delayed onset muscle soreness immediately after training ($DOMS_{post}$) were also observed (p = 0.02, ES = 1.4 to 2.2, large) (Table 4). The maximal heart rate obtained during HIIT sets and recovering sets ($HR_{max-work}$ and $HR_{maxrecovery}$) and $Lactate_{post}$ demonstrated practical increases although these were not significant (p = 0.16 to 0.34, ES = 0.6 to 2.0, moderate to large?. The average heart rate recorded during recovery intervals ($HR_{av\ recovery}$) and the concentration of CK 24-hour after the HIIT session ($CK_{24after}$) decreased practically (p = 0.46 to 0.49, ES = -0.6 to -1.0, moderate to large) (Figure 1). According to the two-way mixed ANOVA analysis (group x time), only $DOMS_{post}$ showed statistical significance (p = 0.017).

*** Table 4 about here***

Figure 1 about here

DISCUSSION

Previous studies have analysed the effects of HIIT in individual exercise modes on a single mode of activity (Cook et al., 2010; Laursen et al., 2002; Sijie et al., 2012). However, the effects of this training method in running or cycling on performance in a single mode such as running in female athletes has not been studied. In the current investigation, only the $HIIT_{run}$ group evoked significant improvement in VO_{2max} during a maximal treadmill test. Neither $HIIT_{run}$ nor $HIIT_{bike}$ significantly enhanced the time to complete 10 km TT, despite a significant decrease in average pace for the $HIIT_{bike}$ participants. Running HIIT generated a significantly greater level of muscular fatigue in non-competitive female runners compared to cycling HIIT.

As noted above, VO_{2max} improved significantly in the $HIIT_{run}$ group while the remaining maximal test variables in each training group were not significantly modified. This situation may be due in part to an excessive training amount accumulated by runners who may not have been accustomed to structured HIIT. Previous investigations observed improvements on VO_{2max} and maximal test variables such as HR and speed or power, however the performance level changed from the current investigation. Rowan et al. (Rowan et al., 2012) observed an enhancement of 4.73% in VO_{2max} after 5-week of 5 x 30 s with 4.5 min recovery in female soccer players, however, similar results were obtained from the control group who performed 40 min continuous running at 80% of VO_{2max}. In another study, Gunnarsson et al. (Gunnarsson and Bangsbo, 2012) showed that 7-weeks of short interval HIIT improved VO_{2max} in moderately trained male and female runners. Mallol et al. (Mallol et al., 2018) concluded that after 4-weeks of a cycling HIIT program in moderately trained triathletes, participants improved 6.7% in VO_{2max} and 15% in peak power. Finally, Lesmes et al. (Lesmes et al., 1978) after 8-week of two types of supra maximal interval training (short duration at 170% of velocity at

VO_{2max} (vVO_{2max}) and long duration at 130% at vVO_{2max}) concluded that the frequency of training, interval distances and intensities were independent of changes in aerobic power and submaximal HR in females, whereas, interval training intensity was essential to improve these variables in males rather than frequency and interval distance. In our study, $HIIT_{run}$ achieved greater changes than $HIIT_{bike}$ and this may be due to the specificity of the activity. For future investigations, it would be relevant to consider the effects of cycling HIIT during a maximal test using a cycle ergometer. Additionally, comparing different HIIT interventions of different intensity and work to rest characteristics.

During the 10 km TT the $HIIT_{run}$ performance remained unchanged but RPE_{av} increased significantly indicating a greater perception of effort. At the same time, HR_{max} decreased after 4-week of $HIIT_{run}$ program. Perceived exertion may have increased during post - intervention running 10 km TT on account of individual fatigue accumulated after the HIIT program possibility due to insufficient recovery after the period of intensified training. Controversially, other researchers have observed improvements in running performances after a HIIT program. Gunnarsson et al. (Gunnarsson and Bangsbo, 2012) obtained an improvement of 6% and 4% in 1500 m and 5 km running tests, respectively. The protocol employed included 7-weeks of interval running working at intensities of 90% of HR_{max} with a 54% training volume reduction in moderately trained females. In addition Paavolainen et al. (Paavolainen et al., 1999) showed an improvement in 5 km run time in well-conditioned athletes with no changes in VO_{2max}, similar to that observed in the current study results for $HIIT_{bike}$ participants. Furthermore, Bangsbo et al.(Bangsbo et al., 2009) observed a decrease of 1 min in 10 km performance (from 37 min to 36 min) after a 6-9-week training period with intervals near maximal speed with a 30% reduced total training volume. However, Iaia et al.(Iaia et al., 2009) determined that after 4-week of 8-12 x 30 s maximal speed intervals and a 64% reduction in total training volume, but there were no improvements in 10 km TT run in these endurance trained participants. The studies mentioned above enhanced running performance after HIIT interventions, however, a number of these studies replaced a part of the participants usual training volume with HIIT sessions. In the current research, the intensities employed during HIIT intervals were maximal or close to maximal which may have generated an excessive training stress, and therefore, excess residual fatigue to the amateur female runners.

By contrast, the $HIIT_{bike}$ participants significantly increased performance ($Pace_{av}$, min/km) during the 10 km TT run with an increased RPE_{max}. Similarly, Mikesell et al.(Mikesell and Dudley, 1984) noted a decrease of 81 s on 10 km distance in well-trained runners after an intensive aerobic program, combining 40 min run “all out” 3 days a week with 5 x 5 min at VO_{2max} intervals with 5 min jogging on the treadmill as recovery. A number of investigations conducted with cyclists concluded that cycling HIIT significantly enhances cycling performance in a range of testing protocols and competitive simulations (Laursen et al., 2002; Lindsay et al., 1996; Stepto et al., 1999). The use of HIIT using identical activity modes to that of competition helped to improve the sports performance. Despite the fact that $HIIT_{bike}$ group did not show significant differences for time to complete 10 km TT, the $Pace_{av}$ manifested a significant decrease, hence, performance during the 10 km TT post-test was enhanced. Whilst the mechanisms accounting for this performance improvement are unknown it is possible that a gain in lower limb muscular power on account of the cycle HIIT sessions led to this improvement. It is also possible that the exercise mode of running presented a higher physiological demand due to a greater muscle recruitment, contraction type and accumulative fatigue which was associated with the different performance adaptations between modes (Le Meur et al., 2011). Nevertheless, the present study results suggest that the $HIIT_{run}$ program did not result in an improvement in 10 km performance considering that a greater $lactate_{post}$ concentration and RPE_{max} were observed post-test despite a similar HR_{av} and similar time to complete the time trial.

This study is novel in that biochemical and perceptive markers associated with muscle soreness were measured in the acute stages following the first (1^{st}) and last (8^{th}) HIIT sessions. Following the $HIIT_{run}$ intervention RPE_{av}, $lactacte_{post}$, and specifically, CK_{pre} were elevated, whereas, distance completed and $Pace_{av}$ remained the same from the 1^{st} HIIT compared with the 8^{th} HIIT session. This potentially indicates a greater level of muscle damage and lack of assimilation to the HIIT running program.By contrast, $HIIT_{bike}$ participants improved $Speed_{av}$ and $Power_{av}$ from the 1^{st} to 8^{th} HIIT session. This enhancement was associated with more positive responses for RPE_{av}, RPE_{max}, $DOMS_{post}$, $lactate_{post}$ and HR_{max}, although HR_{av} decreased during recovery, suggesting that $HIIT_{bike}$ athletes were able to perform more effectively in the session. At the same time both groups showed greater CK_{pre} during the 8^{th} HIIT. However, the difference between sessions were smaller, once again this may have occurred due to fatigue accumulation and lack of assimilation of the high intensity training. Furthermore, CK_{24h} values after the 8^{th} HIIT session decreased compared with the 1^{st} HIIT in the $HIIT_{bike}$ group, which may show a physiological adaptation such that $HIIT_{bike}$ runners were able to achieve a superior level of recovery from muscular fatigue.

Previous studies have focused on markers of muscle damage such as, CK concentration and DOMS after a high intensity training program in runners and cyclist while performing running and cycling testing in isolation (Nieman et al., 2014). In these studies, it was shown that muscle damage was related to activity mode. Nieman et al. (Nieman et al., 2014) analysed differences between running and cycling performances on runners and cyclists after 3 consecutive days of an 'overreaching' training program, concluding that the eccentric contractions intrinsic to running, resulted in 133% greater CK concentration and 87% greater DOMS in runners immediately after 3 days of running training compared with cyclists performing similar training on a cycle ergometer. Additionally, CK concentrations remained more elevated in runners than in cyclists after 1, 14 and 38 h after the training program. Similarly, DOMS presented a comparable pattern to CK at 1 and 14 h and by 38 h post intervention the values were similar in both groups. Likewise, Bruunsgaard et al. (Bruunsgaard et al., 1997) and Proske et al. (Proske and Allen, 2005) concluded that eccentric activities generated higher levels of muscle damage (CK, DOMS and myoglobin) compared with isometric and concentric contractions. In our study, CK_{pre} before the first and last HIIT were greater in the cycling group than the running group. However, the difference between sessions for CK_{post} were similar in both groups. For its part, CK24h results showed that $HIIT_{bike}$ may be able to recover faster than $HIIT_{run}$ after HIIT program.

One of the current research limitations relates to sample size. Longitudinal studies which require the completion of exhaustive and multiple assessments during an intervention, are onerous on participants, particularly taking into account work and family commitments. This can make it difficult to recruit large numbers of participants and contributed to some of the drop out in the current study. Another limitation relates to the timing of the 10 km TT on the same day of, and following, the maximal incremental test, the completion of multiple, exhaustive tests may have detrimentally affected the performance outcomes for subsequent tests on the same day. This is somewhat ameliorated in that all participants undertook the same testing process both before and after the intervention.

CONCLUSIONS

After 4-weeks of HIIT training program, only $HIIT_{run}$ participants improved VO_{2max} whereas no improvements were observed for 10 km TT run performance potentially due to fatigue accumulation generated by the HIIT training itself. Although no significant group by time differences were observed, the $HIIT_{bike}$ participants demonstrated improved 10 km TT run performance ($Pace_{av}$) indicative of positive cross training transfer. This occurred without changes in VO_{2max} during maximal incremental running tests. Both HIIT modes evoked some muscle damage although $HIIT_{bike}$ seems to have achieved faster muscular recovery 24 h after HIIT session completion. Therefore, it appears that a $HIIT_{run}$ program in recreational female athletes produces excessive stress, fatigue and muscle damage which may have resulted in inadequate stimulus for enhancement of running performance, whereas, $HIIT_{bike}$ may be a beneficial training modality that can be used to improve running performance.

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Key points

1. This article observes the effects of a HIIT program in two different modes, i.e. cycling and running, in a hardly investigated population, recreational middle-age female runners.
2. The analysis of physiological variables in a HIIT session, maximal test and 10 km time trial run performance.

Table I. Quantification of training sessions, excluding HIIT sessions, for Run (HIITrun) and Bike (HIITbike) groups.

	$HIIT_{run}$	$HIIT_{bike}$	p	Dif. (%)	ES
Duration (min)	49.97 ± 33.06	50.89 ± 23.99	0.84	1.84	0.0
Running distance (km)	6.59 ± 4.59	7.84 ± 4.22	0.12	18.99	0.3
RPE_{av}	4.31 ± 1.92	4.92 ± 1.90	0.06	14.28	0.3
Session RPE-min (AU)	227.53 ± 217.80	261.27 ± 166.36	0.27	14.83	0.1

Dif. (%) = mean differences in percentage, ES = effect size, RPE_{av} = average rate of perceived exertion, Session RPE-min = control method based on rate of perceived exertion per minute.

Table II. Results for Run ($HIIT_{run}$) and Bike ($HIIT_{bike}$) group in pre and post-intervention testing in maximal oxygen consumption (VO_{2max}), maximum heart rate (HR_{max}) and maximum speed ($Speed_{max}$) obtained during maximal treadmill testing.

	$HIIT_{run}$					$HIIT_{bike}$				
	Pre test	Post test	p	Dif. (%)	ES	Pre test	Post test	p	Dif. (%)	ES
VO_{2max} ($mL·kg^{-1}.min^{-1}$)	42.1 ± 4.9	45.2 ± 5.2**#	0.00	3.1 ± 1.6	0.6	41.0 ± 5.3	41.8 ± 6.5	0.26	0.8 ± 1.5	.1
HR_{max} (bpm)	187 ± 8	181 ±11	0.09	-5.9 ± 7.7	-0.5	174 ±9	173 ±10	0.16	-1.6 ±2.6	-.2
$Speed_{max}$ ($km.h^{-1}$)	14.1 ± 1.4	14.6 ±1.6	0.11	0.4 ± 0.6	0.3	13.8 ±1.5	14.3 ±1.9	0.20	0.5 ±0.8	.3

Dif. (%) = mean differences in percentage, ES = effect size. ** $p < 0.01$ significant differences with pre test. # $p < 0.05$, two way mixed ANOVA analysis (group x time) statistical differences.

Table III. Results for Run ($HIIT_{run}$) and Bike ($HIIT_{bike}$) group in pre and post- intervention tests for, lactate values, average pace ($Pace_{av}$), time (Time), heart rate average (HR_{av}), maximum heart rate (HR_{max}), rating of perceived exertion (RPE_{av}) and maximum rate of perceived exertion (RPE_{max}) obtained in the 10 km time trial.

	$HIIT_{run}$					$HIIT_{bike}$				
	Pre test	Post test	p	Dif. (%)	ES	Pre test	Post test	p	Dif. (%)	ES
Lactate (mmol/l)	3.3 ± 0.8	6.6 ± 0.9	0.18	3.3 ± 0.6	3.6	5.9 ± 2.5	7.8 ± 4.4	0.23	1.8 ± 3.6	0.4
$Pace_{av}$ (min/km)	5.36 ± 0.8	5.36 ± 0.7	0.91	0.0 ± .5	0.0	5.48 ± 1.3	5.30± 1.0*	0.02	-0.4 ± 0.3	-0.4
Time (min)	57.4 ± 7.3	57.8 ± 6.0	0.84	-0.4 ± 4.5	0.1	59.7 ± 11.9	57.5 ± 10.8	0.06	-2.1 ± 2.5	-0.02
HR_{av} (bpm)	172 ± 9	170 ± 8	0.58	-1.4 ± 6.5	-.2	169 ± 10	166 ± 12	0.14	-3.6 ± 5.5	-0.3
RPE_{av} (AU)	5 ± 2	7 ± 1*	0.05	1.5 ± 1.6	1.7	6 ± 2	6 ± 2	0.41	0.4 ± 1.3	0.3
RPE_{max} (AU)	7 ± 2	8 ± 1*	0.04	1.3 ± 1.3	1.6	6 ± 1	8 ± 2*	0.05	1.6 ± 1.7	0.9

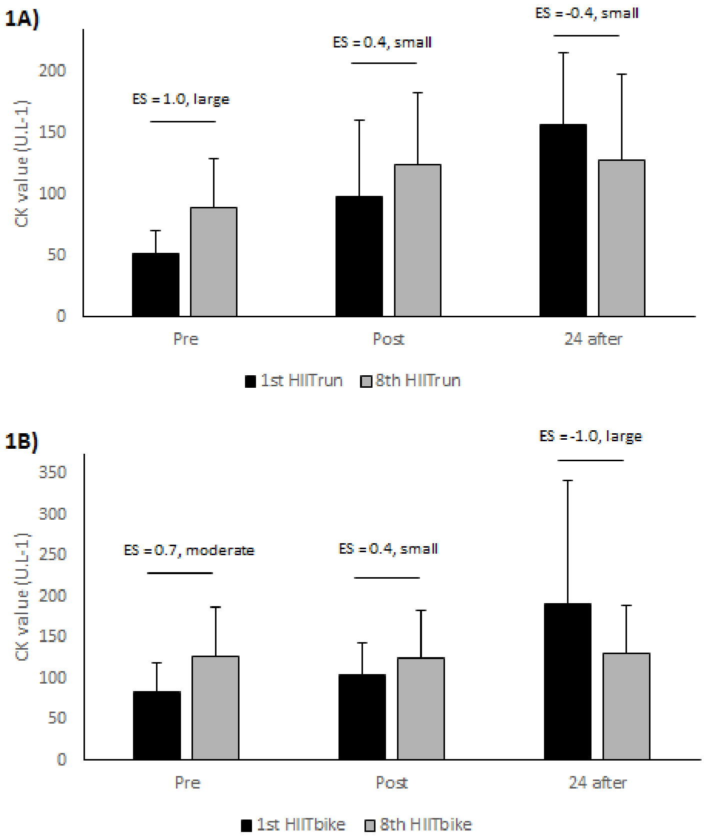
Dif. (%) = mean differences in percentage, ES = effect size. *$p < 0.05$ significant differences with pre test

Table IV. Results in 1st and 8th HIIT session for Run HIIT ($HIIT_{run}$) and for Bike HIIT ($HIIT_{bike}$) group.

		1st HIIT	8th HIIT 8	p	Dif. (%)	ES
$HIIT_{run}$						
	$HR_{av\text{-}work}$ (bpm)	167 ± 5	166 ± 10	0.91	-0.3 ± 6.4	-0.0
	$HR_{max\text{-}work}$ (bpm)	182 ± 6	183 ± 10	0.69	1.0 ± 5.7	0.1
	$HR_{av\ recovery}$ (bpm)	148 ± 9	147 ± 17	0.91	-0.4 ± 9.6	-0.0
	$HR_{max\ recovery}$ (bpm)	181 ± 7	181 ± 10	1.00	0.0 ± 4.2	0.0
	$Pace_{av}$ ($min.km^{-1}$)	4.11 ± 0.5	3.59 ± 0.4	0.27	-0.1 ± 0.3	-0.4
	$Distance_{av}$ (m)	386.2 ± 22.5	389.8 ± 30.6	0.54	3.6 ± 11.9	0.1
	RPE_{av} (AU)	7 ± 1	8 ± 2*	0.03	1.1 ± 1.1	0.8
	RPE_{max} (AU)	10 ± 1	10 ± 1	1.00	0.0 ± 1.0	0.0
	$Lactate_{pre}$ ($U.L^{-1}$)	1.7 ± 0.4	1.6 ± 0.7	0.74	-0.1 ± 0.6	-0.1
	$Lactate_{post}$ ($U.L^{-1}$)	6.3 ± 2.2	8.0 ± 3.2	0.14	1.8 ± 2.8	0.6
	$DOMS_{pre}$ (AU)	0.6 ± 1.5	1.0 ± 2.2	0.20	0.4 ± 0.8	0.2
	$DOMS_{post}$ (AU)	2.0 ± 1.6	2.4 ± 1.9	0.43	0.4 ± 1.1	0.2
	$DOMS_{24After}$ (AU)	1.0 ± 2.4	1.2 ± 2.4	0.36	0.2 ± 0.4	0.1
$HIIT_{bike}$						
	$HR_{av\text{-}work}$ (bpm)	153 ± 6	152 ± 12	0.77	-1.3 ± 11.0	-0.1
	$HR_{max\text{-}work}$ (bpm)	155 ± 23	164 ± 13	0.16	9.2 ± 12.0	0.7
	$HR_{av\ recovery}$ (bpm)	145 ± 15	139 ± 11	0.49	-6.2 ± 20.3	-0.6
	$HR_{max\ recovery}$ (bpm)	156 ± 18	168 ± 6	0.29	12.2 ± 22.3	2.0
	$Speed_{av}$ ($km.h^{-1}$)	33.9 ± 4,5	36.2 ± 3.0*	0.02	2.3 ± 1.8	0.7
	P_{av} (W)	166 ± 49	198 ± 44**	0.01	32.4 ± 20.0	0.7
	P_{max} (W)	240 ± 77	280 ± 63*	0.03	40.0 ± 36.8	0.6
	$Cadence_{av}$ (rpm)	93 ± 12	93 ± 6	0.84	0.7 ± 9.0	0.1
	$Cadence_{max}$ (rpm)	103 ± 13	104 ± 8	0.86	0.7 ± 9.9	0.1
	RPE_{av} (AU)	7 ± 1	8 ± 1*	0.02	1.7 ± 1.5	2.2
	RPE_{max} (AU)	9 ± 1	10 ± 1	0.09	0.7 ± 1.0	1.5
	$Lactate_{pre}$ (mmol/l)	1.8 ± 0.6	1.5 ± 0.6	0.39	-0.3 ± 0.8	-0.5
	$Lactate_{post}$ (mmol/l)	10.3 ± 3.8	11.6 ± 2.3	0.34	1.3 ± 3.4	0.6
	$DOMS_{pre}$ (AU)	0.3 ± 0.8	2.0 ± 2.2	0.12	1.7 ± 2.5	0.8
	$DOMS_{post}$ (AU)	1.9 ± 1.1	6.1 ± 3.0*#	0.02	4.3 ± 3.4	1.4
	$DOMS_{24After}$ (AU)	2.3 ± 2.2	1.6 ±1.4	0.14	-0.7 ± 1.1	-0.5

Variables: Work interval average Heart rate ($HR_{av\text{-}work}$ Work interval maximum Heart rate ($HR_{max\text{-}work}$) , recovery interval average Heart rate ($HR_{av\text{-}recovery}$), recovery interval maximum Heart rate ($HR_{max\text{-}recovery}$), average pace ($Pace_{av}$), work average distance ($Distance_{av}$) average speed ($Speed_{av}$), Power average (P_{av}), Maximum Power obtained(P_{max}), Averge cadence ($Cadence_{av}$), maximum cadence($Cadence_{max}$), average work interval rate of perceived exertion (RPE_{av}) and work interval maximum rate of perceived exertion (RPE_{max}), Lactate concentration pre test ($Lactate_{pre}$), lactate concentration post test ($Lactate_{post}$), Delayed Onset Muscle soreness pre test ($DOMS_{pre}$) , Delayed Onset Muscle soreness post test ($DOMS_{post}$), Delayed Onset Muscle soreness 24 hour after test ($DOMS_{24After}$). Dif. (%) = mean differences in percentage, ES = effect size. *$p < 0.05$, ** $p < 0.01$ significant differences with pre test. # $p < 0.05$, two way mixed ANOVA analysis (group x HIIT session) statistical differences.

Ilustration 1. Comparison between $HIIT_{run}$ and $HIIT_{bike}$ for CK pre, immediately post and 24-hour after HIIT session.



Variables: Creatine Kinase values pre session (pre); Creatine Kinase values immediately post session (post); CK values 24 hour after the session (24 after); First HIIT session of the program (1st HIIT); last session of the program (8th HIIT)

10.6. COMUNICACIONES RELACIONADAS CON LA TESIS

10.6.1. Australian Sports Medicine Conference 2016 (Oral Presentation)

Certificate of Presentation

This is to certify that

Milos Mallol Soler

Presented at the

2016 Sports Medicine Australia Conference

Melbourne Cricket Ground, Melbourne, Australia

12 - 15 October 2016

"Effects of 4 weeks High-intensity training on running and cycling performance in well-trained triathletes"

Ms Kay Copeland

2016 SMA Conference Chair

SPORTS MEDICINE AUSTRALIA

asics

LA TROBE UNIVERSITY

10.6.2. European College of Sport Science annual congress 2017 (Oral Presentation)

European College of Sport Science

Wednesday, 29 November 2017

Confirmation of Participation and Presentation

To whom it may concern,

Milos Mallol Soler attended the 22nd annual Congress of the ECSS in Essen, Germany (5 - 8 July, 2017) and presented the Oral titled "Effects Of High Intensity Interval Training In Cycling On Running Performance In Athletes."

The abstract "Effects Of High Intensity Interval Training In Cycling On Running Performance In Athletes" was also published in the Book of Abstracts of the 22nd Annual ECSS Congress in Essen, 2017.

Yours sincerely,

Thomas Delaveaux
Executive Director

European College of Sport Science
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10.7. OTRAS ACTIVIDADES DE INVESTIGACIÓN Y ACADÉMICAS

10.7.1. Research assistant en University of South Australia (UniSA)

University of South Australia

Human Resources
Division of Health Sciences
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11 January 2017

CONFIDENTIAL

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CRICOS Provider Number 00121B

To whom it may concern

I wish to confirm that Miss Milos Mallol Soler was employed by the University of South Australia as a Casual Research Assistant in the School of Health Sciences, Division of Health Sciences. She was employed on a casual basis for the period 29 March 2016 to 31 July 2016 and was paid for a total of 64.50 hours.

If you have any further queries regarding her employment please contact me on
+61 8 830 21533.

Regards

A Friebe

Amber Friebe
Manager: Human Resources
Division of Health Sciences
University of South Australia

Educating Professionals
Creating and Applying Knowledge
Engaging our Communities

10.7.2. Profesora-tutora de la asignatura E*xercise and Musculoskeletal Physiology* en Flinders University

Associate Professor Belinda Lange

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To Whom It May Concern,

Subject: Letter of Employment Verification for Milos Mallol Soler

Milos Mallol Soler was employed as a casual tutor in the School of Health Sciences (Physiotherapy) at Flinders University from July 25th, 2016 to November 25th, 2016 (total 70 hours).

Please contact me at 08 72218285 if I can be of any additional service.

Sincerely,

Belinda Lange
Associate Professor Belinda Lange BSc, B(Physio)Hons, PhD
Head of Physiotherapy
Coordinator: Master of Physiotherapy
Flinders University
Phone: 08 872218285
Email: belinda.lange@flinders.edu.au

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10.8. LA INVESTIGACIÓN EN IMÁGENES

Todas las fotos adjuntas a continuación han sido obtenidas con el permiso oral de los paticipantes, así como respetando la normativa de la Universidad, la cuál contempla la posibilidad de realizar fotografías durante la investigación. Todas las imágenes son anónimas y consentidas por los/as participantes, así como su propiedad corresponde a la doctoranda.

Figure 2. Test máximo incremental en el cicloergómetro.

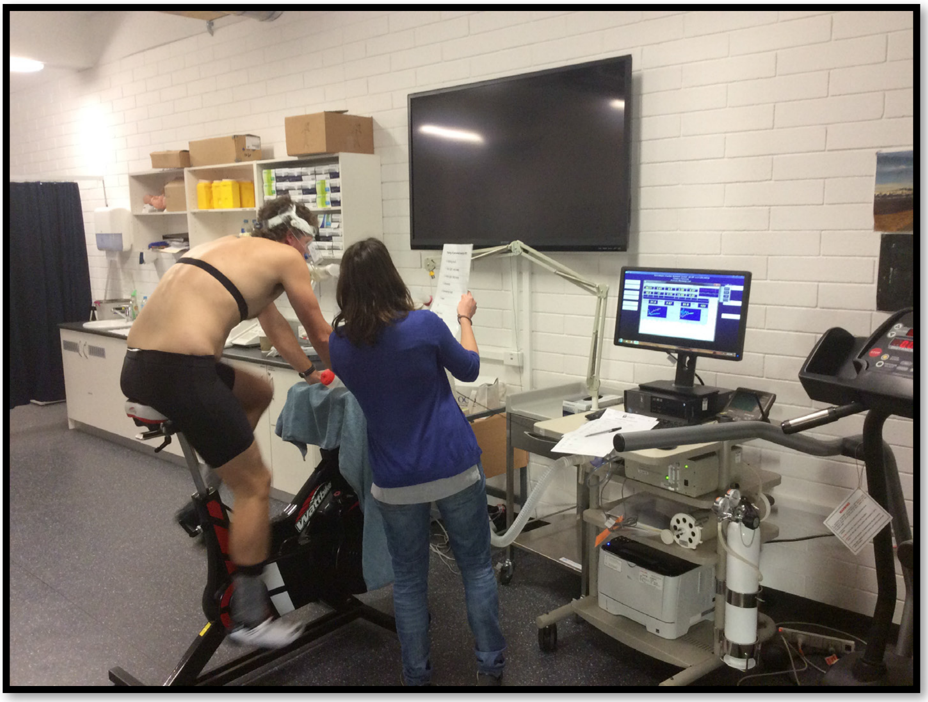

Figura 3. Test máximo incremental en el cicloergómetro. Registro RPE.

Figura 4. Prueba simulada de triatlón 20 km ciclismo + 5 km carrera.

Figura 5. Prueba simulada de triatlón 20 km ciclismo + 5 km carrera

Figura 6. Sesiones HIIT

Figura 7. Sesiones HIIT

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