UCAM
UNIVERSIDAD CATÓLICA
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ESCUELA INTERNACIONAL DE DOCTORADO
Programa de Doctorado en Ciencias del Deporte

Condición física, maduración y características morfológicas en palistas jóvenes de aguas tranquilas

Autor:
D. Daniel López-Plaza Palomo

Directores:
Dr. D. Fernando Alacid Cárceles
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Murcia, mayo de 2019

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La presente tesis doctoral está conformada y diseñada como un compendio de trabajos previamente publicados o aceptados para su publicación. Los artículos que la componen se detallan a continuación.

1. López-Plaza D, Alacid F, Muyor JM, López-Miñarro PÁ. Differences in anthropometry, biological age and physical fitness between young elite kayakers and canoeists. Journal of Human Kinetics. 2017;57(1):181-90.

2. López-Plaza D, Alacid F, Muyor JM, López-Miñarro PÁ. Sprint kayaking and canoeing performance prediction based on the relationship between maturity status, anthropometry and physical fitness in young elite paddlers. Journal of Sports Sciences. 2017;35(11):1083-90.

3. López-Plaza D, Alacid F, Rubio JÁ, López-Miñarro PÁ, Muyor JM, Manonelles P. Morphological and physical fitness profile of young female sprint kayakers. Journal of Strength and Conditioning Research. 2019 (In press).

4. López-Plaza D, Manonelles P, López-Miñarro PÁ, Muyor JM, Alacid, F. A longitudinal analysis of morphological characteristics and body proportionality in young elite sprint paddlers. Physician and Sportsmedicine. 2019 (In press).

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"Ideas geniales son aquéllas de las que lo único que nos sorprende es que no se nos hayan ocurrido antes"

Noel Clarasó

"Vivimos en una época en que las cosas innecesarias son nuestras únicas necesidades"

Oscar Wilde

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INTRODUCCIÓN

ARTÍCULOS CIENTÍFICOS

ESTUDIO 2

ESTUDIO 4

SIGLAS Y ABREVIATURAS

ANOVA: *Analysis of variance*
BM: *Bone mass*
BMI: *Body mass index*
C: Canoístas
CE: Ciclo-ergómetro
CI: *Confidence Interval*
cm: Centímetros
CMJ: *Countermovement jump*
CV: *Coefficient of variation*
DMOA: Déficit máximo de oxígeno acumulado
E: Élite
EC: Edad cronológica
EO: Edad ósea
FM: *Fat mass*
HPM: *Hopkin's magnitude*
ICC: *Intra-class correlation coefficient*
ICF: *International Canoeing Federation*
ISAK: *International Society for the Advancement in Kinanthropometry*
JJOO: Juegos Olímpicos
K: Kayakistas
KE: Kayakergómetro
kg: Kilogramos
L: *Low*
LA: *Large*
M: *Moderate*
m: Metros
min: Minutos
ml: Mililitros

mm: Milímetros
MM: *Muscle mass*
OMBT: *Overhead medicine ball throw*
P: Piragüistas
PHV: *Peak height velocity*
PSLR: *Passive straight leg raise*
s: Segundos
RFEP: Real Federación Española de Piragüismo
SD: *Standard deviation*
SEE: *Standard error of estimate*
SR: *Sit and reach*
TR: Tapiz rodante
TT: *Toe touch*
USA: *United States of America*
UK*: United Kingdom*
VIF: *Variance inflation factor*
VO_2max: consumo máximo de oxígeno
wk: *week*

RESUMEN

Título:

Condición física, maduración y características morfológicas en palistas jóvenes de aguas tranquilas

Introducción:

El rendimiento en el piragüismo de aguas tranquilas depende de una compleja combinación de determinantes que van desde sus características fisiológicas y antropométricas hasta la cinemática del complejo palista-pala-embarcación así como de las fuerzas que actúan sobre el mismo. Tradicionalmente las investigaciones en el área de piragüismo se han centrado en palistas de élite de categoría masculina, principalmente desde un ámbito fisiológico. En deportistas jóvenes, el desarrollo de la maduración biológica, que en cada individuo se manifiesta de una forma y en un tiempo diferente, influye en sus capacidades físicas y rendimiento. Sin embargo, existen escasas investigaciones con piragüistas jóvenes de aguas tranquilas. Los objetivos de la presente tesis doctoral fueron: a) elaborar un perfil antropométrico y de condición física en función de la especialidad y el grado de maduración; b) identificar las variables predictoras del rendimiento en palistas jóvenes y; c) determinar la evolución morfológica en base a la edad biológica y compararla con piragüistas de élite mundial.

Material y métodos:

Participaron un total de 257 palistas en alguno de los 4 estudios realizados. Todos ellos fueron considerados competidores de élite ya que habían sido convocados por la Real Federación Española de Piragüismo (RFEP) para

participar en concentraciones nacionales dentro de los 20-22 mejores de su categoría de edad.

Para la obtención de un perfil físico, antropométrico y madurativo los participantes completaron una batería de mediciones antropométricas (pliegues cutáneos, diámetros, perímetros y longitudes), test de campo para la condición física (capacidad aeróbica, fuerza y movilidad) así como test específicos de rendimiento (200,500 y 1000 m).

Resultados:

Los kayakistas presentaron valores superiores en maduración biológica, masa corporal, talla y talla sentado respecto a los canoístas de la misma categoría de edad ($p < 0,01$). El nivel de condición física mostrada por los kayakistas fue significativamente mayor que la de los canoístas, en los test de salto con contramovimiento, VO_2max estimado, lanzamiento de balón medicinal y extensibilidad isquisural ($p < 0,05$).

Se observaron diferencias significativas entre los grupos madurativos de ambas disciplinas en la mayoría de parámetros antropométricos, fuerza de los miembros superiores y rendimiento específico (pre > circum > post; $p < 0,05$). Asimismo, correlaciones negativas y significativas ($p < 0,01$) fueron identificadas entre edad cronológica, antropometría (masa corporal, talla, talla sentado y estado de madurativo), lanzamiento de balón medicinal y sit-and-reach con el tiempo en cada una las distancias (200, 500 y 1000 m).

El análisis de las mujeres kayakistas de categoría femenina reveló valores antropométricos significativamente mayores en porcentaje de masa muscular, estado madurativo y edad cronológica ($p < 0,05$) en las competidoras de más nivel, mientras que no se encontraron diferencias significativas en la comparación de las capacidades físicas excepto en el salto con contramovimiento ($p < 0,05$).

En 3 años consecutivos, la masa corporal y el tamaño de las extremidades superiores del cuerpo aumentaron significativamente ($p < 0{,}05$), especialmente en categoría masculina. En ambos sexos se detectaron diferencias significativas y tamaños de efecto grandes en la masa muscular ($\eta^2_P > 0{,}64$), mientras que la masa ósea y la masa grasa permanecieron estables en la transición del 1º al 3º año. El análisis de proporcionalidad reveló diferencias significativas, particularmente en categoría masculina, en los perímetros y diámetros de las variables de tronco y extremidades superiores, así como en el diámetro biacromial a lo largo de los 3 años (3º > 2º > 1º; $\eta^2_P > 0{,}62$; $p < 0{,}05$).

Conclusiones:

El grado de condición física de los kayakistas jóvenes es mayor respecto a la observada en canoístas, quizá como consecuencia de una morfología más atlética y robusta y una edad biológica más avanzada teniendo la misma edad cronológica. Asimismo, la maduración biológica es un determinante del rendimiento específico y está asociada con el nivel de fitness y las variables morfológicas en ambas disciplinas en categoría masculina. La masa muscular y la edad biológica parecen parámetros importantes para un óptimo rendimiento en mujeres palistas. Además, los palistas jóvenes desarrollan, en torno a la edad de máximo crecimiento en altura (APHV), los parámetros antropométricos más representativos y característicos de los competidores senior de nivel mundial, como son una morfología compacta y robusta en el miembro superior y pecho.

Palabras clave: Piragüismo. Jóvenes talentos. Antropometría. Atributos físicos. Rendimiento. Edad biológica.

ABSTRACT

Title:

Physical fitness, biological maturity and morphological characteristics in young elite sprint paddlers.

Introduction:

Performance in sprint canoeing relies on a complex combination of determinants such as physiological and anthropometric characteristics, the kinetics of the paddler-paddle-boat as well as the forces that influences boat movement. Traditionally, research in sprint canoeing has focused on male senior elite competitors, especially from a physiological perspective. In young competitors, the development of biological maturity is different in tempo and timing depending on each individual and influences their physical capacities and specific performance. However, only a few investigations have been conducted in young paddlers. The aims of the present doctoral thesis were: a) to develop an anthropometric and physical fitness profile based on the discipline and maturity status; b) to identify the predictive variables of performance in young paddlers and; c) to determine the morphological evolution according to the biological age and compare it with world class senior paddlers.

Material y methods:

A total of 257 paddlers participate in one of the 4 studies conducted. All participants were considered elite level competitors since they had been previously selected by the Royal Spanish Canoeing Federation to take part in the National Development Camps as the top 20-22 best paddlers in their age group.

To determine the physical, anthropometric and maturity profile, all participants completed a battery of anthropometric measurements (skinfold thickness, girths, breadths and lengths), basic physical fitness test (estimated VO_2max, flexibility and strength) and specific performance test (200, 500 and 1000 m).

Results:

Superior values in biological maturity, height, sitting height and body mass were identified in kayakers respect to canoeists of the same age group ($p < 0.01$). Similarly, the physical fitness level observed in kayakers was significantly greater than those determined for canoeists in countermovement jump, estimated VO_2max, medicine ball throw and flexibility ($p < 0.05$).

Significant differences were detected between all maturity groups in both disciplines in most anthropometric attributes, upper body strength and specific performance (pre > circum > post; $p < 0.05$). Additionally, negative and significant correlations ($p < 0.01$) were identified between chronological age, anthropometry (body mass, height, sitting height and maturity status), medicine ball throw and sit-and-reach with all distance times (200, 500 and 1000 m)

The analysis of female kayakers revealed significantly greater morphological values in muscle mass percentage, maturity status and chronological age in the most successful competitors ($p < 0.05$) whereas no significant differences were observed in physical fitness apart from the countermovement jump between groups ($p < 0.05$).

During 3 consecutive years, the muscle mass and the upper limb sizes significantly increases ($p < 0.05$), especially in males. In both sexes, large effect size and significant differences were identified in muscle mass ($\eta^2_p > 0.64$), while bone mass and fat mass remained stable in the transition from 1st to 3rd year. The analysis of proportionality revealed significant greater values, especially in males,

in breadths and girths of chest and upper limbs as well as in biacromial breadth along the 3 years (3º > 2º > 1º; $\eta^2_p > 0.62$; $p < 0.05$).

Conclusions:

Physical fitness level of kayakers is greater than those observed in canoeists, perhaps as a consequence of a more robust and athletic morphology and an advanced biological age in the same age group. Similarly, maturity is a determinant for optimal performance and is related to physical fitness level and anthropometric variables in both male disciplines. Muscle mass and biological age seem to be two important parameters in successful female paddling. In addition, the young elite paddlers developed, around the age at peak height velocity (APHV), a compact and robust morphology especially in the upper body and chest which is common and representative of the world class competitors.

Key words: Sprint canoeing. Young talents. Anthropometry. Physical attributes. Performance. Biological age.

I - INTRODUCCIÓN

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El objetivo principal del piragüismo de competición en aguas tranquilas es recorrer una distancia específica lo más rápido posible, cruzando la línea de meta antes que el resto de participantes (1). Además del nivel físico y fisiológico requerido durante el paleo, el rendimiento de un palista de élite depende de una compleja combinación de determinantes que van desde sus características antropométricas hasta la cinemática del complejo palista-pala-embarcación, así como de las fuerzas que actúan sobre el mismo (2-4).

El deporte del piragüismo y más concretamente las investigaciones en este área se han centrado en palistas hombres de élite (5-7), principalmente desde un ámbito fisiológico para determinar el nivel de condición física y así elaborar programas de entrenamiento adecuados para optimizar dicha condición física (8). Sin embargo, cuando acudimos a la literatura que analiza a piragüistas jóvenes, estas investigaciones, además de escasas, priorizan únicamente un área de estudio (9-11), como la antropometría o la fisiología. Este hecho dificulta una visión más general de las características necesarias que los deportistas deben desarrollar en etapas de formación en una especialidad (12). Lo mismo ocurre con mujeres palistas, cuya representación a nivel científico queda aún muy por detrás de la llevada a cabo con hombres (3, 13, 14).

Tradicionalmente, los primeros estudios en este deporte toman como base las investigaciones realizadas en otros deportes individuales y cíclicos con más tradición como natación y remo (15, 16). De esta forma, el análisis de los parámetros fisiológicos se basa, fundamentalmente, en la metodología usada en tapices rodantes y ciclo-ergómetros (17) al igual que el estudio de los parámetros biomecánicos y cinemáticos que tienen como origen los definidos en los años 70 y 80 del siglo pasado en el área de natación (18). Técnicos y biomecánicos han usado la cinematografía, primero en 2 dimensiones (2D) y posteriormente en 3 (3D), no solo para la determinación de las variables cinemáticas que incluyen frecuencia de paleo, longitud de ciclo y velocidad, sino también para la obtención de modelos biomecánicos que ayudan a definir y mejorar la técnica de paleo (7, 19-21)

Mención aparte merece el estudio de la antropometría. La influencia de ésta sobre el rendimiento deportivo has sido estudiada en el ámbito del piragüismo, mediante la realización de perfiles antropométricos básicos (22) y también buscando su relación con otras variables fisiológicas (5, 6, 15). En atletas jóvenes el desarrollo de estos parámetros antropométricos está asociados al grado de maduración y a la edad biológica que en cada individuo se manifiesta de forma y en un tiempo diferente y que, a su vez, influyen en sus capacidades físicas (12, 23, 24).

Sin embargo, existen escasas investigaciones con piragüistas jóvenes de aguas tranquilas. Además, no se han encontrado que relacionen la composición corporal, la maduración y el rendimiento, no solo de las capacidades físicas básicas sino también en las pruebas específicas de competición de este deporte.

1.1. EL DEPORTE DEL PIRAGÜISMO

El piragüismo es un deporte olímpico en el que el piragüista o los piragüistas navegan sobre una embarcación en dirección al sentido de la marcha usando para propulsarse una pala sencilla o doble, dependiendo de la modalidad (kayak o canoa), pero que en ningún caso está fijada a la embarcación (25). Más de 10 especialidades dentro del piragüismo están reguladas federativamente, pero solo el piragüismo de aguas tranquilas y el slalom son disciplinas recogidas en el programa olímpico actual (25).

En la disciplina de aguas tranquilas existen dos tipos de embarcaciones: kayak (K) y canoa (C). Dependiendo del número de tripulantes pueden ser de 1, 2 ó 4 palistas por embarcación. De esta forma, para definir el tipo de embarcación, primero se escribe la inicial de la misma seguida del número de tripulantes. Por ejemplo, una canoa de 2 tripulantes se denominará C2. En la modalidad de kayak el palista va sentado sobre la embarcación, propulsándose con una pala de doble hoja mediante la acción de paleo que está compuesta por movimientos cíclicos bilaterales realizados por los miembros superiores que se coordinan con movimientos de rotación de tronco así como de pedaleo del miembro inferior (7, 26). Diferente es la posición de paleo en modalidad de canoa, donde el palista va arrodillado sobre una de las extremidades inferiores, con la otra adelantada y la acción de paleo es unilateral usando una pala de hoja simple (16).

Desde una perspectiva temporal, cada palada puede dividirse dos fases: fase acuática (cuando alguna hoja está en contacto con el agua) y fase aérea (cuando no existe contacto de la pala con el agua). Incluidas en las anteriores, podemos diferenciar cuatro subfases que se dan tanto en kayak como en canoa: a) el ataque, que comienza con el primer contacto de la pala con el agua y termina cuando la hoja queda totalmente sumergida; b) la tracción, cuyo comienzo se establece con el fin de la subfase anterior y termina justo antes de la salida de la pala detrás del cuerpo del palista; c) la salida, que empieza con la pala sumergida detrás del cuerpo del palista, justo antes de empezar a salir y termina con la hoja totalmente fuera del agua; y d) el recobro, que es el movimiento aéreo hacia delante de la pala hasta un nuevo contacto con el agua (26).

El piragüismo de aguas tranquilas es disciplina olímpica desde 1936, cuando se implantó en los Juegos Olímpicos de Berlín. Sin embargo, no fue hasta 1948, en Londres, cuando la categoría femenina entró en competición de forma oficial. Desde entonces se han realizado diversos cambios en las distancias olímpicas y las categorías. Cabe destacar que la canoa ha sido recientemente incluida en el programa olímpico en categoría femenina para Tokio 2020. En la tabla 1 podemos observar las pruebas no olímpicas en las que actualmente se compite, según el reglamento de la *International Canoeing Federation* (27) y en la tabla 2 las que se incluyen dentro el programa olímpico para Tokio 2020:

Tabla 1.- Pruebas no olímpicas de piragüismo de aguas tranquilas en categoría masculina y femenina recogidas en el reglamento de la IFC.

	Masculino		Femenino	
	Individuales	Equipos	Individuales	Equipos
200 m	C1	K2 / K4 / C2 / C4	-	K2 / K4 / C2 / C4
500 m	K1 / C1	K2 / C2 / C4	C1	K4
1000 m	-	K4 / C4	K1 / C1	K2 / K4 / C2 / C4
5000 m	K1 / C1	K2 / K4 / C2 / C4	K1	K2 / K4 / C2 / C4

Tabla 2.- Pruebas olímpicas de piragüismo de aguas tranquilas en categoría masculina y femenina recogidas en el reglamento de la IFC para los Juegos Olímpicos de Tokio 2020.

	Masculino		Femenino	
	Individuales	Equipos	Individuales	Equipos
200 m	K1	-	K1 / C1	-
500 m	-	K4	K1	K2 / K4 / C2
1000 m	K1 / C1	K2 / C2	-	-
5000 m	-	-	-	-

Existen varias categorías en función de la edad de los palistas e igual para ambos sexos, según el reglamento general y técnico de la Real Federación Española de Piragüismo (RFEP) en su artículos 23-32, aunque no es lo común para otros deportes individuales como la natación (28). Estas categorías se muestran en la tabla 3.

Tabla 3.- Categorías competitivas en función de la edad de los piragüistas.

Categoría	Edad
Prebenjamín	Hasta los 8 años de edad cumplidos.
Benjamín	Entre 9 y 10 años de edad cumplidos e incluidos.
Alevín	Entre 11 y 12 años de edad cumplidos e incluidos.
Infantil	Entre 13 y 14 años de edad cumplidos e incluidos.
Cadete	Entre 15 y 16 años de edad cumplidos e incluidos.
Junior	Entre 17 y 18 años de edad cumplidos e incluidos.
Sub-23	Entre 19 y 23 años de edad cumplidos e incluidos.
Senior	Desde los 23 años de edad cumplidos e incluidos.
Veterano	A partir de los 35 años de edad cumplidos e incluidos. Esta categoría se subdivide en grupos de edad cada 5 años.

1.2. EQUIPAMIENTO

El piragüismo de aguas tranquilas es un deporte donde las últimas mejoras en material y equipamiento juegan un papel fundamental para obtener buenos resultados en competición. De hecho, los mayores progresos se han relacionado directamente con avances tecnológicos más que con cambios en métodos de entrenamiento (2). En los últimos 30 años, la forma de la embarcación, la pala y la hoja han sido modificadas de forma más significativa que los planes de entrenamiento (3).

1.2.1. Embarcación

Uno de los componentes que más se ha modificado a consecuencia de los avances tecnológicos desde la primera exhibición olímpica en Paris en 1924 ha sido la forma del barco. Nuevos diseños han ido apareciendo desde entonces y han coincidido con los mayores avances de rendimiento ocurridos en la historia de los JJOO respecto a las ediciones anteriores (2). Como ejemplo, Gert Fredriksson consiguió rebajar su mejor tiempo en más de 25 segundos en los JJOO de Helsinki en 1952 gracias a la introducción de la revolucionaria forma en V del casco. Desde entonces, todos los esfuerzos de ingenieros y diseñadores han estado dedicados a reducir la superficie de contacto del casco con el agua así como la sección transversal sumergida, con el objetivo de reducir las fuerzas de rozamiento (2).

Existen dos tipos de fuerzas de resistencia al avance que actúan sobre el movimiento de una piragua (*drag forces*), fuerzas hidrodinámicas y aerodinámicas. Sin embargo, la oposición al movimiento procede principalmente de la fuerza de resistencia hidrodinámica (29). A su vez, podemos encontrar tres tipos de resistencia hidrodinámica que pueden decelerar la velocidad de una embarcación: de oleaje, de presión y de fricción o rozamiento (21, 30); siendo especialmente esta última (fricción) y en menor medida la de oleaje, las que contribuyen de una manera más significativa a la fuerza de arrastre total (21). En un intento de determinar los valores relativos de las fuerzas resistivas, Jackson (29) calculó que la velocidad de la embarcación se reduce en un 0,27% cuando la fuerza de rozamiento aumentaba en un 1%. Se debe tener en cuenta que cuanto menor coeficiente de fricción tenga la superficie del casco en contacto con el agua, menor será la fuerza de rozamiento que actúa sobre el mismo.

Asimismo, otros factores determinantes en la reducción de la fuerza de rozamiento son la superficie sumergida del casco, en gran parte determinada por el peso total del conjunto pala-palista-embarcación (29), así como la sección transversal sumergida que varía según el diseño del casco, los cambios de flotación y la fuerza neta vertical (21, 30). Además, la longitud total de la embarcación juega un papel fundamental en la velocidad de la embarcación ya que con una misma superficie de casco sumergida una embarcación más larga alcanzará mayores velocidades debido, entre otros factores, a la teórica menor sección transversal sumergida (29, 31). De esta manera, desde la ICF se establecen unas longitudes máximas y pesos mínimos para embarcaciones de competición que se muestran en la tabla 4.

Tabla 4.- Limitaciones de dimensión y peso para embarcaciones de competición de piragüismo de aguas tranquilas.

	K1	K2	K4	C1	C2	C4
Longitud máxima (cm)	520	650	1100	520	650	900
Peso mínimo (kg)	12	18	30	14	20	30

Se han realizado numerosos intentos para reducir esta fuerza de rozamiento a través de la disminución del coeficiente de fricción pero la mayoría de ellos han quedado prohibidos por la ICF al poco tiempo. Algunos ejemplos son las superficies de casco rugosas que generan una corriente laminar o los aceites y barnices que repelen las moléculas de agua para tratar de reducir este coeficiente de fricción (2, 4). Actualmente, la mejor manera de reducir la fuerza de rozamiento es manteniendo la superficie sumergida del casco lo más limpia y lisa posible (2).

1.2.2. Pala

En piragüismo, la fuerza necesaria para propulsar la embarcación procede del paleo de los deportistas ya sea mediante una pala de una sola hoja (canoa) o de dos hojas (kayak). Durante la fase acuática de la palada se generan fuerzas propulsivas en la hoja de la pala que resultan en el movimiento de avance de la embarcación. Estas fuerzas propulsivas se transmiten desde el palista hasta el barco a través del asiento y el reposapiés (20) y su relación con las fuerzas de resistencia al avance determinan la velocidad a la que viaja una embarcación. Aunque la manera más eficiente de moverse es a velocidad constante (21), tanto la acción de paleo como los movimientos del palista hacen que la fuerza se transmita de manera discontinua a la embarcación lo que acaba generando fluctuaciones en la velocidad de avance (4, 30).

A lo largo de la historia, la pala de kayak ha sido uno de los elementos que más ha cambiado para aprovechar de forma más efectiva las fuerzas que se combinan para generar movimiento de avance. La fuerza neta generada por una pala está formada por dos componentes que actúan de maneras distintas respecto a la dirección del movimiento de la misma. La fuerza de resistencia actúa de forma paralela a la dirección del flujo relativo mientras que la fuerza de elevación lo hace perpendicularmente (4, 29).

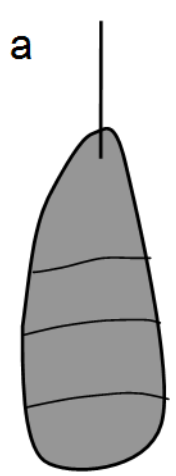

Figura 1.– Diseño de hoja plana tradicional (a) y hoja sueca (b). Adaptado de Jackson (29).

En la figura 1 podemos observar los dos modelos de hoja que se usan actualmente en piragüismo de aguas tranquilas. Tradicionalmente, la pala "plana" ha sido el modelo utilizado por kayakistas y canoístas de todas las categorías y la propulsión está basada, principalmente, en las fuerzas de resistencia que se generan en el paleo en dirección opuesta y paralelas al avance de la embarcación (21, 30). Sin embargo, a partir del desarrollo de la pala sueca en los años 80, las fuerzas de propulsión e incluso la técnica de paleo cambiaron para los kayakistas (32). La forma de "ala de avión" de este diseño permite usar las fuerzas de elevación que se generan en la parte cóncava de la pala como consecuencia de la corriente de paso de agua por esa zona (19). Para generar este tipo de fuerzas en la dirección correcta, la técnica de paleo cambia hacia una trayectoria más diagonal que con un paleo más tradicional (Figura 2).

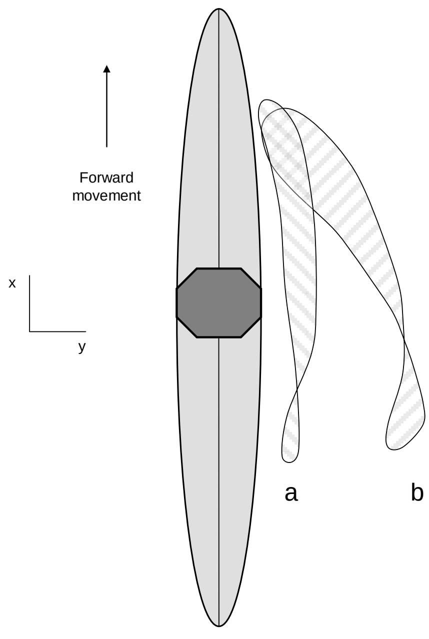

Figura 2.– Vista de plano de una típica trayectoria de palada derecha usando una pala hoja tradicional (a) y una sueca (b).

La superioridad de rendimiento que se obtiene con el uso de la hoja sueca respecto a la tradicional se basa en la mayor efectividad de las fuerzas de elevación para propulsar la embarcación (19, 29). Jackson (29), estimó que la eficiencia sería de un 89% y un 74% para la hoja sueca y la tradicional respectivamente. Entre los factores que podrían explicar la mayor superioridad en la propulsión con este tipo de hoja destacarían los siguientes: a) la trayectoria diagonal permite que el agua en contacto con la hoja no esté en movimiento en el momento de la entrada como ocurre con una trayectoria paralela (33); b) no se producen fuerzas de frenado al introducir la hoja a causa del movimiento de agua en la misma dirección y no se pierde longitud de palada al tratar de evitarlas (2, 32); c) se genera una espiral continua de agua que produce un área de vorticidad de aproximadamente el doble que con la hoja plana (Figura 3) (29, 31); d) la acción de paleo no es tan intermitente y la técnica en diagonal permite movimientos más fluidos y con menos coste energético (32); y e) la orientación de la hoja respecto a la superficie del agua es más vertical durante más tiempo incrementándose así el pico de aceleración horizontal y con ello la efectividad en la propulsión (8, 21).

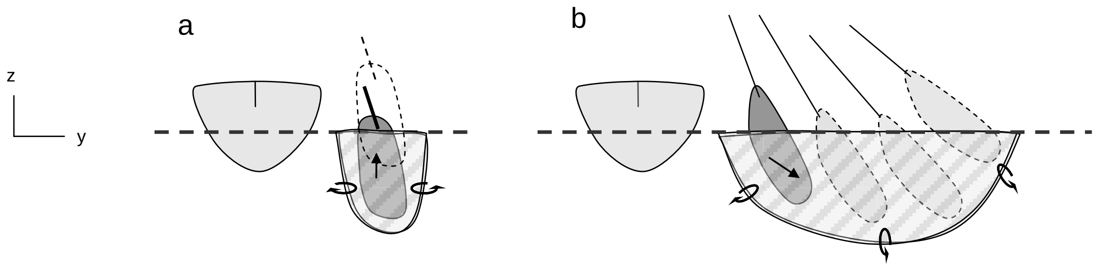

Figura 3.– Ejemplos de los anillos de vórtice formados con la técnica y modelo de pala tradicional (a) y con la técnica y modelo de pala sueca (b). Adaptado de Jackson (29).

Los primeros métodos directos para medir la fuerza que se aplica en cada palada fueron desarrollados en Alemania del Este en los años 80 (34). Insertadas entre la pértiga y la hoja, las agujas de tensión son un método fiable capaz de medir a tiempo real y en condiciones reales la fuerza aplicada por la pala (35). En combinación con el análisis cinético y cinemático, estos datos de fuerza aplicada, pueden proporcionar valiosa información en lo que respecta a cada fase de la palada, no solo a investigadores, también a técnicos y deportistas (36). Los usos de este método de evaluación de la fuerza son muy variados y van desde el control de los valores de este parámetro de un test a otro hasta la identificación de los puntos de baja producción de fuerza dentro de la palada (37).

1.2.3. Otros materiales y configuración del material.

Las mejoras en el equipamiento pueden perder parcialmente su efectividad si este no está correctamente configurado en función de la especialidad, las características físicas o la composición corporal y morfología del palista. La configuración del material no solo influye en la comodidad del deportista durante el paleo, también lo hace en la prevención de posibles lesiones y en la optimización de la producción de fuerza (20).

Escasas investigaciones en el ámbito de los deportes acuáticos se han centrado en la influencia de las características antropométricas sobre la configuración del material y el rendimiento (6, 20, 38). Tradicionalmente, las dimensiones corporales se han usado en piragüismo de aguas tranquilas para la determinación de la longitud óptima de la pala y de la altura y distancia entre reposapiés y asiento (39). Sin embargo, la selección de la mayoría de los materiales y configuraciones como, por ejemplo, las dimensiones de la hoja, dependen de la combinación de otros muchos factores tales como edad, fuerza, disciplina o destreza técnica (16). De este modo, grandes hojas generarán mayores fuerzas propulsivas aunque el coste energético y el tiempo de recuperación aérea se verán incrementados si el palista no posee un apropiado nivel de fuerza (20, 40).

Debido a las restricciones de longitud máxima y forma de la embarcación (27), las modificaciones y cambios permitidos más habituales en el equipo son los que conciernen a la altura del asiento y la distancia entre el reposapiés y el mismo asiento (16, 39). Ong et al., (20), examinó las dimensiones corporales y la configuración de material de palistas de aguas bravas y aguas tranquilas para obtener modelos óptimos e individuales de configuración de material a través de ecuaciones de regresión. Posteriormente, se usaron estas ecuaciones predictivas para analizar el efecto de tres configuraciones diferentes sobre el rendimiento y los parámetros cinemáticos (41). Sin embargo, los resultados sugirieron que no existía una óptima configuración basada en las dimensiones corporales individuales y que otros factores como fuerza, rango de movimiento de la cadera o familiarización juegan un papel fundamental para obtener un rendimiento óptimo de la configuración del material (20, 41).

Numerosos cambios en lo que se refiere al equipamiento auxiliar se han producido a lo largo de la historia del piragüismo, no solo desde el campo científico-desarrollador, sino también desde el de los propios técnicos y deportistas. Algunos de esos cambios proceden de otras disciplinas como el remo o la natación (42, 43). Un ejemplo de ellos es la cinta del reposapiés usada originariamente en remo para un anclaje completo de los pies, que permite movimientos del tren inferior no solo de empuje (43) y una transmisión de fuerza a la embarcación teóricamente más efectiva en el kayak (1). De forma similar, en el año 2005 un nuevo tipo de asiento revolucionario denominado *swivel seat* fue desarrollado con el fin de facilitar la rotación del tronco de los kayakistas durante la acción de paleo mediante un mecanismo de giro libre sobre pletinas en su eje vertical (4, 44). Aparentemente, su utilización está relacionada con mayores valores de producción de potencia de palada (45) y frecuencia de la misma aunque, por el contrario, podría originar episodios de inestabilidad en la embarcación (46). A pesar de estas investigaciones, el estudio de nuevos tipos de materiales es escaso y debería llevarse a cabo, principalmente, en condiciones de competición.

1.3. CONDICIÓN FÍSICA EN PIRAGÜISTAS JÓVENES DE ÉLITE

La acción de paleo en el piragüismo de competición de aguas tranquilas exige a los palistas una excelente condición física debido a las altas demandas, especialmente en las extremidades superiores y el tronco (5). Tradicionalmente, los test de aptitud física (*fitness*) se han usado para la evaluación y monitorización de la condición física general tanto de escolares como de deportistas (47-49). Estos test evalúan, entre otros atributos, la capacidad aeróbica (50); la extensibilidad isquiosural (51); la fuerza y potencia (52); o la velocidad (53).

Las ventajas de este tipo de baterías de pruebas son diversas, destacando el gran número de sujetos que pueden ser evaluados al mismo tiempo, la necesidad de escaso equipamiento o la inmediatez de los resultados. Por otro lado, la principal limitación de estos test es su escasa especificidad cuando se evalúan competidores de un determinado deporte o especialidad. Sin embargo, y cómo ocurre con atletas jóvenes de otros deportes, estas pruebas de condición física han correlacionado significativamente, no solo con test estandarizados específicos, también con el rendimiento del deporte en cuestión (53-56). Ejemplo de ello es la valoración del consumo máximo de oxígeno (VO_2max) en tapiz rodante cuyos resultados correlacionan con los de los test en kayak (15, 57). Por los tanto, la evaluación de la condición física en piragüistas jóvenes a través de estos test parece adecuada para determinar el nivel de los deportistas, orientarlos a una determinada especialidad o identificar los puntos débiles o fuertes para reforzarlos o afianzarlos.

1.3.1. Características metabólicas: capacidad aeróbica y anaeróbica

Tradicionalmente, la vía oxidativa ha sido identificada en la literatura como esencial en la producción de energía durante la acción de paleo (5, 15, 58). Posteriores investigaciones revelaron también el importante papel del metabolismo anaeróbico para la obtención de rendimientos óptimos (59). El grado de contribución de una u otra vía variará en función de la distancia de la prueba, estando más presente la vía aeróbica en distancias largas y perdiendo importancia progresivamente en distancias más cortas en detrimento de la vía anaeróbica (60). De esta forma, en una prueba de 1000 m la contribución aeróbica expresada como fracción del VO_2max será aproximadamente de un 85% mientras que en una prueba de 500 m ésta se verá reducida a un 73% (58).

Los primeros estudios que trataron de analizar las características fisiológicas de los palistas de élite y establecer un perfil metabólico óptimo, se centraron principalmente en el estudio de variables cardiorrespiratorias como frecuencia cardiaca, VO_2max o ventilación (5, 61). El nivel aeróbico de los palistas de élite ha sido tradicionalmente evaluado a través del análisis del VO_2max (tabla 5) en tapices rodantes o ciclo-ergómetros (5, 61-63), kayak-ergómetros (5, 6, 64-66) o en condiciones reales (57, 62, 67, 68). Sin embargo, la mejor manera de evaluar el VO_2max es bajo las mismas condiciones específicas de competición (60) debido a las diferencias significativas encontradas cuando se comparan estos valores con los encontrados con otros métodos (5). Además, otros autores sugieren que el uso de métodos indirectos de estimación del VO_2max como el test de Leger et al., (50) puede ser una buena manera de evaluar grandes grupos, sin medios suficientes y en sujetos con dificultad para palear a VO_2max con el analizador de gases (15).

Tabla 5.- Consumo máximo de oxígeno absoluto y relativo en piragüistas de competición.

		VO_2max absoluto ($L \cdot min^{-1}$)				VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)
Autor	**Participantes**	**Piernas**	**Brazos**	**Ergómetro**	**Kayak (agua)**	
Sidney et al. (61)	3 K senior E ♂	4,45 TR				55,1 TR
Sidney et al. (61)	7 K junior E ♂	3,83 TR				60 TR
Sidney et al. (61)	2 K, E ♀	2,8 TR				49,2 TR
Vrijens et al. (69)	5 K, E ♂		3,92	4,42 CE		
Tesch et al. (62)	4 P senior E ♂	5,4 TR	4,61		4,01-4,42	
Tesch et al. (62)	2 P junior E ♂	4,73 TR	4,16			
Pendergast et al. (57)	8 K amateur ♂	3,1		3,5		
Tesch (5)	6 P senior E ♂	5,36 TR	4,3		4,7(6min)	
Pendergast et al. (67)	17 K, E ♂	4,58 TR	2,82		3,39	
Fry and Morton (6)	7 K senior E ♂			4,78		59,2 KE
Fry and Morton (6)	31 K senior ♂			3,87		54,8 KE
Pelham and Holt (70)	4 K senior ♂			4,04		
Pelham and Holt (70)	7 C senior ♂			4,3		

Pelham and Holt (70)	6 K senior ♀	2,9		
Bishop et al. (65)	9 K senior ♀	3		44,8 KE
van Someren et al., (68)	4 K senior ♂	4,1	4,1(4min)	
Bishop et al. (64)	8 K senior ♂ ♀	3,51-3,65		
van Someren et al., (66)	8 K senior E ♂			53,8 KE
van Someren et al., (71)	13 K senior E ♂	4,45		52,6 KE
van Someren et al., (71)	13 K senior ♂	4,25		54,5 KE
van Someren et al., (72)	18 K senior ♂	4,55		
Forbes et al. (73)	13 K junior ♂ ♀	2,99-3,37		45-49 KE
Borges et al. (74)	21 K junior ♂ ♀	4,1		57 KE
Hamano et al. (63)	12 K ♂	3,81		55,6 KE
Hamano et al. (63)	11 C ♂	3,83		54,3 KE

Notas .
K = Kayakistas; C = Canoístas; P = Piragüistas; E = Élite; TR = Tapiz rodante; CE = Ciclo-ergómetro; KE = Kayak-ergómetro

A pesar de la significativa contribución de la vía aeróbica a las pruebas olímpicas, existe cierta controversia respecto a la importancia del VO_2max en el rendimiento en palistas senior de competición. Algunos autores consideran este parámetro fundamental en pruebas de más de 500 m (5, 15), encontrando correlación con los tiempos de competición y también hallando diferencias significativas entre palistas de diferente nivel (6, 71). Sin embargo, otras investigaciones no han encontrado asociaciones entre VO_2max y rendimiento en palistas de competición senior (72). La mayoría de autores coinciden en que cuando el VO_2max se expresa en valores absolutos ($l \cdot min^{-1}$), los piragüistas de más nivel obtienen valores significativamente mayores, pero cuando este valor se expresa en función del peso ($ml \cdot kg^{-1} \cdot min^{-1}$), estos niveles disminuyen (6, 15, 59, 71). Aparentemente, una morfología grande y robusta, como la que presentan los palistas de más éxito, puede ser negativa para la propulsión del barco en términos de incremento de peso (4). Sin embargo, mejores habilidades técnicas, una alta producción de fuerza y, especialmente, una elevada potencia aeróbica absoluta hacen posible que estos palistas presenten un mejor rendimiento con un peso más elevado (6, 71).

Cuando analizamos el VO_2max en niños y adolescentes, debemos tener en cuenta que el proceso madurativo y la edad biológica de cada individuo tienen una gran influencia sobre su desarrollo (23, 75, 76). Durante la pubertad el VO_2max absoluto aumenta con el desarrollo físico, mientras que los valores relativos no parecen cambiar en exceso (76). Algunos autores han sugerido que el VO_2max tiene un papel secundario en el rendimiento de niños y adolescentes (77). Esta idea podría quedar respaldada por la especialización metabólica tardía (aeróbico – anaeróbico) que no ocurre hasta después del pico máximo de crecimiento en altura (aproximadamente a los 12 años en niñas y a los 14 en niños). En palistas jóvenes, como ocurre con los adultos, no existe consenso sobre la correlación de este parámetro con el rendimiento. Sin embargo, algunas investigaciones han observado asociaciones significativas entre los tiempos de las distancias olímpicas de 200 y 1000 m y la potencia aeróbica en piragüistas junior (74, 78). Desafortunadamente, los pocos estudios de este tipo fueron llevados a cabo con diferentes métodos de medición y en palistas que ya habían pasado su pico máximo de crecimiento (APHV).

Por lo tanto, parece claro que existen otros factores tan determinantes para el rendimiento como el VO_2max, tanto en categorías inferiores como en senior. Aunque poco estudiada, la capacidad de mantener elevados niveles aeróbicos submáximos durante el paleo podría ser un parámetro incluso más importante que la obtención de picos altos de VO_2max momentáneamente (59, 65). Asimismo, diversos autores también apuntan que un elevado umbral anaeróbico (80 – 90% del pico de VO_2max), o una alta capacidad anaeróbica de producir energía, especialmente en las distancias cortas (500 y 200 m), son factores determinantes para un óptimo rendimiento (5, 65, 71, 79). Muestra de ello fueron las diferencias significativas encontradas entre palistas de diferente nivel en parámetros como el déficit máximo de oxígeno acumulado (DMOA) o el Wingate test en pruebas de 200-250 m (80-82).

1.3.2. Movilidad de la cadera

En la práctica deportiva en general, una óptima extensibilidad isquiosural es clave como parte de la condición física del deportista ya que no solo interviene en la adopción de una correcta disposición corporal y raquídea, sino también en la prevención de patologías de la columna y lesiones musculares (83). En ambas modalidades de piragüismo, la acción de paleo es cíclica y repetitiva implicando la combinación de movimientos de rotación y flexión vertebral (26, 83). Diversos estudios han señalado que una excesiva torsión de columna ocasiona valores elevados de torsión y podría afectar negativamente a largo plazo a estructuras como los núcleos pulposos o los discos intervertebrales (84, 85). Si estos movimientos repetitivos de torsión se realizan en posturas inadecuadas, los efectos negativos sobre la columna podrían verse agravados.

Para la valoración de la extensibilidad isquiosural en el ámbito deportivo, varios métodos han sido utilizados independientemente de la especialidad practicada (86). El test *sit and reach* (SR) o el *toe-touch* (TT) han sido tradicionalmente usados, no solo por su sencillez y escaso material, también por la necesidad de una mínima preparación por parte del evaluador. Asumiendo que el procedimiento sea correcto, los resultados de estos test dependen de factores añadidos a la extensibilidad isquiosural (87). Las características antropométricas, la movilidad vertebral y especialmente la cifosis lumbar en kayakistas son ejemplos de ello (83, 86). Por este motivo, algunos investigadores (86, 88) recomiendan el uso de otros métodos para la evaluación de palistas como el *passive straight leg raise* (PSLR) pero que requieren más equipamiento y experiencia por parte del evaluador (86, 87). Sin embargo, la moderada correlación entre el test SR y el PSLR hallada por Baltaci et al., (89) y Simoneau (51), podría justificar el uso del primero en grandes grupos.

Existen diferentes factores que afectan la extensibilidad isquiosural, como la edad, donde la movilidad se reduce con el paso de los años; el sexo, donde los hombres poseen valores generales inferiores; o la disciplina y/o posición de juego, donde ésta vendrá determinada por los requerimientos y particularidades de cada una (90, 91). Como se explicó en el apartado 1.1, en el piragüismo de aguas tranquilas las posiciones y acciones durante el paleo en función de la modalidad son diferentes e implican unas adaptaciones isquiosurales particulares. Mientras que en kayak la acción es simétrica y la tracción ejercida sobre la musculatura isquiosural es similar en ambos lados, en canoa esta tracción se produce fundamentalmente sobre la musculatura de la pierna adelantada. Estudios previos han sugerido que la posición de flexión de tronco a la que están sometidos los kayakistas podría ser responsable de la mayor extensibilidad isquiosural respecto a los canoístas, tanto en la pierna dominante como en la no dominante (83, 90). Además, al comparar con otros deportes practicados en bipedestación, los kayakistas muestran también valores más elevados de movilidad en el SR y en el PSLR (86, 87). De la misma forma, la colocación de la pierna adelantada durante la acción de paleo en canoa parece un factor determinante en las diferencias bilaterales observadas en el PSLR (90).

1.3.3. Fuerza del miembro superior e inferior

La búsqueda de una propulsión óptima durante el paleo en kayak y canoa requiere de una acción repetitiva, rápida y coordinada de las extremidades superiores e inferiores y el tronco a máximo esfuerzo (42). Para ello, parece lógico pensar que los niveles de fuerza que debería producir el palista son, en su mayoría, máximos o submáximos, especialmente en las pruebas más cortas de 500 y 200 m. Desde hace varias décadas, el entrenamiento de fuerza está incluido en la mayoría de los programas de entrenamiento de palistas de élite (15, 92). Además, el desarrollo del componente de fuerza se ha realizado tanto dentro del agua, con ejercicios específicos de potencia, como fuera del agua, con ejercicios como *press* de banca, remo, *pull-ups* o sentadillas (42). Una velocidad de ejecución explosiva de estos ejercicios parece tener efectos positivos sobre el mantenimiento de la velocidad mientras que ejecuciones más lentas ayudarían en la mejora de aspectos como la salida (93, 94).

Varios autores apuntan a la posibilidad de una baja transferencia del entrenamiento de fuerza fuera de agua al rendimiento, pues la mayoría de estos ejercicios son poco específicos y no se ajustan al rango de acción de paleo (42, 95). Existe cierta controversia sobre la correlación de la fuerza máxima y el rendimiento, tanto en kayak como en canoa. Algunas investigaciones han identificado la importancia de ejercicios como el *press* de banca o el remo sobre el rendimiento en piragüismo, con correlaciones por encima de 0,7, especialmente en pruebas cortas de 500 y 200 m en kayakistas (42, 93, 94, 96) y también en canoístas (63). Sin embargo, la mayoría de los palistas que participaron en estos estudios, no eran piragüistas de élite. van Someren et al., (71, 72), analizaron la fuerza isocinética de palistas senior internacionales en kayakergómetro y observaron correlaciones con el rendimiento de bajas a moderadas que aumentaban al reducir la distancia competitiva.

Asimismo, los palistas jóvenes también han mostrado una asociación entre el componente de fuerza máxima y el rendimiento en agua (78). Desafortunadamente, en la literatura existen escasas investigaciones sobre otras categorías a parte de la senior masculino y sobre la fuerza de las extremidades inferiores, a pesar de su implicación en el paleo.

1.4. CARACTERÍSTICAS ANTROPOMÉTRICAS EN PALISTAS JÓVENES

Tradicionalmente, la antropometría ha sido entendida como el estudio de las proporciones y medidas corporales Sin embargo, desde una perspectiva deportiva, el término *"Kinanthropometry"* se ha identificado por Ross et al., (97) para referirse al análisis de la composición, tamaño y forma corporal con el objetivo de "entender el movimiento humano en el contexto del crecimiento, ejercicio, rendimiento y nutrición".

Al igual que ocurre para con las capacidades físicas, las particularidades de cada deporte o posición de juego también definen que características morfológicas son más propicias para un adecuado rendimiento. La búsqueda de un perfil antropométrico óptimo de deportista ha sido objeto de estudio en varios deportes de agua como natación (98), remo (99, 100) o piragüismo (6, 63, 72). Determinar que atributos son comunes a los palistas más exitosos y que influencia tienen sobre el rendimiento puede ayudar en edades tempranas a tareas como la identificación de talento deportivo o la orientación hacia una especialidad u otra (11, 12).

1.4.1. Medidas antropométricas

Las variables antropométricas básicas de los palistas de competición han sido analizadas desde los primeros estudios en piragüismo por su facilidad de evaluación (3, 5, 6, 22, 57, 61, 62). Se han observado tallas medias superiores a 180 cm y 165 cm y pesos medios por encima de 75 kg y 65 kg en hombres y mujeres respectivamente. Cuando se analizan palistas de diferente nivel, aquellos con mejor rendimiento y mejores resultados en competición revelaron unos atributos básicos de masa corporal y talla significativamente mayores (6, 22, 71). Asimismo ocurre con palistas jóvenes cuando estas variables se han comparado con las de población sedentaria (13, 101). Otras investigaciones en jóvenes de diferentes especialidades también han identificado una morfología significativamente más robusta en kayakistas respecto a canoístas y en la modalidad de aguas tranquilas respecto a la modalidad de slalom (11, 102).

En cuanto a los pliegues cutáneos, que determinan la adiposidad corporal subcutánea, debemos señalar los bajos valores respecto a la población general que se han observado en palistas de élite tanto hombres como mujeres (3). Se han identificado varios factores determinantes en el nivel de adiposidad de piragüistas de aguas tranquilas entre las que cabe destacar el sexo (3, 13), la edad (9, 61, 103) o la distancia competitiva (6, 72). Por un lado, las palistas mujeres no solo poseen sumatorios de pliegues superiores al de los hombres, sino también un porcentaje de masa grasa mayor en torno al 20% (3, 10, 13, 65). Además, la evolución de la adiposidad con la edad parece seguir una tendencia negativa si atendemos a los sumatorios de pliegues (9, 10), mientras que los valores de porcentaje de grasa (6 – 14%) no parecen cambiar respecto a la edad adulta, probablemente debido a las diferentes fórmulas usadas para su obtención (61, 103). En lo que respecta a la distancia competitiva, van Someren et al., (71) identificaron correlaciones positivas entre la adiposidad y el rendimiento en 200 m. En la misma línea, Fry & Morton (6) revelaron una correlación negativa entre masa grasa y rendimiento cuanto mayor era la distancia competitiva. Al mismo tiempo, existe cierta controversia respecto a la asociación con el nivel de rendimiento, a pesar de que la mayoría de autores han observado sumatorios de pliegues notablemente más bajos en competidores con mayor nivel (3, 6, 104).

El perfil antropométrico robusto y atlético observado en palistas de élite, también viene determinado por unos perímetros y diámetros corporales superiores a los de la media de la población en el miembro superior (3, 11, 104). Especialmente significativos son los perímetros mesoesternal y de brazo flexionado y los diámetros biacromial, biepicondíleo del húmero y transverso del pecho, con valores del modelo de referencia *Phantom* superiores a 0,8 unidades en todos los casos independientemente del sexo (3, 11, 104). Sin embargo, en el miembro inferior esta tendencia se invierte y se observan variables como el diámetro del fémur y diámetro biiliocrestal significativamente más bajos (3, 11). Además, diversos autores han encontrado características similares tanto en palistas jóvenes (11, 13, 102) como en aquellos con un nivel competitivo mayor (6, 71), observando correlaciones positivas con el rendimiento en la mayoría de ellos (71, 72). Desafortunadamente, no existen apenas investigaciones que comparen éstas variables entre kayakistas y canoístas.

1.4.2. Evolución del perfil antropométrico

Tanto en hombres como en mujeres, la tendencia general de las características morfológicas durante las últimas décadas ha sido hacia la de un morfotipo más compacto y atlético, predominantemente mesomorfo, que se agudiza cuanto mejor es el nivel competitivo (3, 71, 105, 106). La inclusión de programas de entrenamiento más efectivos y especializados y la detección de talentos en deportistas jóvenes podrían tener una influencia sobre esta evolución (3, 15, 65, 92). En este sentido, Bishop (65), observó un incremento en el entrenamiento de fuerza por parte de kayakistas mujeres en los últimos años que involucraría un efecto de hipertrofia muscular.

Parece lógico pensar que el aumento de la masa muscular y las dimensiones de los deportistas en los últimos tiempos podría tener un efecto negativo sobre la velocidad de navegación (11, 71). Un mayor peso en el conjunto palista-pala-embarcación afectaría al nivel de flotación del barco y por ende aumentaría la resistencia de fricción debido a una mayor superficie sumergida del mismo (29). Sin embargo, parece que los palistas de élite y especialmente los velocistas, pueden sobrellevar este aumento de peso total al ser capaces de producir, a su vez, más fuerza y traducirla en velocidades más altas (6, 71).

1.5. MADURACIÓN BIOLÓGICA EN EL PALISTA JOVEN

A menudo, en el ámbito deportivo podemos encontrar sujetos de la misma edad cronológica (EC) con una maduración o edad biológica (EB) significativamente diferente (14, 75). La maduración puede definirse como el *tempo* (la duración y momento) y el *timing* (el ritmo) de crecimiento de los segmentos corporales y de los atributos físicos y fisiológicos de un individuo (107). Para la determinación de la maduración biológica, tradicionalmente se han usado tres métodos: a) la maduración del esqueleto (edad ósea); b) la maduración sexual (características sexuales secundarias); y c) la maduración somática (crecimiento corporal). Sin embargo, la maduración por sí sola aporta poca información, siendo realmente útil cuando la comparamos con la edad cronológica.

1.5.1. Maduración del esqueleto

Durante el periodo de crecimiento las estructuras cartilaginosas de los huesos largos comienzan un proceso de reemplazo por tejido óseo (osificación), que se extiende desde el centro (diáfisis) hasta los márgenes (epífisis). A través de radiografía es posible observar como la placa epifisaria situada entre la diáfisis y la epífisis se va osificando a lo largo de la niñez y adolescencia (108-110). Tradicionalmente, los huesos de la mano-muñeca izquierda se han usado como referencia de este fenómeno y los resultados se han extrapolado para la determinación de la edad ósea (EO) de un individuo (111-113). Este proceso se ha basado en la semejanza de la radiografía de la mano-muñeca con una serie de fotografías predeterminadas asumidas como referencia de diferentes EO (75, 109).

Aunque existen varios métodos de obtención de la EO basados en este procedimiento, como el TW3 (113), Greulich-Pyle (114) o Fels (115), se ha observado una baja concordancia entre ellos (figura 4). Además, este procedimiento tiene algunos inconvenientes como son la emisión de radiación (rayos X), el entrenamiento y la especialización de los evaluadores o la antigüedad del atlas con las radiografías predeterminadas (75, 116).

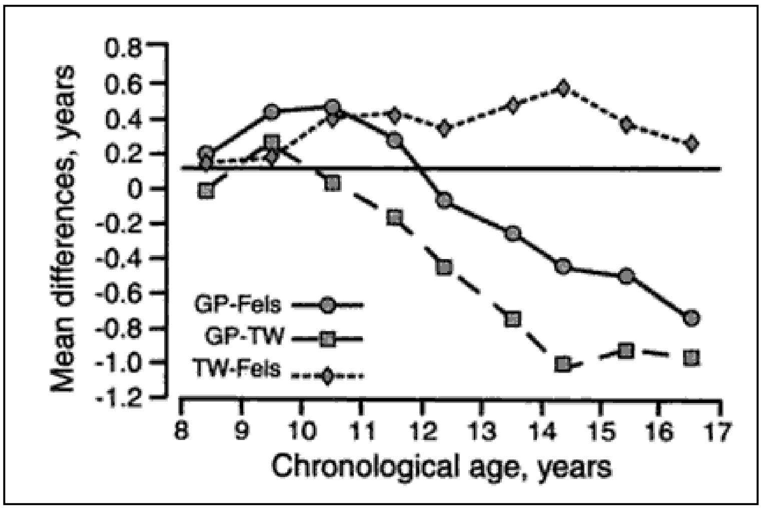

Figura 4.- Diferencias en Edad Ósea entre métodos de valoración. Tomado de Kujawa (117).

Hasta hace solo unas décadas, la determinación de la edad ósea con radiografía era la única técnica disponible para la obtención de la maduración, convirtiéndose en el método *gold standard* (75). Sin embargo, recientemente, ha aparecido un método novedoso para la obtención de la EO basado en las ondas de ultrasonidos (118). La velocidad de paso de las ondas por las estructuras de la mano-muñeca han mostrado una alta correlación con los antiguos métodos readiográficos (119), aunque también pueden llegar a sobreestimar o subestimar los valores cuando la EO difiere mucho de la EC (120).

A partir de la comparación del EO y el EC se puede obtener el estado madurativo de un individuo, que puede clasificarse en tres grupos:*"early maturer"* (EO un año o más por delante de la EC), *"average maturer"* (EO menos de un año arriba o abajo respecto a la EC) y *"late maturer"* (EO un año o más por detrás de la EC) (23, 75, 107, 121). Al mismo tiempo, con esta información también es posible predecir la estatura final que alcanzará un sujeto en la edad adulta (108).

1.5.2. Maduración sexual

La determinación de la maduración sexual o edad sexual de un individuo se ha basado en la observación de las características sexuales secundarias (pecho, genitales y vello púbico) de acuerdo con el procedimiento descrito por Tanner (122). De esta manera, el crecimiento de los atributos sexuales se compara y se identifica con uno de los 5 estadíos de desarrollo sexual predeterminados para asignarles una puntuación (122).

Habitualmente, la identificación de las características sexuales se ha realizado de forma directa por medio de un observador externo, tanto en hombres (pene, testículos, vello púbico) como en mujeres (menarquia, pecho, vello púbico). Sin embargo, a consecuencia del evidente problema de invasión de la intimidad, la autovaloración también ha sido introducida pero con resultados menos fiables (111, 122). Otros inconvenientes del uso de este método incluyen la falta de concordancia intraobservador o la limitación de aplicación a individuos únicamente durante la pubertad (75, 116).

1.5.3. Maduración somática

A partir de la tendencia de crecimiento de variables antropométricas como la estatura y las dimensiones corporales, se puede determinar el grado de maduración somática de un individuo (75). Aunque es un método indirecto para la estimación de la maduración biológica, se puede considerar un procedimiento "no invasivo" que puede usarse antes y después del periodo puberal (108).

En base a los cambios en las proporciones corporales durante el periodo de crecimiento es posible determinar la edad cronológica a la que un individuo alcanza su pico máximo de crecimiento en altura o APHV (*age at peak heigh velocity*) y que ha sido definido por Mirwald et al., (23) como referencia para la determinación del estado madurativo. Estudios previos han determinado que, habitualmente y como referencia, el APHV ocurre alrededor de los 14 años en chicos y de los 12 años en chicas (107, 123). Sin embargo, no todos los adolescentes alcanzan el APHV a esa edad cronológica (23, 111). La maduración biológica se identifica a partir de la diferencia, en años, que ha pasado (valores positivos) o que queda (valores negativos) desde o hasta el APHV de un individuo. En función de este valor y de la edad cronológica, puede determinarse el APHV de un individuo. Además, pueden establecerse grupos de maduración cuando se compara con el APHV de referencia (tabla 6), encontrando: "maduradores tempranos" (*early maturers*), "maduradores medios" (*average maturers*) o "maduradores tardíos" (*late maturers*). Por ejemplo, una chica de 12 años con una diferencia de -0,6 tendrá el APHV a los 12,6 años (12 - (- 0,6 años)) siendo maduradora media, mientras que un chico de 14,2 años con una diferencia de +1,4 habría tenido el APHV a los 12,8 años (14,2 - 1,4 años) siendo un madurador temprano.

Tabla 6.- Grupos de maduración en función del APHV según Sherar (121).

	Temprana (Early)	**Media** (Average)	**Tardía** (Late)
APHV ♂ (Diferencia en años)	< 13 (-1)	13-15	> 15 (+1)
APHV ♀ (Diferencia en años)	< 11 (-1)	11-13	> 13 (+1)

Notas.
APHV = age at peak height velocity

En función del estado madurativo y de las características personales de un individuo, no solo el APHV puede cambiar, también la duración y los ritmos de crecimiento varían (111). Sherar et al., (121), identificó una tendencia progresiva y decreciente del crecimiento conforme el grupo madurativo avanzaba (tempranos > medios > tardíos). De esta manera, se ha observado que los maduradores tempranos crecen más (pico de crecimiento en centímetros) y antes en el tiempo que los maduradores medios y tardíos (figura 5, a), además de hacerlo durante más tiempo (figura 5, b).

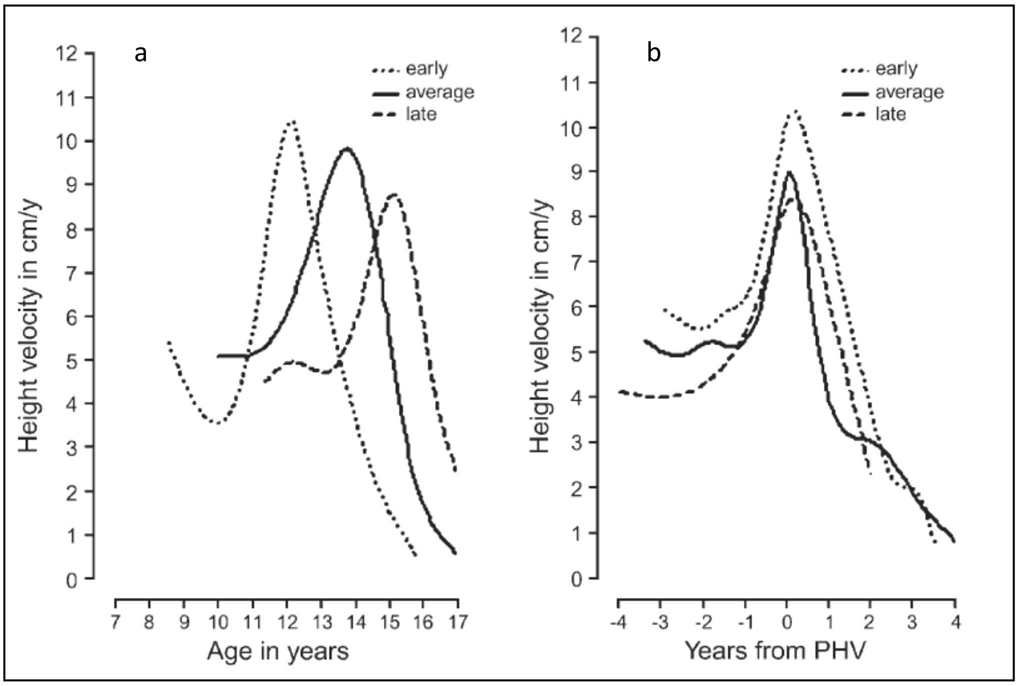

Figura 5.- Crecimiento en centímetros de los 3 grupos madurativos en función de la edad cronológica (a) y la maduración somática (b) en chicos. Tomado de Sherar (121).

El uso de este método para la valoración de la maduración biológica, es fácil, poco costoso y fiable (111, 124) y además permite la estimación de la estatura adulta final (121). Sin embargo, las proporciones de crecimiento varían en función de la etnia y pueden comprometer la estimación de la maduración en individuos diferentes (111). Asimismo, otros estudios también señalan como un importante inconveniente la baja fiabilidad en la predicción del APHV cuando los sujetos se alejan de la edad cronológica de referencia del APHV (111, 116, 125). Concretamente, el APHV tendería a sobreestimarse en edades cronológicas tempranas y a subestimarse en las tardías, originando, de esta manera, un agrupamiento en la categoría de maduradores medios (116).

La estimación del porcentaje de la estatura adulta final a la que se encuentra un individuo en un cierto momento también ha sido utilizada como método para describir el estado madurativo (75). Uno de los métodos más conocidos para esta estimación es el desarrollado por Khamis & Roche (126) que utiliza la estatura de los padres. En los últimos años, otras investigaciones han simplificado el proceso de identificación de los predictores de la estatura adulta final, reduciéndolo a solo unos pocos parámetros antropométricos básicos (127, 128).

1.5.4. Capacidades físicas y maduración

Aunque existe consenso sobre la influencia de la maduración biológica sobre el desarrollo de los atributos físicos durante la infancia y adolescencia (12, 107, 129), pocos estudios han profundizado en este análisis. El crecimiento de las dimensiones corporales y los cambios en el sistema nervioso como consecuencia del proceso madurativo son, en gran medida, responsables de la evolución de la condición física (23, 76, 129) y el rendimiento (130).

Durante la pubertad, la mayoría de las capacidades físicas experimentan su mayor evolución en torno al APHV y ligeramente antes de la misma (23, 131). Es el caso de la velocidad (111), la capacidad aeróbica (76, 77) o la coordinación motriz (129). Sin embargo, otros atributos como la fuerza o la capacidad anaeróbica parecen desarrollarse en mayor medida justo después del APHV coincidiendo con la especialización metabólica del individuo (76, 132-134).

Las características y los espacios donde se desarrolla el piragüismo de aguas tranquilas hacen muy difícil la valoración *in situ* de las capacidades físicas de los deportistas (135, 136). Tradicionalmente, para facilitar la evaluación del palista se han usado kayak-ergómetros en laboratorios que reprodujesen las condiciones de paleo en un entorno estable (135, 136). A pesar de su falta de especificidad, los test de campo también pueden ser herramientas muy útiles a la hora de valorar los atributos físicos, especialmente en deportistas jóvenes y grandes grupos sin necesidad de costosas inversiones. Asimismo, la facilidad de utilización y rapidez de resultados permitiría un uso continuado en el seguimiento de palistas jóvenes en formación.

Diversas investigaciones en piragüistas jóvenes han analizado de forma aislada algunos de los atributos físicos más determinantes en el rendimiento en palistas senior, como la capacidad aeróbica o la fuerza máxima (74, 101). Asimismo, la maduración biológica ha sido también investigada en competidores jóvenes de varias especialidades, como las aguas tranquilas y el slalom, encontrando una relación positiva con las dimensiones corporales y el rendimiento (14). Sin embargo, no existen apenas estudios que investiguen cómo el proceso de maduración biológica influencia la condición física y el rendimiento específico en el agua.

1.6. IDENTIFICACIÓN DE JÓVENES TALENTOS EN PIRAGÜISMO

Actualmente, en la mayoría de países las competiciones deportivas y los grupos de entrenamiento en categorías inferiores están organizadas por grupos de edad (137). De esta manera, en una misma prueba y categoría compiten juntos deportistas nacidos en el mismo año natural, a pesar de que puedan existir hasta 12 meses de diferencia entre ellos (12, 121). Además, y como se ha comentado en el capítulo anterior (1.5), durante la adolescencia el *tempo* y *timing* del proceso madurativo puede ser muy diferente entre individuos del mismo año de nacimiento (12, 107). Estas diferencias biológicas tienen un gran impacto en los atributos físicos y morfológicos y, a su vez, en el potencial de rendimiento de los deportistas jóvenes (130). Por lo tanto, aquellos competidores nacidos en la primera parte del año y/o con una maduración temprana, partirían con "ventaja" en las competiciones deportivas (75, 121). A este fenómeno se la ha denominado "efecto de la edad relativa" y no solo afecta a la competición, también a la selección y detección de jóvenes talentos (12, 75, 138).

Los programas de identificación de talento que existen actualmente, han seguido y aún siguen procedimientos basados en el rendimiento puntual de los deportistas (12). Lo mismo ocurre en deportes individuales como el piragüismo, con la selección para competiciones internacionales por parte de federaciones o la especialización para una disciplina determinada (75). Aquellos deportistas menos maduros biológicamente, tienen menos posibilidades de ser seleccionados y por lo tanto de progreso dentro del deporte, lo que implicaría un estado de desmotivación para el deportista (137). De este modo, individuos con gran potencial pero que aún no se han desarrollado física y morfológicamente y sus resultados no destacan en su edad podrían abandonar la actividad o especializarse erróneamente (75, 121). Por otro lado, los deportistas más maduros a edades tempranas pueden crear falsas expectativas en cuanto a su potencial de adultos, puesto que sus atributos tenderán a desarrollarse menos o estancarse antes de esta fase (12).

Algunos autores han sugerido que la especialización en kayak o canoa en piragüismo, podría estar relacionada con el nivel de condición física y habilidad técnica, siendo la canoa la especialidad elegida por los deportistas más técnicos y menos nivel físico (102). Asimismo, existen ciertos parámetros antropométricos relacionados con el rendimiento en piragüismo senior de élite, como los perímetros mesoesternal y del brazo flexionado o el diámetro biepicondileo del húmero y biacromial (apartado 1.5), cuya evolución debería considerarse durante las etapas de formación (3, 102).

Sería recomendable que todos los programas de detección de jóvenes talentos tuvieran en cuenta las diferencias morfológicas, físicas y madurativas de los deportistas, tanto para ser seleccionados como para garantizar un programa de entrenamiento adecuado a sus características (137). Igualmente, los programas de desarrollo deberían llevarse a cabo a largo plazo desde una perspectiva no solo física y de rendimiento, también holística considerando el potencial técnico y de progreso del deportista (139). Esta idea no es nueva ya que a principios del siglo XX, nace el concepto del *Bio-banding*, que tiene como objetivo la agrupación de deportistas jóvenes por características físicas y no por edad cronológica. Aunque en la historia no se han implementado muchas iniciativas bajo estos principios, en los últimos años parece que el *Bio-banding* ha comenzado a utilizarse en países como el Reino Unido en futbolistas jóvenes con resultados positivos (137).

II – JUSTIFICACIÓN, HIPÓTESIS Y OBJETIVOS

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El planteamiento general de la presente tesis se basó en la idea de llevar a cabo una serie de estudios con un eje central, el perfil morfológico y físico del piragüista joven de élite, y que tuviera una utilidad tanto para entrenadores como para investigadores en la identificación de talento deportivo. La información aportada no solo permitiría la identificación de determinantes físicos y antropométricos importantes para el rendimiento, sino también el refuerzo de estos parámetros o la adecuación de las características individuales a las diferentes especialidades.

2.1. JUSTIFICACIÓN

En la literatura especializada en deportes náuticos, existen escasas investigaciones en el área de piragüismo si las comparamos con las de otros deportes practicados en el mismo medio, como remo (140) o natación (141). Considerando que el piragüismo de aguas tranquilas es un deporte individual, un óptimo rendimiento dependerá de una combinación de determinantes, no solo fisiológicos y biomecánicos, también morfológicos, físicos y cinemáticos entre otros (2-4). Tradicionalmente, la mayoría de las investigaciones en este área se han llevado a cabo en competidores adultos de categoría masculina, centrándose en variables fisiológicas o biomecánicas de la acción de paleo.

Asimismo, pocos estudios han analizado las características de palistas jóvenes en formación, y la mayoría de estos lo ha hecho de manera aislada en deportistas con poca experiencia (74, 101) o de diferentes niveles (78). Desde el punto de vista del análisis de los resultados, es importante tener en cuenta las diferencias biológicas en deportistas adolescentes, puesto que éstas van a influir sobre el resto variables individuales. Además, para garantizar que en los programas de jóvenes talentos estén los palistas con más proyección de éxito en posteriores categorías sénior de élite; técnicos y seleccionadores deben contar con las herramientas e información más adecuadas (12). Sin embargo, en la realidad de los clubes y centros de tecnificación donde entrenan la mayoría de palistas, existen pocos recursos humanos y materiales para analizar las características de sus deportistas y detectar aquellos con más potencial para una disciplina u otra.

Por lo tanto, a modo de resumen, se nos plantearon los siguientes problemas en la situación actual de piragüismo y su investigación en etapas de formación:

a) No existe evidencia científica que relacione la composición corporal, la maduración y la condición física general con el rendimiento en las pruebas específicas de kayak y canoa.
b) La mayoría de los estudios se han llevado a cabo en categoría adulta masculina en la especialidad de kayak.
c) Actualmente la evaluación de los atributos físicos y antropométricos no está al alcance de clubes y federaciones de manera fácil, poco costosa y fiable.
d) Existe poca evidencia sobre los atributos físicos y antropométricos más determinantes y comunes con los palistas sénior de élite y si éstos son importantes en el alto rendimiento.

2.2. HIPÓTESIS, OBJETIVOS Y DISEÑO GENERAL

A partir del análisis del escenario científico en el que se encontraba el piragüismo de aguas tranquilas, se plantearon los siguientes estudios:

✓ Estudio 1: *Diferencias antropométricas, edad biológica y condición física entre kayakistas y canoístas jóvenes de élite.*

- Tipo de estudio:
  Descriptivo, transversal y comparativo
- Objetivo:

Identificar el perfil antropométrico y de condición física de palistas jóvenes de élite y compararlos en función de su especialidad.

- Método:

  Participantes: Ochenta y nueve kayakistas y ochenta y dos canoístas hombres jóvenes.

  Procedimiento: Batería de test de campo para condición física (fuerza, movilidad, capacidad aeróbica), medidas antropométricas y estado madurativo.

✓ Estudio 2: *Predicción del rendimiento en kayak y canoa a partir de la relación entre estado madurativo, características antropométricas y condición física en jóvenes palistas de élite.*

- Tipo de estudio:

  Descriptivo, transversal, comparativo y predictivo.

- Hipótesis:

  La edad biológica, la morfología robusta y atlética y el nivel de fitness son los factores de predicción de rendimiento más importante.

- Objetivos:

  i. Comparar las diferencias morfológicas, físicas y de rendimiento en función de la maduración.

  ii. Determinar la importancia relativa de estos atributos en la predicción del rendimiento en las pruebas específicas de 200, 500 y 1000 m.

- Método:

  Participantes: Ciento setenta y un palistas jóvenes de categoría masculina (89 kayakistas y 82 canoístas)

  Procedimiento: Agrupación por disciplina y estado madurativo. Evaluación de condición física (fuerza, movilidad, capacidad aeróbica) y composición corporal. Análisis de los determinantes y predictores del rendimiento.

✓ Estudio 3: *Perfil antropométrico y condición física en jóvenes mujeres kayakistas de élite.*

- Tipo de estudio:

  Descriptivo, transversal, comparativo y relacional.
- Hipótesis:

  Las kayakistas mostrarían unas características morfológicas y físicas similares a las de sus homólogos masculinos al comparar entre niveles competitivos.
- Objetivos:
  1. Determinar y comparar las características antropométricas y físicas en función del nivel de rendimiento competitivo.
  2. Identificar los determinantes que se asocian con el rendimiento específico en palistas femeninas de élite.
- Método:

  Participantes: ochenta y seis jóvenes mujeres kayakistas

  Procedimiento: Agrupación por ranking (Top 10 y Top 20-22). Comparación de condición física (fuerza, movilidad, capacidad aeróbica) y composición corporal. Asociación de esas variables con los tiempos de pruebas de 200, 500 y 1000-m.

✓ Estudio 4: *Análisis longitudinal de las características morfológicas y proporcionalidad corporal en palistas jóvenes de élite.*

- Tipo de estudio:

  Descriptivo, longitudinal y comparativo.
- Hipótesis:

  Los atributos propios de un perfil sénior de élite se evidencian a través de los años y vienen influidos por la maduración biológica
- Objetivo:

  Identificar la evolución de los determinantes antropométricos y compararlos con aquellos asociados a un óptimo rendimiento en palistas adultos de nivel mundial.

- Método:

Participantes: Trece palistas jóvenes de élite (7 masculinos y 6 femeninas).

Procedimiento: Seguimiento de los parámetros morfológicos durante 3 años. Comparación de los 3 grupos (3 años) y comparación con valores de élite sénior.

III – MATERIAL Y MÉTODOS

III – MATERIAL Y MÉTODOS

3.1. PARTICIPANTES

Un total de 257 palistas de categoría infantil y cadete, de ambos géneros y diferentes modalidades (kayak y canoa) tomaron parte en alguno de las 4 investigaciones realizadas. Todos ellos estaban entrenando de manera regular en el momento de tomar parte en los estudios (al menos 4-6 días a la semana y 2 horas al día). Además, fueron seleccionados por encontrarse entre los mejores de su categoría para su asistencia a las concentraciones Nacionales de su grupo de edad realizadas dentro del Programa Nacional de Tecnificación del Consejo Superior de Deportes y la Real Federación Española de Piragüismo.

Aquellos que presentaron síntomas de enfermedad y/o lesión, estaban bajo tratamiento farmacológico o dietas alimentarias específicas en el momento de las valoraciones quedaron excluidos de los estudios.

- ✓ Estudio 1: en el primer estudio tomaron parte 89 kayakistas y 82 canoístas hombres de categoría infantil (13,68 ± 0,55 y 13,69 ± 0,60 años de edad, respectivamente), de élite y con una experiencia previa de 3,80 ± 1,78 y 2,51 ± 1,38 años, respectivamente.

- ✓ Estudio 2: para el segundo estudio comparativo participaron voluntariamente 171 palistas hombres de categoría infantil de 13,69 ± 0.57 años de edad. Los deportistas fueron divididos en 3 grupos en función de su maduración biológica obtenida a través de su pico máximo de crecimiento en altura o *age at peak height velocity* (APHV).

- ✓ Estudio 3: la muestra del tercer estudio estuvo compuesta por un total de 86 kayakistas jóvenes de categoría femenina (13,62 ± 0,57 años de edad). Cada año (durante 4 años) se valoraron a las 20-22 mejores del ranking y después éstas se agruparon 2 categorías: Top10 (las 10 mejores del ranking cada año) y top20-22 (las 10-12 siguientes).

- ✓ Estudio 4: en el último estudio y el único de carácter longitudinal, fueron valorados 7 palistas hombres y 6 mujeres. Durante 3 años consecutivos, los deportistas fueron valorados, desde su etapa infantil hasta la categoría cadete.

Todos los procedimientos de los estudios fueron aprobados por el Comité de Ética Institucional. Asimismo, se obtuvo consentimiento informado por parte de todos los deportistas así como del padre, madre o tutor legal de los participantes.

3.2. PROCEDIMIENTO

Las valoraciones de los deportistas se llevaron a cabo en 4 concentraciones nacionales del Plan Nacional de Tecnificación a lo largo de los 4 días que duraban cada una de ellas. El orden y horario de los test de valoración fueron similares en todos los estudios. Por la mañana se realizaron las mediciones antropométricas y a continuación los diferentes test de campo para la valoración de la condición física (1 o 2 al día) mientras que por la tarde se realizaron los test de rendimiento en agua (1 al día) con el objetivo de asegurar suficiente descanso y prevenir posible fatiga. Los palistas y entrenadores fueron informados con antelación de no realizar sesiones de entrenamiento intensas (al menos 48 horas antes) ni ingerir cafeína o sustancias similares antes de los test de condición física y rendimiento en agua.

3.2.1. Variables antropométricas

Todas los participantes completaron una batería de valoraciones antropométricas tomadas por un antropometrista acreditado de, al menos, nivel II, siguiendo las indicaciones descritas por la ISAK (*International Society for the Advancement in Kinanthropometry*) (142).

Las medidas se tomaron dos o tres veces, si la diferencia entre las dos primeras era superior al 5% en pliegues y al 1% en el resto de medidas, tomando la media o la mediana, respectivamente, para la realización de los análisis y procesamiento de la información posteriores.

Todo instrumental usado fue calibrado con antelación para prevenir errores en la medición. Para la determinación del peso se utilizó una báscula SECA 862 (Báscula digital, SECA, Alemania) de 100 g de precisión; para los pliegues un plicómetro Harpenden (British Indicators, United Kingdom) de 0,2 mm de precisión; para la envergadura y los perímetros una cinta metálica inextensible milimetrada Lufkin W606PM (Lufkin, EE.UU); y para la talla, talla sentado, alturas, longitudes y diámetros, un antropómetro Siber-Hegner GPM (Siber-Hegner, Suiza) y un paquímetro Holtain (Holtain Ltd. Reino Unido), ambos con una precisión de 1 mm.

A partir de estas mediciones se calcularon el índice de masa corporal, los sumatorios de seis y ocho pliegues cutáneos (tríceps, subescapular, bíceps, iliocrestal, supraespinal, abdominal, muslo anterior y pierna medial) y los perímetros corregidos siguiendo las indicaciones de Martin et al., (143) . Las ecuaciones de Carter & Heath (144) se utilizaron para calcular cada uno de los componentes del somatotipo y la estrategia del Phantom (145) para la determinación de los valores de proporcionalidad Z de cada una de las variables. Asimismo la determinación de la masas muscular y grasa se realizó a través de las ecuaciones de Poortmans et al., (146) y Slaughter et al., (147), respectivamente. Mientras que para el último estudio, la composición corporal se obtuvo con la estrategia de cinco componentes definida por Kerr (148).

3.2.2. Maduración

El protocolo propuesto por Mirwald et al., (23) para la determinación de la maduración biológica a través de variables antropométricas, fue usado para obtener los años que faltaban o habían pasado hasta la edad de máximo crecimiento en altura (APHV) de cada individuo. El APHV fue identificado como referencia en el punto 0 de maduración. De esta manera, los valores negativos indicaban el tiempo que faltaba hasta el APHV y los positivos el tiempo que había pasado desde el APHV. En el segundo estudio se establecieron 3 grupos en función de los valores de maduración biológica: pre (< - 0,5), circum (> -0,5 y < 0,5) y post (> 0,5).

3.2.3. Condición física

Los deportistas completaron una batería de 4 test de condición física para valorar la capacidad aeróbica, la fuerza en las extremidades superiores e inferiores y la movilidad de la cadera. Previo a cualquier valoración física, los participantes completaron un calentamiento general y específico (8-15 min) dirigido por un preparador físico y un periodo de familiarización (5 min) con los materiales y procedimientos que se detallan a continuación.

El test de carrera de ida y vuelta de la Universidad de Montreal (version mp3 audio, Coachwise United Kingdom) se llevó a cabo para estimar el VO_2max. Se siguió el procedimiento estándar descrito por Leger & Lambert (149) donde los palistas completaron progresivamente cada estación de 20 m a tiempo de cada "beep" de la grabación. Dos avisos fueron dados cuando una estación no era completada a tiempo quedando eliminados a la siguiente. La última repetición completa fue utilizada para la estimación del VO_2max registrándose además la frecuencia cardiaca de los participantes inmediatamente tras el último estadío correctamente completado (150).

La valoración de la fuerza y potencia de las extremidades inferiores fue realizada a través del Test de Bosco de salto vertical (151). Se llevaron a cabo 3 repeticiones, separadas por al menos 5 minutos, de salto vertical con contramovimiento *Countermovement Jump Test* (CMJ) y se valoró el salto con más altura de ambos. El test se realizó con una plataforma de contacto (Bosco System, Barcelona, España) de forma que a través del tiempo de vuelo (s) se analizó la altura alcanzada (m) (47).

La fuerza de las extremidades superiores fue valorada a través del Test de Lanzamiento de Balón Medicinal o *Overhead Medicine Ball Throw* (OMBT). Para tal propósito se usó un balón medicinal de 3 kg de peso lanzado por encima de la cabeza hacia delante desde posición parada de pie (152). Durante la preparación, los balanceos y contramovimientos estuvieron permitidos siempre y cuando los pies se mantuvieran estáticos. Los deportistas completaron 3 lanzamientos separados por al menos 5 minutos, registrándose el mejor de ambos para su posterior análisis.

Para la valoración de la movilidad los deportistas siguieron el protocolo *Sit-and-Reach* (SR) para la extensibilidad isquiosural (90). Desde posición sentada y sin calzado, los palistas mantuvieron las rodillas estiradas y juntas con las plantas apoyadas y en contacto con el fondo del cajón de valoración (Richflex System, Sportime, EEUU). Con las palmas de las manos hacia abajo, el objetivo era deslizar las manos despacio, una sobre la otra, los más lejos posible y mantener la posición al menos 2 segundos sin flexionar las rodillas. La distancia alcanzada fue valorada mediante una cinta métrica estándar colocada encima del cajón, con el 0 representando el punto en el que los dedos de la mano estuvieran en línea con las plantas de los pies. De esta manera, los valores negativos representaron no sobrepasar la línea de las plantas de los pies. La mejor de 3 repeticiones fue considerada para posterior análisis.

3.2.4. Rendimiento específico

En días separados, todos los participantes completaron individualmente 3 test de 200, 500 y 1000 m a máxima velocidad en su modalidad (kayak o canoa) y con el equipo y material habitual de competición y entrenamiento. Al inicio de cada prueba se llevó a cabo un calentamiento general (5-10 min) y otro específico en el agua (8-10 min) supervisado por los entrenadores. Todas las pruebas comenzaron con una señal sonora del técnico responsable y finalizaron cuando los palistas cruzaron la línea de llegada, registrándose en vídeo todas las actuaciones. Las grabaciones se realizaron a 30 fotogramas/segundo con una cámara JVC Everio MG-135 (Victor Company, Japón) y fueron tomadas desde una embarcación paralela a la trayectoria del palista dejando al menos 5 m de separación. Para determinar el tiempo de cada prueba, se calcularon los fotogramas desde el inicio de la tracción hasta cruzar la línea de llegada mediante el software Virtualdub 1.8.8 (Avery Lee) y a continuación se dividieron entre la velocidad de grabación (30 fotogramas·s^{-1}). Aquellos días con viento superior a 2 m·s^{-1}, se pospusieron los test para evitar su influencia sobre los resultados finales.

3.3. ANÁLISIS ESTADÍSTICO

Todos los análisis estadísticos fueron realizados mediante el software informático SPSS v22.0 (SPSS Inc., Chicago IL, EEUU). Las medidas de homogeneidad y dispersión en cada uno de los estudios fueron presentadas como media y desviación estándar. Asimismo, las hipótesis de homogeneidad y normalidad de distribución de la muestra fueron investigadas con los test de Levene y Kolmogorov–Smirnov, respectivamente, excepto para el último estudio donde se usó el test de Shapiro-Wilk por tener una muestra menor. Además, en todas las investigaciones el nivel de significancia se estableció en $p < 0,05$.

✓ <u>Estudio 1</u>

Cuando la muestra fue identificada como normal y homogénea se usó una prueba t-test para muestras independientes en la comparación entre grupos. Para muestras sin distribución normal se realizó el test no paramétrico de Mann-Whitney. Asimismo, el tamaño del efecto se investigó a través de los valores *d* de Cohen considerándose pequeño cuando los valores se situaron entre 0,2 y 0,5, moderado entre 0,5 y 0,8, y grande cuando los valores superaron 0,8 (153).

✓ <u>Estudio 2</u>

La comparación entre grupos de maduración se realizó mediante el test ANOVA de un factor con 3 niveles (pre, circum, post) aplicando la prueba *post hoc* de Bonferroni para identificar los grupos en caso de significación y cuando la muestra mostró normalidad y homogeneidad. Cuando la distribución de la muestra no mostró normalidad, el test no paramétrico de Kruskal–Wallis y el test *post hoc* de Mann–Whitney con correcciones de Bonferroni (0,05/3) fueron completados para investigar si existía significación e identificar los grupos. Para el análisis de las asociaciones lineales entre parámetros se utilizaron los coeficientes de correlación de Pearson (r), cuando la distribución de la muestra era normal, y el de Spearman (r_s) cuando la muestra no lo era. Asimismo, se realizó un test de regresión múltiple de pasos sucesivos para determinar las variables predictoras del rendimiento con aquellas que resultaron significativas en la correlación lineal. Una vez analizada la colinearidad, aquellas variables predictoras con un factor de inflación de varianza mayor a 10 y/o un nivel de tolerancia menor a 0,1 fueron excluidas del modelo.

✓ <u>Estudio 3</u>

Para la comparación de las medias entre los grupos establecidos se usó el t-test para muestras independientes mientras que cuando no se demostró una distribución normal de la muestra la comparación se efectúo mediante el test no paramétrico de Mann-Whitney. El análisis *d* de Cohen fue usado para investigar el tamaño del efecto. Además, se analizaron las interrelaciones lineales entre los parámetros con el mismo procedimiento que en el Estudio 2 mientras que las magnitudes de las correlaciones fueron valoradas de acuerdo con Hopkins et al., (154). Igualmente, se realizaron un test de regresión múltiple y colinearidad siguiendo los procedimientos descritos en el estudio anterior.

✓ <u>Estudio 4</u>

El test ANOVA para medidas repetidas fue utilizado para el análisis de las medias entre los 3 años observados cuando la muestra resultó normal y homogénea. Si el análisis de la varianza (ANOVA) revelaba significancia éstas se identificaban mediante el test *post hoc* de Bonferroni. En caso de distribución no normal, el test de Friedman y test *post hoc* de Wilcoxon con correcciones de Bonferroni (0,05/3) fueron ejecutados. El tamaño del efecto entre grupos fue investigado mediante el cálculo de eta cuadrado parcial (η^2_p), identificando un efecto pequeño con valores entre 0,01 y 0,06, moderado entre 0,06 y 0,13 y grande con valores superiores a 0,13.

IV-ARTÍCULOS CIENTÍFICOS

ESTUDIO 1

Título

Differences in anthropometry, biological age and physical fitness between young elite kayakers and canoeists

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Section III – Sports Training

DE GRUYTER OPEN

Differences in Anthropometry, Biological Age and Physical Fitness Between Young Elite Kayakers and Canoeists

by
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The aim of this study was to determine the anthropometric and physical characteristics of youth elite paddlers and to identify the differences between kayakers and canoeists. A total of 171 male paddlers (eighty-nine kayakers and eighty-two canoeists), aged 13.69 ± 0.57 years (mean ± SD) volunteered to participate in this study. The participants completed basic anthropometric assessments (body mass, stretch stature, sitting height, body mass index, maturity level, sum of 6 skinfolds and fat mass percentage) as well as a battery of physical fitness tests (overhead medicine ball throw, counter movement jump, sit-and-reach and 20 m multi-stage shuttle run tests). The anthropometric results revealed a significantly larger body size (stretch stature and sitting height) and body mass in the kayakers ($p < 0.01$) as well as a more mature biological status ($p = 0.003$). The physical fitness level exhibited by the kayakers was likewise significantly greater than that of the canoeists, both in the counter movement jump and estimated VO2max ($p < 0.05$), as well as in the overhead medicine ball throw and sit-and-reach test ($p < 0.01$). These findings confirm the more robust and mature profile of youth kayakers that might be associated with the superior fitness level observed and the specific requirements of this sport discipline.

Key words: *anthropometry, physical fitness, biological age, kayak, canoe.*

Introduction

Systematic sport training has been related to the development of certain physical attributes along with specific changes in the morphological characteristics of athletes (Gabbett and Georgieff, 2007; Ross and Marfell-Jones, 1991). Although a complex group of different variables favours performance in a given sport, there are some attributes which seem to be common in the most successful athletes (Leone et al., 2002). Over the past few years, research into the relationship between anthropometry and performance has increased (Gabbett and Georgieff, 2007; Mielgo-Ayuso et al., 2015). In most sports, the athletes' overall status may be determined by means of general and specific field tests, since a strong correlation has been consistently reported between the fitness level and the individual performance attained (Pyne et al., 2006; van Someren and Howatson, 2008). Traditionally, the determination of a physical profile in a given sport involves the use of predictive testing as a measure of power and strength (Cronin and Hansen, 2005), speed (Gabbett and Georgieff, 2007), aerobic fitness (Leone et al., 2002) or flexibility (Simoneau, 1998). Along with measurements of body dimensions, predictive

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fitness tests provide an appraisal of the structural and physical status that may be used to describe the 'typical' successful athlete in a given sport (Ross and Marfell-Jones, 1991).

Within particular sports, there exist various disciplines or playing positions with specific demands that require different approaches in training and are associated with different physical and morphological characteristics (Gabbett and Georgieff, 2007; Mielgo-Ayuso et al., 2015). Sprint canoeing is a cyclic sport which consists of two disciplines - kayaking and canoeing - both aiming to cover a specific distance as quickly as possible, and crossing the finish line before the opponents (Aitken and Neal, 1992; Shephard, 1987). From a biomechanical perspective, movement in kayaking consists of double-blade paddle cyclic movements on both sides of the boat, coordinated through pedalling movements and trunk rotation in a seated position, whereas canoeing consists of single-blade paddle cyclic movements performed on the same side of the boat from a kneeling position (up on one knee). Although there have been relatively few studies comparing the anthropometric attributes of both disciplines, the majority have agreed on the greater size and body mass of the kayakers (Arlettaz et al., 2004; Hirata, 1977). Conversely, a trend towards a larger thigh girth has been exhibited in canoeists, which might be related to the greater sum of 8 skinfolds observed in these athletes (Alacid et al., 2015; Ridge et al., 2007).

Traditionally, research into kayaking is primarily focused on physiological testing of the athletes in order to determine fitness levels and then designing training programs to optimize physiological fitness (Aitken and Neal, 1992). Early studies only analysed VO2max to monitor and assess the physiological capacity of elite kayakers (Pendergast et al., 1979; Tesch et al., 1976). Nevertheless, the measurement of maximal oxygen uptake of paddlers is not the only possible determinant of performance. While characteristics of the sport demand that kayakers paddle most of the race at or around peak VO2 (Bishop et al., 2002), requiring high aerobic power, the anaerobic aspects should not be overlooked (Fry and Morton, 1991; Tesch et al., 1976). Other variables apart from VO2 have been associated with optimal performance in paddling (Pendergast et al., 1979; Tesch et al., 1976). Fry and Morton (1991) using a battery of anthropometric and physiological tests, determined the most important attributes of elite sprint kayakers. Anthropometric variables such as muscle mass, height, body fat, and limb length have been identified as factors contributing to obtain optimal performance (Fry and Morton, 1991; Shephard, 1987; Sklad et al., 1994). The relationship between anthropometry and performance has also been confirmed by other studies (Ackland et al., 2003; Gobbo et al., 2002; van Someren et al., 2001) in an attempt to determine elite kayaking profiles in seniors and juniors, while in canoeing this relationship has not yet been studied, making a comparison between disciplines impossible.

Research into sprint paddling has focused only on investigating each variable separately, and has never taken field-based testing into consideration in the determination of paddler profiles, offering only a limited picture of the overall status of the athletes. Therefore, the purpose of this study was to identify the anthropometric and physical profile of youth elite paddlers competing at a high level and to compare them between disciplines. It was hypothesized that kayakers and canoeists would have different anthropometric and physical characteristics, as a result of different demands of each sport discipline.

Material and Methods

Participants

A total of 171 youth male paddlers (eighty-nine kayakers and eighty-two canoeists), aged 13.69 ± 0.57 years (mean ± SD), with training experience of 3.80 ± 1.78 and 2.51 ± 1.38 years (mean ± SD), respectively, participated in this study. The inclusion criteria were (a) training on regular basis between 4 and 6 $d \cdot wk^{-1}$, (b) at least 2 hours of daily training and (c) being selected that year by the Royal Spanish Canoeing Federation as the best in their age category to participate in National Development Camps between 2005 and 2008. The Institutional Ethics Committee of the Catholic University of San Antonio approved the study and a signed written informed consent form was obtained from the participants and their parents before the beginning of testing. Any participant reporting illness or pharmacological treatment during the testing period was excluded from the study.

Procedures

A series of physical and anthropometric tests was performed over a 3 day period at the National Development Camps. Before the beginning of each physical test, clear instructions were given to all participants, as well as a warm-up time consisting of 6-8 minutes of multi-directional running and 5 minutes of upper and lower limb general dynamic stretching supervised by a strength coach. A 5-minute familiarisation time with the materials and procedures was also provided as part of the specific warm-up for each test. The testing session began with anthropometric assessments followed by upper and lower body physical tests to prevent any potential body composition changes (Gabbett and Georgieff, 2007). In addition, the participants were required to abstain from intensive training sessions 48 hours before the National Camps and retain their normal pre-training diet prior to testing.

Anthropometry

Anthropometric variables included age (years), body mass (kg), stretch stature (cm), sitting height (cm), and the sum of 6 skinfolds (mm) (triceps, subscapular, supraspinale, abdominal, front thigh and medial calf), and were measured following the guidelines described by the International Society for the Advancement of Kinanthropometry (ISAK) (Stewart et al., 2011). Body mass was evaluated using a SECA 862 scale (SECA, Germany); stretch stature and sitting height were determined with a GPM anthropometer (Siber-Hegner, Switzerland), and skinfolds with a Harpenden skinfold calliper (British Indicators, UK). All instruments were calibrated at the beginning of each testing session to prevent measurement errors. A fully certified Level-2 ISAK anthropometrist measured each variable two or three times, if the difference between the first two measurements were greater than 5% for the skinfolds and 1% for the rest of the dimensions, with the mean values (or median in the last case) used for further data analysis. The intra-rater technical error of measurement was set at 3.05% for the skinfolds and 0.69% for the other variables. The body mass index (BMI) was determined by the equation: body mass (kg)/ stretch stature^2 (m), while fat mass content (%) was calculated following the procedures defined by Slaughter et al. (1988), which take into consideration the sum of 6 skinfolds. The measurements showed an intra-class correlation coefficient (ICC) of 0.85 for test-retest reliability and a coefficient of variation (CV) of 3.8%.

Maturity

Biological maturity was estimated for each participant according to the procedures described by Mirwald et al. (2002). The age at peak height velocity (APHV) was considered as a maturational benchmark (0 value) and each measurement was described as years from peak height velocity (PHV), assuming the difference in years as a value of the maturity offset.

Upper body power assessment

To evaluate upper body muscular power, the Overhead Medicine Ball Throw test (OMBT) was performed using a 3-kg medicine ball (Gabbett and Georgieff, 2007; Mielgo-Ayuso et al., 2015). From a standing and arm-relaxed position the participants were instructed to throw the ball as far forward as possible. Counter movements were allowed as long as the feet were not moved during the test. The distance of the throw was recorded to the nearest centimetre, taking for analysis the best of 3 throws with at least 2 min rest between attempts. The measurements showed an intra-class correlation coefficient (ICC) of 0.95 for test-retest reliability and a coefficient of variation (CV) of 3.2%.

Lower body power assessment

The Counter Movement Jump test (CMJ) was used for the determination of lower body strength following the recommendations described by Temfemo et al. (2009). All jumps were performed on a Bosco platform (Bosco System) which recorded athletes' contact time ($m \cdot s^{-1}$). A counter movement until approximately 90º of knee flexion was allowed prior to the jump. The best of 3 attempts, with at least 3 min rest in-between was recorded for posterior Jump height (m) calculations. An intra-class correlation coefficient (ICC) of 0.99 for test-retest reliability and a coefficient of variation (CV) of 2.2% were shown by the CMJ test.

Flexibility

A Sit-and-Reach test (SR) was selected to determine hamstring flexibility. The participants were required to sit with their legs together and knees extended with heels flat against the bottom of a testing board (Richflex System, Sportime, Atlanta). By sliding their hands together one over the other, participants were asked to slowly reach as far forward as possible along the testing board and to hold the resulting position for at least two seconds. The examiner then registered the distance reached to the nearest centimetre by means of a tape measure placed on the top of the board with the zero mark representing the plantar surface. Therefore, positive values were considered once participants had reached beyond their toes. The best result of 3 attempts was recorded for further analysis, with a rest time between attempts of at least 3 minutes. The measurements showed an intra-class correlation coefficient (ICC) of 0.90 for test-retest reliability and a coefficient of variation (CV) of 2.9%.

Maximum oxygen uptake

Maximal aerobic capacity (VO_{2max}) was estimated following the procedures described by Lager and Lambert (1982) for the multi-stage shuttle run test (mp3 version, Coachwise, UK). Each participant was required to perform a progressively faster 20-m shuttle run, being timed with an audible "beep", until reaching volitional exhaustion. If two consecutive shuttles were not completed in time, the participant was excluded for the next repetition; this being considered the end of the test. The last successful repetition made by the athlete was registered for subsequent VO_{2max} estimation using the regression equation defined by Ramsbottom et al. (1988). The measurements showed an intra-class correlation coefficient (ICC) of 0.92 for test-retest reliability and a coefficient of variation (CV) of 2.6%.

Statistical analysis

The hypotheses of normality and homogeneity of variance were verified using the Kolmogorov-Smirnov test and the Levene's test, respectively. When statistical tests revealed no violations of the assumptions of normality and homogeneity, the difference between the mean values between groups was analysed using a t-test for independent samples. The Mann-Whitney non-parametric test was used when normality supposition of data was rejected. The level of significance was set at $p < 0.05$. Cohen's d was used to measure the effect size of observed differences, and was considered small when between 0.2 and 0.5, moderate when between 0.5 and 0.8, and large when the effect was > 0.8 (Cohen, 1988). All statistical analyses were conducted using SPSS v22.0 (SPSS Inc. Chicago IL, USA).

Results

The results of the anthropometric variables are summarised for each discipline (kayak and canoe) in Table 1. It can be observed that kayakers were significantly heavier and taller ($p < 0.01$) than the canoeists, showing small effect size in body mass (Cohen's $d = 0.4$) and medium effect size values in stretch stature and sitting height (0.6 in both cases). The analysis also revealed a significantly greater maturity status in the kayakers ($p = 0.003$) when comparing the years from/to the age at peak height velocity (0.48 ± 0.76 vs 0.10 ± 0.91 for kayakers and canoeists, respectively). Conversely, no differences between means or meaningful effect size values were found regarding the BMI, sum of skinfolds or fat mass percentage.

The results of the field based test variables in both kayakers and canoeists are presented in Table 2. Significantly greater values were observed in kayakers than in canoeists in the OMBT test (6.09 ± 1.31 m and 5.56 ± 1.21 m, respectively) and SR test (8.49 ± 6.17 cm and 3.47 ± 7.77 cm, respectively). Cohen's d calculations revealed medium effect size values for both OMBT ($d = 0.7$) and SR ($d = 0.4$). Similarly, significantly higher values were detected in the CMJ and estimated VO_{2max} variables in the kayakers whereas the analysis of the effect size only revealed a medium effect value for VO_{2max} (Cohen's $d = 0.5$).

Discussion

The main objective of this research was to determine the anthropometric and physical characteristics of youth elite paddlers. It should be highlighted that this is the first comparative interdisciplinary study between kayaking and canoeing. The main finding was the significantly greater physical fitness level and a more robust and mature anthropometric profile exhibited by the kayakers. These results provide normative data about the status of youth male paddlers competing at a high level which allow for the identification of an optimal profile for each discipline.

The basic anthropometric variables have been seen to be important when identifying the most talented paddlers (Ackland et al., 2003; Alacid et al., 2011; Ridge et al., 2007). Considering the anthropometric results of the present study, kayakers revealed a significantly taller and heavier profile than canoeists. These differences in the stretch stature (4-5 cm) and body mass (4-5 kg) are in agreement with those reported in previous research (Hirata, 1977) that indicated even greater variations in youth male paddlers (approximately 8-9 cm and 6-9 kg, respectively) (Arlettaz et al., 2004). When kayakers' and canoeists' results are compared separately with studies of other age groups, analogous values are obtained in the stretch stature and body mass (Alacid et al., 2011; Cuesta et al., 1991) as well as in sitting height (Alacid et al., 2011, 2015). Previous studies conducted on Olympic and other elite paddlers reported BMI values no lower than 23 kg · m^{-2} (Ackland et al., 2003; Gobbo et al., 2002; Hirata, 1977), which are far beyond those observed in the current investigation (20.9 and 20.6 kg · m^{-2} for kayakers and canoeists, respectively), perhaps due to the larger lean mass and robust somatotypes revealed in elite adult paddlers (Ackland et al., 2003; Alacid et al., 2011; Ridge et al., 2007). Furthermore, the BMI and lean body mass, along with other basic anthropometric variables such as the stretch stature and body mass have been positively related to better performance not only in kayaking and canoeing (Fry and Morton, 1991; van Someren and Palmer, 2003), but also in rowing (Sklad et al., 1994). However, no performance data were collected in the current study to corroborate this relationship. Comparing the current research results with previous studies conducted on youth paddlers, similar patterns can be observed, as canoeists presented slightly lower BMI values than kayakers, reaching values below 22 kg · m^{-2} (Alacid et al., 2011; Cuesta et al., 1991). Nonetheless, the importance of compact and robust somatotypes for the most successful sprint paddlers has been strongly supported, as mentioned above, and should be taken into consideration as a factor for talent identification.

Table 1

Mean values (± SD) and 95% confidence intervals for the means of the anthropometric variables and maturity status in kayakers and canoeists

	Kayak		Canoe		p	Effect size (Cohen's d)
	Mean ± SD	95% CI	Mean ± SD	95% CI		
Age (years)	13.68 ± 0.55	13.56 - 13.80	13.69 ± 0.60	13.56 - 13.80	0.767	0.1
Body mass (kg)	59.79 ± 9.50	57.73 - 61.85	55.45 ± 12.17	52.72 - 58.17	0.008	0.4
Stretch Stature (cm)	168.59 ± 6.80	167.12 - 170.07	163.01 ± 9.76	160.82 - 165.19	< 0.001	0.6
Sitting Height (cm)	89.06 ± 4.27	88.14 - 89.99	86.09 ± 5.45	84.87 - 87.31	< 0.001	0.6
BMI (kg · m-2)	20.94 ± 2.37	20.43 - 21.46	20.64 ± 2.93	19.98 - 21.29	0.125	0.1
Sum of 6 skinfolds	64.31 ± 24.80	58.93 - 69.70	64.77 ± 34.43	57.06 - 72.48	0.150	0.1
Fat mass percentage (%)	15.88 ± 5.66	14.72 – 17.03	15.58 ± 7.67	14.06 – 17.30	0.150	0.1
Maturity (years from/to APHV)	0.48 ± 0.76	0.32 - 0.65	0.10 ± 0.91	-0.11 - 0.30	0.003	0.5

APHV: Age at Peak Height Velocity; BMI: Body Mass Index

Table 2

Mean values (± SD) and 95% confidence intervals for the means of the physical fitness variables in kayakers and canoeists

	Kayak		Canoe		p	Effect size (Cohen's d)
	Mean ± SD	95% CI	Mean ± SD	95% CI		
OMBT (m)	6.09 ± 1.31	5.81 - 3.38	5.56 ± 1.21	5.29 - 5.83	0.009	0.4
CMJ (m)	0.36 ± 0.07	0.34 - 0.37	0.34 ± 0.07	0.32 - 0.35	0.035	0.3
SR (cm)	8.49 ± 6.17	7.15 - 9.83	3.47 ± 7.77	1.73 - 5.21	< 0.001	0.7
VO2max (ml · kg-1 · min-1)	50.43 ± 4.73	49.41 - 51.46	47.88 ± 4.84	46.80 - 48.97	0.049	0.5

CMJ: Counter Movement Jump; OMBT: Overhead Medicine Ball Throw; SR: Sit and Reach

The level of adiposity plays an important role in the total paddler-boat weight since it directly affects the boat submerged area and increases friction drag which may cause decreases in boat's speed (Alacid et al., 2011; Jackson, 1995). In the current study, young kayakers presented no significant differences in the percentage of fat mass and the sum of 6 skinfolds compared to canoeists. Unfortunately, not many comparisons between both disciplines have been conducted in the literature, focusing instead on gender differences and the paddling level (Fry and Morton, 1991; Sidney and Shephard, 1973). Previous studies of youth kayakers reported lower adiposity values to those described here, ranging from 6 to 13% (Arlettaz et al., 2004; Cuesta et al., 1991; Gobbo et al., 2002; Sidney and Shephard, 1973). When observing elite adult paddlers, greater adiposity (14.1%) and sum of 6 skinfolds were identified by van Someren and Palmer (2003) among the most successful paddlers. Conversely, Fry and Morton (1991) detected that the greater fat mass, the poorer the race time achieved in 1,000 m and 500 m events, and also found a negative relationship between body fat and performance as race distance increased. There is evidence to suggest that the age and the nature of the event are determinants in adiposity levels, since older and shorter event paddlers presented larger fat mass values (Fry and Morton, 1991; Sidney and Shephard, 1973; van Someren and Palmer, 2003). From the several equations for estimating the fat mass percentage, the formula described by Slaughter et al. (1988) was selected, since it was considered the most accurate in measuring the youth population (Mendez-Villanueva et al., 2011). However, any kind of comparison between studies must be treated with caution due to the different methods for estimating the percentage of fat mass. In other water sports such as swimming, the fat mass values of youth athletes seem to be lower (Laett et al., 2010). Perhaps this fact and the evidence of large body mass and BMI variations observed between elite paddlers (Ackland et al., 2003) might indicate that the morphological characteristics of the athletes are not as much of a determinant of performance as in other sports, where the body has to perform movements in direct contact with the particular physical environment of the sport discipline.

An analysis of maturation is especially

important in individual sports where the physical level is paramount in the attainment of optimal performance (Vaeyens et al., 2008). Relatively few studies into maturation suggest a development of superior physical attributes in the most biologically mature athletes at the same chronological age (Mendez-Villanueva et al., 2011; Mirwald et al., 2002; Vaeyens et al., 2008). Following Alacid et al. (2015), the biological maturation observed in the current research in kayakers was significantly higher than in canoeists, even more than it could be expected from the height and body mass variables. According to previous research conducted by Alacid et al. (2015), the superior biological maturation observed in kayakers compared to canoeists might be expected from the differences in body height and mass variables identified between disciplines.

Traditionally, all beginners start by learning the fundamentals of paddling in a kayak, and only later decide to either move to canoeing or remain and excel in the kayak. The decision to move to canoeing in youth paddlers is apparently influenced by maturity, since to achieve optimal performance in kayaking demands an early strong physical development, while canoeing involves more technical ability (Alacid et al., 2015). Therefore, it seems reasonable that athlete selection programs should take into account not only the performance level, but its relationship with maturation in order to ensure a complete picture of the paddlers' potential, and so as not to make premature decisions on athlete selection at young ages (Mirwald et al., 2002; Vaeyens et al., 2008; Welsman and Armstrong, 2000).

The importance of the fitness level has been demonstrated not only when describing the athletes' physical fitness profile, but also when identifying potential successful athletes for certain sports (Gabbett and Georgieff, 2007; Leone et al., 2002). This is the first study which analyses the fitness level of youth elite paddlers using a battery of field based tests, and which demonstrates the significantly superior level of physical fitness in the kayakers within all the tested variables. The OMBT and CMJ tests were used in accordance with previous studies as the better predictor of limb power (Gabbett and Georgieff, 2007; Temfemo et al., 2009). In fact, there was some evidence to suggest a meaningful correlation between the power production of the lower and upper limbs when performing explosive movements, as this depends on neural coordination and postural control (Debanne and Laffaye, 2011; Mayhew et al., 2005). Additionally, other factors associated with anthropometry and maturation may explain the better performance exhibited by the kayakers regarding the arm span, leg length and lean mass (Cronin and Hansen, 2005; Temfemo et al., 2009).

Hamstring flexibility is an important factor in the fitness level and the prevention of spinal injuries, and especially in kayaking where systematic trunk rotation along with lumbar flexion occur (López-Miñarro et al., 2008). The hamstring extensibility values obtained in the present study are similar to the findings observed in previous studies conducted on young paddlers, with slightly lower SR values not exceeding 6 cm for kayakers and 3 cm for canoeists (Lopez-Miñarro et al., 2008, 2013). The expected greater flexibility revealed in the kayakers might be determined by the great lumbar flexion used during the paddling action (López-Miñarro and Alacid, 2010), which is very different than the one used in canoeing. The SR test is an appropriate mean of determining spine flexibility and range of motion in the pelvic tilt, whereas its validity as a measure of hamstring flexibility has been reported as moderate (Muyor et al., 2014). While hamstring extensibility in kayakers exhibits no significant differences between legs, the kneeling position necessary in canoeing appears to be responsible for the greater values observed in the forward leg as opposed to the kneeling leg (Lopez-Miñarro et al., 2008, 2013). For these reasons the straight leg raise or knee extension tests are more appropriate. However, the sit-and-reach test was used as a measure of hamstring flexibility because it represents an agile field test for large group assessments, and can be easily used by coaches (Simoneau, 1998). Thus, it seems desirable that stretching is included in training programmes (López-Miñarro and Alacid, 2010).

Maximum oxygen uptake has been the main physiological variable studied in the kayak literature due to its relationship with race times (Pendergast et al., 1979; Shephard, 1987; Tesch et al., 1976). However, in youth athletes it seems that VO2max values and performance in a given sport are not significantly related (Bar-Or, 1987).

Unsurprisingly, the kayakers exhibited significantly larger estimated VO2max values that confirm their greater aerobic capacity. Expressing VO2max relative to body mass has also revealed superior aerobic endurance of the kayakers regardless of their size and higher maturity levels. Previous research had indicated significantly higher VO2max levels than those observed here in both ergometer and treadmill tests, reporting values not lower than 54 ml • kg-1 • min-1 in either case (Fry and Morton, 1991; Shephard, 1987; Sidney and Shephard, 1973). However, any kind of comparison between studies must be carefully regarded due to the different protocols applied to estimate oxygen uptake.

Conclusions

The current investigation demonstrated the kayaker's superior size and body mass that indicates more robust and compact morphology when compared to canoeists. Similarly, analysis of the fitness tests revealed a significantly greater fitness level in the youth kayakers compared to youth canoeists, which is perhaps a consequence of the lower maturity status of the latter. These findings confirm the hypothesis that the differences between kayakers and canoeists may be related to the different requirements of each sport discipline and biological status. Nevertheless, further research should be carried out in order to confirm these findings and investigate their relationship with on-water performance.

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ESTUDIO 2

Título

Sprint kayaking and canoeing performance prediction based on the relationship between maturity status, anthropometry and physical fitness in young elite paddlers.

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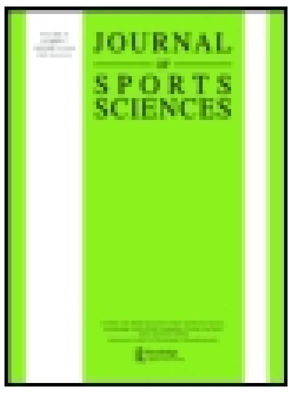

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Sprint kayaking and canoeing performance prediction based on the relationship between maturity status, anthropometry and physical fitness in young elite paddlers

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ABSTRACT

This study aimed to identify the maturity-related differences and its influence on the physical fitness, morphological and performance characteristics of young elite paddlers. In total, 89 kayakers and 82 canoeists, aged 13.69 ± 0.57 years (mean ± s), were allocated in three groups depending on their age relative to the age at peak height velocity (pre-APHV, circum-APHV and post-APHV) and discipline (kayak and canoe). Nine anthropometric variables, a battery of four physical fitness tests (overhead medicine ball throw, countermovement jump, sit-and-reach test and 20 m multistage shuttle run test) and three specific performance tests (1000, 500 and 200 m) were assessed. Both disciplines presented significant maturity-based differences in all anthropometric parameters (except for fat and muscle mass percentage), overhead medicine ball throw and all performance times (pre > circum > post; $P < 0.05$). Negative and significant correlations ($P < 0.01$) were detected between performance times, chronological age and anthropometry (body mass, height, sitting height and maturity status), overhead medicine ball throw and sit and reach for all distances. These findings confirm the importance of maturity status in sprint kayaking and canoeing since the more mature paddlers were also those who revealed largest body size, physical fitness level and best paddling performance. Additionally, the most important variables predicting performance times in kayaking and canoeing were maturity status and chronological age, respectively.

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KEYWORDS
Maturity; fitness level; morphology; kayaking; canoeing

Introduction

During childhood and adolescence, several physical and physiological changes occur as a result of maturation and pubertal growth (Mendez-Villanueva et al., 2011; Mirwald, Baxter-Jones, Bailey, & Beunen, 2002; Philippaerts et al., 2006; Sherar, Esliger, Baxter-Jones, & Tremblay, 2007). However, the tempo and timing of those changes vary depending on each individual between the ages of 8 and 16 years (Welsman & Armstrong, 2000). At the same chronological age, critical differences can be observed between young athletes in body size as during the growth phase body weight typically increases by approximately 160% and height by 40% (Vaeyens, Lenoir, Williams, & Philippaerts, 2008; Welsman & Armstrong, 2000). Along this morphological development, physical attributes such as strength or aerobic power also improve around 150% as a consequence of maturation (Falk & Bar-Or, 1993; Mirwald et al., 2002) and become determining factors in success in certain sports. Especially during pubertal years, significant associations have been observed between performance and body size with correlations coefficients exceeding $r = 0.7$ in several sports such as cycling and running (Armstrong & Welsman, 1997; Welsman & Armstrong, 2000). Current talent identification programmes only search for young athletes with the best performance results and the superior physical attributes that typically characterise professional athletes. Usually those attributes are identified in older athletes and their presence in young athletes does not automatically translate into exceptional performance in adulthood. In addition, the development of physical and anthropometric factors during puberty is influenced by maturation and many young athletes with optimal attributes are not able to retain them throughout the process (Vaeyens et al., 2008). Nevertheless, to date the main criterion to establish categories in youth sports has been the chronological age, not taking into consideration maturity status that could be easily determined by the age at peak height velocity (APHV) (Mirwald et al., 2002).

Traditionally, kayak research has focused on determining the physiological level and anthropometric characteristics of international kayakers in an attempt to identify the determinants of optimal performance (Ackland, Ong, Kerr, & Ridge, 2003; Tesch, 1983; van Someren & Howatson, 2008). Most successful paddlers have shown larger anthropometric parameters resulting in a more robust and compact morphology (Fry & Morton, 1991; van Someren & Palmer, 2003). In addition, the impact of anthropometry on performance has been largely confirmed as several variables such as muscle mass, height,

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body fat and length of the limbs have been identified as contributing factors to peak performance in senior and junior paddlers (Alacid, Marfell-Jones, Lopez-Minarro, Martinez, & Muyor, 2011; Fry & Morton, 1991; Ridge, Broad, Kerr, & Ackland, 2007; Shephard, 1987; Sklad, Krawczyk, & Majle, 1994; van Someren & Palmer, 2003). Similarly, strong correlations between fitness level and performance have consistently been reported in many sports (Gabbett & Georgieff, 2007; Pyne, Gardner, Sheehan, & Hopkins, 2006; van Someren & Howatson, 2008). Early studies in sprint kayaking only used VO_{2max} test to evaluate the physiological capacity of elite kayakers (Pendergast, Cerretelli, & Rennie, 1979; Tesch, 1983). Nevertheless, recent research by van Someren and Howatson (2008) used predictive equations to identify the contribution of anthropometric and physiological variables to performance and then predict race times in flatwater kayaking in senior paddlers. However, in sprint kayaking and canoeing the use of specific field tests has been limited to typically determine aerobic power and isokinetic strength in order to identify paddler's overall status (Fry & Morton, 1991; Hamano et al., 2015; van Someren & Howatson, 2008).

To date, sprint kayaking and canoeing research has tried to identify performance determinants exclusively from senior elite paddlers. Moreover, the limited number of investigations conducted with young paddlers did not take into account maturational factors such as skeletal age or APHV in the determination of paddler profiles and in the identification of future talents. Therefore, the main purpose of this study was to investigate the possible influence of maturation on the physical characteristics and performance of highly trained young kayakers and canoeists. Specifically the aims of this investigation were (1) to compare the maturity-related differences in anthropometry, physical fitness and performance times between three maturity groups; and (2) to determine the relationship and the relative importance of anthropometric and physical fitness attributes and their ability to predict performance times over 1000, 500 and 200 m.

Method

Participants

A total of 171 young male paddlers (89 kayakers and 82 canoeists), aged 13.69 ± 0.57 years (mean ± s), were recruited for this study. All participants were training on a regular basis (at least 2 h per day between 4 and 6 days per week) and were selected by the Royal Spanish Canoeing Federation to participate in National Development Camps based on their age group-level results. The experimental procedures were approved by the Institutional Ethical Committee and written parental or guardian informed consent was obtained before the beginning of the study. Participants were excluded from assessment if they presented signs of disease or who were under pharmacological treatment during the testing period.

Procedures

During the National Development Camps, a series of physical and anthropometric assessments were performed over 4 days. All participants were instructed to avoid strenuous exercise and caffeine ingestion and to maintain their regular pre-training diet at least 48 h before the tests. Clear instructions of each physical test procedure were provided prior to the general warm-up consisting of 6–8 min of multidirectional running activity and 5 min of upper and lower limbs general dynamic stretching delivered and supervised by a strength and conditioning coach. The specific warm-up involved 5 min of familiarisation time with the materials and procedures used shortly before the beginning of each test. In the assessment of physical fitness, only the best of three attempts in each test was considered for analysis, giving at least 3 min rest between attempts, except for 20 m multistage shuttle run test which was performed only once. To prevent any potential body composition changes, anthropometric assessments were performed early in the morning (Gabbett & Georgieff, 2007), followed by field-based physical tests. After a minimum of 4 h rest, participants concluded each testing session with one specific performance test on water.

Anthropometry

All measurements were taken by a fully certified level 2 anthropometrist following the procedures described by the International Society for the Advancement of Kinanthropometry. Body mass (kg) was determined using a SECA 862 (Digital scale, SECA, Germany); height (cm) and direct lengths (cm) with a GPM anthropometer (Siber-Hegner, Switzerland); girths (cm) with a metallic non-extensible tape Lufkin W606PM (Lufkin, USA) and skinfold thickness (mm) was measured at six sites (triceps, subscapular, supraspinale, abdominal, front thigh and medial calf) with a Harpenden skinfold calliper (British Indicators, UK). The equation body mass (kg)/height^2 (m) was used for body mass index (BMI) calculations. Muscular mass percentage was determined by the anthropometric formula described by Poortmans, Boisseau, Moraine, Moreno-Reyes, and Goldman (2005), whereas fat mass percentage was estimated using triceps and subscapular skinfolds according to the equation defined by Slaughter et al. (1988). To avoid measurement errors, all instruments were calibrated before the beginning of each testing session. The variables were taken twice, or three times, if the difference between the first two measurements was greater than 5% for the skinfolds and 1% for the rest of the dimensions, with the mean values (or median in the last case) used for data analysis. The intra-rater technical error of measurement for skinfold thickness was 3.05% and for the rest of the variables 0.69%.

Maturity status

Maturity status was defined as the current age of the athlete relative to his APHV. The APHV was estimated using the procedures described by Mirwald et al. (2002) and was considered a maturational benchmark (0 value) representing the time of maximum growth in stature. Each measurement was described as years from/to peak height velocity (PHV) assuming the difference in years as a value of maturity offset. Thus, negative values indicated the years remaining until APHV, whereas positive values indicated the years past from APHV. On this basis, all participants were distributed into three groups depending on their maturity status (Mendez-Villanueva et al., 2010) at the time of the assessment: pre-APHV (<−0.5 years to PHV), circum-APHV (>−0.5 years to PHV to <0.5 years to PHV) and post-APHV (>0.5 years to PHV).

Physical fitness assessment

The overhead medicine ball throw test was selected to evaluate upper body muscular power (Gabbett & Georgieff, 2007). Participants were required to throw a 3 kg medicine ball as far forward as possible from a standing and arm-relaxed position. As long as the feet were not moved during the test, countermovements were allowed.

Lower body power was determined using the countermovement jump test (CMJ) following the recommendations described by Temfemo, Hugues, Chardon, Mandengue, and Ahmaidi (2009). A countermovement until approximately 90º of knee flexion was allowed prior to the jump on a Bosco platform (Bosco System, Barcelona, Spain) which recorded athlete's contact time (s) and jump height (m).

The sit-and-reach test was used to determine hamstring flexibility (Lopez-Miñarro et al., 2013). From a seated position with no shoes, participants were instructed to keep their legs together and knees extended whilst their heels were flat against the bottom of a testing board (Richflex System, Sportime, USA). The objective was to slowly reach as far forward as possible by sliding the hands together one over the other along the testing board and to hold the resulting position for at least 2 s. The distance reached was then registered to the nearest centimetre by means of a tape measure placed on the top of the board with the zero mark representing the plantar surface. Therefore, positive values were considered once participants had reached beyond the toes.

The multistage shuttle run test (mp3 version, Coachwise, UK) was used to estimate the maximal aerobic capacity (VO_{2max}) according to the procedures described by Lager and Lambert (1982). Paddlers were required to run a 20 m shuttle progressively increasing in speed, being timed with an audible "beep" until reaching volitional exhaustion. When two consecutive shuttles were completed out of time, it was considered the end of the test, registering the last successful repetition made for subsequent $VO2_{max}$ estimation using the regression equation defined by Ramsbottom, Brewer, and Williams (1988).

Performance parameters

On three separate days, participants were required to complete three trials of 1000, 500 and 200 m at maximum effort (one per day). All tests were performed under race conditions on a measured flatwater course and were laterally recorded by a JVC Everio MG-135 (Victor Company, Japan) at 30 frames per second. For that purpose, a motorboat followed the navigation trajectory of the paddler, leaving at least 5 m separation between crafts to avoid water influence. To determine performance time, the frames from the first traction movement to the finish line were calculated by the Virtualdub software 1.8.8 (Avery Lee). Performance tests were postponed when wind velocity was above $2\ m \cdot s^{-1}$ to avoid its influence on race time.

Statistical analyses

Measures of homogeneity and spread are reported as mean and standard deviation (s). The hypotheses of normality of the distribution and homogeneity of variance were investigated using the Kolmogorov–Smirnov test and Levene's test, respectively. The comparisons of maturation group means were performed using one-way analysis of variance (ANOVA) test with three levels (pre, circum, post) when statistical tests revealed no violations of the assumptions of normality and homogeneity. If one-way ANOVA analysis revealed significant differences, *post hoc* Bonferroni tests were conducted to allocate the differences between groups. Kruskal–Wallis test was used when normality supposition of data was rejected and *post hoc* Mann–Whitney tests with Bonferroni corrections (0.05/3) were performed if any significant difference was detected. The level of significance was set as $P < 0.05$. Pearson's correlation coefficient (r) was used to determine the interrelationships between performance times and anthropometry and between performance times and physical fitness. When the assumptions of normality were violated, Spearman's correlation coefficient (r_s) was used. In addition, stepwise multiple linear regression analysis was conducted to determine which anthropometric and physical fitness attributes could predict performance times. All non-significant variables in the linear correlation were excluded from the stepwise regression analysis. Collinearity was investigated using the variance inflation factor and the collinearity tolerance statistics. Predictor variables with variance inflation factor values greater than 10 and/or tolerance level of less than 0.1 were not included in the model. All statistical analyses were conducted using SPSS v22.0 (SPSS Inc., Chicago IL, USA).

Results

The anthropometric and physical fitness characteristics and performance times of both kayakers and canoeists are presented in Table 1 according to maturity groups. In kayakers, significant differences ($P < 0.05$) were observed in all anthropometric characteristics between pre and post, and circum and post groups apart from sum of six skinfolds, fat mass percentage, muscle mass percentage and BMI. Circum kayakers only presented significantly higher values than pre kayakers in body mass, height, sitting height and maturity status. Similarly, post canoeists revealed significant greater values than pre in all anthropometric variables ($P < 0.05$) including maturity status while circum canoeists showed significantly different values than pre and post canoeists except for sum of six skinfolds, fat mass percentage and muscle mass percentage. Results from physical fitness tests showed significantly higher overhead medicine ball throw values in both post kayakers and canoeists when compared with their other two maturity groups ($P < 0.05$), whereas no significant differences were observed in estimated VO_{2max}. Significantly greater CMJ values were detected in post than in circum kayakers (0.38 ± 0.07 and 0.34 ± 0.08 m, respectively; $P < 0.05$). For canoeists, higher sit-and-reach values were observed for post compared with the pre group (5.69 ± 8.24 and 0.52 ± 7.45 cm, respectively; $P < 0.05$). In both kayakers and canoeists, all performance times were significantly different between the groups ($P < 0.05$) with the exception of the 1000 m kayak between circum and pre groups.

Table 1. Anthropometric, physical fitness and performance parameters for the three maturity levels in kayakers and canoeists (mean ± s).

	Kayak			Canoe		
	Pre (n = 9)	Circum (n = 36)	Post (n = 44)	Pre (n = 22)	Circum (n = 30)	Post (n = 30)
Chronological age (years)	13.08 ± 0.28	13.35 ± 0.41	14.07 ± 0.38†§	13.22 ± 0.46	13.61 ± 0.53*	14.15 ± 0.42†§
Anthropometry						
Body mass (kg)	48.40 ± 6.27	56.35 ± 6.80*	64.78 ± 8.66†§	42.97 ± 6.55	54.36 ± 9.67*	64.82 ± 8.60†§
Height (cm)	158.30 ± 5.21	165.70 ± 4.65*	172.94 ± 4.75†§	153.13 ± 7.69	162.30 ± 7.17*	170.73 ± 5.56†§
Sitting height (cm)	82.07 ± 2.83	86.89 ± 2.19*	92.91 ± 2.64†§	79.60 ± 3.42	85.77 ± 2.30*	91.17 ± 2.90†§
BMI ($kg \cdot m^{-2}$)	19.27 ± 1.79	20.49 ± 1.98	21.63 ± 2.49†	18.25 ± 1.68	20.55 ± 2.76*	22.22 ± 2.69†§
Sum of six skinfolds(mm)	62.10 ± 27.02	63.12 ± 20.43	66.16 ± 26.64	48.70 ± 19.75	63.79 ± 34.46	73.34 ± 39.49†
FM percentage (%)	15.11 ± 6.05	15.47 ± 4.64	16.39 ± 6.39	12.30 ± 4.45	15.43 ± 7.36	18.16 ± 9.00†
MM percentage (%)	46.85 ± 1.80	46.34 ± 2.06	46.93 ± 2.15	47.44 ± 3.15	46.14 ± 3.11	45.84 ± 2.70
Maturity status (years from/to APHV)	−0.76 ± 0.32	0.02 ± 0.30*	1.11 ± 0.40†§	−1.03 ± 0.46	−0.01 ± 0.32*	1.03 ± 0.37†§
Physical fitness						
OMBT (m)	5.20 ± 0.65	5.85 ± 1.00	6.64 ± 1.12†§	4.61 ± 0.81	5.36 ± 0.89*	6.48 ± 1.11†§
CMJ (m)	0.34 ± 0.08	0.34 ± 0.06	0.38 ± 0.07§	0.32 ± 0.06	0.33 ± 0.07	0.35 ± 0.08
SR (cm)	7.78 ± 5.52	7.84 ± 6.34	9.19 ± 6.43	0.52 ± 7.45	3.17 ± 7.84	5.69 ± 8.24†
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	49.71 ± 6.03	49.62 ± 4.03	51.2 ± 4.83	48.32 ± 3.63	47.73 ± 4.44	47.95 ± 5.93
Performance						
1000 m time (s)	287.53 ± 17.09	279.69 ± 14.76	262.40 ± 11.50†§	351.01 ± 21.39	332.58 ± 19.35*	312.58 ± 20.04†§
500 m time (s)	147.18 ± 12.58	139.14 ± 7.08*	129.93 ± 7.29†§	184.71 ± 18.82	169.78 ± 16.97*	159.80 ± 17.20†§
200 m time (s)	53.59 ± 4.20	50.44 ± 2.89*	46.41 ± 2.63†§	68.11 ± 6.00	61.91 ± 5.16*	58.11 ± 5.16†§

APHV, age at peak height velocity; BMI, body mass index; CMJ, countermovement jump; FM, fat mass; MM, muscle mass; OMBT, overhead medicine ball throw; SR, sit and reach.
*Significant difference (P < 0.05) between circum and pre paddlers.
†Significant difference (P < 0.05) between post and pre paddlers.
§Significant difference (P < 0.05) between post and circum paddlers.

Table 2. Correlation between anthropometric and physical fitness characteristics and performance in kayakers and canoeists (r).

	Kayak			Canoe		
	1000 m	500 m	200 m	1000 m	500 m	200 m
Chronological age (years)	−0.720**	−0.600**	−0.712**	−0.670**	−0.688	−0.654**
Anthropometry						
Body mass (kg)	−0.441**	−0.325**	−0.423**	−0.376**	−0.301**	−0.347**
Height (cm)	−0.495**	−0.433**	−0.510**	−0.479**	−0.368**	−0.403**
Sitting height (cm)	−0.514**	−0.622**	−0.643**	−0.531**	−0.397**	−0.530**
BMI ($kg \cdot m^{-2}$)	−0.280**	−0.183	−0.273**	−0.298**	−0.220	−0.245*
Sum of six skinfolds (mm)	0.061	0.145	0.103	−0.027	0.087	0.048
FM percentage (%)	0.027	0.118	0.094	−0.053	0.039	0.023
MM percentage (%)	−0.091	−0.240*	−0.203	−0.133	−0.172	−0.151
Maturity status (years from/to APHV)	−0.628**	−0.674**	−0.731**	−0.653**	−0.546**	−0.632**
Physical fitness						
OMBT (m)	−0.514**	−0.436**	−0.513**	−0.612**	−0.483**	−0.618**
CMJ (m)	−0.229*	−0.390**	−0.231*	−0.341**	−0.364**	−0.267*
SR (cm)	−0.293**	−0.460**	−0.518**	−0.376**	−0.375**	−0.452**
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	−0.166	−0.218*	−0.188	−0.326**	−0.286*	−0.334**

APHV, age at peak height velocity; BMI, body mass index; CMJ, countermovement jump; FM, fat mass; MM, muscle mass; OMBT, overhead medicine ball throw; SR, sit and reach.
*Significant differences (P < 0.05).
** Significant differences (P < 0.01).

Table 2 summarises the relationship between anthropometric and physical fitness variables with performance times according to discipline. Chronological age, body mass, height, sitting height and maturity status were negatively associated with performance time (P < 0.01) over 1000, 500 and 200 m in both kayakers and canoeists. The negative relationship between BMI and performance time was only significant in 1000 and 200 m (P < 0.01), whereas sum of six skinfold, fat mass percentage and muscle mass percentage presented no significant correlation with any distance either in kayak or canoe apart from muscle mass percentage with 500 m kayaking (P < 0.05). Analysis of physical fitness parameters revealed significant negative association of overhead medicine ball throw and sit and reach with performance time (P < 0.01) over the three distances and also of CMJ with 1000, 500 (P < 0.01) and 200 m performance times (P < 0.05) in both disciplines. Only significant correlations were observed between estimated VO_{2max} and performance time in 500 m kayaking and canoeing (P < 0.05) and 1000 and 200 m kayaking (P < 0.01).

The stepwise linear regression equations that identify determining factors that predict performance times are presented in Tables 3 and 4 for kayakers and canoeists, respectively. In kayakers, chronological age, maturity status and overhead medicine ball throw significantly contributed to predict 1000 m performance time (P < 0.01); maturity status, height, sit and reach and CMJ to predict 500 m performance time (P < 0.01); and maturity status, CMJ, height and overhead medicine ball throw to predict 200 m performance time (P < 0.01). Similarly, for canoeists 1000 m time was significantly

Table 3. Regression equations for kayakers to predict performance over 1000, 500 and 200 m.

Distance (m)		r^2	SEE (s)
1000	1000 m time = 405.319 − (8.101 × chronological age) − (3.225 × OMBT) − (6.108 × maturity status)**	0.45	11.8
500	500 m time = 51.704 − (11.049 × maturity status) − (0.406 × SR) + (0.599 × height) − (24.324 × CMJ)**	0.61	5.78
200	200 m time = 20.380 − (4.305 × maturity status) − (11.781 × CMJ) + (0.227 × height) − (.558 x OMBT)**	0.67	2.02

CMJ, countermovement jump; OMBT, overhead medicine ball throw; SEE, standard error of estimate; SR, sit and reach.
**Significant contribution ($P < 0.01$) to the predictive model.

Table 4. Regression equations for canoeists to predict performance over 1000, 500 and 200 m.

Distance (m)		r^2	SEE (s)
1000	1000 m time = 759.974 − (20.233 × chronological age) − (4.826 × OMBT) − (1.004 × VO_{2max}) − (.900 × sitting height)**	0.62	15.80
500	500 m time = 465.723 − (21.411 × chronological age) − (0.586 × SR)**	0.52	13.91
200	200 m time = 164.883 − (4.187 × chronological age) − (1.335 × OMBT) − (0.320 × VO_{2max}) − (0.254 × sitting height) − (0.138 × SR)**	0.60	4.34

OMBT, overhead medicine ball throw; SEE, standard error of estimate; SR, sit and reach.
**Significant contribution ($P < 0.01$) to the predictive model.

predicted by chronological age, overhead medicine ball throw, estimated VO_{2max} and sitting height ($P < 0.01$); 500 m by chronological age and sit and reach ($P < 0.01$); and 200 m by chronological age, overhead medicine ball throw, estimated $VO2_{max}$, sitting height and sit and reach ($P < 0.01$). Additionally, the linear relationship between maturity status and performance times and between chronological age and performance times is shown in Figures 1 and 2 for kayakers and canoeists, respectively. Kayakers revealed significant r^2 values from 0.40 to 0.54 in the relationship between maturity status and performance time for all distances, whereas better associations were identified for canoeists between

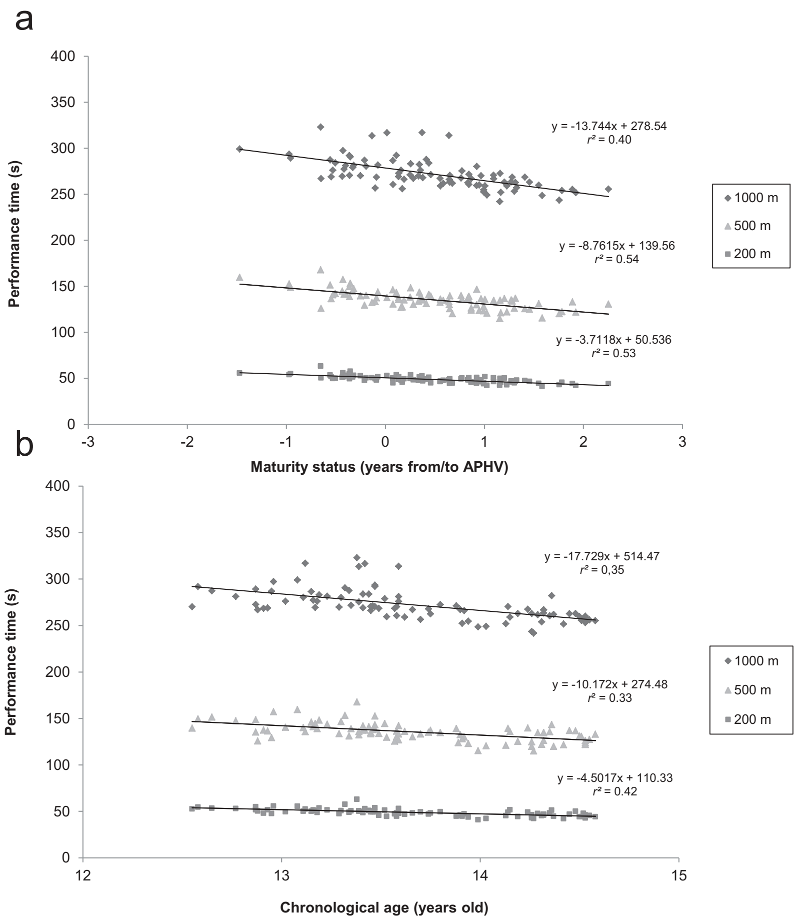

Figure 1. Linear relationship between (a) performance time and maturity status and between (b) performance time and chronological age in kayakers.

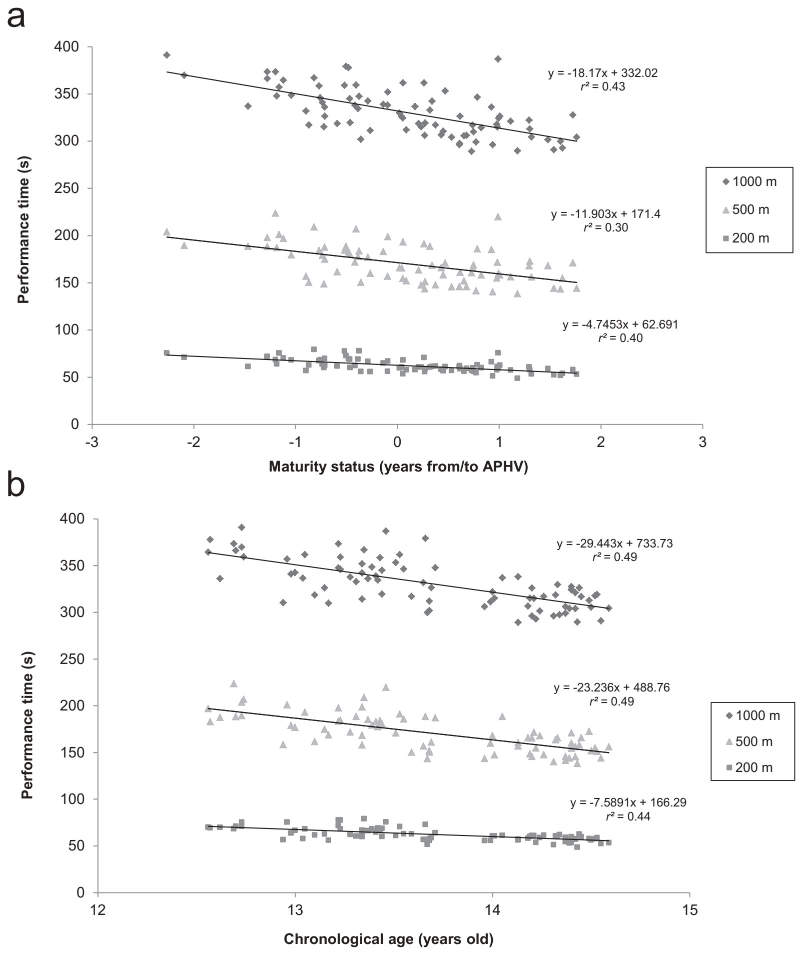

Figure 2. Linear relationship between (a) performance times and maturity status and between (b) performance time and chronological age in canoeists.

chronological age and performance times, observing values from 0.44 to 0.49.

Discussion

The main finding of our research was the significantly superior fitness and anthropometric attributes as well as better race times observed by the paddlers with greater maturity status. In addition, performances in all distances were mainly associated with basic anthropometric parameters and explosive strength tests. Maturity status was identified as the greatest predictor of performance times in kayaking, whereas chronological age was the parameter that better predicted canoeing performance times. These results provide normative data about the relative importance of physical attributes and maturity status in the determination of performance on sprint kayaking and canoeing.

In open water sports such as rowing and canoeing, common anthropometric characteristics have been observed according to the level of performance (Fry & Morton, 1991; Hamano et al., 2015; Sklad et al., 1994) and have been used as determinants of top athletes (Ackland et al., 2003). Present results revealed positive tendencies for the majority of the basic anthropometric attributes in the transition from pre to post, when the maturity status increased, but only significant differences between the three groups were observed in body mass, height and sitting height. The tallest and heaviest kayakers and canoeists were also those who presented the more advanced maturity status, suggesting the greater the maturity the more athletic morphology. These findings support previous research with young competitive and non-competitive athletes in the analysis of basic anthropometric parameters and maturity status at different stages (Falk & Bar-Or, 1993; Mendez-Villanueva et al., 2010; Mirwald et al., 2002). Regarding kayak research, Alacid, Muyor, Vaquero-Cristobal, and Lopez-Minarro (2012) compared young white water with sprint kayaking women at the same chronological age. Similarly, they found that sprint kayakers presented larger maturity status and also exhibited superior anthropometric values in stature, height and sum of six skinfolds (Alacid et al., 2012).

Although no significant differences were detected in fat mass percentage between maturity groups, a positive tendency was observed from pre to post groups, especially in canoeists, with adiposity values ranging from 12% to 18%. Changes in adiposity levels have been associated with maturity status and chronological age growth in the few kayak studies where young paddlers have been analysed (Alacid et al., 2012; Sidney & Shephard, 1973). Despite the fact that muscle mass percentage remains stable in the transition to a greater maturity status, these results confirm that both young kayakers and canoeists significantly tended to develop a larger and more athletic morphological profile as maturity status increases.

In the present study, only sit and reach in canoeists and overhead medicine ball throw in both disciplines revealed significant differences in the transition from pre to post maturity groups. Nevertheless, the majority of the physical parameters analysed presented positive tendencies. The parallel increases of overhead medicine ball throw and CMJ tests with maturity status might confirm the findings from previous studies about peak strength development around PHV (Armstrong & Welsman, 1997; Mirwald et al., 2002) since strength components have been associated with these power tests (Gabbett & Georgieff, 2007; Temfemo et al., 2009). According to other maturity-based analyses in sports science, changes in performance and physical attributes are particularly evident just before and during peak height PHV, with lower rates of change after that point (Mirwald et al., 2002; Welsman & Armstrong, 2000). In contrast, Philippaerts et al. (2006) determined that flexibility exhibited peak development during the years after PHV. The current results in sit and reach only demonstrated positive tendencies as maturity status increases in kayaking and canoeing but significant increases in sit-and-reach values when comparing pre and post groups of canoeing. A possible explanation may be the paddling position adopted by canoeists where a major degree of flexibility is required in the front leg (Lopez-Miñarro et al., 2013). Regarding estimated VO_{2max}, slight increases paralleled maturity development in kayakers, while canoeists' level of aerobic power tended to stabilise along puberty. Likewise, prior studies determined that peak aerobic power remains stable during several stages of pubertal growth when expressed relative to weight (Falk & Bar-Or, 1993), whereas absolute VO_{2max} seems to increase along with biological growth (Falk & Bar-Or, 1993; Krahenbuhl, Skinner, & Kohrt, 1985).

The influence of biological maturation on paddling performance was demonstrated since significant race time improvements were observed parallel to maturity status in both paddling disciplines. The fact that significant differences were observed between all maturity groups in the three distances revealed the great importance of maturity status at similar chronological age, suggesting that maturity status is a predictor of race performance. Additionally, due to the relatively low variation of the estimated VO_{2max} in the transition from pre to post maturity groups, performance progressions seem to come from anaerobic power that especially improves after PHV (Falk & Bar-Or, 1993).

Previous research in the last decade has focused on anthropometric factors in young paddlers but its association with race performance remains unexplored. The finding from the present investigation that body dimensions (weight, height, sitting height and BMI) were significantly correlated with performance times ($P < 0.01$) were consistent with previous investigations in senior elite paddlers since larger paddlers tend to show improved race times (Ackland et al., 2003; Hamano et al., 2015; van Someren & Palmer, 2003). Even though weight increments result in larger hull friction drag that negatively affects boat speed (Jackson, 1995), it appears that larger paddlers have the ability to generate greater power relative to body mass, making it possible to improve performance and increase weight simultaneously (van Someren & Howatson, 2008). When analysing body mass composition, no correlation was determined between fat mass percentage and muscle mass percentage with performance at any distance. These findings might suggest that weight increments associated with better performances are explained by general biological growth of all attributes rather than body mass percentage changes along puberty. In senior paddlers, previous research (van Someren & Howatson, 2008; van Someren & Palmer, 2003) identified no correlation between somatotypes and performance times in 1000, 500 and 200 m while in 200 m fat mass and sum of skinfolds were inversely related to race time ($r = -0.76$, $P < 0.01$; $r = -0.72$, $P < 0.01$, respectively). In contrast, Fry and Morton (1991) detected poorer performances associated with large adiposity levels at longer distances (500 and 1000 m). Apparently, the nature of the event and the maturity status seem to be determinants of body composition in adult kayakers (Fry & Morton, 1991; van

Someren & Palmer, 2003). In any case, previous research suggests that a robust and compact somatotype is common among top paddlers and its development might be beneficial to performance in young paddlers as well (Alacid et al., 2011; Ackland et al., 2003; van Someren & Palmer, 2003). As for maturity status in the current investigation, it is worth mentioning that a high negative correlation with performance times were observed ($P < 0.01$) across all distances and disciplines, with r values higher than −0.54.

Physical fitness tests have been occasionally used by coaches not only for monitoring individual fitness level but also as criteria for recruiting best athletes (Gabbett & Georgieff, 2007; Leone, Lariviere, & Comtois, 2002). Power test results, particularly those from upper limbs (overhead medicine ball throw), demonstrated the importance of power and strength in the achievement of fast race times especially by canoeists at 200 and 1000 m. Although these results might seem contradictory due to the different nature of both events, similar findings can be observed in prior research. Using an isokinetic dynamometer, Fry and Morton (1991) revealed that larger distances presented greater correlation with muscular power than sprint events, while van Someren and Howatson (2008), on the other hand, identified greater associations with shortest distances. However, comparisons with the current results must be treated with caution since different methodology was used for determining muscular power and strength. Regarding sit and reach, a negative association with performance time was identified in canoeists, observing an increasing tendency when distance decreased. It could mean that short events demand a greater flexibility degree perhaps as a consequence of the use of larger and more forward attacks by sprinters.

Traditionally, VO_{2max} has been associated with optimal performance (Pendergast et al., 1979; Shephard, 1987; Tesch, 1983), especially in the longest sprint distance of 1000 m (Fry & Morton, 1991). Nevertheless, the present study only found correlations between these two parameters in all distances in canoeing and 500 m kayaking, observing even better VO_{2max} associations with 200 m than with 1000 m in both disciplines. Similarly, the secondary role of aerobic power in pubertal athletes' performance has been previously reported by Bar-Or (1987), likely as a result of the metabolic specialisation into aerobic or anaerobic that occurs after PHV (Falk & Bar-Or, 1993). Taking into consideration this late metabolic specialisation, it was unsurprising that the best paddlers performed equally well across the three Olympic distances. In addition, contradictory results have also been observed in the latest kayak investigations with adults. No correlation between peak VO_2 and 1000, 500 and 200 m race times was determined, whereas the VO_2 at threshold was positively correlated with 1000 m performance (van Someren, Backx, & Palmer, 2001; van Someren & Howatson, 2008). Similarly, Bishop, Bonetti, and Dawson (2002) only identified significance differences in total VO_2 but not in peak VO_2 when paddling at different pacing strategies. These latest findings might suggest the importance of the maintenance of submaximal and supramaximal intensities rather than the achievement of greater peak VO_2 momentarily.

During puberty, several changes, mainly affected by physical and physiological development, make talent identification difficult from only specific performance data. Particularly in kayaking, maturity status highly contributes to performance since it explains a large variance in the regression equations of all three distances in the prediction of performance time. Maturity status seems to be especially important in the shorter distances as r^2 values increased when distance decreased. Moreover, the presence of CMJ, overhead medicine ball throw and sit and reach in the prediction equations might indicate the importance of muscular power and flexibility to predict kayak performance. As for canoeing, chronological age, sitting height and physical fitness were identified as the best determinants to predict performance times. No remarkable differences were detected between distances perhaps as a result of the lack of distance specialisation at early ages. These findings confirmed the greater importance of maturity status and physical fitness in kayakers in comparison with canoeists. Apparently, to achieve optimal performance kayaking demands an early high physical development whilst canoeing involves more technical ability (Alacid, Marfell-Jones, Muyor, López-Miñarro, & Martínez, 2015).

Conclusions

The results of the current investigation demonstrated the maturity-related differences of young highly trained kayakers and canoeists, confirming that the more biologically mature paddlers were also those who revealed the largest and most robust profiles, greatest physical fitness level and best paddling times. In agreement with prior research (Fry & Morton, 1991; van Someren & Howatson, 2008), superior physical fitness and body size were associated with greater performance and were identified along with maturity status and chronological age as the best predictors of kayaking and canoeing performance times, respectively. Therefore, these findings provide valuable information about the determinants of kayak and canoe performance and indicate that traditional methods for determining and recruiting young talents typically based on performance and chronological age seem to be outdated. The inclusion of maturity status into talent identification programmes is highly recommended as a more accurate index of performance potential, especially in kayakers. In addition to maturity–performance relationship, physical fitness and anthropometry should be taken into consideration as determinants of athlete's overall status and to also identify potential talented athletes among non-practitioners and late maturing paddlers that otherwise would be overlooked.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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ESTUDIO 3

Título

Morphological and physical fitness profile of young female sprint kayakers.

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Morphological and Physical Fitness Profile of Young Female Sprint Kayakers

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Abstract

López-Plaza, D, Alacid, F, Rubio, JÁ, López-Miñarro, PÁ, Muyor, JM, and Manonelles, P. Morphological and physical fitness profile of young female sprint kayakers. *J Strength Cond Res* XX (X): 000–000, 2018—Traditionally, physical and anthropometrical profiles of the most successful kayak athletes have been identified in male kayakers. This study attempted to identify the differences in morphology and fitness level of 2 performance-based groups of young elite female paddlers. Eighty-six female kayakers, aged 13.62 ± 0.57 years (mean ± *SD*), were allocated in 2 groups (Top-10 and Rest) depending on their ranking in the 3 Olympic distances (200, 500, and 1,000 m). All subjects underwent a battery of anthropometrical (heights, weight, girths, and sum of skinfolds), physical fitness (overhead medicine ball throw, countermovement jump, sit-and-reach test, and 20-m multistage shuttle run test), and specific performance assessments (200, 500, and 1,000 m). Best paddlers presented significantly greater anthropometrical values in muscle mass percentage, maturity status, and chronological age ($p \le 0.05$), whereas physical fitness comparison only revealed significant differences in countermovement jump ($p \le 0.05$). Furthermore, aerobic power and muscle mass percentage seem to be crucial in achieving optimal performances at long (1,000 m) and short duration races (200 and 500 m). These findings confirm the importance of a larger and compact morphology, as well as superior fitness level, for success in female kayakers. The current results not only identify the weak areas on body composition and physical fitness depending on the maturity status but also the development of specific training programs for females.

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Key Words body composition, performance, maturity status, talent identification, fitness level

Introduction

Sprint canoeing became an Olympic sport for men in Berlin in 1936, but female kayaking was not introduced at the Olympic program until 1948 in London. Nowadays, only 3 distances are performed by paddlers at the Olympics (200, 500, and 1,000 m) in 2 modalities, kayaking and canoeing (19). First studies have traditionally focused on the physiological characteristics of both sexes, specifically the aerobic and anaerobic metabolic contribution (27,33). However, a complex blend of different parameters determines optimal kayak performance (9,13). In recent decades, studies on anthropometric characteristics and their relationship with performance revealed an increasing robust and compact somatotype in the most successful kayakers, regardless of sex (2,16,25,39).

Each sport is related to singular anthropometric and physical characteristics that suit the particularities of a specific sport or discipline (14,37). For the determination of an optimal performance profile, predictive tests have typically been used as a measure of power, speed, aerobic fitness, or flexibility (14,17). Although most of these tests are only representative of a nonspecific capacity, significant correlations have been observed with specific performance in team sports (17,20). Nevertheless, the few investigations that have conducted studies on individual water sports have revealed contradictory results about the relationship between performance and physical fitness (10,15,16,25).

In addition, the study of physical and anthropometric variables and their relationship with certain disciplines or playing positions have been undertaken in several sports (14,17,21) and have become paramount in the determination of a typical athlete profile (36). Similarly, in male sprint kayaking and canoeing, different disciplines and events seem to be optimally performed by athletes with certain morphology and physical attributes (13,39). Previous studies have revealed taller and heavier somatotypes, lower skinfolds values and superior upper-body girths and isokinetic force in the most successful senior paddlers (1,13,37). Furthermore, age-group kayakers seem to show greater body mass, size, and physical capacities than canoeists (4,24). The identification of these attributes is especially important at early ages and during adolescence, not only for the development of particular capacities but also for sport and discipline specialization (2,5,24). In an attempt to determine the optimal kayaker profile, only males and adult female paddlers have been analyzed (1,38).

It was hypothesized that young female paddlers would exhibit similar physical and morphological characteristics to those observed in young male paddlers depending on the performance level. Therefore, the aims of this investigation were: (a) to determine and compare the anthropometric characteristics and physical fitness level between 2 performance-based groups of female kayakers and (b) to identify their relationship with performance at different events.

Method

AU2 Experimental Approach to the Problem

A comparative description (cross-sectional study) was conducted to assess the differences in anthropometry and physical fitness in young elite female paddlers based on their performance level. A variety of assessment test items were used as dependent variables to offer a wide description of the representative successful paddler depending on the performance level (independent variable). The Leger test (22) was used to estimate $\dot{V}O_2max$, which has been shown to provide compatible values between treadmill and on water paddling tests in kayakers (29,32). Performance tests were conducted outside, and the weather conditions were not identical from 1 day to the other. However, wind velocity was measured to assure values below 2 $m \cdot s^{-1}$ at the beginning of each test to guarantee a minimum influence on performance results (40). Moreover, paddling experience and training volume were not collected as variables for posterior analysis and perhaps, in future research, they might be taken into account as control variables. Based on previous studies aimed to identify typical athletes' profiles, traditional field-based physical tests were selected, as they provide valid and reliable information that can be used as normative data for further comparison using limited resources.

AU3 Subjects

Between 2006 and 2009, a total of 160–180 female kayakers per year (depending on the year) were found eligible to participate in this study. Only the top 20–22 paddlers based on the Spanish national championship ranking each year were preselected to take part in this study, as they were chosen by the Spanish Federation to participate in National Development Camps. A total of 86 young female kayak paddlers, aged 13.62 ± 0.57 years (mean ± *SD*), finally were recruited and volunteered to collaborate in this study. Afterward, subjects were ranked depending on their positions in each of the 3 distances performed during the Camp (200, 500, and 1,000 m), where the mean ranking was subsequently used to allocate them in 2 groups: Top-10 (best 10 kayakers of each year) and Rest (kayakers between Top-10 and Top 20–22). The procedures were approved by the Institutional Ethical Committee. Written signed informed consent was obtained from all subjects and their parents before the start of the study. During the testing period, subjects under pharmacological treatment or presenting any disease were excluded from assessment. All subjects were required to avoid caffeine ingestion and hard work sessions 48 hours before the measurements.

Procedures

A battery of field-based tests to measure physical fitness status and body size composition was performed on 3 separate days. Clear instructions about the procedures were given to all subjects before the beginning of each test. All physical fitness tests were performed 3 times, recording only the best attempt for posterior analysis. Maximum oxygen consumption estimation and the 3 specific race tests were measured just once because of the high physical demands required for completion. In addition, a 15-minute warm-up consisted of 5 minutes of general aerobic activity and 10 minutes of specific joint movements and familiarization with materials and procedures was provided. To prevent any potential morphology changes and to provide sufficient rest time, the order of the assessments was as follows: (a) anthropometry (early morning of the first day); (b) physical fitness (midday of the 3 separate days); and (c) specific performance on water for the 3 specific distance (afternoon of the 3 separate days).

Anthropometric Parameters

All anthropometric measurements were taken following the procedures of the International Society for the Advancement of Kinanthropometry (ISAK) by a fully certified level-2 ISAK anthropometrist (26). The parameters analyzed included body mass (kg), 2 heights (cm), 8 skinfolds (mm), and 6 breadths (cm). Body mass was measured using an SECA 862 scale (SECA, Hamburg, Germany); stretch stature and sitting height with a GPM anthropometer (Siber-Hegner, Switzerland); girths with a metallic nonextensible tape AU4 Lufkin W606PM (Lufkin, USA), and skinfolds with a Harpenden skinfold caliper (British Indicators, United Kingdom). AU5 Each parameter was measured 2 or 3 times, if the difference between the first 2 measures was greater than 5% for the skinfolds and 1% for the rest of the dimensions. The mean values (or median in the last case) were used for further analysis. Body mass index was calculated by the equation: body mass (kg)/stretch stature^2 (m), whereas muscle mass percentage (%MM) was determined using corrected arm, thigh, and calf girths values following the anthropometric formula defined by Poortmans et al. (30). For the determination of fat mass percentage (%FM), triceps and subscapular skinfolds

Table 1. Mean values of the anthropometric parameters.*†

	Top-10 (n = 40)		Rest (n = 46)			Effect size
	Mean ± *SD*	95% CI	Mean ± *SD*	95% CI	*p*	(Cohen's *d*)
Chronological age (y)	13.86 ± 0.53	13.69–14.03	13.42 ± 0.54	13.26–13.58	< **0.001**	0.80
Body mass (kg)	55.39 ± 7.88	52.87–57.91	54.56 ± 8.18	52.13–56.99	0.63	0.12
Height (cm)	163.48 ± 4.99	161.89–165.07	162.16 ± 6.10	160.35–163.97	0.27	0.25
Sitting height (cm)	87.87 ± 2.22	86.84–88.90	86.97 ± 3.44	85.95–88.00	0.22	0.31
BMI ($kg \cdot m^{-2}$)	20.65 ± 2.16	19.96–21.34	20.70 ± 2.46	19.97–21.43	0.93	0.02
Sum of 6 skinfolds (mm)	72.76 ± 19.70	66.46–79.06	72.91 ± 20.10	66.95–78.88	0.97	0.01
Sum of 8 skinfolds (mm)	98.13 ± 27.87	87.72–108.54	98.76 ± 25.91	89.57 ± 107.95	0.93	0.02
FM (%)	23.00 ± 4.28	21.63–24.37	22.95 ± 4.33	21.66–24.24	0.96	0.01
MM (%)	41.31 ± 1.87	40.72–41.71	40.14 ± 2.02	39.54–40.74	**0.01**	0.60
Maturity status (y from APHV)	1.82 ± 0.47	1.67–1.97	1.56 ± 0.56	1.39–1.72	**0.02**	0.50

*CI = confidence interval; BMI = body mass index; FM = fat mass; MM = muscle mass; APHV = age at peak height velocity.
†Mean ± *SD* and the lower and upper bound 95% confidence intervals for the mean. Significant differences are highlighted in bold text.

were used according to the equation described by Slaughter et al. (34).

Maturity status was estimated taking into consideration the age at peak height velocity (APHV) following the guidelines described by Mirwald et al. (28). Because APHV was considered a maturational benchmark (0 value), the difference in years between APHV and each measurement (described as years from PHV) was considered as a value of maturity offset.

Physical Fitness and Performance Assessment

According to the procedures described by Lager and Lambert (22) maximum oxygen consumption ($\dot{V}O_2max$) was estimated using the multistage shuttle run test (mp3 version; Coachwise, Leeds, United Kingdom). Subjects were required to run 20-m shuttles progressively in speed and in time with an audible "beep" until reaching volitional exhaustion. The test was concluded if 2 consecutive shuttles were completed out of time, considering the last successful repetition for subsequent $\dot{V}O_2max$ estimation by the regression equations described by Ramsbottom et al. (31).

For the determination of upper- and lower-body power, countermovement jump (CMJ) test and overhead medicine ball throw (OMBT) test were used, respectively. Countermovement jump test was performed on a Bosco platform (Bosco System, USA) to record athlete's contact time ($m \cdot s^{-1}$) in accordance with the recommendations described by Temfemo et al. (35). During the action, a countermovement of approximately 90° of knee flexion was permitted. The OMBT test was evaluated using a 3-kg medicine ball (14). Subjects were requested to throw the ball over the head as far forward as possible from a standing and arm-relaxed position, registering the distance to the nearest centimeter. Countermovements were allowed during the act of throwing since the feet remained motionless.

To determine hamstring flexibility, sit-and-reach (SR) test was used according to the procedures described by López-Miñarro et al. (23). Subjects were instructed to sit with no shoes, keep the legs together, and the knees extended while the heels were flat against the bottom of a testing board (Richflex System, Sportime, USA). The maximum distance reached and maintained for 3 seconds by sliding the hands together along the testing board was then registered to the nearest centimeter. A tape measure placed on the top of the board, with the zero mark representing the plantar surface, was used for that purpose.

Specific performance tests were performed over 200, 500, and 1,000 meters on separate days. Subjects were required to complete the 3 distances at maximum effort on a measured flatwater course under race conditions. All tests were laterally recorded by a JVC Everio MG-135 (Victor Company, Japan) at 30 frames per second from a motorboat, following each paddler and leaving at least 5 m of separation. Race times were obtained throughout the calculation of the frames from the first traction movement to the finish line using Virtualdub software 1.8.8 (Avery Lee).

Statistical Analyses

All statistical analyses were conducted using SPSS v22.0 (SPSS Inc., Chicago IL, USA). The hypotheses of normality and homogeneity of variance were analyzed using the

Table 2. Mean values of the physical and performance parameters.*†

	Top-10 ($n = 40$) Mean ± *SD*	95% CI	Rest ($n = 46$) Mean ± *SD*	95% CI	*p*	Effect size (Cohen's *d*)
SR (cm)	11.73 ± 5.53	9.99–13.46	10.14 ± 7.33	7.96–12.32	0.43	0.25
OMBT (m)	4.97 ± 0.63	4.76–5.18	4.71 ± 0.64	4.52–4.91	0.07	0.41
CMJ (m)	0.30 ± 0.05	0.28–0.32	0.27 ± 0.03	0.26–0.28	**0.01**	0.73
$\dot{V}O_2max$ (ml·kg^{-1}·min^{-1})	46.18 ± 3.46	45.04–47.31	44.69 ± 3.38	43.68–45.71	0.05	0.44
1,000-m time (s)	289.28 ± 7.99	286.73–291.83	304.55 ± 9.63	301.69–307.41	**<0.001**	1.73
500-m time (s)	146.69 ± 6.44	144.63–148.75	154.93 ± 5.79	153.22–156.66	**<0.001**	1.35
200-m time (s)	53.16 ± 2.24	52.44–53.87	56.35 ± 2.82	55.52–57.19	**<0.001**	1.25

*CI = confidence interval; SR = sit and reach; OMBT = overhead medicine ball throw; CMJ = countermovement jump.
†Mean ± *SD* and the lower and upper bound 95% confidence intervals for the mean. Significant differences are highlighted in bold text.

Kolmogorov-Smirnov test and Levene's test, respectively. The difference between the mean values between groups was analyzed using *t*-test for independent samples when statistical tests revealed no violations of the assumptions of normality and homogeneity. When normality supposition of data was rejected, the Mann-Whitney nonparametric test AU6 was used. Statistical significance was set at the $p \leq 0.05$ level of probability. To measure the effect size of observed differences, Cohen's *d* analysis was used, considering small effect between 0.2 and 0.5, moderate between 0.5 and 0.8, and large when it was >0.8 (11). The relationships between anthropometric characteristics and performance and between physical fitness and performance were investigated using Pearson's correlation coefficient (*r*) or Spearman correlation coefficient (r_s) when the assumption of normality was violated. The magnitude of the correlations was assessed

Table 3. Relationship between anthropometric and physical fitness characteristics and performance.*

	1,000-m time	HPM	500-m time	HPM	200-m time	HPM
Anthropometry						
Chronological age (y)	−0.490†	M	−0.272‡	L	−0.640†	LA
Body mass (kg)	−0.013	–	0.035	–	−0.083	–
Height (cm)	−0.187	L	−0.067	–	−0.078	–
Sitting height (cm)	−0.332†	M	−0.333†	M	−0.183	L
BMI (kg·m^{-2})	−0.113	L	0.101	L	−0.068	–
Sum of 6 skinfolds (mm)	0.129	L	0.100	L	0.117	L
Sum of 8 skinfolds (mm)	0.146	L	0.081	–	0.246	L
FM (%)	0.075	L	0.070	–	−0.026	–
MM (%)	−0.320†	M	−0.337†	M	−0.352†	M
Maturity status (y from APHV)	−0.441†	M	−0.267‡	L	−0.459†	M
Physical fitness						
SR (cm)	−0.232‡	L	−0.256‡	L	−0.149	L
OMBT (m)	−0.278‡	L	−0.222‡	L	−0.289†	L
CMJ (m)	−0.072	–	−0.065	–	−0.231‡	L
$\dot{V}O_2max$ (ml·kg^{-1}·min^{-1})	−0.307†	M	−0.186	L	−0.181	L

*HPM = Hopkins' magnitude; M = moderate; L = low; LA = large; BMI = body mass index; FM = fat mass; MM = muscle mass; APHV = age at peak height velocity; SR = sit and reach; OMBT = overhead medicine ball throw; CMJ = countermovement jump.
†Significant correlation ($p \leq 0.05$).
‡Significant correlation ($p < 0.01$).

TABLE 4. Regression equations to predict performance over 1,000, 500, and 200 m.*†

Distance		r^2	SEE
1,000 m	1,000-m time = 525.04 − (7.93 × chronological age) − (1.17 × $\dot{V}O_2$max) − (0.42 × SR) − (0.71 × sitting height)†	0.39	9.36 s
500 m	500-m time = 265.12 − (1.24 × %MM) − (0.73 × sitting height)†	0.21	6.54 s
200 m	200-m time = 113.65 − (3.23 × chronological age) − (0.36 × %MM)†	0.47	2.26 s

*SEE = standard error of estimate; SR = sit and reach; MM = muscle mass.
†Significant contribution ($p < 0.01$) to the predictive model.

according to Hopkins et al. (18). Stepwise multiple linear regression analysis was conducted using the significant variables from the linear correlation to determine which ones could predict performance times. In addition, collinearity was analyzed using the variance inflation factor (VIF). When VIF values were greater than 10, predictor variables were excluded from the model.

RESULTS

The results of the anthropometric characteristics for both groups of kayakers, depending on their performance level, are presented in Table 1. Significant differences ($p \leq 0.05$) between the Top-10 and the Rest groups were identified in chronological age, %MM, and maturity status. Cohen's *d* analysis revealed moderate effect sizes in these parameters, with *d* values ranging from 0.50 to 0.80.

Table 2 summarizes the physical fitness and race parameters of the 2 performance-based groups of kayakers. The independent *t*-test analysis revealed significant differences in CMJ (0.30 ± 0.05 vs. 0.27 ± 0.03 cm for Top-10 and Rest kayakers, respectively), whereas OMBT, SR, and estimated $\dot{V}O_2$max presented no significant differences between mean values. Although moderate effect size was only identified in CMJ (0.73), OMBT and estimated $\dot{V}O_2$max showed meaningful small effect sizes of 0.41 and 0.44, respectively. Highly significant lower race times ($p < 0.001$) were observed in the Top-10 group compared with the Rest group in all 3 distances performed (1,000, 500, and 200 m). In addition, Cohen's *d* calculations revealed large effect sizes with values not lower than 1.25 for any distance.

Pairwise correlations between the anthropometric, physical fitness variables, and race times in all 3 distances are presented in Table 3. Furthermore, Table 4 shows the stepwise linear regression models to identify the determining factors that predict race times over 200, 500, and 1,000 m. Chronological age, sitting height, %MM, and maturity status were negatively and significantly associated with all distances ($p < 0.01$), except for sitting height with 200-m race time. Several and substantial relationships were also observed between physical fitness and race times. Sit-and-reach and OMBT revealed negative and significant correlations with race time over 1,000 and 500 m ($p \leq 0.05$), whereas over 200 m only OMBT presented a significant correlation ($p < 0.01$). Conversely, no significant associations were observed for the rest of parameters analyzed apart from estimated $\dot{V}O_2$max with 1,000 m ($r = 0.31$; $p < 0.01$) and CMJ with 200-m race time ($r = 0.23$; $p \leq 0.05$). Chronological age, sitting height, estimated $\dot{V}O_2$max, and %MM significantly contributed as predictor variables of 1,000-, 500-, and 200-m time, observing r^2 values not greater than 0.47.

DISCUSSION

The main objectives of this study were to determine the differences in anthropometry and physical fitness and to identify their relationship with race times between the more successful (Top-10) and the rest (Rest) of the young elite female paddlers. In addition, other findings revealed the importance of chronological age, maturity status, upper-body strength, and MM in obtaining optimal results over the 3 Olympic distances.

Traditionally, the typical morphology of the more successful kayakers involved superior anthropometric parameters than their opponents, mainly in weight, height, and lean mass, resulting in larger and heavier somatotypes (1,13,39). Over the past decades, these differences in somatotype have been intensified, especially for female athletes competing not only in paddling (1) but also in rowing (8). Although, in the current research, only significant differences were discovered in chronological age, %MM, and maturity, the greater values observed in most parameters for the Top-10 kayakers support the affirmations of a more solid and robust somatotype in the best paddlers. Similar results in the basic anthropometric attributes were observed by Alacid et al. (3,4), except for the greater sum of 6 and 8 skinfolds (above 88 and 110 mm, respectively) in a group of young female kayakers. Previous investigations with senior female competitors reported heavier and taller morphology but similar FM percentage values than those observed here (1,2,9,33). Previous analysis of proportionality of the sum of 8 skinfolds revealed that young female kayakers presented higher levels of adiposity in comparison with Olympic paddlers (ranging from −0.6 to −0.7 vs. −2.2 in the Phantom Z-score, respectively) (1,3).

One of the main anthropometric differences between both performance-based groups was identified in %MM. The significantly greater muscularity in the more successful kayakers (41.3 vs. 40.1% of MM) has traditionally been stated in previous research with male competitors (9,13,39). Despite the fact that no data about MM in female paddlers were found in the literature, greater levels of certain variables that are typically associated with greater muscularity such as relaxed and contracted arm girths were observed in the more successful female competitors (1,2). In addition, the higher ratings of mesomorphy exhibited by the Olympic and international kayakers in comparison with younger and national paddlers may be mainly explained by larger %MM (1,3,39). In recent years, more resistance workouts have been added to female training programs (9) contributing, perhaps, to the observed increases in MM increases.

Along with these morphological differences, Top-10 kayakers also showed significantly higher levels of maturation than the Rest, partially explained by the significantly greater chronological age observed in the first group. In most sports, the improvements in physical attributes and morphology as a result of maturation have been well documented (12,28). In water sports, the few investigations in analyzing athletes' physical fitness reported superior results in the most mature male paddlers (25) and the most experienced female rowers (8). In the current investigation, Top-10 paddlers were also those who showed superior results in all physical parameters but only significantly in CMJ. Best paddlers seem to have greater power and strength because better results were obtained in the OMBT and CMJ tests traditionally used as upper and lower limb power predictors (14,35). In both tests, overall moderate effect sizes were also observed between performance groups. This suggests that not only meaningful power and strength levels are essential for talent identification at early ages but also for optimal long-term development in young female paddlers. In addition, there is some evidence supporting these affirmations when comparing the isokinetic strength between different level male paddlers (13,39). Perhaps, these superior levels of power production may be related to the larger muscularity shown above in the most successful female kayakers.

To date, the association between performance at different events and physical and anthropometric characteristics has only been investigated in elite male kayakers (13,25,37). The performance of the female kayakers in all distances was significantly related to chronological age and maturity, especially in 200 m. Nevertheless, only chronological age was identified as a predicting factor of 1,000 and 200 m perhaps due to the fact that all kayakers had already reached PHV
AU7 a long time before and/or as a consequence of maturity status calculations from other anthropometric parameters. Regarding previous studies with female paddlers, Aitken and Jenkins (2) found no correlation between anthropometry and 500-m performance. Male kayak research has revealed contradictory results in morphology, except for chest and arm girths correlations with performance (13,16,37). In addition, as distance decreases, there is an increasing association of %MM with performance which is consistent with the high relationship between mesomorphy and short events observed by van Someren et al. (37,39) and the presence of %MM in the 500- and 200-m predictive equations. Along with the significant associations of the power tests with 200-m time ($r = -0.289$; $p \leq 0.05$ and $r = -0.231$; $p \leq 0.05$ for OMBT and CMJ, respectively) observed in the current investigation, it appears that muscular factors seem to be a determinant for optimal sprint performance irrespective of sex.

The analysis of maximum oxygen consumption has usually been used to evaluate the aerobic power in sprint canoeing (27,33). Previous research comparing different male paddlers' level reported contradictory results when $\dot{V}O_2$max was analyzed. Fry and Morton (13) determined greater values in the best 1,000-m adult kayakers, whereas van Someren and Palmer (39), conversely, identified slightly lower peak $\dot{V}O_2$ levels in 200-m sprinters, perhaps because of the larger anaerobic metabolic contribution in this event. In the current investigation, the effect size observed in the estimated $\dot{V}O_2$max would suggest that the enhancement and monitoring of this capacity during adolescence would be important in the development process of successful female kayakers. Furthermore, the estimated values of both groups were consistent with those identified in previous research for female kayakers, ranging from 44 to 49 $ml \cdot kg^{-1} \cdot min^{-1}$ (9,33).

Concerning the relationship between maximum oxygen consumption and performance, Bishop (9) reported significant correlations between 500-m race time and $\dot{V}O_2$ in female kayakers ($r = 0.72$), finding even greater correlations for relative peak $\dot{V}O_2$ ($r = 0.82$) that suggests a significant influence of body mass on this variable. In addition, the presence of estimated $\dot{V}O_2$max in the predictive equation for 1,000-m might suggest a greater importance of aerobic power over long distances than that previously revealed by the linear correlation analysis ($r = -0.307$; $p < 0.01$). The results from the current investigation are in agreement with previous research that identified greater aerobic contribution at longer distances (13). On the contrary, van Someren and Howatson (37) revealed no significant relationships between peak $\dot{V}O_2$ and 200, 500, or 1,000-m race times. Nevertheless, the fact that some evidence only found meaningful associations in absolute and threshold $\dot{V}O_2$ (37) may indicate the importance of not only the achievement of high $\dot{V}O_2$max levels but also of the maintenance of maximal and supramaximal intensities. Unfortunately, most investigations on young paddlers have focused on male kayakers, limiting the possibility for further comparisons.

As for the relationship among all these parameters, especially at early ages, performance and aerobic power seems to be largely influenced by morphology, therefore, $\dot{V}O_2$ parameters were typically normalized for body mass (9). Although the improvement of aerobic power during puberty is difficult to predict because of maturational changes (36), biological and chronological age plays an important role in its development (12). Interestingly, aerobic power in pubertal athletes may not be as influential on performance as other physiological parameters (7). The metabolic specialization into aerobic or anaerobic that occurs late in the maturity process may be responsible for the secondary role of this parameter (12). In addition, best kayakers performed equally better ($p < 0.001$) over the 3 Olympic distances (200, 500, and 1,000 m) compared with the Rest, suggesting that specific distance specialization observed in elite adult paddlers arises likely as a result of this posterior metabolic specialization.

The results of the current investigation demonstrated the importance of physical and morphological parameters for success in young female kayakers. Best paddlers exhibited a significantly greater %MM but only slightly larger body sizes than less successful competitors. In addition, chronological age, MM, and physical fitness level seems to be associated with better performances at the 3 Olympic distances. All these findings may be explained by the AU8 superior maturity status also identified in the best competitors. Therefore, assuming that there is an influence of biological age on performance, this parameter should be taken into consideration as critical factor in the talent identification programs. Currently, the parameters used in the selection process of future talents among age-group paddlers are mainly race time–based tests (25). To date, this is the first research conducted with female paddlers that provided normative data regarding the optimal profile of successful kayakers, which may be useful for early talent identification.

Practical Applications

For coaches, this is the first study to analyze the anthropometric and physical fitness profile of young female paddlers based on field tests. The anthropometric characteristics of the current female kayakers are consistent with those previously reported for both male kayakers and canoeists (3,6,25). Thus, the findings presented here provide valuable information about the characteristics of the paddlers depending on their level and may be a useful tool and guide for talent identification among young athletes. The physical fitness results may allow for identification of the weak areas of the strength and conditioning programs that might need to be reinforced for optimal athlete performance depending on individual maturity status. Currently, most specific training programs followed by female paddlers are based on previous male scientific knowledge or on coach training experience. Therefore, these results may also help to improve individual program designs for females, developing specific paddler training to allow for a smooth transition to the professional field. In addition, all test and assessments could be performed with little equipment by following the procedures defined in the methods, making it accessible for teams and athletes with limited resources.

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ESTUDIO 4

Título

A longitudinal analysis of morphological characteristics and body proportionality in young elite sprint paddlers.

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CLINICAL FEATURE
ORIGINAL RESEARCH

A longitudinal analysis of morphological characteristics and body proportionality in young elite sprint paddlers

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ABSTRACT

Introduction: There are certain anthropometric attributes common to most high-level paddlers and among the determinants for optimal performance consecution in senior categories.

Objective: The present investigation aimed to determine the evolution of morphological characteristics of elite paddlers during adolescence and to compare them with the values exhibited by Olympic competitors.

Methods: In a longitudinal study, thirteen young elite paddlers (seven boys and six girls) completed a battery of anthropometric tests (heights, weight, girths, lengths, and sum of skinfolds) and on-water performance assessments (200 and 500 m) during three consecutive years.

Results: Body mass and upper body sizes significantly change over the years ($p < .05$), especially in boys. Both male and female paddlers presented significant differences and large effect sizes in muscle mass and skin mass values ($\eta^2_p > .64$) whereas bone mass and fat mass remained stable from the 1st to the 3rd year. Proportionality analysis revealed girths and breadths differences in arm and chest variables as well as large effect sizes in biacromial breadth among all years ($\eta^2_p > .62$; $p < .05$), particularly in boys. Similarly, significant improvements in 200-m performance times were observed for both sexes.

Conclusions: The findings of the current investigation might suggest a tendency towards a leaner and more robust morphological profile of elite paddlers in the transition from young to senior categories. In addition, the presence of superior relative body dimensions from young categories seems to be paramount in the evolution to later successful paddling.

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Anthropometry; sprint canoeing; adolescence; morphological development; performance

1. Introduction

Optimal performance in paddling has traditionally been studied from a physiological and biomechanical perspective [1–5]. Over the past decades, anthropometric characteristics have also been investigated as contributing factors for effective paddling. Having a bigger and leaner morphology has been a common attribute identified in the profiles of most successful competitors, especially in elite male categories [3,6,7]. Significant associations between muscularity, upper body breadths and race times have been reported in kayak literature at short distances [7,8]. In addition, previous research has also confirmed the relationship between body composition and performance at young categories [9–11].

During childhood and puberty, physical and anthropometric characteristics remarkably change mainly as a consequence of biological maturation. Frequently, age-group athletes with similar chronological age develop their anthropometric attributes at different tempo and timing, observing large morphology differences among individuals [12,13]. Apparently, the age at peak height velocity (APHV) is usually the point with the greater evolution of physical fitness and anthropometric attributes [14,15]. Philippaerts et al. [16] showed that peak growth in physical performance in young soccer players coincides with peak growth in height and weight. In previous research, associations between performance and body size were also determined in cycling and running, with correlations coefficients over .7 [17,18]. Similarly, predicting factors of performance were analyzed in young male and female kayakers and included biological maturation determinants such as age at peak height velocity (APHV), chronological age, sitting height and muscular mass [11,19]. In one of the first longitudinal studies on kayaking, McKean, and Burkett [20] determined significant increases of strength measures along three consecutive years in junior competitors over APHV. Unfortunately, sprint kayak studies about performance and body composition evolution during puberty are limited.

Despite the fact that most anthropometric attributes for optimal performance are equally exhibited by adult and young kayakers, the way they develop in the transition to senior categories is unknown. Additionally, proportionality and morphological indexes offer valuable information for coaches in talent identification processes of specific profiles [21,22]. However, since few studies have focused on these parameters there is a lack of normative data in kayaking literature. It was hypothesized that biological maturity might influence the process of consolidation of an optimal anthropometric profile. Therefore, the aim of the

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present investigation was to determine the evolution of morphological characteristics of elite paddlers during adolescence and to compare them with the values exhibited by Olympic competitors.

2. Materials and methods

2.1. Participants

The selection of the participants involved in this study was performed based on three inclusion criteria: a) All participants were top 10 qualifiers in their categories among 160–180 paddlers in the Spanish National Championships along three consecutive years; b) They were recruited by the Royal Spanish Canoeing Federation to participate in National Development Camps each of the three years; and c) All paddlers were training on a regular basis (at least 2 h/day between 4 and 6 days/week) during the season and at the moment of measurements. Finally, thirteen young elite paddlers (seven male and six female athletes) fulfill all the requirements and volunteered to collaborate in this study along three consecutive years. Any participant that showed signs of any disease or under pharmacological or medical treatment was excluded from assessment. Before the beginning of the study, the Institutional Ethical Committee approved all experimental procedures. In addition, signed assent and consent forms were obtained from the participants and their parents or guardians, respectively.

2.2. Procedures

During three consecutive years, paddlers underwent a battery of anthropometric measurements and on-water performance tests once every year in the course of the National Development Camps in summer. Anthropometric assessment was conducted early in the morning to prevent from potential body composition changes associated with physical activity and training while performance tests were measured in the afternoon on separate days. Before the beginning of performance tests, a 5 min of general and 10 min of specific warm-up supervised by a coach were provided. Additionally, all participants were required to avoid stimulating substances ingestion and intense training sessions at least 48 h before the beginning of the Development Camp.

2.3. Data collection

A total of 32 anthropometric measurements were taken in accordance with the guidelines of the International Society for the Advancement of Kinanthropometry (ISAK) by a certified level-3 ISAK anthropometrist. The variables included: body mass (kg) that was determined with a digital scale SECA 862 (SECA, Germany); stretch stature (cm), lengths (cm), and breadths (cm) measured with a GPM anthropometer (Siber-Hegner, Switzerland); skinfolds (mm) with a Harpender skinfold caliper (British Indicators, UK); and girths (cm) with a metallic non-extensible tape Lufkin W606PM (Lufkin, USA). All parameters were measured twice or three times (if the difference between the first two measures was greater than 5% for the skinfolds and 1% for the remaining variables). The mean (or median in the last case) was used for further data analysis. In addition, to avoid measurements errors, all instruments were calibrated before each testing session.

Body mass index (BMI) was calculated using the formula: BMI = body mass (kg) • height^{-2} (m) whereas muscular mass (MM_P) and fat mass (FM_S) were obtained by the anthropometric equations described by Poortmans et al. [23] and Slaughter et al. [24], respectively. In addition, body composition was also analyzed by the five-component model according to the instructions defined by Kerr [25]. Likewise, body mass ratios were obtained from the measurements of the five-component model, and all variables obtained by Kerr were identified using a 'K'. Corrected girths for the skinfold at the corresponding site were calculated by the formula: corrected girth = girth − (π • skinfold thickness). Body proportionality indexes were determined according to the procedures and equations described by Canda [26] and included: relative arm span, cormix index, manouvrier index, acromial-iliac index, and braquial index. To determine the *Z-scores* of the anthropometric variables, the equation of the Phantom Stratagem described by Ross and Marfell-Jones [27] was used. Moreover, Z-scores were compared with the values of Olympic competitors reported by Ackland et al. [6] which were considered a reference for an optimal anthropometric profile in senior categories.

To determine maturity status, the procedures described by Mirwald et al. [13] were followed. For that purpose, age at peak height velocity (APHV) was estimated and considered a maturational benchmark with the 0 value representing the chronological age of maximum growth in stature.

Performance tests included a 200-m and 500-m paddling on-water at maximum effort and were completed on separate days to ensure enough recuperation. Both tests were recorded following the paddler laterally from a motorboat using a video camera JVC Everio MG-135 (Victor Company, Japan) at 30 frames per second. To determine performance times, the recordings were analyzed using the frames from the first traction movement to the finish line by the Virtualdub software 1.8.8 (Avery Lee). When wind velocity was above 2 m · s^{-1}, assessments were postponed to avoid influence on race times.

2.4. Statistical analyses

All statistical analyses were conducted using the Statistical Package for the Social Sciences v24.0 (SPSS Inc. Chicago IL, USA). To determine the normality of the distribution and the homogeneity of variance, Shapiro–Wilk test and Levene's test were performed, respectively. Analysis of variance (ANOVA) for repeated measures was used to compare the means between groups when the assumptions of normality and homogeneity were confirmed. If ANOVA analysis revealed significant differences, post hoc Bonferroni tests were used to allocate the differences between groups. Non-parametric test (Friedman test) was conducted in case of rejection of normality distribution of data and *post hoc* Wilcoxon signed-rank tests with Bonferroni corrections (.05/3) were used when any significant difference was identified. The level of significance was set as $p < .05$. The effect size between groups was investigated by the calculation of partial eta squared (η^2_p), and was considered small when between .01 and .06, moderate when between .06 and .13, and large when the effect was >.13.

3. Results

The anthropometric characteristics and performance times of males and females paddlers along three years are compared in Tables 1 and 2, respectively. Male athletes presented significant differences in all basic anthropometric characteristics ($p < .05$), observing the largest effect size values among the three years in chronological age, arm span and body mass ($\eta^2_p > .82$). Skin mass, MM_K and; residual mass also exhibited significant different values among all years ($p < .05$) whereas in MM-BM and Acromial-Iliac ratios only significant differences were detected between the 3rd and the 1st year. Partial eta-squared analysis revealed large effect size values ranged from .59 to .91 in all cases. Similarly, only the 200-m performance time significantly changed in the transition from the 1st to the 3rd year. In girls, significantly large effect size values were identified among all groups in chronological age, maturity status, APHV, MM_P and MM_K ($\eta^2_p > .85$; $p < .05$). Body mass, sitting height, FM_S, MM-BM ratio, MM-FM ratio and 200-m performance times also presented significant differences when the paddler's age increased ($p < .05$) with partial eta-squared values superior to .58 in all cases.

Anthropometric Z-Scores evolution in males and females competitors is summarized in Tables 3 and 4, respectively. The proportionality analysis of male paddlers revealed significant changes in upper limb and chest girths, biacromial and transverse chest breadths in the 3rd year when compared with the 1st ($\eta^2_p > .58$; $p < .05$). Conversely, the analysis of female kayakers' Z-Scores revealed significant differences only in the comparison between the 3rd and the 2nd year in corrected arm and chest girths and between the 3rd and 1st year in biacromial breadth ($p < .05$).

A comparison of the Z-scores with those reported by Ackland et al. [6] in Olympic elite competitors is presented in Figure 1 for males and females paddlers. Increasing proportionality tendencies were observed in most parameters in male kayakers (3rd > 2nd > 1st > Ackland et al. [6]), while in the Z-Score of the sum of eight skinfolds and the femur breadth the opposite tendency was detected. Similar results were identified in female kayakers, especially in flexed and tensed arm, chest, and waist girths.

4. Discussion

The main finding of the present investigation was the consistent evolution of the basic anthropometric attributes and body proportionality observed in young elite paddlers towards similar values typically representative of elite senior

Table 1. Morphological characteristics and performance tests of young male paddlers in three consecutive years.

	1st year	2nd year	3rd year	
	Mean ± SD (95% CI)	Mean ± SD (95% CI)	Mean ± SD (95% CI)	η^2_p
Chronological age (years)	13.41 ± 0.47 (12.97–13.84)	**14.24 ± 0.31* (13.95–14.53)**	**15.64 ± 0.66‡Ω (15.02–16.25)**	0.91
Body mass (kg)	58.21 ± 11.56 (47.52–68.90)	**64.80 ± 11.90* (53.80–75.80)**	**69.74 ± 10.30‡Ω (60.22–79.27)**	0.82
Stretch stature (cm)	166.70 ± 5.73 (161.40–172.00)	171.09 ± 5.02 (166.44–175.73)	**174.27 ± 4.93‡Ω (169.71–178.84)**	0.81
BMI (kg · m^{-2})	20.80 ± 3.01 (18.02–23.59)	22.01 ± 2.85 (19.37–24.64)	**22.86 ± 2.19‡ (20.83–24.88)**	0.75
Sitting height (cm)	87.57 ± 5.42 (82.56–92.58)	90.07 ± 3.24 (87.08–93.07)	**91.96 ± 3.96‡ (88.30–95.62)**	0.63
Arm span (cm)	167.71 ± 6.92 (161.31–174.12)	**174.93 ± 5.00* (170.31–179.55)**	**178.07 ± 4.87‡Ω (173.57–182.57)**	0.83
Maturity (years from APHV)	0.15 ± 0.88 (−0.66–0.97)	0.95 ± 0.58 (0.41–1.48)	**1.97 ± 0.89‡Ω (1.15–2.79)**	0.90
APHV (years)	13.25 ± 0.65 (12.65–13.85)	13.29 ± 0.45 (12.88–13.71)	13.66 ± 0.47 (13.23–14.09)	0.44
∑ 6 Skinfolds (mm)	63.37 ± 27.87 (37.60–89.15)	67.61 ± 29.50 (40.33–94.90)	60.67 ± 18.07 (43.96–77.38)	0.08
∑ 8 Skinfolds (mm)	79.59 ± 36.99 (45.38–113.80)	85.74 ± 39.37 (49.34–122.15)	77.04 ± 21.82 (56.86–97.22)	0.08
Endomorphy	2.59 ± 1.25 (1.44–3.75)	2.71 ± 1.24 (1.57–3.86)	2.38 ± 0.76 (1.68–3.09)	0.12
Mesomorphy	4.46 ± 0.46 (3.76–5.16)	4.65 ± 1.13 (3.45–5.86)	4.51 ± 1.11 (3.49–5.54)	0.05
Ectomoorphy	3.10 ± 1.14 (2.05–4.15)	2.76 ± 1.05 (1.79–3.73)	2.50 ± 0.74 (1.82–3.18)	0.17
FM_S percentage (%)	16.22 ± 5.57 (11.07–21.37)	16.91 ± 5.13 (12.17–21.66)	14.85 ± 4.31 (10.86–18.84)	0.13
FM_S (kg)	9.93 ± 5.62 (4.74–15.13)	11.44 ± 5.78 (6.10–16.78)	10.52 ± 3.79 (7.01–14.02)	0.11
MM_P percentage (%)	43.05 ± 1.79 (41.40–44.71)	42.78 ± 1.28 (41.60–43.96)	44.33 ± 1.28 (43.15–45.52)	0.34
MM_P (kg)	24.99 ± 4.65 (20.69–29.29)	**27.74 ± 5.39* (22.76–32.73)**	**30.97 ± 4.97‡Ω (26.37–35.56)**	0.84
5-component model (Kerr, 1988)				
Skin mass (kg)	3.40 ± 0.36 (3.07–3.73)	**3.63 ± 0.35* (3.31–3.95)**	**3.80 ± 0.31‡Ω (3.51–4.08)**	0.82
BM (kg)	7.86 ± 1.79 (6.21–9.51)	8.29 ± 1.99 (6.45–10.13)	8.00 ± 1.30 (6.80–9.22)	0.13
FM_K (kg)	16.03 ± 5.45 (11.00–21.07)	17.77 ± 6.16 (12.07–23.47)	17.24 ± 3.92 (13.61–20.86)	0.11
MM_K (kg)	23.52 ± 7.38 (16.69–30.35)	**29.53 ± 8.16* (21.98–37.08)**	**35.53 ± 8.37‡Ω (27.79–43.27)**	0.86
Residual mass (kg)	7.53 ± 1.88 (5.79–9.27)	**8.50 ± 1.95* (6.69–10.30)**	**9.19 ± 1.76‡Ω (7.57–10.82)**	0.84
Total mass predicted (kg)	60.03 ± 15.35 (43.98–76.08)	**69.50 ± 18.73* (52.19–86.83)**	**75.36 ± 15,22‡Ω (61.28–89.45)**	0.68
Body mass-Predicted body mass difference	3.47 ± 6.48 (−2.52–9.46)	5.47 ± 7.19 (−1.18–12.11)	6.44 ± 5.67 (1.20–11.68)	0.19
MM-FM ratio	1.60 ± 0.20 (1.42–1.78)	**1.81 ± 0.21* (1.62–2.01)**	**2.19 ± 0.25‡Ω (1.96–2.41)**	0.88
MM-BM ratio	3.16 ± 0.43 (2.76–3.56)	3.78 ± 0.52 (3.30–4.27)	**4.63 ± 0.63‡Ω (4.04–5.21)**	0.88
Waist-Hip ratio	0.84 ± 0.04 (0.81–0.88)	0.83 ± 0.03 (0.81–0.85)	0.83 ± 0.02 (0.81–0.85)	0.16
Relative arm span (cm)	100.62 ± 2.84 (97.99–103.25)	102.26 ± 1.79 (100.61–103.92)	102.20 ± 1.91 (100.43–103.97)	0.41
Cormix index	52.49 ± 1.51 (51.09–53.89)	52.64 ± 0.92 (51.79–53.49)	52.76 ± 1.29 (51.56–53.95)	0.02
Manouvrier index	90.65 ± 5.52 (85.54–95.75)	90.00 ± 3.26 (86.99–93.02)	89.65 ± 4.59 (85.40–93.90)	0.02
Acromial-Iliac index	82.99 ± 4.02 (79.27–86.71)	77.62 ± 7.13 (71.03–84.23)	**71.86 ± 3.76‡ (68.38–75.35)**	0.59
Braquial index	77.23 ± 2.70 (74.74–79.73)	79.04 ± 3.15 (76.13–81.95)	78.24 ± 2.54 (75.89–80.60)	0.14
Performance				
200-m (s)	58.39 ± 8.65 (138.94–179.48)	**52.98 ± 7.31* (124.60–153.56)**	**46.46 ± 6.62‡Ω (120.74–158.97)**	0.98
500-m (s)	159.21 ± 21.92 (50.39–66.39)	**139.08 ± 15.66* (46.22–59.74)**	139.86 ± 20.67 (40.34–52.58)	0.62

Note. BMI = Body Mass Index; APHV = Age at Peak Height Velocity; FM_S = Fat Mass (Slaughter et al., 1988); MM_P = Muscle Mass (Poortmans et al., 2005); BM = Bone Mass; FM_K = Fat Mass (Kerr, 1988); MM_K = Muscle Mass (Kerr, 1988).
*Significant difference between 2nd and 1st year paddlers, $p < .05$.
‡Significant difference between 3rd and 1st year paddlers, $p < .05$.
ΩSignificant difference between 3rd and 2nd year paddlers, $p < .05$.

Table 2. Morphological characteristics and performance tests of young female paddlers in three consecutive years.

	1st year	2nd year	3rd year	
	Mean ± SD (95% CI)	Mean ± SD (95% CI)	Mean ± SD (95% CI)	η^2_p
Chronological age (years)	13.29 ± 0.32 (12.96–13.62)	**14.26 ± 0.31* (13.94–14.58)**	15.72 ± 0.80ǂΩ (14.88–16.57)	0.95
Body mass (kg)	50.62 ± 7.39 (42.86–58.37)	54.65 ± 5.49* (48.89–60.41)	56.00 ± 4.55 (51.22–60.78)	0.68
Stretch stature (cm)	161.50 ± 2.47 (158.91–164.09)	163.62 ± 2.39 (161.11–166.12)	163.98 ± 2.08 (161.80–166.16)	0.63
BMI (kg · m^{-2})	19.38 ± 2.59 (16.66–22.10)	20.40 ± 1.80 (18.51–22.29)	20.81 ± 1.46 (19.27–22.35)	0.55
Sitting height (cm)	84.40 ± 2.42 (81.86–86.94)	86.22 ± 1.65 (84.49–87.95)	87.03 ± 1.90ǂ (85.04–89.03)	0.59
Arm span (cm)	160.25 ± 4.49 (155.54–164.96)	162.27 ± 3.96 (158.11–166.42)	162.00 ± 4.82 (156.95–167.05)	0.34
Maturity (years from APHV)	1.27 ± 0.35 (0.91–1.64)	**1.98 ± 0.22* (1.75–2.21)**	2.82 ± 0.53ǂΩ (2.27–3.37)	0.95
APHV (years)	12.02 ± 0.24 (11.77–12.26)	**12.28 ± 0.20* (12.07–12.48)**	12.90 ± 0.34ǂΩ (12.54–13.26)	0.88
∑ 6 Skinfolds (mm)	80.52 ± 19.95 (59.58–101.45)	90.23 ± 12.15 (77.49–102.98)	84.02 ± 13.32 (70.04–97.99)	0.32
∑ 8 Skinfolds (mm)	103.60 ± 27.06 (75.20–132.00)	114.35 ± 16.05 (97.51–131.19)	105.52 ± 16.20 (88.51–122.52)	0.27
Endomorphy	3.48 ± 0.92 (2.51–4.44)	3.61 ± 0.62 (2.96–4.27)	3.44 ± 0.57 (2.84–4.04)	0.09
Mesomorphy	4.15 ± 0.99 (3.11–5.19)	3.88 ± 0.94 (2.89–4.87)	3.76 ± 0.68 (3.04–4.47)	0.24
Ectomoorphy	3.50 ± 1.38 (2.05–4.94)	3.03 ± 0.88 (2.10–3.96)	2.83 ± 0.71 (2.08–3.57)	0.44
FM_S percentage (%)	22.44 ± 3.65 (18.62–26.27)	24.48 ± 3.13 (21.19–27.76)	23.96 ± 3.38 (20.41–27.51)	0.44
FM_S (kg)	11.58 ± 3.55 (7.86–15.30)	**13.50 ± 3.07* (10.28–16.72)**	13.52 ± 2.86 (10.52–16.52)	0.58
MM_P percentage (%)	39.35 ± 1.85 (37.40–41.29)	39.11 ± 1.75 (37.27–40.94)	39.97 ± 1.70 (38.19–41.74)	0.15
MM_P (kg)	19.88 ± 2.77 (16.97–22.78)	**21.41 ± 2.74* (18.53–24.29)**	22.38 ± 2.09 (20.19–24.57)	0.64
5-component model (Kerr, 1988)				
Skin mass (kg)	3.20 ± 0.22 (2.97–3.43)	**3.34 ± 0.17* (3.17–3.52)**	3.38 ± 0.14Ω (3.24–3.53)	0.70
BM (kg)	7.00 ± 1.12 (5.82–8.18)	7.13 ± 1.57 (5.48–8.77)	6.53 ± 0.74 (5.75–7.30)	0.23
FM_K (kg)	17.34 ± 3.23 (13.95–20.72)	19.35 ± 2.05 (17.20–21.50)	18.49 ± 2.24 (16.14–20.83)	0.42
MM_K (kg)	18.95 ± 3.97 (14.78–23.12)	**21.25 ± 3.54* (17.54–24.97)**	22.93 ± 2.69ǂ (20.11–25.76)	0.71
Residual mass (kg)	5.98 ± 1.08 (4.85–7.11)	6.11 ± 0.66 (5.41–6.80)	6.34 ± 0.55 (5.77–6.92)	0.24
Total mass predicted (kg)	54.23 ± 9.65 (44.10–64.36)	59.56 ± 7.88 (51.30–67.83)	59.97 ± 6.50 (53.15–66.79)	0.51
Body mass-Predicted body mass difference	3.61 ± 2.50 (0.99–6.24)	4.91 ± 2.64 (2.14–7.68)	3.97 ± 2.14 (1.73–6.21)	0.15
MM-FM ratio	1.21 ± 0.04 (1.16–1.25)	1.22 ± 0.10 (1.11–1.32)	1.37 ± 0.07ǂΩ (1.30–1.44)	0.77
MM-BM ratio	2.98 ± 0.21 (2.76–3.21)	3.36 ± 0.44 (2.90–3.82)	3.88 ± 0.33ǂ (3.54–4.22)	0.79
Waist-Hip ratio	0.74 ± 0.03 (0.70–0.77)	0.73 ± 0.03 (0.69–0.76)	0.74 ± 0.02 (0.72–0.76)	0.18
Relative arm span (cm)	99.21 ± 1.44 (97.69–100.73)	99.17 ± 1.45 (97.64–100.69)	98.78 ± 2.04 (96.64–100.92)	0.10
Cormix index	52.26 ± 1.29 (50.90–53.62)	52.71 ± 1.45 (51.18–54.23)	53.08 ± 1.03 (51.99–54.16)	0.25
Manouvrier index	91.45 ± 4.76 (86.45–96.44)	89.85 ± 5.17 (84.42–95.27)	88.47 ± 3.67 (84.62–92.33)	0.25
Acromial-Iliac index	90.16 ± 5.20 (84.71–95.62)	83.12 ± 10.50 (72.10–94.14)	75.09 ± 4.15ǂ (70.73–79.44)	0.67
Braquial index	75.50 ± 2.99 (72.36–78.64)	78.54 ± 3.44 (74.93–82.16)	78.09 ± 3.11 (74.82–81.35)	0.24
Performance				
200-m (s)	55.25 ± 1.59 (139.27–160.50)	**52.11 ± 1.41* (145.26–154.80)**	51.26 ± 1.99ǂ (137.41–147.68)	0.88
500-m (s)	149.88 ± 10.11 (53.58–56.92)	150.03 ± 4.55 (50.63–53.59)	142.55 ± 4.89 (49.17–53.35)	0.28

Note. BMI = Body Mass Index; APHV = Age at Peak Height Velocity; FM_S = Fat Mass (Slaughter et al., 1988); MM_P = Muscle Mass (Poortmans et al., 2005); FM_K = Fat Mass (Kerr, 1988); MM_K = Muscle Mass (Kerr, 1988).
*Significant difference between 2nd and 1st year paddlers, $p < .05$.
ǂSignificant difference between 3rd and 1st year paddlers, $p < .05$.
ΩSignificant difference between 3rd and 2nd year paddlers, $p < .05$.

competitors. This tendency was identified along three consecutive years not only in body composition but also in performance times in male and female paddlers. Specially, upper body girths and breadths values exhibited a significant increasing evolution in male kayakers. Since this is the first longitudinal study with young elite paddlers, these results provide with normative data about the development of anthropometric characteristics at young ages and allow the identification and enhancement of the most important attributes for senior successful performance.

Over the three consecutive years, an increase in basic anthropometric attributes resulting in a more robust and compact profile was determined, especially in boys. The tendency towards taller and heavier competitors is in agreement not only with the findings revealed by Alacid et al. [28], when compared young paddlers with one year differential, but also with previous investigations in senior world-class competitors of different levels [3,6,8]. Biological maturation plays a key role in the development of anthropometric characteristics during adolescence [29]; observing that the age at peak height velocity (APHV) occurs around the age of 14 in boys and around 12 years old in girls [13]. Perhaps, the fact that male's chronological ages were closer to their APHV than females' would partially explain the superior differences among groups observed here in the basic anthropometric attributes of male paddlers. Similarly, in a soccer longitudinal study, Méndez-Villanueva et al. [30] reported larger magnitudes of difference between age groups closer to APHV. In addition, according to Welsman et al. [18], body size and stature also seem to change more remarkably in boys than in girls between the ages of 6 and 18 (160% vs 125% and 40% vs 30%, respectively).

The estimation of APHV increased in the transition over the three years studied only in female kayakers. Nevertheless, APHV should not change for an individual regardless of the time of measurement and chronological age. Prior studies have observed a less reliable and accurate estimation in late maturers [15] and when chronological age it is far from APHV [31]. According to this, the differences detected in female kayakers might result from estimation errors that increase throughout the years.

Substantial muscularity levels have been typically identified in most successful male paddlers [7,10]. Similarly, the few studies in female competitors determined superior levels of muscularity and mesomorphy in older and more successful kayakers [6,19]. Although, to date, no muscularity data has been reported in Olympic competitors, large values in some

Table 3. Body proportionality of young male paddlers in three consecutive years.

	1st year	2nd year	3rd year	
	Mean ± SD (95% CI)	Mean ± SD (95% CI)	Mean ± SD (95% CI)	η^2_p
Z Body mass	−0.37 ± 0.87 (−1.18–0.43)	−0.15 ± 0.78 (−0.88–0.57)	0.00 ± 0.54 (−0.50–0.50)	0.40
Z Sitting height	−0.13 ± 0.57 (−0.66–0.40)	−0.07 ± 0.35 (−0.39–0.25)	−0.03 ± 0.49 (−0.48–0.42)	0.02
Z Arm span	0.09 ± 0.61 (−0.53–0.59)	0.26 ± 0.27 (0.03–0.54)	0.27 ± 0.31 (−0.01–0.56)	0.14
Z Triceps skinfold	−1.14 ± 0.92 (−1.99 − −0.29)	−1.16 ± 0.81 (−1.91 − −0.41)	−1.58 ± 0.65 (−2.18 − −0.98)	0.26
Z Subescapular skinfold	−1.71 ± 0.94 (−2.58 − −0.84)	−1.61 ± 0.97 (−2.51 − −0.71)	−1.73 ± 0.42 (−2.12 − −1.33)	0.01
Z Biceps skinfold	−1.47 ± 1.11 (−2.50 − −0.45)	−1.50 ± 1.10 (−2.52 − −0.49)	−2.05 ± 0.41 (−2.43 − −1.67)	0.31
Z Iliac crest skinfold	−2.23 ± 1.15 (−3.30 − −1.17)	−2.56 ± 0.32 (−2.86 − −2.26)	−2.72 ± 0.12 (−2.83 − −2.61)	0.29
Z Supraspinale skinfold	−1.75 ± 0.78 (−2.47 − −1.02)	−1.61 ± 0.87 (−2.41 − −0.81)	−1.80 ± 0.56 (−2.32 − −1.28)	0.03
Z Abdominal skinfold	−1.66 ± 0.84 (−2.44 − −0.88)	−1.58 ± 0.86 (−2.37 − −0.78)	−1.81 ± 0.49 (−2.27 − −1.35)	0.10
Z Front thigh skinfold	−1.49 ± 0.70 (−2.13 − −0.84)	−1.44 ± 0.76 (−2.14 − −0.73)	−1.62 ± 0.54 (−2.12 − −1.12)	0.08
Z Medial calf skinfold	−1.13 ± 0.71 (−1.78 − −0.47)	−1.03 ± 0.68 (−1.66 − −0.40)	−1.27 ± 0.63 (−1.86 − −0.69)	0.09
Z Relaxed arm girth	−0.23 ± 1.25 (−1.39–0.92)	0.09 ± 1.16 (−0.98–1.16)	**0.96 ± 0.83‡Ω (0.19–1.73)**	0.73
Z Flexed and tensed arm girth	0.03 ± 1.28 (−1.16–1.21)	0.44 ± 1.16 (−0.64–1.51)	**0.88 ± 0.82‡ (0.12–1.64)**	0.59
Z Corrected arm girth	0.56 ± 0.90 (−0.28–1.39)	0.96 ± 0.90 (0.13–1.79)	**2.33 ± 0.82‡ (1.57–3.09)**	0.93
Z Forearm girth	−0.34 ± 1.46 (−1.69–1.02)	0.20 ± 1.17 (−0.88–1.29)	0.76 ± 0.95 (−0.11–1.64)	0.48
Z Chest girth	−0.37 ± 1.10 (−1.38–0.65)	0.58 ± 0.92 (−0.27–1.43)	**1.19 ± 0.57‡ (0.67–1.72)**	0.71
Z Thigh girth (1cm)	−0.65 ± 1.09 (−1.65–0.36)	−0.38 ± 1.05 (−1.35–0.59)	−0.74 ± 0.70 (−1.39 − −0.08)	0.11
Z Thigh girth	−1.08 ± 0.69 (−1.72 − −0.44)	−0.85 ± 0.83 (−1.61 − −0.08)	−0.74 ± 0.66 (−1.35 − −0.13)	0.14
Z Medial calf girth	−0.80 ± 1.05 (−1.77–0.17)	−0.85 ± 1.07 (−1.84–0.14)	−0.81 ± 1.29 (−2.01–0.38)	0.01
Z Corrected thigh girth	−0.72 ± 0.88 (−1.53–0.10)	−0.83 ± 0.75 (−1.53 − −0.14)	−0.55 ± 1.04 (−1.51–0.41)	0.05
Z Arm length	−0.78 ± 0.63 (−1.36 − −0.20)	−0.60 ± 0.39 (−0.96 − −0.24)	−0.15 ± 0.40 (−0.52–0.22)	0.38
Z Forearm length	−0.38 ± 0.65 (−0.98–0.22)	0.22 ± 0.68 (−0.41–0.85)	0.49 ± 0.52 (0.00–0.97)	0.37
Z Biacromial breadth	−1.05 ± 0.68 (−1.62–0.01)	**−0.30 ± 0.50* (−0.69–0.19)**	**0.08 ± 0.66‡ (−0.48–0.75)**	0.78
Z Biiliocristal breadth	0.08 ± 1.05 (0.08–1.53)	0.22 ± 1.53 (−1.27–1.62)	−0.72 ± 0.77 (−1.47 − −0.05)	0.29
Z Transverse chest breadth	−0.65 ± 0.84 (−1.33–0.44)	0.20 ± 0.63 (−0.36–1.24)	**0.96 ± 0.50‡ (0.55–1.60)**	0.82
Z Anterio-Posterior chest breadth	0.83 ± 0.84 (−0.32–2.56)	1.55 ± 1.36 (0.32–2.82)	1.49 ± 1.38 (0.01–2.52)	0.22
Z Wrist breadth	1.41 ± 1.03 (0.46–2.36)	1.63 ± 0.67 (1.01–2.25)	0.50 ± 0.74 (−0.18–1.19)	0.58

Note.
*Significant difference between 2nd and 1st year paddlers, $p < .05$.
‡Significant difference between 3rd and 1st year paddlers, $p < .05$.
ΩSignificant difference between 3rd and 2nd year paddlers, $p < .05$.

Table 4. Body proportionality of young female paddlers in three consecutive years.

	1st year	2nd year	3rd year	
	Mean ± SD (95% CI)	Mean ± SD (95% CI)	Mean ± SD (95% CI)	η^2_p
Z Body mass	−0.63 ± 0.89 (−1.56–0.30)	−0.36 ± 0.61 (−1.01–0.28)	−0.24 ± 0.49 (−0.75–0.28)	0.43
Z Sitting height	−0.22 ± 0.49 (−0.73–0.30)	−0.05 ± 0.55 (−0.62–0.52)	0.09 ± 0.39 (−0.32–0.50)	0.25
Z Arm span	−0.47 ± 0.72 (−0.86–0.66)	−0.48 ± 0.34 (−0.84 − −0.13)	−0.57 ± 0.47 (−1.06 − −0.08)	0.43
Z Triceps skinfold	−0.20 ± 0.87 (−1.11–0.72)	−0.06 ± 1.05 (−1.16–1.04)	−0.17 ± 0.76 (−0.96–0.63)	0.09
Z Subescapular skinfold	−1.51 ± 0.44 (−1.97 − −1.05)	−1.41 ± 0.24 (−1.66 − −1.16)	−1.49 ± 0.36 (−1.87 − −1.10)	0.07
Z Biceps skinfold	−0.19 ± 1.13 (−1.38–0.99)	−0.19 ± 0.78 (−1.00–0.63)	−0.75 ± 0.58 (−1.36 − −0.15)	0.41
Z Iliac crest skinfold	−2.17 ± 0.33 (−2.52 − −1.83)	−2.17 ± 0.23 (−2.41 − −1.93)	−2.34 ± 0.17 (−2.52 − −2.16)	0.42
Z Supraspinale skinfold	−1.15 ± 0.96 (−2.16 − −0.15)	−1.16 ± 0.68 (−1.86 − −0.45)	−1.35 ± 0.66 (−2.05 − −0.66)	0.11
Z Abdominal skinfold	−1.36 ± 0.67 (−2.05 − −0.66)	−1.03 ± 0.41 (−1.46 − −0.61)	−1.33 ± 0.40 (−1.74 − −0.91)	0.31
Z Front thigh skinfold	−0.82 ± 0.66 (−1.51 − −0.12)	−0.46 ± 0.58 (−1.07–0.15)	−0.73 ± 0.56 (−1.32 − −0.13)	0.40
Z Medial calf skinfold	−0.12 ± 0.61 (−0.76–0.51)	0.41 ± 0.41 (−0.02–0.84)	0.31 ± 0.71 (−0.44–1.05)	0.45
Z Relaxed arm girth	−0.38 ± 0.89 (−1.31–0.55)	−0.07 ± 0.88 (−0.99–0.85)	0.20 ± 0.77 (−0.61–1.01)	0.42
Z Flexed and tensed arm girth	−0.63 ± 0.88 (−1.55–0.30)	−0.13 ± 0.66 (−0.82–0.56)	0.02 ± 0.56 (−0.57–0.60)	0.60
Z Corrected arm girth	−0.31 ± 0.60 (−0.94–0.32)	−0.04 ± 0.41 (−0.47–0.39)	**0.37 ± 0.43Ω (−0.08–0.82)**	0.56
Z Forearm girth	−0.71 ± 1.53 (−2.32–0.89)	−0.54 ± 1.09 (−1.68–0.60)	−0.23 ± 0.77 (−1.04–0.58)	0.20
Z Chest girth	−0.14 ± 0.77 (−0.95–0.66)	0.20 ± 0.47 (−0.29–0.70)	**0.56 ± 0.50Ω (0.04–1.08)**	0.55
Z Thigh girth (1cm)	0.09 ± 1.08 (−1.04–1.22)	−0.03 ± 1.00 (−1.09–1.02)	−0.40 ± 0.50 (−0.92–0.12)	0.18
Z Thigh girth	−1.04 ± 0.74 (−1.81 − −0.26)	−0.80 ± 0.77 (−1.61–0.01)	−0.71 ± 0.57 (−1.31 − −0.11)	0.29
Z Medial calf girth	−0.53 ± 1.25 (−1.84–0.78)	−0.35 ± 1.03 (−1.43–0.73)	−0.21 ± 0.99 (−1.25–0.83)	0.25
Z Corrected thigh girth	−1.29 ± 0.76 (−2.08 − −0.49)	−1.55 ± 0.93 (−2.52 − −0.58)	−1.03 ± 0.63 (−1.70 − −0.37)	0.49
Z Arm length	−0.63 ± 0.60 (−1.27–0.00)	−0.72 ± 0.61 (−1.36 − −0.09)	−0.67 ± 0.79 (−1.50–0.15)	0.01
Z Forearm length	−0.63 ± 0.76 (−1.43–0.17)	−0.03 ± 0.70 (−0.76–0.70)	−0.10 ± 0.39 (−0.51–0.32)	0.31
Z Biacromial breadth	−1.12 ± 0.71 (−1.86 − −0.37)	−0.40 ± 1.02 (−1.47–0.67)	**−0.12 ± 0.72‡ (−0.88–0.64)**	0.62
Z Biiliocristal breadth	1.16 ± 0.69 (0.43–1.88)	1.19 ± 2.10 (−1.02–3.40)	−0.28 ± 0.61 (−0.91–0.36)	0.32
Z Transverse chest breadth	−0.61 ± 0.71 (−1.36–0.13)	−0.33 ± 0.51 (−0.86–0.21)	0.11 ± 0.39 (−0.30–0.51)	0.42
Z Anterio-Posterior chest breadth	0.99 ± 1.29 (−0.36–2.34)	0.77 ± 0.63 (0.12–1.43)	0.31 ± 0.88 (−0.62–1.23)	0.38
Z Wrist breadth	0.58 ± 0.98 (−0.45–1.60)	0.27 ± 1.11 (−0.90–1.43)	−0.45 ± 1.32 (−1.83–0.94)	0.65

Note.
‡Significant difference between 3rd and 1st year paddlers, $p < .05$.
ΩSignificant difference between 3rd and 2nd year paddlers, $p < .05$.

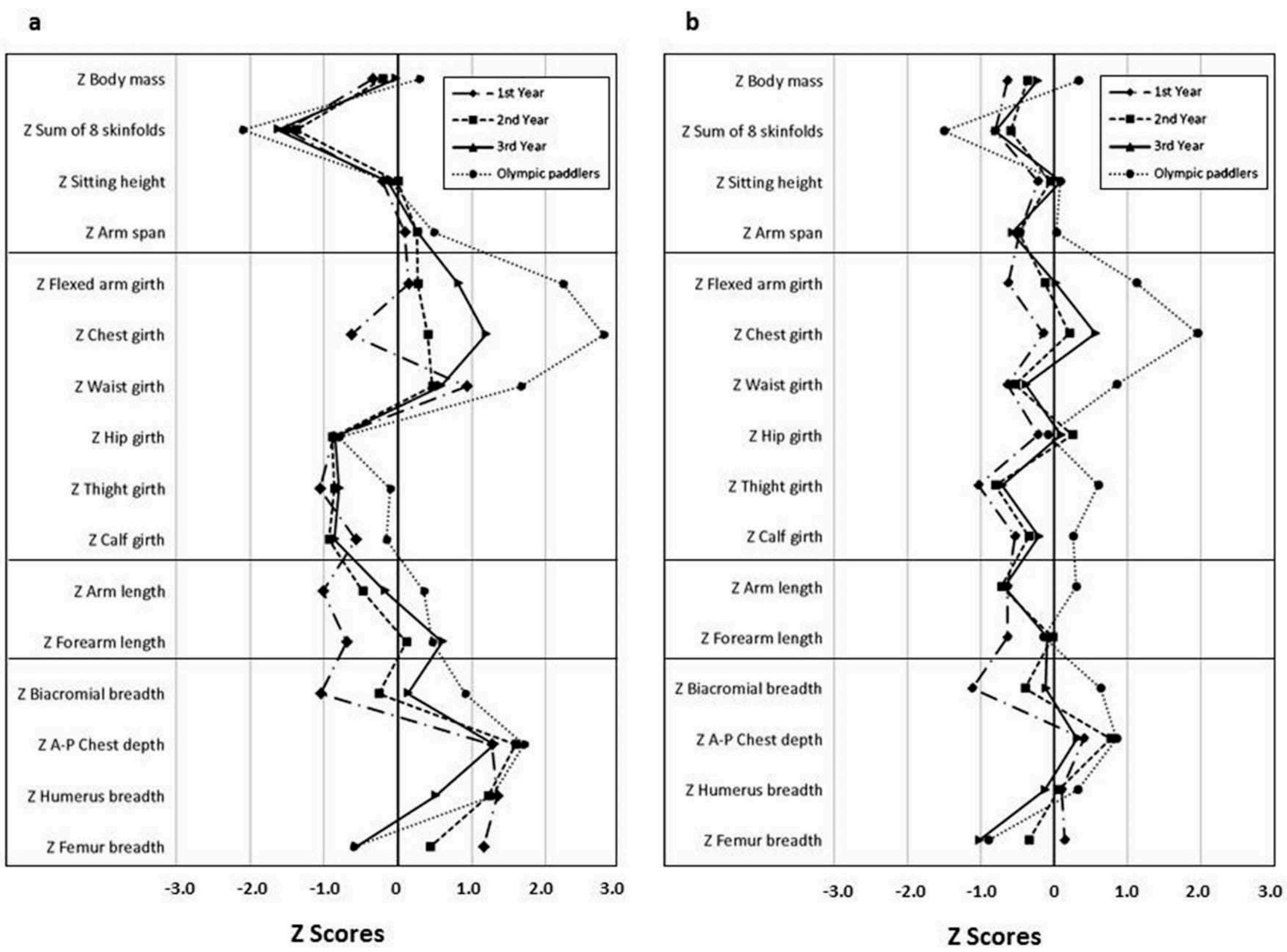

Figure 1. Proportionality evolution of anthropometric characteristics in young (a) male and (b) female paddlers.

of the typical anthropometric parameters associated with this attribute such as flexed arm girth have been determined [6]. In the current investigation, significant evolutions of MM levels over the three years were also identified in boys and girls, according to both the equation described by Poortmans et al. [23] and the equation determined by Kerr [25]. In addition, the tendencies observed in MM-FM and MM-BM ratios confirm that MM proportionality increased respect to fat mass and bone structure, which seems not to significantly change after APHV. Since large muscularity is related to better force production [7], these findings support the introduction of more resistance workouts observed in recent years in top kayakers training schedules [9], especially after APHV.

As for adiposity, FM_S values only change significantly in female competitors between the 2nd and the 3rd year. Previous studies have determined similar adiposity levels in young female paddlers [9,19] but an increasing tendency by boys and girls in the transition to senior category [1,6,8]. When observing the sum of eight skinfolds in Olympic competitors, remarkable lower levels than those observed here have been reported [6]. However, wide ranges in the values of this parameter were also identified (30.9–116.1 mm and 52.9–103.7 mm for males and females, respectively). The importance of adiposity level in paddling is associated with its potential influence on body mass. An increase in the total weight of the boat-paddler unit would result in larger submerged area of the boat and more resistance to the displacement [32]. However, prior studies have reported contradictory results in the association of performance and adiposity levels [1,3,8]. Apparently, long distance paddlers would better perform with lower FM values [3] while sprint paddlers might overcome this increased weight by greater power production [7]. Nevertheless, in the present investigation, FM_S% and MM_P% remain stable over the years, suggesting that the changes of those parameters are proportional to body mass evolution.

According to previous studies, general performance improves along with chronological age [1,20] and level of maturity [11]. Significant increases were observed here in 200-m time in both males and females paddlers, however, in 500-m only slightly better results were identified in male competitors. Performance at shorter events has been associated with better strength levels [7,20] and anaerobic power [2,3]. Moreover, both attributes seem to largely improve near APHV and just after metabolic specialization, respectively [33]. Observing longer distances, VO_{2max} has been traditionally identified as a major contributor for optimal performance in senior boys [3,34] and girls [5]. Conversely, contradictory results have been identified in recent years not only in senior paddling but also at younger ages [8,11,34] when the relative VO_{2max} seems to barely change along puberty [33]. Perhaps, these results would suggest that sprint specialization is more effective after APHV while long distance enhancement might be more challenging in the transition to senior categories. Moreover, the superior distance from APHV identified in female respect to male competitors might be related to the lower evolution of performance parameters observed in the first group.

Traditionally, anthropometric indexes and Z-Scores have scarcely been used in kayak and canoeing investigations. In the present investigation, relative biacromial dimensions significantly increase over the years as it can be observed from Acromial-Iliac index and Z-biacromial breadth evolution. Prior studies also reported greater biacromial dimension by elite paddlers of both sexes in comparison with non-paddlers [9,35], with younger competitors [21] and in senior elite athletes [6]. Additionally, Z-Scores analysis of upper body size also revealed and increasing tendency towards a superior arm girths and chest measures over the years, especially in male kayakers. As it has been reported by Ackland et al. [6], these parameters have been identified to be common and representative to Olympic competitors, with Z-Scores greater than 2 in most variables. According to this, the evolution of biacromial, chest and arm parameters relative to other body measures would be determinant when successfully moving to senior categories. To date, proportionality parameters have been underused in kayaking and canoeing and might become valuable tools for talent identification and specific physical development at young ages.

To the best of our knowledge, this is the first longitudinal study analyzing the evolution of body composition and anthropometric characteristics of young males and females paddlers. One limitation of the present study was the restricted number of participants recruited. However, the high athletic level of paddlers and the longitudinal nature of the investigation limited the number of selectable candidates for the study. For talent identification programs, the present investigation may allow the detection of the anthropometric determinants for successful paddling in the formative period at young ages. Since there is a critical period in most individual sports in the transition to senior categories, these findings would help to identify the potential athletes that more effectively might move to the professional field based on their morphological characteristics. In addition, these results might provide with valuable information for coaches not only about the specific parameters to develop from young categories in the search of an optimal paddler profile but also about the weak areas that as far as possible might be reinforced.

5. Conclusion

The results of the current investigation demonstrated a tendency towards a larger and more robust profile over the years as a consequence of the increasing body mass, stature and muscularity. Indeed, biological maturity and performance level also progressed in the transition to senior categories, observing that the most remarkable changes in the anthropometric attributes occurred near APHV. Simultaneously, in the transition from the 1st to 3rd year paddlers also exhibited superior biacromial, chest and arm proportionality values that support the evolution to a bigger and more compact morphology representative of the world-class competitors. Regarding sexes, greater progression of anthropometric attributes was determined in boys, perhaps as a result of closer APHV values than girls.

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Declaration of interest

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

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V – RESULTADOS Y DISCUSIÓN GENERALES

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A continuación, se muestran los hallazgos más significativos así como una discusión general de cada uno de los estudios realizados.

✓ <u>Estudio 1</u>

Los kayakistas mostraron una maduración biológica y unas dimensiones corporales significativamente mayores en cuanto a masa corporal, talla y talla sentado respecto a los canoístas de la misma categoría de edad (p < 0,01). La mayor edad biológica observada en los kayakistas podría explicar las diferencias morfológicas identificadas entre las distintas disciplinas (102). Estudios previos en palistas senior han identificado un perfil más atlético, compacto y robusto en aquellos con mejor nivel competitivo y rendimiento (3, 6, 71).

Asimismo, el nivel de condición física exhibida por los kayakistas fue significativamente mayor que el de los canoístas, tanto en el salto con contramovimiento y estimación de VO_2max (p < 0,05), como en el lanzamiento de balón medicinal y la movilidad de cadera (p < 0,01). Aparentemente, el nivel madurativo y la ventaja morfológica de los kayakistas podrían estar relacionados con estos resultados (23). La importancia del nivel de condición física se ha demostrado no solo en la determinación de perfiles físicos, sino también en la identificación de potenciales talentos deportivos (53, 155). Es importante señalar que este es el primer estudio en analizar la condición física general de palistas jóvenes mediante test de campo por su facilidad de uso y rapidez y utilidad de los resultados (53, 155).

✓ <u>Estudio 2</u>

En ambas disciplinas (kayak y canoa) se encontraron diferencias significativas entre los grupos madurativos en todos los parámetros antropométricos (excepto porcentaje de grasa y masa muscular), lanzamiento de balón medicinal y rendimiento específico en las 3 distancias olímpicas (pre > circum > post; $p < 0,05$). Estos resultados están de acuerdo con estudios previos en deportistas de diferentes modalidades (23, 156) y palistas jóvenes (14), ya que los parámetros morfológicos básicos y el rendimiento específico siguen una tendencia de crecimiento positiva a lo largo de las diferentes etapas madurativas.

Además, en este estudio se detectaron correlaciones negativas y significativas ($p < 0,01$) en los tiempos de todas las distancias (200, 500 y 1000 m), con la edad cronológica, estado madurativo y diferentes variables antropométricas (masa corporal, talla, talla sentado y estado de madurativo), lanzamiento de balón medicinal y *sit-and-reach*. Aunque la influencia de ciertos atributos físicos son discutibles en el rendimiento en piragüismo, como el VO_2max o la potencia de los miembros inferiores (6, 71), existen otros como la fuerza de los miembros superiores que son fundamentales para un óptimo rendimiento, especialmente en palistas jóvenes (42) y en distancias cortas (71). Asimismo, diversos estudios han determinado que los palistas más exitosos también revelaron perfiles morfológicos más robustos, pesados y atléticos (3, 6).

Actualmente, los programas de identificación de talento deportivo solo tienen en cuenta el rendimiento específico de los deportistas (12). Ante la innegable relación de la maduración biológica con el desarrollo morfológico y de los atributos físicos, sería recomendable que este parámetro fuese considerado dentro de los programas de identificación y de selección de deportistas en etapas de formación (23, 75, 137).

✓ Estudio 3

Las mejores palistas presentaron valores antropométricos significativamente mayores en porcentaje de masa muscular, estado madurativo y edad cronológica ($p < 0,05$), mientras que en la comparación de las capacidades físicas solo se observaron diferencias significativas en el salto con contramovimiento ($p < 0,05$). De manera similar, en la literatura se han identificado competidores hombres con un perfil predominantemente mesomórfico que presentaron un mayor nivel competitivo y de rendimiento tanto en categoría senior (6, 71) como en junior (Estudio 2). La introducción de más y mejores programas de fuerza en las palistas de élite en las últimas décadas podría estar relacionado con este fenómeno (65). Asimismo, en uno de los pocos estudios con mujeres practicantes de deportes individuales de agua se identificaron niveles de condición física significativamente mayores en aquellas con un estado madurativo mayor (156). Sin embargo, en este estudio no se observaron diferencias en el resto de parámetros antropométricos y de condición física, como cabía esperar a partir de estudios similares con hombres de diferentes niveles (6, 71).

Además, en base a los resultados de correlación lineal obtenidos en este estudio, la potencia aeróbica parece ser un factor importante para lograr un rendimiento óptimo en pruebas largas (1000 m), mientras que el porcentaje de masa muscular lo sería para pruebas de corta duración (200 y 500 m). A pesar de que existe una contradicción en la relación entre la capacidad aeróbica y el rendimiento en categoría senior masculina (6, 59, 71), lo cierto es que existen evidencias de asociaciones significativas cuando hablamos de categorías inferiores (42) y mujeres (65).

✓ Estudio 4

A lo largo de los 3 años de seguimiento, la masa corporal y el tamaño de las extremidades superiores del cuerpo aumentaron significativamente ($p < 0,05$), especialmente en palistas de categoría masculina. Los palistas de ambos sexos presentaron crecimientos significativos y tamaños de efecto grandes en la masa muscular y piel ($\eta^2_P > 0,64$) entre todos los años, mientras que la masa ósea y la masa grasa permanecieron estables desde el 1º al 3º año. Aparentemente, el aumento de la masa corporal podría ser consecuencia del incremento de la masa muscular, que resulta esencial en la producción de fuerza y está relacionada con un óptimo rendimiento en pruebas cortas en piragüismo (71). Asimismo, se han observado tamaños y masas corporales significativamente mayores en palistas olímpicos e internacionales cuando se comparan con los de menor nivel competitivo. A pesar del incremento de peso total embarcación-palista con este tipo de perfiles antropométricos, la mayor producción de fuerza de éstos lo compensaría, resultando en una mayor propulsión (29, 72).

El análisis de la proporcionalidad reveló diferencias significativas en los perímetros y diámetros de las variables de la extremidad superior y tórax, así como valores grandes en el tamaño del efecto del diámetro biacromial a lo largo de los 3 años (3º > 2º > 1º; $\eta^2_p > 0,62$; $p < 0,05$), particularmente en categoría masculina. Del mismo modo, se observaron mejoras significativas en los tiempos de rendimiento de 200 m para ambos sexos. Cuando estos hallazgos se compararon con valores *Phantom* de palistas de élite olímpicos, se pudo observar una tendencia positiva y significativa a lo largo de los 3 años en las variables más características y comunes de estos palistas de élite (3). Aunque esta progresión se identificó en ambos sexos, las diferencias más significativas se determinaron en los palistas hombres, probablemente por la mayor proximidad al APHV (23, 76).

VI – FUTURAS LÍNEAS DE INVESTIGACIÓN

VI – LÍNEAS FUTURAS DE INVESTIGACIÓN

Las investigaciones en el ámbito del piragüismo de aguas tranquilas y más concretamente en palistas de categorías inferiores han sido escasas en comparación con otros deportes náuticos como el remo o la vela. Este hecho hace que las perspectivas de investigación en piragüismo puedan tomar diversas direcciones.

Una potencial línea de investigación futura podría ser la relacionada con la valoración de los atributos físicos y de rendimiento en un ambiente y condiciones que reproduzcan los de la competición. Un ejemplo de ello sería la determinación del VO_2max mediante analizador de gases durante el paleo. Asimismo, la determinación de otras variables cinéticas y cinemáticas a tiempo real podrían ser de gran utilidad para entrenadores y técnicos, como la fuerza de palada mediante agujas de tensión o las variaciones de velocidad y movimiento de la embarcación a través de acelerómetros. A pesar de que ya existen investigaciones de este tipo, son escasas y fueron llevadas a cabo con deportistas adultos.

Otras investigaciones futuras podrían centrarse en el análisis de diferentes programas de entrenamiento en jóvenes palistas y cómo éstos influyen en su rendimiento y sus características físicas, fisiológicas y morfológicas. Estos programas de entrenamiento podrían comenzar con intervenciones específicas para una capacidad, como fuerza o resistencia, y más tarde desarrollar otros programas a largo plazo de carácter más general.

Por último, y en línea con el último estudio de la presente tesis doctoral, se podría realizar un estudio longitudinal con los palistas más exitosos desde la categoría infantil hasta la senior de nivel internacional. Esta investigación implicaría la participación de un gran número de palistas en las primeras etapas y la implicación y disponibilidad continuada de los deportistas. Con una muestra mayor que en el estudio 4, el objetivo sería corroborar qué variables son más determinantes para llegar a convertirse en un palista de élite adulto y en qué etapas de maduración se desarrollan las mismas.

Actualmente, el grupo de investigación está inmerso en un proyecto de *Bio-banding* en colaboración con la Real Federación Española y la Federación Portuguesa de Piragüismo que consiste en valorar la edad biológica de los deportistas participantes en campeonatos nacionales para elaborar un ranking en función de su grado de maduración y alternativo a la clásica clasificación por edades.

VII – CONCLUSIONES

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- ✓ **Primera**: Los deportistas hombres jóvenes de la especialidad de kayak presentaron una maduración y medidas antropométricas básicas superiores en cuanto a tamaño y peso respecto a los canoístas del mismo nivel y edad.

- ✓ **Segunda**: El nivel de condición física en kayakistas jóvenes fue mayor que el observado en canoístas, quizá como consecuencia de una morfología más atlética y robusta.

- ✓ **Tercera**: La maduración biológica fue un determinante del rendimiento específico en palistas jóvenes de élite, especialmente en la disciplina de kayak.

- ✓ **Cuarta**: El nivel de condición física (principalmente fuerza y potencia muscular) y la composición corporal estuvieron influidos por el grado de maduración biológica y relacionados con el rendimiento específico en agua en palistas hombres jóvenes de élite.

- ✓ **Quinta:** En categoría femenina cadete, la maduración, la masa muscular y, en menor medida, la fuerza de las extremidades inferiores estuvieron asociadas con el rendimiento y fueron factores representativos de las mejores kayakistas.

- ✓ **Sexta**: La edad biológica debería tenerse en cuenta, no solo para la identificación y selección de jóvenes talentos, sino también para adecuar los programas de entrenamiento al desarrollo de los deportistas.

- ✓ **Séptima:** La evolución de los parámetros antropométricos más característicos de los palistas senior de élite se produjo de manera más evidente en torno a la edad de máximo crecimiento en altura (APHV) en deportistas jóvenes, especialmente de categoría masculina.

- ✓ **Octava:** En categorías jóvenes se observó una tendencia de proporcionalidad corporal hacia una morfología compacta, robusta y atlética representada por valores *Phantom* positivos en las extremidades superiores y tronco, especialmente en los perímetros y diámetros.

VIII – REFERENCIAS BIBLIOGRÁFICAS

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IX - APÉNDICES

APÉNDICE 1: Calidad de las publicaciones

- ✓ Estudio 1.- López-Plaza D, Alacid F, Muyor JM, López-Miñarro PÁ. Differences in anthropometry, biological age and physical fitness between young elite kayakers and canoeists. Journal of Human Kinetics. 2017;57(1):181-90.
    - Índice de impacto (*Journal Impact Factor*): 1,174
    - Puesto en el *Journal of Citation Report* (JCR): 61
    - Área de conocimiento: *Sport Sciences*
    - Cuartil: Q3
    - Número de citas (JCR): 1

- ✓ Estudio 2.- López-Plaza D, Alacid F, Muyor JM, López-Miñarro PÁ. Sprint kayaking and canoeing performance prediction based on the relationship between maturity status, anthropometry and physical fitness in young elite paddlers. Journal of Sports Sciences. 2017;35(11):1083-90.
    - Índice de impacto (*Journal Impact Factor*): 2,73
    - Puesto en el *Journal of Citation Report* (JCR): 19
    - Área de conocimiento: *Sport Sciences*
    - Cuartil: Q1
    - Número de citas (JCR): 3

3. López-Plaza D, Alacid F, Rubio JÁ, López-Miñarro PÁ, Muyor JM, Manonelles P. Morphological and physical fitness profile of young female sprint kayakers. Journal of Strength and Conditioning Research. 2019 (In press).

- Índice de impacto (*Journal Impact Factor*): 3,02 (2018)
- Puesto en el *Journal of Citation Report* (JCR): 29
- Área de conocimiento: *Sport Sciences*
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- Número de citas (JCR): -

4. López-Plaza D, Manonelles P, López-Miñarro PÁ, Muyor JM, Alacid, F. A longitudinal analysis of morphological characteristics and body proportionality in young elite sprint paddlers. Physician and Sportsmedicine. 2019 (In press).

    - Índice de impacto (*Journal Impact Factor*): 1,87
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