UNIVERSIDAD POLITÉCNICA DE MADRID
Facultad de Ciencias de la Actividad Física y del Deporte (INEF)

Nutrition in High Performance Wheelchair Basketball in Two European Countries

NUTRICIÓN EN ALTO RENDIMIENTO DE BALONCESTO EN SILLA DE RUEDAS EN DOS PAÍSES EUROPEOS

Tesis Doctoral

Lena Grams

Magistra Artium of Sport Science

Master of Science in Physical Activity and Sport

Madrid, 2016

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Ernährung und Nahrungszusammensetzung von
Hochleistungssportlern im Rollstuhlbasketball in zwei
europäischen Ländern

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Abstract

Interest in Paralympic sports, especially wheelchair basketball has been growing over the last several years, and achieving high performance levels is challenging for every athlete. Already small variations of performance can determine the difference between winning and losing and therefore, in addition to physical condition, an optimized diet is important to enhance performance. Some studies have shown that wheelchair athletes have a restricted energy intake in comparison to able-bodied athletes and therefore an optimal macro- and micronutrient intake should be achieved through a nutrient-dense diet, such as the Mediterranean diet. Furthermore, body composition plays a key role in performance to assure successful training and competition, with nutrition being an important factor in that relation.

Because little is known regarding wheelchair sports, nutrition, and body composition, this thesis tries to add new insights in these areas and the relations among them. Therefore, data of the Spanish male and female as well as the German male national wheelchair basketball teams were analyzed between May 2013 and August 2015, each time in the precompetitive phase of each year. The thesis consisted of four separate studies, which evaluated macronutrient and micronutrient intakes in the first two studies in the male Spanish team, body composition and the relation between anthropometric variables and nutrition in the Spanish male and female teams in the third study, and nutritional intake and the adherence to the Mediterranean diet in the male Spanish and German national teams were evaluated in the fourth study.

In the first study the diet composition and meal frequency of the Spanish male national team were estimated using a three day food-weighing diary in May and June 2013. From six possible meals per day, the players consumed 3.8 ± 0.8 meals in May and 4.0 ± 0.8 in June. The distribution of macronutrients was 3.8 ± 1.3 g/d carbohydrates, 1.7 ± 0.6 g/d protein and $36 \pm 5\%$ of energy derived from fat in May and 4.2 ± 1.9 g/d carbohydrates, 1.5 ± 0.5 g/d protein and $32 \pm 5\%$ of energy comes from fat in June. The results revealed several inadequacies (carbohydrate intake below and fat intake above recommendations) concerning the principles of sports nutrition and individual requirements have to be taken into account due to high variability of age and weight in this group. Improvements of dietary patterns have been observed, but further nutritional advice for wheelchair players seems necessary to correct imbalances and ensure health and performance improvements.

In the second study macro- and micronutrient intake of the Spanish male national team were determined using a three day food-weighing diary during three training camps in two consecutive years. After categorizing the consumed food into fourteen food groups these groups were used to identify the best predictors of the adequacy of intake for seventeen

micronutrients of particular interest for athletes. Total energy intake correlated positively with the adequacy of all micronutrient intake levels, except for vitamins A and E. Five B vitamins and phosphorus, selenium, and iron showed 100% adequacy. All other micronutrient intake levels were found to be inadequate. The fruit, fish and cereal food groups were found to be predictors of adequate intake of most micronutrients. Together with energy intake, the intake of the fruit and egg food groups increased significantly over time, along with improved iodine and magnesium adequacy levels. Because the adequacy of micronutrient intake correlates positively with energy intake, a varied diet that includes cereals, fish and fruits, is especially important for players with low levels of energy intake. Supplements may be a possible solution in case adequate micronutrient intake cannot be achieved through regular dietary intake alone.

The third study was conducted during a five day training camp, where the Spanish male and female national teams were evaluated regarding nutrition and body composition by standardized anthropometric assessments. Anthropometric analysis showed no differences in the sum of all eight skinfolds thickness between males and females. The sum of four skinfolds was negatively related to the percentage of energy intake derived from carbohydrates but positively related to the percentage of energy derived from fat. Male wheelchair athletes had a better overall diet quality than female athletes due to greater fruit and vegetable intake. The relationship between body composition and nutrition showed lower skinfold thickness for athletes who had a higher percentage of carbohydrates and a lower percentage of fat intake.

The last study of this thesis evaluated diet composition by recall questionnaires in the German and Spanish male national teams. The adherence to a Mediterranean diet was analyzed using the Mediterranean Adherence Index (MAI) and the quotient of unsaturated to saturated fatty acids. The energy from fat was higher in the Spanish ($43\pm5\%$) than in the German team ($32\pm6\%$). The MAI did not differ and both teams barely adhered to the Mediterranean diet. The quotient of unsaturated to saturated fatty acids was higher in the Spanish (2.08 ± 0.26) due to the consumption of olive oil compared to the German athletes (1.54 ± 0.30). Both teams consumed an unbalanced diet with high amounts of fat and carbohydrate intake below recommendations.

Generally speaking, more nutritional knowledge is necessary for wheelchair basketball athletes to make optimal food choices, such as replacing energy-dense with nutrient-dense foods. In order to achieve this, short-term nutritional advice is essential. In addition, body composition through anthropometric measurements is a practical, easy applicable, and cost effective tool and useful to monitor training and/or nutrition interventions in wheelchair athletes.

Resumen

El interés en los deportes paraolímpicos, especialmente en el baloncesto en silla de ruedas se ha ido incrementando en los últimos años, por otra parte en esta población de igual manera que en otros deportistas el hecho alcanzar altos niveles de rendimiento constituye el principal objetivo o reto común. Es evidente que, pequeñas variaciones de rendimiento pueden determinar la diferencia entre ganar y perder y por tanto además de la condición física, hay que asegurar otros factores que potencialmente podrían afectar al rendimiento; entre ellos destacar el consumir una dieta óptima enfocada a conseguir mejorar el rendimiento físico. Algunos estudios, han demostrado que los deportistas en silla de ruedas, siguen un patrón alimentario con una restricción de energía en comparación con deportistas no discapacitados; por lo tanto la ingesta de macro y de micro nutrientes óptima, debe lograrse a través de una dieta de alta densidad en micronutrientes, como es la dieta mediterránea. Por otra parte la composición corporal está relacionada con el patrón nutricional, que constituye otro factor determinante del rendimiento físico y podría al menos en parte, asegurar una adecuada respuesta y adaptación al entrenamiento y /o a la competición.

Debido a que aún es escasa la investigación en el ámbito de los deportes en silla de ruedas y que es reducido el número de trabajos publicados acerca de su patrón alimentario y de su composición corporal, esta tesis trata de añadir nuevos conocimientos en ambas áreas. Se recogieron datos en los equipos nacionales femenino y masculino de España, así como en el equipo nacional masculino de baloncesto en silla de ruedas de Alemania durante el periodo comprendido entre mayo del año 2013 y agosto del año 2015; dichas tomas se realizaron cada año en la misma fase de entrenamiento, en concreto en la etapa precompetitiva. La tesis consistió en cuatro estudios separados; en los dos primeros se evaluó la ingesta de macronutrientes y micronutrientes en el equipo español masculino; en el tercer estudio se determinó la composición corporal y la relación entre las variables antropométricas y nutricionales en los equipos masculino y femenino de España; el cuarto estudio se analizó la ingesta nutricional en los equipos de la selección de baloncesto en silla de ruedas masculino de los dos países (España y Alemania) centrándose en comparar la adherencia a la dieta mediterránea en ambas selecciones.

En el primer estudio, se analizó la composición de la dieta y la frecuencia o número de comidas diarias realizadas en la selección nacional masculina española, dicha evaluación se realizó mediante la pesada de la ingesta alimentaria durante dos periodos de tres días en dos meses consecutivos (mayo y junio). Al analizar el patrón alimentario, se encontró que de las seis posibles comidas diarias, los jugadores consumieron $3,8 \pm 0,8$ comidas diarias en la

concentración del mes de mayo, y que ésta se incrementó hasta $4,0 \pm 0,8$ comidas diarias en la concentración de junio del mismo año. Referente a la ingesta de macronutrientes, se encontró que en el mes de mayo se consumieron $3,8 \pm 1,3$ g/kg de peso corporal de hidratos de carbono y $1,7 \pm 0,6$ g/kg de proteína y que en esta ocasión un $36 \pm 5\%$ de la energía derivó de los lípidos; con respecto a la siguiente valoración llevada a cabo durante el mes de junio se aportaron $4,2 \pm 1,9$ g/kg hidratos de carbono y $1,5 \pm 0,5$ g/kg proteínas y un $32 \pm 5\%$ de la energía provino de los lípidos. Estos resultados pusieron de manifiesto una ingesta deficiente en hidratos de carbono y un consumo de grasa por encima de las recomendaciones, al compararlo con los recomendaciones establecidas en el ámbito de la nutrición deportiva, no cumpliendo los requisitos individuales, teniendo en cuenta la gran variabilidad en cuanto a la edad y peso corporal de este grupo. Entre los dos periodos (mayo y junio) se observaron mejoras de los patrones dietéticos, por lo que se requiere más formación y asesoramiento nutricional para estos jugadores en silla de ruedas, con el objetivo de corregir los desequilibrios y garantizar las mejoras en su salud y en su rendimiento físico.

En el segundo estudio de análisis de ingesta de macro y micronutrientes de la selección española masculina se realizó una recogida de datos mediante la pesada de todos los alimentos consumidos en periodos de tres días, durante tres concentraciones de entrenamiento llevadas a cabo en dos años consecutivos. Se realizó la subdivisión de todos los alimentos por ellos consumidos en catorce categorías, con el objetivo de identificar las mejores alimentos que fueron predictores de la adecuación de la ingesta de diecisiete micronutrientes seleccionados por su particular interés para los deportistas. La ingesta total de energía se correlacionó positivamente con la ingesta adecuada de casi todos los micronutrientes, a excepción de las vitaminas A y E. Se determinó que la ingesta de cinco vitaminas del grupo B, además del fósforo, selenio y hierro se cubrieron con la dieta alcanzando el 100% de sus requerimientos. Por otra parte, el resto de la ingesta de micronutrientes fue inadecuado, ya que no alcanzó las recomendaciones. Se encontró que los grupos de alimentos de frutas, pescado y cereales fueron predictores de la ingesta adecuada de mayoría de los micronutrientes. A lo largo del periodo de valoración se observó un aumento en el consumo de energía, así como en el de frutas y huevos lo que condujo a un incremento en el aporte de yodo y a alcanzar las recomendaciones de ingesta de magnesio. Debido a que la ingesta adecuada de micronutrientes se correlacionó positivamente con la ingesta de energía, se concluyó que una dieta variada que incluya cereales, pescado y frutas, es especialmente importante para aquellos jugadores que consuman dietas muy restringidas en energía. En ciertos casos, se determinó que sugerir la ingesta de suplementos podría ser una posible solución cuando no se alcanzase la ingesta recomendada de micronutrientes a través de su

alimentación habitual.

El tercer estudio se llevó a cabo durante una concentración de entrenamiento que duró cinco días, en la que coincidieron las selecciones nacionales femenina y masculina españolas, se realizó la evaluación de la nutrición y de su composición corporal mediante mediciones antropométricas estandarizadas. En el análisis antropométrico no se mostraron diferencias en la suma de los ocho pliegues cutáneos entre varones y mujeres. Se determinó que la suma de cuatro pliegues cutáneos presentó una correlación negativa con el porcentaje de energía de la dieta derivada de los hidratos de carbono; por el contrario se encontró una relación positiva al relacionar dicha suma, con el porcentaje de energía de la dieta derivada de los lípidos. Se determinó que los baloncestistas en silla de ruedas varones tenían una calidad superior de la dieta con respecto a las mujeres del mismo deporte, concretamente se observó en los varones un mayor consumo de frutas y de verduras. Se demostró una relación entre la composición corporal y la nutrición ya que, fue menor el espesor de varios pliegues cutáneos cuando se consumieron dietas con un mayor porcentaje de energía en forma de hidratos de carbono y un menor porcentaje en forma de lípidos.

El último estudio de esta tesis, analizó la composición de la dieta que fue valorada mediante cuestionarios de recuerdo en los equipos masculinos alemán y español. La adherencia a la dieta mediterránea, se analizó mediante el Índice de Adherencia Mediterránea (MAI) y a través del cociente de las grasas no saturadas con respecto a las saturadas. El porcentaje de energía derivada de los lípidos en la dieta fue más elevado en el equipo español ($43\pm 5\%$) que en el equipo alemán ($32\pm 6\%$). El índice MAI fue similar y se observó una baja adherencia a la dieta mediterránea en ambos equipos. En el cociente de distribución de grasas, se observaron valores más altos en el equipo español ($2,08\pm 0,26$) frente a los alemanes ($1,54\pm 0,30$), lo que se asoció a un mayor consumo de aceite de oliva entre los españoles. Ambos equipos consumieron una dieta desequilibrada con una alta ingesta de lípidos y un bajo consumo de hidratos de carbono. En términos generales, es necesario una mayor formación en aspectos nutricionales en baloncestistas en silla de ruedas con el objetivo de promover la selección de alimentos óptimos; en general se sugiere inducir a la sustitución de alimentos de alta densidad energética por alimentos de alta densidad en micronutrientes pero de baja densidad energética, y para lograr este objetivo a corto plazo se hace necesario un asesoramiento nutricional. Por otra parte, determinar la composición corporal a través de la medición antropométrica puede ser un instrumento económico, práctico y de fácil uso en estos baloncestistas en silla de ruedas por su utilidad para controlar las intervenciones de entrenamiento y / o de nutrición.

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ACSM	American College of Sports Medicine
BMI	Body mass index
C1-C7	7 cervical vertebrae
CHO	Carbohydrate
CV	Coefficient of variation
d	Cohen's d
DASH	Dietary Approaches to Stop Hypertension
DKSH	Diethelm Keller Siber Hegner
DNA	Deoxyribonucleic acid
DRI	Dietary Reference Intake
DXA	Dual energy X-ray absorptiometry
EAR	Estimated Average Requirements
EE	Energy expenditure
e.g.	for example
EI	Energy intake
et al.	and others
FNB	Food and Nutrition Board
g	Hedges' g
IGF-1	Insulin-like growth factor-1
IPC	International Paralympic Committee
ISAK	International Society for the Advancement of Kinanthropometry
ISSN	International Society of Sports Nutrition
IWBF	International Wheelchair Basketball Federation
L1-5	5 lumbar vertebrae
MAI	Mediterranean Adequacy Index
n	number of participants
n.s.	not significant
p	p-value
r	Correlation coefficient
RDA	Recommended Dietary Allowance
RNA	Ribonucleic acid
S1-5	5 sacral vertebrae

Index of Abbreviations

SCI	Spinal cord injury
SD	Standard deviation
SPSS	Statistical Package for the Social Sciences (statistic program)
T1-12	12 thoracic vertebrae
TC1-3	Training Camp 1-3
UL	Tolerable Upper Intake Level
W	Kendall's W
η^2	Partial eta-squared
ΣSK_{41}	Sum of biceps, triceps, subscapular, and iliac crest skinfolds
ΣSK_{42}	Sum of triceps, subscapular, iliac crest, and abdominal skinfolds
ΣSK_8	Sum of eight skinfolds
ΣSK_{Trunk}	Subscapular, abdominal, and iliac crest skinfolds
ΣSK_{Legs}	Thigh and calf skinfolds

Chapter One

Introduction

1.1 Research background

Chapter One outlines the most important areas concerning Paralympic athletes with special focus on athletes with spinal cord injuries (SCI) and amputations. Due to the topic of the thesis, nutritional aspects are described more detailed than other areas about disabled athletes and wheelchair basketball.

1.1.1 Wheelchair basketball

Interest in wheelchair sports has been growing over the last several years (Rastmanesh et al. 2007, Krempien and Barr 2011) and the Paralympic Games for athletes with an impairment has become one of the world's largest sporting events. At the start of the Paralympic Movement in 1960 with the first Paralympic Games held in Rome 400 athletes from 23 countries took part in the games. Nowadays over 4,328 athletes from 160 countries participated in the last Paralympic Games in Rio 2016 (International Paralympic Committee 2016). One of the initial eight sports, which were part of the first Paralympic Games, was wheelchair basketball and it has emerged since then into one of the most popular wheelchair sports with overall 12 men's and 10 women's teams participating in the last Paralympic Games in Rio 2016 (International Paralympic Committee 2016). Therefore, the rising competitive demands, external pressures and the need for high performance levels are becoming more challenging for athletes (Rastmanesh et al. 2007, Krempien and Barr 2011). Likewise the differences between success and failing in Paralympic events are becoming smaller over the years (Perret 2015). Hence, athletes should consider all factors that can help enhance their health and performance (Broad and Burke 2014).

In wheelchair basketball, performance is based on three factors: the athlete, the wheelchair and the interaction between the two (Goosey-Tolfrey 2010a). The adaption of the wheelchair to the game has led to wheelchairs with minimized weight (Cooper and De Luigi 2014) and improved propulsion through biomechanical enhancements (Vanlandewijck et al. 2001), which both allow higher levels of performance. Finally, the athletes' physical condition plays an important role, and they are undertaking training programs that are comparable to those of their able-bodied counterparts (Broad and Burke 2014).

A team of wheelchair basketball players will have a wide range of disabilities, as per rule of the International Wheelchair Basketball Federation (IWBF) each player is assigned a classification according between 1.0 and 4.5 points. In a game the total points of a team of five players must not exceed 14 points (International Wheelchair Basketball Federation 2016). The classification is based on the ‘volume of action’ in three directions (vertical, forward, and sideways plane), the ‘pelvic stability’ (active and passive), and the ‘characteristics of basketball movement’ (pushing, breaking/pivoting, dribbling, passing/catching, shooting/rebounding, and contact), together with some special considerations for players with lower and upper limb deficiencies which have to be taken into account (International Wheelchair Basketball Federation 2014). Although this classification is related to the player’s athletic ability and skill and not directly to the degree of impairment, players with an amputation will be classified higher than players with SCI.

1.1.2 Medical conditions in athletes with spinal cord injuries and amputations

Overall, despite their impairment, there are no large differences between disabled athletes in general and abled-bodied athletes regarding medical issues despite their impairment (Strupler and Perret 2014). For instance, substrate oxidation rates are comparable (Knechtle et al. 2003), and no strong evidence exists that muscles of athletes with SCI responded differently than those of able-bodied. However, some specific issues should be mentioned to understand consequences, possibly occurring in athletes with SCI.

The spinal cord controls three main functions: motor functions to voluntarily control skeletal muscles, sensory functions to transmit sensory information to the brain, and vegetative functions, which are controlled by the autonomic nervous system and including e.g. cardiovascular functions, digestion, respiration, or thermoregulation (Goosey-Tolfrey 2010b). The spinal cord can be injured in various ways, such as diseases (e.g. poliomyelitis), congenital malfunctions (e.g. spina bifida), or accidents. Affected functions and its severity depend on the level and completeness of injury (Van de Vliet et al. 2011). The protection of the spinal cord, the spinal column, consists of 33 vertebrae, which are divided into five regions. Individual vertebrae are named by region and position from top to bottom: 7 cervical (C1 to C7), 12 thoracic (T1 to T12), 5 lumbar (L1 to L5), 5 sacral (S1 to S5), and 4 coccygeal (fused) vertebrae. The spinal cord itself is divided into 31 segments: 8 cervical (C1 to C8), 12 thoracic (T1 to T12), 5 lumbar (L1 to L5), 5 sacral (S1 to S5), and 1 coccygeal segments. Each segment has a pair of nerves for the left and right body side (Goosey-Tolfrey 2010b).

After injury the connection between the brain and the injured segment as well as all segments below lesion can be affected, though control above lesion level remains. Lesions at or above T1 are called *quadriplegia*, because all four limbs are affected, whereas lesions below T1 are called *paraplegia*, in which the upper limbs can be fully controlled. If some function below lesion level still remains, the injury is known as *incomplete* otherwise as *complete*. The loss of motor, sensory, and vegetative function in SCI may lead to complications such as autonomic dysreflexia¹, pressure ulcers, and urinary tract infections (Strupler and Perret 2014).

Additionally, some medical conditions have to be considered, particularly in this rarely investigated population, which influence nutrition. A slightly higher intake of protein may be necessary to support and promote healing of pressure ulcers or wounds, which are often seen in wheelchair athletes (Lee et al. 2006, Reddy et al. 2008), or pressure sores at the stump of amputation (Strupler and Perret 2014). A poor nutritional status is part of this pathology and screenings for certain proteins (albumin, ferritin, and hemoglobin) and vitamins (vitamin B₁₂ and folic acid) are recommended to avoid pressure ulcers (Cruse et al. 2000). Athletes with SCI also have a limited sweating response (Price 2006, Hopman et al. 1993) or an altered maintenance of bowel function (Levine et al. 1992), which have to be taken into account when nutritional strategies are developed. Thus colonic transit time may be in- or decreased depending on the consumed foods (Cameron et al. 1996, Faaborg et al. 2011) and gastric emptying after solid meals is prolonged in SCI (Fynne et al. 2012, Kao et al. 1999, Segal et al. 1995). Therefore the individual bowel functions and habits of each athlete have to be known to avoid negative impacts on performance during sporting events (Goosey-Tolfrey et al. 2014). In addition SCI affects the bladder function depending on the level, duration, and severity of the lesion (Cruz and Cruz 2011) and as a consequence of a ‘neurogenic bladder’² athletes with SCI often have to use intermittent or continuous bladder catheterization to empty their bladder (Goosey-Tolfrey et al. 2014).

Another common medical problem in athletes with SCI is osteoporosis as a consequence of inactivity of the paralyzed extremities and although athletes with SCI have higher bone mineral densities than sedentary persons with SCI (Goktepe et al. 2004), compared to able-bodied athletes their bone mineral density is lower (Miyahara et al. 2008). Therefore, micronutrients involved in bone health such as calcium, magnesium, and vitamin D are

¹ Autonomic dysreflexia: Acute episodic hypertension resulting from sympathetic hyperactivity.

² Neurogenic bladder: Lacking bladder control due to damaged nerves, which control the muscles responsible for holding urine and emptying the bladder.

tremendously important for wheelchair athletes. A screening for vitamin D deficiencies is therefore recommended for athletes (Strupler and Perret 2014), especially in winter or for indoor sports (e.g. wheelchair basketball) in general with limited sun exposure to maintain optimal health and performance (Flueck et al. 2016).

Micronutrient deficiencies in general are common in disabled athletes mainly due to a restricted energy intake (Krempien and Barr 2011). Such inadequate micronutrient intakes may weaken one's immune system while increasing risks of illness. In fact, during the 2012 Paralympic Games in London, the incidence of illness was high among disabled athletes, with 19% of all participating male wheelchair athletes being affected (Schwellnus et al. 2013), and resulted in time away from training and competition in some cases (Derman et al. 2014). In contrast, only 9% of all male able-bodied athletes suffered from an illness during the 2012 Summer Olympic Games (Engebretsen et al. 2013).

The intake of medications is not uncommon in Paralympic athletes, especially when treating the above-mentioned conditions. Hence complications can occur related to intense sport participation, impairment and medication (Van de Vliet et al. 2011). However, such complications are a common problem in able-bodied athletes as well (Engebretsen et al. 2013). Athletes and coaches have to be aware of these circumstances and besides medications, its side effects, and anti-doping regulations, possible interactions with supplements intake or even general food intake have to be taken into account (Strupler and Perret 2014).

1.1.3 Sports nutrition – Macro- and micronutrients and fluids

The principles of sport nutrition should be considered to support training effectiveness and to improve performance levels during training and competition (Rodriguez et al. 2009, Kreider et al. 2010). Following these principles will lead to an optimized and well-balanced diet with sufficient energy intake and optimal timing of macronutrient intake to compensate the high energy expenditure during training and competition and adapt positively to training (Kreider et al. 2010, Rodriguez et al. 2009, Thomas et al. 2016).

An optimal dietary intake of carbohydrates maintains body weight and replenishes glycogen stores, protein builds and repairs tissue, and fat provides essential fatty acids and fat-soluble vitamins (Kreider et al. 2010, Thomas et al. 2016).

Recommendations for able-bodied athletes regarding dietary intake in relation to exercise

intensity took only two macronutrients, carbohydrates and protein, into account (Kreider et al. 2010, Thomas et al. 2016). Besides the amount of carbohydrates and proteins consumed per day the timing in relation to exercise is pivotal, because liver and muscle glycogen stores are limited and carbohydrate loading is recommended before and during long lasting exercise (Kerksick et al. 2008, Kreider et al. 2010, Potgieter 2013, Thomas et al. 2016). After exercise depleted glycogen stores and muscle protein should be refueled to recover from exercise between training sessions or competitive events (Kreider et al. 2010, Thomas et al. 2016).

However, existing recommendations from the American College of Sports Medicine (ACSM), the International Society of Sports Nutrition (ISSN) for macronutrient intake and from the United States and Canada Dietary Reference Intakes (DRI) to determine adequate micronutrient intake are based on able-bodied athletes. No specific recommendations for Paralympic sports (Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2011, Kreider et al. 2010, Jeukendrup 2013, Thomas et al. 2016), and neither for other special populations or in specific extreme conditions (high or low temperature, pressure both hyperbaric³ or hypobaric as under space conditions) yet exist.

An appropriate fluid status is also essential in athletes for optimal health and performance during exercise, because athletes can lose great amounts of water and minerals (e.g. sodium, potassium, magnesium and calcium) through sweat during exercise additionally to the usual daily losses. Although beneficial effects of hydration are similar in able-bodied and disabled athletes, such as the positive effect of fluid replacement on the cardiovascular drift during prolonged exercise (Zacharakis et al. 2013), regarding disabled athletes some practical and medical issues have to be considered. These issues often lead to individualized fluid intake strategies. Some wheelchair athletes may restrict their fluid intake due to difficulties in accessing bathrooms especially during training sessions or competitions. As mentioned previously, athletes with SCI may also have a limited sweating response (Price 2006) and a reduced ability to sweat below lesion level due to no sweat gland activity below lesion (Pritchett et al. 2015); this has to be taken into account especially in athletes with quadriplegia (Goosey-Tolfrey et al. 2014, Hopman et al. 1993). A determination of sweat rates under various environmental conditions to define individual hydration strategies is recommended (Goosey-Tolfrey et al. 2014). This was not an aim of this thesis and therefore it was not examined.

³ Hyperbaric: Atmospheric pressure greater than at sea level.

Beside a balanced macronutrient intake, adequate intakes of micronutrients including vitamins and minerals are essential to maintain health and regulate body functions. For athletes their roles in energy metabolism, blood and bone health, and antioxidant function are very important (Rodriguez et al. 2009, Kreider et al. 2010). The B group vitamins (thiamin, riboflavin, niacin, vitamin B₆, pantothenic acid, folic acid, and vitamin B₁₂) and the minerals iodine, iron, magnesium, and zinc assist in the conversion of macronutrients into energy and therefore are essential in athletes regarding their high energy expenditure. As the red blood cell production is increased in athletes, iron as part of hemoglobin and folic acid and vitamin B₁₂ for the synthesis of Deoxyribonucleic acid (DNA) and Ribonucleic acid (RNA) are needed (Deakin 2011). To prevent stress fractures calcium, phosphorus, and vitamin D are required to improve bone mineral density (Deakin 2011). The antioxidants vitamin A, C, and E and the minerals selenium and zinc protect cells and tissues against damage from free oxygen radicals, which are increased by exercise (Deakin 2011). Although athletes may have slightly higher requirements for these micronutrients, there are no special recommendations for the requirements of micronutrients for athletes compared to healthy non-athletes (Rodriguez et al. 2009, Thomas et al. 2016, Kreider et al. 2010, Zello 2006).

1.1.4 Dietary pattern and the Mediterranean diet

A well balanced diet consists of a variety of food items consumed throughout the day. The daily food choice is motivated by external signals like food availability and diversity, social and culture settings, time of the day, and internal signals such as stomach contractions and hypothalamic responses (Birkenhead and Slater 2015, Burke and King 2012, Cummings and Overduin 2007), that makes us feel hunger, appetite, and satisfaction. The portion sizes, proportions, variety, and combinations of these habitually consumed food items together with the frequency of their intake are defined as a dietary pattern (U.S. Department of Health and Human Services 2015). Besides different individual dietary patterns there are some dietary patterns with typical consumptions that are named e.g. after the food items consumed such as the vegetarian or the vegan dietary pattern, the region, where they are mainly consumed, such as the Western or the Mediterranean dietary pattern or their purpose such as the DASH (Dietary Approaches to Stop Hypertension) dietary pattern (Schwingshakl and Hoffmann 2015). In case of a healthy dietary pattern the consumed food items fit together to meet the requirements of all essential nutrients without exceeding their limits.

The healthy Mediterranean diet, which was traditionally consumed only in the Mediterranean region (mainly Greece, Italy, France, and Spain) (Ortega 2006, Zazpe et al. 2014), is characterized by the consumption of typical food groups such as fruit, vegetables, cereals, legumes, nuts, fish or olive oil (Alberti et al. 2009, Castro-Quezada et al. 2014). Nowadays the name ‘Mediterranean diet’ corresponds more to the dietary pattern than to the region (Bere and Brug 2010), because many countries that are not located in the Mediterranean area have adapted parts of it to their own eating patterns (Serra-Majem et al. 2009). In general, the quantity of micronutrients is very high in Greek foods, one of the origins of the Mediterranean diet (Vasilopoulou and Trichopoulou 2009). In fact, the food groups typically characterizing the Mediterranean diet, cereals, fruit, legumes, and vegetables, are rich in antioxidants, minerals, and vitamins, fish rich in n-3 fatty acids, and olive oil and nuts rich in unsaturated fats. The balance of both macro- and micronutrients seems to be favorable in the Mediterranean diet, which additionally has low intakes of energy-rich or nutrient-poor food groups, such as meat, prepared meals or fast food (Zazpe et al. 2014). Besides the positive effect of its components, such as a prevention of cardiovascular disease and stroke by consumption of wholegrain cereals and legumes (Flight and Clifton 2006), its positive health outcomes as a whole have been demonstrated in various epidemiological studies. A substantial protection against cardiovascular disease (Martinez-Gonzales et al. 2011) and diabetes (Martinez-Gonzales et al. 2008), a lower risk of certain chronic diseases (Estruch et al. 2006, Goulet et al. 2003) and metabolic disorders (Trichopoulos and Lagiou 2004), a treatment of the metabolic syndrome (Babio et al. 2014) or beneficial effects of metabolic risk factors (Garcia et al. 2016) have been proven. Additionally, the Mediterranean diet has been shown to be favorable on lipid metabolism, blood pressure, and inflammation. Especially impacts on the immune system are important for athletes (Marcos et al. 2003), knowing that exhaustive exercise generates transient acute inflammation and oxidative stress (Bruunsgaard 2005). Hence, these effects can be limited by a Mediterranean diet, as it contains high amounts of fruits, vegetables, nuts (Sánchez Benito et al. 2009) and fiber. Vitamins, minerals, flavonoids, and terpenes provided by fruits also protect against oxidative processes (Serra-Majem et al. 2004). Following a Mediterranean diet seems to ensure the intake of recommended specific minerals like zinc (Mesias et al. 2009) or calcium (Seiquer et al. 2008) and leads to a positive relationship between monounsaturated fat, carbohydrate, and cholesterol intake as described by a study completed in France (Maillot et al. 2011).

In the last few decades advances in food processing has led to lifestyle changes in the modern Western society and resulted in an unhealthier dietary pattern, which increasingly replaced the

Mediterranean diet even in the Mediterranean region (Odermatt 2011, Sánchez-Benito et al. 2009). This so-called 'Western diet' is often associated with negative health outcomes (Mozaffarian et al. 2016, Odermatt 2011), which is characterized by rather high contents of refined sugars, cereal grains, alcohol, salt, fatty domestic meats, and a high amount of processed foods (Cordain et al. 2005). Contrary to the Mediterranean diet, the Western diet is high in saturated fat but rather low in mono- and polyunsaturated fatty acids, plant-derived proteins, and fiber (Odermatt 2011), resulting in deficiencies of certain micronutrients such as vitamin A, C, D, and E, calcium, and magnesium (Millen et al. 2016).

Instead of preferring a specific dietary pattern the recommendations for athletes emphasize a well-balanced diet to meet vitamin and mineral requirements (Thomas et al. 2016, Rodriguez et al. 2009, Kreider et al. 2010). These recommendations are based on the assumption that athletes have high energy intakes to compensate their high energy expenditure (Thomas et al. 2016, Rodriguez et al. 2009, Kreider et al. 2010). Therefore, athletes with restricted energy intakes are at an elevated risk of inadequacies of vitamins and minerals, and a healthy and nutrient-dense⁴ diet like the Mediterranean diet may be especially important for wheelchair athletes to avoid such inadequacies. Research has shown that small changes in food choices to typical Mediterranean food groups would improve food habits to cover the daily requirements of macro- and micronutrients (Mailliot et al. 2011).

1.1.5 Energy expenditure

Energy expenditure is important and necessary to assess the energy balance with energy intake or to help athletes change their body composition. However, calculation of energy expenditure is a complex task, as it demands the measurement or estimation of the resting metabolic rate, the thermic effect of food, and the energy expenditure of exercise (Thomas et al. 2016, Price 2010). Although all three can be measured through expensive methods like the doubled labeled water technique or separately through special equipment like the indirect calorimetry, these techniques are normally not practical especially in team sports (Slater 2014). But the energy expenditure can also be estimated instead of measured with one of many published equations, which differ in the required components, e.g. age, sex, body mass, height, and/or lean body mass, and in the populations in which they were developed.

⁴ Nutrient-density: The amount of micronutrients in food. Nutrient-dense foods are the opposite of energy-dense foods (see Footnote 8) and contain a high amount of micronutrients but relatively low energy.

Therefore the resting metabolic rate can be calculated for able-bodied athletes e.g. with the Cunningham equation (Cunningham 1980), if the lean body mass is formerly measured, or by applying the Harris-Benedict equation (Harris and Benedict 1919), if only body mass can be determined. For disabled athletes, an equation according to Abel et al. (2008) can be applied. Afterwards the resting metabolic rate has to be multiplied with a physical activity factor to estimated energy expenditure. In order to calculate the physical activity factor, the energy expenditure of each daily activity can be estimated through the Compendium of Physical Activities (Ainsworth et al. 2011) for able-bodied athletes, or using values provided by Collins et al. (2010) for athletes with SCI, and by Abel et al. (2008) and Bernardi et al. (2010) for amputees. As these calculations can only estimate the actual energy expenditure, body composition measurements over time are required to examine the effectiveness of nutritional interventions.

The separation between able-bodied and disabled athletes for the estimation of energy expenditure is necessary, because energy expenditure of players with an amputation, who do not use a wheelchair for day-to-day mobility, may be increased due to their different movement pattern compared to able-bodied athletes (Meyer and Edwards 2014). In contrast the resting metabolic rate and also the energy expenditure of exercise in athletes with SCI are likely to be lower due to a smaller active muscle mass as a result of paralysis (Glaser 1985). This is caused by a reduced sympathetic nervous system activity below lesion levels (Leicht et al. 2012), and less activity or even immobility (Croft et al. 2010, Price 2010).

1.1.6 Body composition

The human body can be divided in different components, which range from atoms, molecules, and cells up to tissues depending on the level of observation. Thereby the tissues consist of muscle, skeletal, and adipose tissue with the remaining mass representing organs. This level of body composition is commonly used in athletes to examine the effectiveness of training and/or nutritional interventions over time by assessing changes in muscle and fat mass. The methods to determine body composition differ in a number of factors including technical and practical issues as well as the impact of the athlete's impairment on the measurement. The two most frequently used assessment methods for body composition in able-bodied athletes are the field-based method of skinfolds thickness, an anthropometric technique, followed by the laboratory method of dual energy X-ray absorptiometry (DXA) (Meyer et al. 2013). Several studies showed that both methods could be applied to wheelchair athletes (Sutton et

al. 2009, Granados et al. 2015, Inukai et al. 2006, Willems et al. 2015). In case of the doubled indirect measurement technique of skinfolds thickness, muscle and fat mass can only be estimated out of the raw data through regression equations. Taking skinfolds is an anthropometric measurement that is also widely used in different clinical areas. In particular certain skinfolds showed a good correlation with total body fat, depending on the time of the life cycle and sex. However, in order to use such equations some assumptions are necessary. On one hand the skinfold positions must be representative and reliable and on the other hand the subcutaneous adipose tissue measured must represent the total body fat. Finally, the study population used to develop an equation must be representative to the person measured.

Despite the existence of various validated equations, all of them are based on able-bodied athletes and cannot be transferred to disabled athletes (Sutton et al. 2009, Willems et al. 2015, Goosey-Tolfrey et al. 2016). However, if the skinfold thickness measurement is standardized, e.g. following the standards of International Society for the Advancement of Kinanthropometry (ISAK), and the raw data are used, the effectiveness of training and/or nutritional interventions can be evaluated through changes of skinfold thickness in relation to changes of body mass over time.

Skinfold thickness measurement can also be used to assess the changes of different body segments, which is an important concern in wheelchair athletes, because the body composition of their upper body differs from their lower body as consequence of muscle atrophy below lesion level in athletes with spinal cord injury and daily wheelchair use combined with high level sport participation (Miyahara et al. 2008, Sutton et al. 2009).

The above-mentioned areas around Paralympic sport, particularly wheelchair basketball, are raising several interesting and important research questions regarding nutrition and body composition in disabled athletes.

1.2 Statement of problems

Until now, very few studies have examined the energy intake patterns of wheelchair athletes, and all of these studies have reported nutritional key points such as general low energy intake levels. Apparently, a low carbohydrate intake, together with a high fat intake within Paralympic athletes and wheelchair basketball players (Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2011, Krempien and Barr 2012), have been detected. Low energy intakes often lack dietary variety, which can result in inadequate micronutrient intakes, followed by a weaker immune system and altered body functions. To avoid such inadequacies a healthy nutrient-dense diet may be beneficial (Goosey-Tolfrey et al. 2014). One such recognized diet is the Mediterranean diet, which is supposed to be traditionally consumed in Spain and therefore Spanish wheelchair players may have fewer inadequacies than players of non-Mediterranean nations (Ortega 2006).

Beside dietary intake also body composition plays a pivotal role in performance and is related to nutrition and training. Therefore, body composition could be used to monitor and investigate nutrition and training interventions. However, this requires a method of body composition measurement that is cost effective, reliable and practical to be performed frequently (Slater 2014). For this reason, we chose to examine body composition by applying skinfold thickness as an anthropometric method, which incorporates all these demands. Unfortunately, data of anthropometric reference values are lacking and cannot be used by athletes, nutritionists, and trainers to assess the athlete's standing in relation to other Paralympic athletes.

Knowledge about the stated problems and the collection of further data can help to avoid nutritional mistakes and improve the athletes' health and performance.

Hence objectives of this thesis are to evaluate the macro- and micronutrient intake before and after nutritional advice; to assess body composition and its relation to dietary intake; and to examine the influence of dietary pattern on nutrient adequacy.

1.3 General aims of the current thesis

- (A) Description of nutritional habits of elite wheelchair basketball players during different times of the year in the precompetitive period.
- (B) Evaluation of body composition by applying anthropometric analysis in elite wheelchair basketball players.

1.3.1 Aims of the first study (Chapter Two)

- (A) Description of dietary patterns pre and post nutritional advice in elite male wheelchair basketball.
- (B) Evaluation of meal frequency during a precompetitive period in elite male wheelchair basketball.

1.3.2 Aims of the second study (Chapter Three)

- (A) Evaluation of micronutrient intakes in elite male wheelchair basketball players based on the latest Food and Nutrition Board (FNB) guidelines.
- (B) Analysis of food groups that are crucial for the adequacy of micronutrient intakes.
- (C) Examination, whether nutritional advice after one month and again one year after the initial recommendations improve diet quality levels.

1.3.3 Aims of the third study (Chapter Four)

- (A) Examination and description of segmental body composition data in male and female high-performance wheelchair basketball players.
- (B) Analysis of dietary intake and its relationship to body composition and further anthropometric variables in male and female high-performance wheelchair basketball players.

1.3.4 Aims of the fourth study (Chapter Five)

- (A) Comparison of the diet composition of high performance German and Spanish male wheelchair basketball athletes during precompetitive training camps.
- (B) Evaluation of the quality of the players' diets with particular focus on whether the teams followed the Mediterranean diet.

1.4 Structure of the thesis

Each chapter of this thesis is written following the same structure (Introduction, Methods, Results, Discussion, Limitations), because each one has been either already published (Chapter Two and Three) or is currently under review by a peer reviewed international journal (Chapter Four and Five). Despite the fact, that the layout had to be adapted to each different journal, the author decided to use the same structure for each chapter. Because the published article of Chapter Two included additional data of biomechanical speed measurements, which are not relevant for this thesis due to the focus on nutrition, the corresponding parts are excluded in Chapter Two. The complete article could be found in Appendix D.

The study populations of the whole thesis were elite Spanish male and female wheelchair basketball players as well as male German wheelchair basketball players belonging to the national teams.

Chapter Two describes the macronutrient intake and meal frequency of the Spanish men's national team, that has been evaluated twice in the precompetitive phase before the European Championships in 2013.

In Chapter Three, the previously mentioned team was evaluated regarding nutrition, focusing this time on micronutrient intake. Besides looking at specific food groups and their relation to the micronutrient adequacy of the players, the improvements of dietary intake over one year of evaluation have been part of that study.

The fourth Chapter includes data from 2015, where both, the male and female Spanish national team of wheelchair basketball, have been evaluated regarding nutrition and body composition. Apart from gender differences in nutrition and body composition, this chapter further compares available anthropometric data of able-bodied players with the results of the study's participants.

Chapter Five describes a study that has been realized in 2015 in Germany and Spain, where the dietary intakes of the male Spanish and German national teams in wheelchair basketball have been compared with a special focus on the Mediterranean diet and the adherence of both teams to it.

Chapter Six concludes the findings of the conducted studies of this thesis, mentions general limitations and describes practical research applications and future study ideas.

In Chapter Seven the references are displayed and the appendix incorporates all used questionnaires and consent forms of this study in English, Spanish, and German and the published version of the article presented in Chapter Two and Three.

Chapter Two

Nutritional habits in male elite wheelchair basketball players during a precompetitive period⁵

2.1 Introduction and aims of the study

Interest in wheelchair sports has been growing over the last several years (Krempien and Barr 2011, Rastmanesh et al. 2007) and the Paralympic Games have become one of the world's largest sporting events. Therefore, the rising competitive demands, external pressures and the need for high performance levels are becoming more challenging for athletes (Krempien and Barr 2011, Rastmanesh et al. 2007). In wheelchair basketball, which is one of the most popular wheelchair sports, performance is based on three factors: the athlete, the wheelchair, and the interaction between the two (Goosey-Tolfrey 2010a). The adaption of the wheelchair to the game has led to wheelchairs with minimized weight (Cooper et al. 2014) and to improve propulsion through biomechanical enhancements (Vanlandewijck et al. 2001) both of which allow for higher levels of performance. Finally, the athletes' physical condition plays an important role, and therefore, they are undertaking training programs that are comparable to those of their able-bodied counterparts (Broad and Burke 2014).

In addition to physical fitness, optimal nutrition is required to achieve the goals of performance in games and high-volume training (Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2011, Rastmanesh et al. 2007) as well as to compensate for the high-energy expenditure of training (Kreider et al. 2010, Rodriguez et al. 2009, Thomas et al. 2016). An optimal dietary intake of carbohydrates maintains body weight and replenishes glycogen stores; protein builds and repairs tissue; and fat provides essential fatty acids and fat-soluble vitamins (Kreider et al. 2010, Rodriguez et al. 2009, Thomas et al. 2016). Existing recommendations from the ACSM and the ISSN for nutrient intake in relation to exercise intensity are based on non-disabled athletes, and no specific recommendations for Paralympic sports exist to date (Goosey-Tolfrey and Crosland 2010, Kreider et al. 2010, Krempien and Barr 2011, Rodriguez et al. 2009, Thomas et al. 2016). Although some differences have to be

⁵ Published in: Ferro A, Garrido G, Villacieros J, Grams L. Nutritional habits and performance in male elite wheelchair basketball players during a precompetitive period. *Adapted Physical Activity Quarterly* 2016 (accepted for publication). See Appendix D.

considered, such as a smaller muscle mass (Goosey-Tolfrey and Crosland 2010), a limited sweating response (Price 2006) or an altered maintenance of bowel function in athletes with SCI (Levine et al. 1992), the principles of sports nutrition can be transferred to Paralympic athletes. However, existing studies have demonstrated inadequate nutritional key points, such as low carbohydrate or high fat intake in Paralympic and wheelchair basketball athletes (Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2011, Krempien and Barr 2012). Because of these insufficiencies and the above-mentioned differences to non-disabled athletes, meal frequency, including the intake of snacks between meals, may play an important role in reaching nutritional guidelines and has not yet been studied for wheelchair athletes.

Therefore, aims of this study were to: A) describe dietary patterns pre and post a nutritional advice intended to reach sports nutrition recommendations during a precompetitive period in wheelchair basketball and B) to evaluate the meal frequency of the wheelchair basketball players on the Spanish men's national team during two training camps.

2.2 Methods

2.2.1 Participants

Eleven elite male wheelchair basketball players from the Spanish national team participated in this study. The research was conducted during two high-intensity training camps in the precompetitive period between May and June in one year. None of the participants experienced injuries that had the potential to constrain their ability to perform the research task. The Ethics Committee of the Technical University of Madrid (Spain) approved the study, and it was undertaken in accordance with the Helsinki Conference for research on humans (Williams 2008). The volunteer participants were informed about the purpose of the study and gave their written consent before taking part.

2.2.2 Anthropometrics

Height was determined to the nearest 0.1 cm using a stadiometer (DKSH Switzerland Ltd, Switzerland) in a standing position if possible, and the formula recommended by Canda (2009) was applied to estimate height based on arm span and seated height for athletes who were unable to stand. Body weight was measured to the nearest 0.1 kg with athletes wearing minimal clothing using a calibrated scale (Kern, Twister Medical, Spain).

2.2.3 Diet composition

Diet composition was estimated using a food-weighing diary (1 g accuracy; Mettler-Toledo S.A.E, Barcelona, Spain) over three consecutive days in May and again in June. The weighing of each individual food item was performed by researchers during main meals: breakfast, lunch, and dinner. All foods and energy containing drinks consumed outside the main meals were considered as snacks. Snacks were taken from the buffet or from vending machines at the training site and were also weighed and noted as snacks. Before the next measurement possible leftovers of the snacks were collected and weighed. Food and beverages from the vending machines, which were not free of charge, have been reported and players provided leaflets of consumed food and drinks, which consisted of cookies, prepared cakes and isotonic drinks. All players ate together and chose their food freely from a buffet at the Higher Sport Council in Madrid (Spain); the buffet included starters, main courses, salads, fruits, deserts, and a variety of bread. As it is common for national teams to hold training camps in the precompetitive period and during championships, it seems likely that their food selection represented their normal habits for these important periods. The buffet offered the same food choices during the second evaluation. The recipes of each meal were provided by the kitchen staff and recipes not already included in the food composition database were added. To determine supplement intake, the players reported the daily amounts taken and leaflets, labels or packaging information of each supplement, which were also included in the database. DIAL v.2 software (Alce Ingeniería, Madrid, Spain) was used to determine daily nutrient intake including the macro- and micronutrient composition.

After the first period, a nutritionist provided individual written reports, including nutritional modifications with specific food intake recommendations, to optimize each player's diet composition, based on anthropometric data, energy expenditure, and personal intentions estimated through a questionnaire prior to the first period such as gaining or losing weight. Additional individual feedback was given before the second period and the importance of meal frequency and snacks was also emphasized. All nutritional advices applied to recommendations for able-bodied athletes due to the lack of specific recommendations for Paralympic athletes (Kreider et al. 2010, Rodriguez et al. 2009, Thomas et al. 2016). Therefore, macronutrients were expressed in grams per kilogram of body weight to give more practical advice for the player: carbohydrates 5-8 g/kg, protein 1.2-2 g/kg and fat 0.5-1.5 g/kg (Kreider et al. 2010, Rodriguez et al. 2009). Because the study was conducted before the updated recommendations from the ACSM were published, we used the ACSM

recommendations published in 2009 for nutritional optimizations (Rodriguez et al. 2009, Thomas et al. 2016).

Energy expenditure during each training camp was estimated through a 24 hour written activity protocol. Resting energy expenditure was estimated according to Abel et al. (2008). To determine the energy cost of physical activities the compendium of Collins et al. (2010) was used for athletes with SCI and Bernardi et al. (2010) or Abel et al. (2008) was used for other athletes, such as amputees. The estimated energy expenditure was used to compare the intensity of each training camp both taken place during the precompetitive period.

2.2.4 Statistical analysis

Normal distribution was tested with the Shapiro-Wilk test. To establish possible differences in the distribution of meals, analysis of variance with repeated measurements was performed with post hoc tests corrected by Bonferroni and with η^2 as effect size. For comparing the two periods, May and June, paired two-sided Student t-tests for parametric and Wilcoxon tests for non-parametric data were performed. Cohen's d was determined to estimate the effect size. Fisher's exact tests were used to test the proportion of players reaching the recommendations between the two periods. All data are given as the mean $\pm$ standard deviation. Significance was accepted at $p < 0.05$. All tests were performed with SPSS Version 22 (IBM Corp., Armonk, NY, USA).

2.3 Results

Characteristics of the participants are shown in Table 2.1. Their body weight and body mass index (BMI) remained stable during the two training camps (Table 2.1). The intensity of the camps showed no significant difference ($p > 0.05$) (Table 2.2).

Table 2.1. Characteristics of the participants

		May					June				
		Amputee or SCI	Age (years)	Body height (cm)	Body weight (kg)	BMI (kg/m ²)	EI (kcal)	Body weight (kg)	BMI (kg/m ²)	EI (kcal)	Personal intention
Amputee					102.0		2564	102.0		2486	
Amputee					88.5		2437	88.5		2558	
Amputee					75.0		2849	75.7		2386	
SCI					72.0		2111	81.5		2437	gaining weight
SCI					61.9		2939	61.9		2424	
SCI					73.5		2004	73.5		2195	
SCI					68.0		2183	68.0		1910	
SCI					47.0		2524	47.5		3000	
SCI					69.0		3127	69.0		3446	
SCI					75.0		2191	72.0		2732	
SCI					90.6		2479	86.4		1597	losing weight
30±6		179±6	74.8±14.9	23.3±4.0	2492±362	75.1±14.5	23.4±3.9	2470±497			

BMI, body mass index; EI, energy intake; SCI, spinal cord injury (including spina bifida).

BMI, body mass index; EI, energy intake; SCI, spinal cord injury (including spina bifida).

2.3.1 Diet composition

Total energy intake was 34.8 ± 9.8 kcal/kg in May and 34.7 ± 12.6 kcal/kg in June ($p > 0.05$). Energy intake and distribution of macronutrients showed no significant differences for main dishes between May and June (Table 2.2). Six players reached the recommendations for carbohydrates in May and nine in June ($p > 0.05$); for protein, six in May and seven in June ($p > 0.05$); and for fat, four in May and nine in June ($p > 0.05$). There was a significant difference between May and June in the energy intake of the main dishes ($p < 0.001$, $\eta^2 = 0.80$), with lunch being the highest-energy meal in both May and June in terms of energy distribution ($p < 0.001$, $\eta^2 = 0.74$), carbohydrate distribution ($p < 0.001$, $\eta^2 = 0.78$), protein distribution ($p = 0.002$, $\eta^2 = 0.46$), and fat distribution ($p < 0.001$, $\eta^2 = 0.72$). The significances of the post hoc tests are shown in Table 2.2. The distribution of energy intake from lunch was significantly higher in June compared to May ($p = 0.020$, $d = 0.46$) (Table 2.2). Daily water intake did not differ significantly between May (2565 ± 917 ml) and June (2640 ± 697 ml).

The combined energy intake and the distribution of macronutrients of all three snacks showed no significant differences between May and June (Table 2.2).

Table 2.2. Daily energy intake and macronutrient distribution for main meals and combined snacks and calculated energy expenditure

	May					June				
	Energy (kcal)	Energy (%)	CHO (%)	Protein (%)	Fat (%)	Energy (kcal)	Energy (%)	CHO (%)	Protein (%)	Fat (%)
Breakfast	406±208 ^{ab}	16.0±7.5 ^{ab}	57.0±13.2 ^{ab}	15.0±4.9 ^a	27.3±12.4 ^b	430±187 ^{ab}	16.7±6.0 ^{ab}	66.8±12.2 ^{ab}	13.4±4.9 ^b	17.2±10.8 ^{ab}
Lunch	1022±252 ^{bc}	41.4±10.1 ^{bc*}	42.2±9.7 ^a	20.8±4.6 ^a	35.7±6.4 ^c	1144±228 ^{bc}	47.3±10.3 ^{bc*}	45.5±10.2 ^a	17.7±3.0	35.1±7.9 ^a
Dinner	835±184 ^{bc}	33.5±6.0 ^{bc}	34.9±12.4 ^b	19.9±5.7	43.8±8.3 ^{bc}	704±230 ^{bc}	28.6±7.6 ^{bc}	35.0±12.1 ^b	20.3±6.7 ^b	42.4±10.5 ^b
Snacks	227 ±251	9.0±9.6	44.4±28.1	12.3±14.5	22.0±18.4	191±165	7.3±6.2	48.1±31.7	15.3±17.3	16.8±12.3
Total	2492±362		45.3±7.3	19.1±4.8	35.5±4.7	2470±497		49.3±8.2	17.0±2.8	32.1±5.3
EE	3591±711					3791±732				

CHO, carbohydrate; EE, energy expenditure; total, energy intake including main dishes and snacks.

* $p < 0.05$ May vs June.^a Breakfast vs Lunch, ^b Breakfast vs Dinner, ^c Lunch vs Dinner $p < 0.05$.

Table 2.3. Macronutrient intakes for all six meals

	May			June		
	CHO (g/kg)	Protein (g/kg)	Fat (g/kg)	CHO (g/kg)	Protein (g/kg)	Fat (g/kg)
Breakfast	0.83±0.46*	0.20±0.11	0.18±0.15	0.97±0.49*	0.22±0.14	0.13±0.09
Morning Snack	0.11±0.12	0.07±0.12	0.06±0.09	0.18±0.29	0.07±0.10	0.02±0.04
Lunch	1.53±0.68	0.73±0.28	0.56±0.17	1.91±0.92	0.69±0.20	0.61±0.20
Afternoon Snack	0.20±0.25	0.05±0.10	0.03±0.05	0.22±0.25	0.03±0.05	0.04±0.07
Dinner	1.05±0.64	0.57±0.20	0.56±0.17	0.92±0.62	0.46±0.13	0.43±0.12
Evening Snack	0.03±0.06	0.07±0.19	0.01±0.01	0.04±0.08	0.01±0.02	0.01±0.02
Total	3.76±1.30	1.68±0.64	1.39±0.43	4.24±1.92	1.48±0.45	1.23±0.41

CHO, carbohydrate.

* $p < 0.05$ May vs June.

Macronutrient intakes in gram per kilogram of body weight for all six meals are shown in Table 2.3. The amount of carbohydrates consumed at breakfast was significantly higher in June than in May ($p = 0.044$, $d = 0.29$).

Figure 2.1 provides the profile of fat intake and shows a significant increase of polyunsaturated fat ($p = 0.034$, $d = 1.02$) and a significant reduction of saturated fats ($p = 0.045$, $d = 1.05$), with two players under the recommended 10% in May and seven in June ($p = 0.080$). Cholesterol intake was likewise significantly reduced in June (322 ± 94 mg) compared to May (478 ± 215 mg, $p = 0.026$, $d = 0.94$). One player in May was under the recommended amount of 300 mg, and six were under in June ($p = 0.063$).

Figure 2.1. Fat intake profiles in relation to total energy intake

2.3.2 Meal frequency

From the six possible meals per day the players consumed 3.8 ± 0.8 meals in May and 4.0 ± 0.8 in June, with 9 players eating all three main dishes in May and 10 in June. No player consumed three snacks per day; the average was 0.8 ± 0.8 in May and 1.0 ± 0.8 in June. In addition the players drank only water outside the main dishes 0.5 ± 0.5 times a day in May and 0.5 ± 0.4 times in June.

2.4 Discussion

This study describes the meal frequency and meal composition of elite male wheelchair basketball players twice in the precompetitive phase. During the studied days in May and June, players ate 3.8 ± 0.8 and 4.0 ± 0.8 meals per day, with 82% consuming all three main meals in May and 91% in June. Only 27% of all possible snacks were eaten in May and 34% in June, which showed a tendency for an increased snack frequency but without significant differences. Together with the fact that approximately one-third of all foods and drinks consumed outside the main dishes were merely fluids, it seemed likely that the players were more aware of fluid replacement and not of the possible benefits of snacks containing carbohydrates and protein during, before, and after exercise (Kreider et al. 2010, Price 2006). It is rather unlikely for highly organized sports teams to not consume snacks during exercise (Erdmann et al. 2013). However, keeping in mind that access to a toilet can be difficult for wheelchair users; it might be an individual strategy not to consume snacks or drinks to avoid interrupting training sessions or games. On the other hand, for athletes with SCI gastrointestinal conditions and their digestion system may have tremendous influence on their eating habits due to longer digestion time (Lin et al. 2002), which makes their timing of nutrition more difficult than it is for able-bodied athletes.

The athletes' daily energy intake and the intensity of the training camps did not differ between both camps, which took place in the precompetitive period. Their energy intake was higher in both May and June (2497 ± 362 kcal and 2470 ± 497 kcal, respectively) compared to other elite male wheelchair basketball and tennis players (2060 kcal) (Goosey-Tolfrey and Crosland 2010), but lower compared to elite able-bodied basketball players (4284 kcal) (Bescos-Garcia and Rodriguez-Guisado 2011).

The contribution of macronutrients was at the lower limit of the carbohydrates intake (45–65%) and at the upper limit of the fat intake (20–35%) based on current recommendations (Kreider et al. 2010). The same tendency was shown by Goosey-Tolfrey and Crosland (2010) and by Krempien and Barr (2011), but other training intensity recommendations would suggest a higher amount of carbohydrates and a lower fat intake (Kreider et al. 2010). Although there are to date no nutritional recommendations for disabled athletes, the existing recommendations for able-bodied (Kreider et al. 2010, Rodriguez et al. 2009) can be applied to disabled athletes if their impairment is taken into account. In the case of SCI, no strong evidence exists that the muscles of these athletes responded differently than those of able-bodied athletes, and substrate oxidation rates are comparable (Knechtle et al. 2003). However,

the muscle mass of disabled athletes is smaller, because of paralysis and a reduced sympathetic nervous system activity below the level of lesion, and leads to a reduced aerobic capacity (Leicht et al. 2012). Therefore, energy expenditure and requirements for athletes with SCI are lower than for their able-bodied counterparts (Croft et al. 2010). But how much lower is difficult to assess, because the calculation of energy expenditure by existing estimations such as the compendium by Collins et al. (2010), used in this study to calculate the intensity of the training camps, could not be easily transferred to wheelchair athletes, since even the experience of wheelchair propulsion can reduce energy expenditure in trained compared to novice wheelchair users (Croft et al. 2013).

To date, no recommendations for meal frequency other than before, during, and after exercise exist (Kreider et al. 2010, Rodriguez et al. 2009). Nevertheless, more meals per day seem to be a logical strategy to increase energy intake without the side effects of gastric discomfort from larger meals (Broad and Burke 2014). Burke et al. (2003) showed a moderate correlation between eating intervals and energy intake in able-bodied male Australian endurance athletes, with an intake of 3033 ± 979 kcal divided into 5.6 ± 1.1 meals. The same eating habits with 5 meals per day were also determined in able-bodied male Canadian (3055 ± 947 kcal) and Brazilian (3678 ± 1075 kcal) athletes (Erdmann et al. 2013, Nogueira and Da Costa 2004). The eating habits of wheelchair athletes of one main meal seems not uncommon, as other studies have discovered similar results and only the time of day, e.g., lunch or dinner, varied (Burke et al. 2003, Erdmann et al. 2014, Garrido et al. 2007, Nogueira and Da Costa 2004). The energy intake for lunch was comparable between the participants and the Brazilian athletes, whose total energy intake was the highest of all studies analyzed (Burke et al. 2003, Erdmann et al. 2013, Nogueira and Da Costa 2004). This could be due to the buffet-style diet at trainings camp, which contained a great variety of food (Garrido et al. 2007). However, we believe that the participants' eating habits during these intensive weekends were comparable to those at international competitions, so the choice of meals should be representative. In fact, during both periods, they had the possibility to choose their food freely from a buffet offering the same choices that were available at training site.

Recommendations for able-bodied athletes regarding dietary intake in relation to exercise intensity took only two macronutrients, carbohydrates and protein, into account, with daily amounts of 5 to 10 g/kg carbohydrates, depending on exercise intensity, relative to 1 to 2 g/kg protein (Kreider et al. 2010, Rodriguez et al. 2009). Regarding the lower energy expenditure in wheelchair basketball, we expected that the participants' carbohydrates needs would be at

the lower limit of the recommendations (Croft et al. 2010, Kreider et al. 2010, Rodriguez et al. 2009). This consideration was supported by Goosey-Tolfrey and Crosland (2010) and Krempien and Barr (2012), who showed dietary intakes of 4.3 g/kg and 4.4 g/kg of carbohydrates, respectively. Additionally, calculating an intake of 5 g/kg of carbohydrates, which is at the lower limit of the recommendations of the ACSM for healthy active people (Rodriguez et al. 2009), would result in 1500 kcal for a body weight of 75 kg, leading to a high contribution of 60% carbohydrates by an assumed energy intake of 2500 kcal. Interestingly, the athletes did not reach these smaller amounts of carbohydrates in either May (3.8 ± 1.3 g/kg) or June (4.2 ± 1.9 g/kg) except for one athlete in May and three in June, which is attributed to their high fat intake during the training camps, that was at the upper limit of recommendations and could have been reduced in favor of carbohydrates. In contrast, their protein intakes in May and June were 1.7 ± 0.6 and 1.5 ± 0.5 g/kg, respectively, which were well within the recommendations. Even if the participants reached protein recommendations for optimal recovery as a group, special care should be taken for each individual because a higher intake of protein might be necessary to support and promote the healing of pressure ulcers or wounds, which are often seen in wheelchair athletes (Lee et al. 2006).

In addition to the amount of carbohydrates consumed per day, the timing of consumption in relation to trainings sessions is also important and the training sessions were held twice per day in the morning and afternoon. In able-bodied athletes, limited glycogen stores lasted from 90 minutes up to 3 hours, depending on exercise intensity, so carbohydrate intake between 1 and 4 g/kg is recommended before exercise (Kreider et al. 2010, Kerksick et al. 2008, Rodriguez et al. 2009). Our results showed a significant increase in carbohydrate intake at breakfast from May to June, from 0.8 ± 0.5 to 1.0 ± 0.5 g/kg which reached the lower limit of the recommendations. On an individual level, approximately half the players achieved 1 g/kg, but after an overnight fast with depleted glycogen stores particularly liver levels and training sessions in the morning, it should be favorable for all players to reach even the lower limit of the recommendations (Kreider et al. 2010, Rodriguez et al. 2009).

Another important component to discuss is the avoidance of fatigue and hypoglycaemia during exercise of more than 60 minutes because of low liver and muscle glycogen stores. Therefore, a 30 to 90 g/h carbohydrate intake during exercise is recommended (Kreider et al. 2010, Rodriguez et al. 2009, Thomas et al. 2016). Because the participants consumed only half of the possible snacks during exercise, the amount of carbohydrates was below this

recommendation. Reasons could be less intensive training sessions than assumed or the strategy to avoid using the toilet during training.

Finally, to recover from exercise, refuelling of glycogen stores with 1 to 1.2 g/kg carbohydrates is recommended between training sessions (Kreider et al. 2010, Rodriguez et al. 2009). During lunch, the participants consumed higher amounts of carbohydrates in May than in June (1.5 ± 0.7 and 1.9 ± 0.9 g/kg, respectively), with 8 athletes above the upper limit in May and 7 in June. One to 1.5 g/kg carbohydrates should be ingested to refuel after exercise (Kreider et al. 2010, Rodriguez et al. 2009). At dinner, we found a carbohydrate intake of 1.1 ± 0.6 g/kg in May and 0.9 ± 0.6 g/kg in June, with 7 athletes in both May and June below the recommendations. This amount could have easily increased with an appropriate evening snack. In fact, besides common reasons to avoid an evening snack such as over-consumption at dinner or being exhausted and going early to bed digestion time differs widely among individuals with SCI and therefore individual solutions for disabled athletes seem essential to overcome these difficulties.

Overall, the ratio between carbohydrates and fat was insufficient, with fat consumption above the recommendations. Although the composition of breakfast improved significantly, both the total amount and the distribution of fat at lunch did not change despite our written and oral feedback. A reduction of fat at lunch should have led to higher carbohydrate amounts, reaching recommendations of 5 g/kg carbohydrates (Kreider et al. 2010, Rodriguez et al. 2009). In contrast, the recommended protein intake could be reached with a normal diet without supplements, as previously shown by Goosey-Tolfrey and Crosland (2010) and Krempien and Barr (2012). One-third of the participants failed to reach the recommendations, which was comparable to the findings of Ribeiro et al. (2005), who reported that 35% of wheelchair athletes had below-normal levels of the serum insulin-like growth factor-1 (IGF-1), a sensitive indicator of protein nutritional status. Our advice between the two training camps regarding the personal intentions were successful and the two players, who had an intention, reached their goal to gain respectively to lose weight.

Our results revealed the limited usefulness of calculating energy expenditure of wheelchair athletes with existing estimations. So overestimated the energy expenditure calculated according to Collins et al. (2010) the energy intake of our athletes by about 1000 kcal/day, but their body weight remained stable from May to June; indicating that their real energy expenditure was much closer by their energy intake than that 1000 kcal/day gap implies.

However, because we expected an overestimation, we used the compendium from Collins et al. (2010) only to compare the intensity of the training camps.

Wheelchair basketball players showed a lower meal frequency than able-bodied athletes. Although their energy expenditure is lower, their low snack frequency leads to higher energy intake during main meals in relation to total energy intake. Therefore, nutritional advice for wheelchair players seems to be necessary to correct imbalances, such as carbohydrate intake below recommendations and fat intake above recommendations. As this is the first study that investigated meal frequency in wheelchair basketball athletes, our results could not be compared to other investigations (Burke et al. 2003, Erdman et al. 2013, Garrido et al. 2007, Nogueira and Da Costa 2004). Although trainings camps during precompetitive phases and championships are common in elite athletes, future studies should investigate meal frequency of wheelchair basketball players at home.

2.5 Limitations

This was the first nutritional evaluation that has been conducted with these athletes and they did not know the researches beforehand. That might have influenced their eating behavior during the first period, which was intended to determine their usual nutritional habits prior to their advice. Furthermore, the reported food and beverages from the vending machines between each meal have been reported orally by the athletes, and they might have been wrong, reporting higher or lower amounts, which could not be verified by the researchers. Additionally, even if the second evaluation had been completed under the same conditions as the first one, it is hard to know if and how athletes would have transferred the feedback they got into their daily live and training routine

Another aspect that has to be mentioned is that data on body composition was not possible to take, so possible changes in body fat or muscle mass could not be determined.

2.6 Conclusion

In conclusion, the present study observed a lower energy expenditure of wheelchair basketball players compared to their able-bodied counterparts on one hand, and on the other, a high energy intake in main meals in relation to total energy intake. Therefore, the strategy to reach energy balance through higher meal frequency and lower energy intake during the main meals might be one possible solution to enhance performance. Following sports nutrition principles

for nutrient timing, particularly for carbohydrates in relation to training sessions, could improve their performance and their macronutrient contribution because of more balanced main dishes and more frequently snacks. The individual requirements always have to be taken into account, and longer nutritional interventions are required to correct imbalances and improve dietary habits of male wheelchair basketball players, as shown in our study. Basic knowledge about sports nutrition should be improved to ensure health and performance improvements.

2.7 Future lines

Future studies should investigate meal frequency of wheelchair basketball players at home and several times over the whole year, because seasonal changes of training load have to be taken into account. Additionally, basic knowledge about sports nutrition should be evaluated in future studies to ensure health and performance improvements.

Chapter Three

Marginal Micronutrient Intake in High-Performance Male Wheelchair Basketball Players: A Dietary Evaluation and the Effects of Nutritional Advice⁶

3.1 Introduction

In high-performance sports, differences in the factors that determine winning and losing can be small (Perret 2015). Hence, athletes should consider all factors that can help enhance their performance. In wheelchair basketball, three main factors are involved: the wheelchair, the athlete, and the interactions between them (Goosey-Tolfrey 2010a). As athletes undergo training programs, which are comparable to those of their able-bodied peers (Broad and Burke 2014), the principles of sports nutrition should be considered to support effective training and to improve performance levels during training and competition (Kreider et al. 2010, Rodriguez et al. 2009⁷). In addition to control the macronutrients energy distribution and timing of energy intake throughout the day, ensuring an adequate intake of micronutrients may also have a positive impact on performance (Thomas et al. 2016).

Micronutrients, including vitamins and minerals, are required in small amounts and interact with one another to regulate physiological functions (Kreider et al. 2010, Rodriguez et al. 2009). For athletes, the roles of micronutrients in energy metabolism, blood and bone health and antioxidant functioning are extremely important, and the B vitamin group (e.g., thiamin, riboflavin, niacin, vitamin B₆, folic acid, and vitamin B₁₂) and minerals (e.g., iodine, iron, magnesium, and zinc) facilitate the conversion of macronutrients into energy and are therefore essential to athletes because of their high levels of energy expenditure (Kreider et al. 2010, Rodriguez et al. 2009). In athletes, red blood cell production is often increased, requiring an increased intake of iron, a component of hemoglobin, and folic acid and vitamin B₁₂, which are also needed for the synthesis of DNA and RNA (Deakin 2011). Furthermore, adequate

⁶ Published in: Grams L, Garrido G, Villaciers J, Ferro A. Marginal Micronutrient Intake in High Performance Male Wheelchair Basketball Players: A Dietary Evaluation and the Effects of Nutritional Advice. PlosOne 2016 Jul 6;11(7):e0157931. See Appendix E.

⁷ Because the study, on which Chapter Three is based on, was conducted before the newest guidelines of the ACSM were published in 2016, the previous guidelines published in 2009 have been used. For publication the 2016 guidelines have been added and therefore both guidelines were cited.

levels of calcium, phosphorus and vitamin D ensure the maintenance of sufficient bone mineral density, helping to prevent stress fractures (Deakin 2011, Halliday et al. 2011, Ruohola et al. 2006). Certain antioxidants (vitamin A, C, and E) and minerals (selenium and zinc) protect cells and tissues against damage from free oxygen radicals, which increase in number as a result of exercise (Deakin 2011). Although athletes may have slightly higher micronutrient requirements because exercise stresses many of the metabolic pathways in which micronutrients are involved, no special recommendations have been described for these requirements (Kreider et al. 2010, Rodriguez et al. 2009). To date, there is no evidence of altered micronutrient requirements for wheelchair athletes, with the exception of those related to vitamin D, as osteoporosis is associated with vitamin D deficiency, which is common in athletes with SCI (Flueck et al. 2016, Goktepe et al. 2004, Miyahara et al. 2008). Therefore, we used the existing United States and Canadian DRI values to determine adequate micronutrient intake levels (Institute of Medicine 2011, National Research Council 2006).

Both the ACSM and the ISSN recommend a well-balanced diet to meet vitamin and mineral requirements (Kreider et al. 2010, Rodriguez et al. 2009). Nevertheless, athletes with restricted energy intake are at an increased risk of inadequate nutrient intake (Kreider et al. 2010, Rodriguez et al. 2009). Until now, very few studies have examined the energy intake patterns of male wheelchair athletes, and all of these studies have reported low energy intake levels within this group relative to the intake levels of able-bodied athletes (Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2011, Krempien and Barr 2012). Only one study, on male Canadian wheelchair athletes, has shown inadequacies in the micronutrient intake (Krempien and Barr 2011), and because inadequate micronutrient intake can weaken one's immune system, increasing the risks of illness, the intake of nutrient-dense foods, that can improve the adequacy of micronutrients, could improve the health of these athletes.

Therefore, the aims of this study were to (1) evaluate micronutrient intake by elite wheelchair basketball players based on the latest Food and Nutrition Board (FNB) guidelines, (2) analyze which food groups are crucial for the adequacy of micronutrient intake, and (3) examine whether nutritional advice provided one month and again one year after the initial recommendations can improve diet quality.

3.2 Methods

3.2.1 Participants and study design

Seventeen male wheelchair basketball players of the Spanish National Team participated in this study, which was conducted in Madrid (Spain) at the Higher Sport Council during three training camps held in the precompetitive season in two consecutive years. To compare the adequacy of micronutrient intake at the group level, data for all players participating in the camps in May (Training Camp 1 (TC1), 14 players) and June of the first year (Training Camp 2 (TC2), 12 players) and in June of the second year (Training Camp 3 (TC3), 11 players) were used (Figure 3.1). Disabilities ranged from amputations to spina bifida and spinal cord injuries. The effectiveness of the nutritional advice given was determined in consultation with the eight players who participated in all the camps.

Figure 3.1. Timeline of all training camps (TC1, TC2 and TC3)

The Ethics Committee of the Technical University of Madrid (Spain) approved the study, which was conducted according to the Helsinki Declaration for research on humans (Williams 2008). Before participating, players provided their written consent.

3.2.2 Anthropometrics

Height was measured using a stadiometer (DKSH Switzerland Ltd, Switzerland) to the nearest 0.1 cm in a standing position if possible, and for athletes who were unable to stand, the formula recommended by Canda (2009) was applied to estimate height based on arm span and seated height. Body weight was determined using a calibrated scale (Kern, Twister Medical, Spain) to the nearest 0.1 kg with athletes wearing minimal clothing.

3.2.3 Diet composition

Diet compositions were estimated using a food-weighing diary (1 g accuracy; Mettler-Toledo S.A.E, Barcelona, Spain) over three consecutive days during each camp. Experienced researchers weighed and recorded each food component at breakfast, lunch and dinner. The players orally reported the types and quantities of snacks consumed outside of the main meal times and the time of day they were consumed. Likewise, supplement intake for each player was determined, and players provided leaflets, labels or packaging information. To analyze micronutrient intake from food alone, the intake due to supplements was determined separately. During each camp, the players ate together at the Centre of Higher Sport Council, selecting their food from a buffet offering a wide variety of food options. Occasionally some players chose to eat at home or outside the hotel area and orally reported the types and quantities of food they have consumed. The software program DIAL version 2 (Alce Ingeniería, Madrid, Spain) was used to determine the nutrient composition of the meals. The recipes of each meal were discussed with the kitchen staff to identify the separate food components so that they could be assigned to food groups, and recipes not already included in the food composition database were added. The weights of the food components were then entered into DIAL to analyze diet composition and categorize the components into fourteen food groups (Table 3.5).

3.2.4 Adequacy of micronutrient intake

Ten vitamins (vitamin A, thiamin, riboflavin, niacin, vitamin B₆, folic acid, vitamin B₁₂, vitamin C, vitamin D, and vitamin E) and seven minerals (calcium, iodine, iron, magnesium, phosphorus, selenium, and zinc) of special relevance to athletes were examined (Kreider et al. 2010, Rodriguez et al. 2009). Individual intake was determined using the probability approach recommended by the American Dietetic Association (Institute of Medicine 2000, Murphy and Barr 2011). Furthermore, to determine intake adequacy at the group level, the Estimated Average Requirements (EAR)-cutpoint method with the latest DRI values from the FNB was applied (Institute of Medicine 2000, Institute of Medicine 2001, Murphy and Barr 2011). According to the definition of the DRI, a probability of micronutrient intake of 50% corresponds with the EAR, and a probability of 100% corresponds with the Recommended Dietary Allowance (RDA) (Murphy and Barr 2011). The Tolerable Upper Intake Level (UL) was set as the highest safe limit (National Research Council 2006). If the calculated probability of adequate intake for a micronutrient was stable at 100%, the amount in grams

was used as the intake level instead of the probability. This was the case for niacin, riboflavin, vitamin B₆, vitamin B₁₂, iron, phosphorus, and selenium. In our study, the sum of all micronutrients with a probability of at least 50% (adequacy_{SUM}) was calculated as the overall adequacy score to determine longitudinal improvement levels.

3.2.5 Nutritional advice

After each of the three nutritional evaluations (TC1, TC2, TC3), individual written reports and personal interviews were conducted to optimize diet composition and micronutrient intake (e.g., daily amounts, food group variation, pre- and post-exercise snacks). All evaluations were held under the same conditions and during the same time of the year. Individual feedback was provided after each evaluation.

Resting energy expenditures were estimated according to Abel et al. (2008), and energy expenditures were calculated using written activity protocols and values provided by Collins et al. (2010) for athletes with SCI and by Abel et al. (2008) and Bernardi et al. (2010) for amputees.

3.2.6 Statistics

Normal distributions were tested for using the Shapiro-Wilk test and the Kolmogorov-Smirnov test. Pearson and Spearman correlations were computed for parametric and non-parametric data, respectively, to determine the linear relation between energy and micronutrient intake. Stepwise multiple linear regressions were conducted for each micronutrient intake as a dependent variable, and food groups were used as independent variables so that we could determine the relationship between micronutrient intake and dietary variation. Differences in micronutrient intake between all three evaluations were tested via analyses of variance (ANOVA) with repeated measurements for parametric data or via Friedman tests for non-parametric data. For post hoc tests we used paired Student's t-tests for parametric data and Wilcoxon tests for non-parametric data, using Bonferroni corrections with partial eta-squared (η^2) and Kendall's W to represent the effect size, respectively. Parametric data are given as the mean±standard deviation values and non-parametric as median [minimum; maximum] values. Significance was accepted at $p < .05$, and all tests were performed using SPSS version 22 (IBM Corp., Armonk, NY, USA).

3.3 Results

3.3.1 Participants

Characteristics for each player (5 amputees and 12 athletes with spina bifida or SCI, age 30 [22;41] years) are shown in Table 3.1.

Table 3.1. Player characteristics and diet composition shown as the mean values over the number of diaries

Player	Number of diaries	Height (cm)	Weight (kg)	BMI (kg/m ²)	SCI or amputee
1	1	189	84.0	23.5	Amputee
2	3	181	102.8	31.4	Amputee
3	2	187	88.5	25.3	Amputee
4	3	186	76.8	22.2	Amputee
5	2	183	75.3	22.5	Amputee
6	3	182	88.2	26.6	SCI
7	2	178	76.8	24.2	SCI
8	3	170	73.9	25.6	SCI
9	2	171	61.9	21.2	SCI
10	1	190	82.3	22.8	SCI
11	3	175	75.3	24.6	SCI
12	3	184	69.9	20.6	SCI
13	3	170	46.7	16.1	SCI
14	1	186	74.1	21.4	SCI
15	1	176	69.0	22.3	SCI
16	1	173	65.0	21.7	SCI
17	3	183	70.6	21.1	SCI
		182 [170;190]	75.5±13.5	23.3±3.7	

BMI, body mass index; SCI, spinal cord injury

3.3.2 Diet composition

Overall, 37 food diaries were examined. Mean energy intake was 2,673±485 kcal/d (1,597 to 3,651 kcal/d) and 36.8±10.5 kcal/kg (24.6 to 63.5 kcal/kg). Macronutrient intake relative to

body mass was $3.9 [1.8;8.1]$ g/kg for carbohydrates and 1.7 ± 0.6 g/kg for protein, excluding supplements. The percentage of energy derived from fat was $33.7 \pm 5.5\%$.

3.3.3 Micronutrient intake

The estimated adequate intake probabilities at the group level are shown in Figure 3.2. The levels shown exceed the RDA for niacin, riboflavin, vitamin B₆, and vitamin B₁₂ and for various minerals (iron, phosphorus, and selenium) for all the players. No player exceeded the UL for any micronutrient. Adequacy_{SUM} was found to be 13.2 ± 2.0 , with no player achieving adequate intake levels for all 17 micronutrients but with 35% taking in adequate levels for 16 micronutrients.

Figure 3.2. Probability of adequate micronutrient intake

One player used supplements on all three occasions, achieving adequate calcium and vitamin D levels for Training Camp TC1 and adequate intake levels for all micronutrients and calcium for Training Camp TC2. Two players used mineral supplements on one occasion, achieving levels of calcium above adequacy.

The correlation of total energy intake with adequacy_{SUM} and micronutrient intake adequacy is shown in Table 3.2.

Table 3.2. Correlation between total energy intake and the probability of adequate micronutrient intake

	Correlation coefficient	<i>p</i> -Value
Adequacy _{SUM}	0.64	<0.001
Vitamins		
Vitamin A	0.29	0.087
Folic acid	0.50	0.002
Niacin (mg) ^a	0.59	<0.001
Riboflavin (mg) ^a	0.63	<0.001
Thiamin	0.44	0.006
Vitamin B ₆ (mg) ^a	0.59	<0.001
Vitamin B ₁₂ (μg) ^a	0.53	<0.001
Vitamin C	0.33	0.044
Vitamin D	0.54	<0.001
Vitamin E	0.29	0.082
Minerals		
Calcium	0.44	0.006
Iodine	0.64	<0.001
Iron (mg) ^a	0.53	<0.001
Magnesium	0.55	<0.001
Phosphorus (mg) ^a	0.65	<0.001
Selenium (μg) ^a	0.41	0.013
Zinc	0.59	<0.001

^a The probability of adequate intake is constant at 100%

Players with higher adequacy_{SUM} levels consumed more fruit, dairy, fat, oil, and cereals (Table 3.3).

Table 3.3. Beta coefficients of stepwise multiple linear regressions with the probability of adequate micronutrient intake as a dependent variable and energy intake levels from different food groups as independent variables

	R ²	Cereals	Legumes	Vegetables	Fruits	Dairy	Meats	Fish	Eggs	Sugars and sweets	Fats and oils	Beverages	Prepared meals	Appetizers	Sauces
Adequacy _{SUM}	0.72	0.27			0.58	0.22					0.42				
Vitamins															
Vitamin A	0.25							0.36					-0.30		
Folic acid	0.71			0.30	0.66				0.40	0.33					-0.25
Niacin (mg) ^a	0.87	0.24		0.29	0.21		0.66	0.38	0.21						
Riboflavin (mg) ^a	0.54	0.43							0.49						0.38
Thiamin	0.26	0.51													
Vitamin B ₆ (mg) ^a	0.49				0.35		0.30		0.44						
Vitamin B ₁₂ (μg) ^a	0.85					0.30	0.55	0.64	0.26				0.26		
Vitamin C	0.50				0.30								-0.38	-0.41	
Vitamin D	0.24							0.49							
Vitamin E	0.62				0.50						0.51				-0.27
Minerals															
Calcium	0.40					0.63									
Iodine	0.61					0.36	0.41				0.46			-0.27	
Iron (mg) ^a	0.55	0.39		0.35	0.48		0.40								
Magnesium	0.67	0.51			0.42			0.27							
Phosphorus (mg) ^a	0.75	0.38				0.34	0.29	0.41	0.30						
Selenium (μg) ^a	0.66	0.37			-0.21			0.60							
Zinc	0.21	0.46													

^a The probability of adequate intake was constant at 100%

3.3.4 Effects of nutritional advice

Anthropometric data and diet compositions for the eight players who took part in all three evaluations are shown in Table 3.4. Although body weight and BMI levels changed significantly over time, post hoc tests showed no significance. Total energy intake increased significantly during the evaluation at TC3 relative to values recorded for TC1 ($p = .017$) and TC2 ($p = .046$). Similar results were found for fruit ($p = .032$, $\eta^2 = 0.39$) and egg intake levels ($p = .036$, Kendall's $W = 0.42$), although significant post hoc test results were not found.

Table 3.4. Anthropometric data and diet compositions for the eight players who took part in all three evaluations

Parameter	Training Camp TC1	Training Camp TC2	Training Camp TC3	p -Value	η^2
Age (years)	29.9±6.5	30.0±6.5	31.0±6.5	---	
Height (cm)	178.9±6.3		178.9±6.3	---	
Body weight (kg)	75.0±16.2	74.3±15.6	77.3±16.5	0.029	0.40
BMI (kg/m ²)	23.4±4.7	23.1±4.5	24.1±4.7	0.032	0.39
Total energy intake (kcal/d)	2441±341 ^b	2446±588 ^a	2968±453 ^{a,b}	0.009	0.49
Carbohydrate (g/kg)	3.1 [2.8;7.1]	3.5 [1.8;8.1]	4.9 [2.7;7.4]	0.197	
Protein (g/kg)	1.6±0.7	1.5±0.5	1.9±0.7	0.071	
Fat (%)	35.1±4.7	33.7±4.8	32.1±5.9	0.599	
Cholesterol (mg)	401 [263;947]	317 [226;518]	669 [216;992]	0.012	0.25
BMI, body mass index	^a TC2 vs. TC3 $p < .05$, ^b TC1 vs. TC3 $p < .05$				

The probabilities of adequate micronutrient intake for the three evaluations are shown in Figure 3.3. Iodine ($p = .008$, $W = 0.61$; TC1-TC2 n.s., TC2-TC3 $p = .035$, TC1-TC3 $p = .045$) and magnesium ($p = .030$, $W = 0.44$; TC1-TC2 n.s., TC2-TC3 $p = .788$, TC1-TC3 $p = .023$) showed significant differences, with three players over the EAR for iodine at TC1, one over at TC2 and seven over at TC3 and with three over the EAR for magnesium at TC1, two over at TC2 and three over the RDA at TC3.

Figure 3.3. Probabilities of adequate vitamin (a) and mineral intake (b) for the eight players who took part in all three evaluations (TC1, TC2 and TC3)

The adequacy_{SUM} values were 12.5 ± 2.4 at TC1, 12.3 ± 1.8 at TC2 and 14.0 ± 1.7 at TC3 ($p = .039$, $\eta^2 = 0.37$, TC1-TC3 $p = .043$).

3.4 Discussion and limitations

3.4.1 Discussion

Our study reveals a relationship between total energy intake and adequate micronutrient intake in male wheelchair basketball players. Additionally, it shows that a variety of food groups are needed for one to achieve adequate micronutrient intake.

Although a higher total energy intake among able-bodied athletes should result in adequate micronutrient intake (Kreider et al. 2010, Rodriguez et al. 2009), it is less certain whether sufficient energy intake can help Paralympic athletes to achieve this goal. Athletes with SCI in particular often have a lower muscle mass than able-bodied athletes as a result of paralysis (Glaser 1985), which is caused by a reduction in sympathetic nervous system activity below the level of the lesion (Leicht et al. 2012). Together with lower activity levels or even immobility in the affected limbs, this leads to less active muscle mass, and therefore, their energy expenditure is likely to be lower than that of their able-bodied peers (Croft et al. 2010,

Price 2010). Likewise, their total energy intake may be equally reduced to maintain energy balance, possibly resulting in inadequate micronutrient intake. Krempien and Barr (2012) reported on the energy intake levels of male Canadian wheelchair athletes, and Goosey-Tolfrey and Crosland (2010) reported similar results for male British wheelchair athletes. Both groups were found to have lower intake levels than able-bodied professional basketball players (Bescos-Garcia and Rodriguez-Guisado 2011). Although the mean total energy intake levels found in the present study are higher than those found for comparable disabled athletes (Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2012), the values ranged from 1,597 to 3,651 kcal/d, highlighting the need for individualized nutritional advice for athletes with different disabilities and even among those who play the same sport. Similarly, the participants in the present study varied in terms of body weight, explaining the similarly high variability in energy intake relative to body weight, which ranged from 25 to 64 kcal/kg.

However, total energy intake is not the only factor that affects the adequacy of micronutrient intake. For example, similar energy intake levels of 2,558 kcal/d and 2,479 kcal/d were found in our study between two players and resulted in the adequate intake of ten micronutrients for one player and sixteen for the other, with only vitamin D showing inadequate intake levels, which will be discussed later. Consequently, a varied diet is also important (Kreider et al. 2010, Rodriguez et al. 2009). In our study, intake of eleven of the fourteen food groups we examined (see detailed information in Table 3.5) showed a positive correlation with adequate intake levels for at least one micronutrient. From these groups, four (cereals, fruits, dairy, and fats and oil) accounted for 72% of the variance in the overall adequacy of micronutrient intake (Table 3.4). Fruits were found to be associated with five vitamins and three minerals, fish were associated with four vitamins and three minerals, and cereals were associated with three vitamins and five minerals. Dairy was the only significant source of calcium intake found, even though we expected additional sources (e.g., specific vegetables or legumes) to play an important role as the food available in the buffet included all the necessary food groups to support optimal nutritional requirements.

Compared with the levels found in the study by Krempien and Barr (2011) on male Canadian athletes with SCI, micronutrient intake levels were generally found to be higher in our study. This observation can partly be explained by the higher energy intake levels used ($2,673 \pm 486$ kcal/d) relative to those employed by Krempien and Barr (2011) (2,285 kcal/d). However, Krempien and Barr (2011) did not consider issues relating to dietary variety, which we found to have a considerable effect. Comparisons between energy intake levels of non-athlete adults

with SCI revealed even greater differences, with Perret and Stoffel-Kurt (2011) reporting an energy intake of 1,775 kcal/d and lower absolute micronutrient intake levels, with the exception of those for calcium.

The dietary intake levels of our participants showed a high adequacy for 13.3 ± 2.1 of the 17 micronutrients examined. Micronutrients involved in bone health, such as calcium, magnesium, and vitamin D, showed low adequacy levels, and the levels of phosphorus were high in relation to those of calcium (Calvo and Tucker 2013), which could negatively affect progress among wheelchair athletes who are susceptible to osteoporosis (Miyahara et al. 2008). Only one player, an amputee, used a multivitamin and mineral supplement that included calcium and vitamin D, which provided adequate levels of both micronutrients for this individual.

However, the DRI for vitamin D represents intake levels under minimal sun exposure conditions, and in the summer, the endogenous synthesis of vitamin D in Madrid, Spain, (40° in latitude) is achieved with 10 minutes of daily sunlight exposure. Nonetheless, limited sun exposure can occur because of the season and at latitudes higher than 35° . In such cases, calcium and vitamin D supplements should be considered during fall and winter and especially for athletes presenting low total energy intake levels.

In addition to improve performance, micronutrients play an important role in enhancing immune function, and illness can result in players being absent from training and competition (Derman et al. 2014, Goosey-Tolfrey and Crosland 2010). To prevent the spread of illness and to support immune system health, ensuring adequate levels of vitamins A, D, E, C, B₆, and B₁₂, as well as folic acid, iron, and zinc should be of great concern (Gleeson 2013, Hemila and Chalker 2013). In our study, vitamin B₆ and vitamin B₁₂ intake levels were found to be adequate as animal food groups were well represented and no player followed a vegetarian diet. Vitamin A, vitamin C, iron, and zinc intake levels were above their EAR. Various food groups served as significant sources of vitamin A and iron, although only fruits served as sources of vitamin C, and only cereals served as sources of zinc. Regarding the low adequacy levels of vitamin E and folic acid intake, a higher intake of nutrient-dense legumes may prove beneficial, as legumes are good sources of these micronutrients. However, due to the low legume intake in this study, legumes were not found to serve as a significant source of any micronutrient. Although digestion is slower in players with SCI (Lin et al. 2002) and certain food groups induce flatulence, it seems likely that some legumes or vegetables (e.g., boiled greens, potatoes, carrots, and alliums) offered as purees would be easier to digest and

could be beneficial nutrient-dense foods. In this regard, individual solutions should be found (Thomas et al. 2016) and discussed between the athlete and nutritionist.

Nutritional advice was found to increase the overall adequacy of micronutrient intake after one year, which can be attributed to a higher total energy intake and to a more varied diet characterized by the higher fruit and egg intake of our participants. Considering the marginal differences found after the second training camp (TC2), which was only four weeks after the first (TC1), it appears that eating habits take time to change and that advice should be given more frequently than it was in our study to achieve adequate micronutrient intake. Even a nutrition education program involving three sessions over four months did not improve micronutrient intake among able-bodied professional handball players (Molina-Lopez et al. 2013), despite the fact that the motivation of elite athletes should be high to support effective training and to improve performance levels during training and competition. Despite lower levels of cholesterol intake found after four weeks (TC2), our data revealed an increasing trend after one year (TC3) (Table 3.4). This finding could partly be explained by a higher egg intake, which on the one hand led to a high protein intake but on the other hand led to a cholesterol intake that was above the recommended amount (Table 3.4). Our recommendations to increase the consumption of fat-free and fat-reduced dairy products were not followed over a full year. Consequently, nutritional advice seems more effective when provided over a shorter timeframe.

3.4.2 Limitations

Although the DRI values were used to study the intake adequacy of all micronutrients, our analysis conducted over three consecutive days may have been too short to fully analyze the requirements for some micronutrients (Murphy and Barr 2011). Other potential reasons for intake deficiencies (e.g., the bioavailability of micronutrients) were not examined in this study and should be considered before vitamin or mineral supplements are recommended. Blood analyses must also be conducted when confirming inadequate intake. In regards to vitamin D status, varying levels of sun exposure across seasons have a considerable effect on the endogenous synthesis, and therefore, supplements may prove beneficial during fall and winter but are likely unnecessary during spring and summer. Finally, the micronutrient contents in food are unstable, so the actual levels taken in may be different than we estimated, and some of our data on nutrient content may have been inaccurate, as food databases do not include the chemical compositions of all available foods.

3.5 Conclusion

The adequacy of the micronutrient intake by elite male Spanish wheelchair basketball players is positively related to their total energy intake. However, a variety of food groups must be included in one's diet to achieve adequate levels for the most important micronutrients, and nutrient-dense food groups such as fruit are associated with more micronutrients than less nutrient-dense groups. As some micronutrients showed inadequate intake levels, additional nutritional advice should be provided to avoid adverse effects resulting from personal dislike of certain food groups, and the consumption of beneficial foods (especially vegetables and legumes prepared in ways that are easy to digest) should be promoted as some of these groups, legumes in particular were only consumed in minimal amounts. In addition, shorter time frames between nutritional advice are more successful than longer periods, such as one year.

Food variety with special attention to nutrient-dense foods is especially important in players with low energy intake. Consequently, it might be necessary to use supplements for players with SCI, especially for micronutrients involved in bone health. Nutritional monitoring in Paralympic athletes should be incorporated into the regular routine of their training periods throughout the year so that a short time frame between repeated sessions of receiving nutritional advice can be used to raise their knowledge of the benefits of sports nutrition.

3.6 Future lines

Future studies should evaluate nutrition in shorter time frames, several times over the whole year. Monitoring vitamin C, D, and iron is important and supplementation studies are required. Moreover, blood samples should be taken and analyzed as part of the micronutrient adequacy evaluation. Furthermore, individual solutions concerning certain food choices should be investigated, to help the athletes eating a well-balanced diet.

3.7 Supplements

Table 3.5. Food groups and their components

Food group	Component
Cereals	Grains and flour Breakfast cereals Bread Pasta Low fat cookies Low fat pastries
Legumes	Dry legumes Canned legumes Derivatives of legumes
Vegetables	Fresh vegetables Frozen vegetables Canned vegetables Natural vegetables juices Canned vegetables juices Tuber, root vegetables Canned tuber, root vegetables Mushrooms Canned mushrooms
Fruits	Fresh fruits Derivatives of fruits Dried fruits Nuts Natural fruit juices
Dairy	Milk Yoghurt and fermented milk Cheese Milk desserts Milk shakes Cream
Meats	Beef Pig Lamb Poultry Guts Sausages Smoked meat Other meat

Food group	Component
Fish	White fish Blue fish Frozen fish Canned fish Smoked fish Seafood and derivatives Canned seafood and derivatives Salted fish
Eggs	Eggs
Sugars and sweets	Sugar Chocolate Sweets Full fat pastries Other sweets High fat cookies
Fats and oils	Vegetable Oils Butter and margarines Other fats
Beverages	Soft-drinks Coffee and tea Herbal tea Isotonic beverages Commercial juices Other soft-drinks without alcohol Alcoholic drinks
Prepared meals	Prepared commercial dishes ready to eat (e.g. Pizza, Fast food)
Appetizers	Appetizers (e.g. Potato chips, Tortilla chips)
Sauces	Commercial and handmade sauces Spices

Chapter Four

Body Composition and Nutrition of High-Performance Male and Female Wheelchair Basketball Players

4.1 Background

Body composition is a key factor in performance and general health of athletes (Thomas et al. 2016) and can be used to determine the long-term effectiveness of training and/or nutrition interventions. Currently, high-performance Paralympic athletes are already involved in training programs similar to their able-bodied counterparts (Broad and Burke 2014). The difference between success and failure in Paralympics events has become smaller over the years (Perret 2015). Thus, monitoring and enhancing body composition is a potential strategy to further optimize performance of wheelchair athletes (Goosey-Tolfrey et al. 2003).

In contrast to able-bodied athletes, the composition of the upper body in wheelchair athletes differ from their lower body due to muscle atrophy below the lesion level of athletes with a SCI and daily wheelchair use combined with high-level sport participation (Miyahara et al. 2008, Sutton et al. 2009). Therefore, the focus for wheelchair athletes should be a segmental rather than a whole-body composition determination as normally done for able-bodied athletes.

The two most frequently used assessment methods for body composition in able-bodied athletes are the field-based method of skinfold thickness followed by the laboratory method of DXA (Meyer et al. 2013). Both methods can be used to determine segmental body composition. In the case of skinfolds, the raw data must be used as emphasized by the ISAK to avoid errors by converting skinfolds into percentage of body fat due to the upper body muscular development combined with the lower body muscular atrophy in wheelchair athletes (Goosey-Tolfrey et al. 2016). While no validated equation for wheelchair athletes yet exists, several studies have shown that both methods could be applied to wheelchair athletes (Sutton et al. 2009, Goosey-Tolfrey et al. 2016, Granados et al. 2015, Inukai et al. 2006, Willems et al. 2015). However, none of these studies have compared the raw data of skinfolds with DXA nor reported all segmental skinfolds as specified by the ISAK, which could be used as reference values for coaches or athletes.

Body composition is a very important variable influencing performance, but as recent studies

have demonstrated, this influence is rather difficult to prove. Goosey-Tolfrey (2005) and Iturricastillo et al. (2015) found that although oxygen consumption and physical abilities have improved in male wheelchair basketball players after a training period, a significant change in body composition could not be determined. In both studies, dietary intake was not controlled, but because nutrition has a significant role in body composition, a possible influence of diet has to be taken into account. So both variables should be simultaneously examined in elite athletes.

So far, there are no specific recommendations regarding nutrition for Paralympic sports. Therefore, the recommendations based on able-bodied athletes from the ACSM or the ISSN for nutrient intake in relation to exercise intensity must be transferred to Paralympic athletes (Rodriguez et al. 2009, Goosey-Tolfrey and Crosland 2010, Jeukendrup 2013, Kreider et al. 2010, Krempien and Barr 2011, Thomas et al. 2016). On that point, at least two elements should be considered: the lower energy expenditure in athletes with SCI as a result of the smaller muscle mass below the lesion level (Goosey-Tolfrey and Crosland 2010, Croft et al. 2010) and the higher inter-individual variability in dietary intake in male and female wheelchair athletes (Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2011, Krempien and Barr 2012). These factors among others demonstrate the need to monitor diet and body composition in Paralympic athletes and to develop anthropometric reference values in this population group, given that this is the most commonly used assessment method for body composition.

Because wheelchair basketball has emerged into one of the most popular Paralympic sports, an optimized performance is especially important for wheelchair basketball players to compete at the highest level. Consequently, the aims of this study were to (1) examine and describe segmental body composition data, and (2) analyze dietary intake and its relationship to body composition and other anthropometric variables in male and female high-performance wheelchair basketball players.

4.2 Methods

4.2.1 Characteristics of the participants

Two groups of Paralympic athletes (12 males and 10 females) belonging to the Spanish national wheelchair basketball team participated in the study. Diagnoses in both teams were spinal cord injuries (males $n=12$, females $n=9$) resulting either from accidents, spina bifida, or

infections, and amputation (females $n=1$). Because only one female athlete occurred to have an amputation, the teams were not separated according to their disability.

Evaluations were conducted during a five-day training camp in Madrid (Spain) in the precompetitive phase by June 2015, where the teams stayed in two different hotels. The Ethics Committee of the Technical University of Madrid (Spain) approved the study, and it was undertaken in accordance with the Helsinki Conference involving research on humans (Williams 2008). The volunteer participants were informed about the purpose of the study and gave their written consent before taking part.

4.2.2 Body composition

All anthropometric measurements were completed following the standardized principles from the ISAK (Marfell-Jones et al. 2012) by ISAK-certified Level I anthropometrists. For athletes who were able to stand (males $n=4$, females $n=1$), the measurements were done in the proposed standing position; all other athletes were measured in a standardized seating position. Every measure was performed twice, and when any unacceptable error between data occurred, a third measurement was taken. For analysis, the average of two measurements was used, and in the case of a third measurement, the median was considered.

Height was measured on a stadiometer (DKSH Switzerland Ltd, Switzerland) to the nearest 0.1 cm in a standing position when possible. For athletes who were unable to stand (males $n=8$, females $n=9$), the formula according to Canda (2009) was applied to estimate the height from the measured arm span and seated height. Body weight was determined on a calibrated scale (Kern MWS, Twister Medical, Barcelona, Spain) to the nearest 0.1 kg in minimal clothing. Participants were first weighed in their wheelchair; subsequently, the chair was weighed without the participant, and the wheelchair weight was then subtracted from the combined weight.

Skinfold thickness was measured in a seated position, using a caliper (GPM, Skinfold Caliper, DKSH Switzerland Ltd, Switzerland) with a measuring range of 0–45 mm at the triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, thigh, and medial calf in accordance with the ISAK protocol. All measurements were taken on the right side. Two sums were calculated, each with four upper body skinfolds: ΣSK_{41} (biceps, triceps, subscapular, and iliac crest) and ΣSK_{42} (triceps, subscapular, iliac crest, and abdominal). The sum of all eight skinfolds ΣSK_8 was calculated as well.

4.2.3 Diet composition

Diet composition was determined by a daily intake food protocol during each day of the camp. All participants received a previously written and personal oral explanation about how to deal with the nutritional and physical activity protocol during the training camp.

The meal plan of both hotels was known. Breakfast was offered as a buffet, from which the participants were able to choose their food from a continental breakfast. It was also possible to take snacks for the breaks between training sessions. Lunch and dinner were served on plates, where both groups had an appetizer, main dish and a dessert. In both hotels, water was the only beverage offered during each meal. Bread rolls and a standard serving of each dish had been weighed in both hotels using an electronic scale (1 g accuracy; Mettler-Toledo S.A.E, Barcelona, Spain). All nutritional data were analyzed using the DIAL version 2 program (Alce Ingeniería, Madrid, Spain).

To assess diet quality, the “overall” index, consisting of a qualitative and quantitative evaluation of the data, was calculated using the DIAL software for the five different food groups (cereals and legumes; vegetables; fruits; dairies; meat, fish and eggs) together with the percentage of fat (%kcal); the energy of saturated fatty acids (%kcal); cholesterol (mg); salt and food variety. Each food group index was defined by the number of portions and ranged from 0 to 10, with higher values representing better quality. Portion size references for food items and numbers of items were taken from recommendations for healthy and active people in the Spanish population (Dapcich et al. 2004).

Energy expenditure was calculated using written activity protocols for each day. Resting energy expenditure was estimated according to Abel et al. (2008). To calculate the energy cost of physical activities, the compendium of Collins et al. (2010) was used for athletes with a spinal cord injury or Abel et al. (2008) and Bernardi et al. (2010) for amputees.

4.2.4 Statistical analysis

Normal distributions were tested using the Shapiro-Wilk test. Sex differences were examined via independent two-sided Student's t-tests for parametric data and Mann-Whitney-U-tests for non-parametric data, with Hedges' *g* used as the effect size. Pearson and Spearman correlations for parametric and non-parametric data, respectively, were computed to determine the linear relationship between nutrition and body composition. To compare the skinfold thickness with the values for able-bodied basketball players, percentiles were

calculated for the skinfold sum of the trunk ΣSK_{Trunk} (subscapular, abdominal, and iliac crest) and the legs ΣSK_{Legs} (thigh and calf) using the reference values reported by Santos et al. (2014). Data are reported as the mean $\pm$ standard deviation. Significance was accepted at $p < 0.05$, and all tests were performed using SPSS version 23 (IBM Corp., Armonk, NY, USA).

4.3 Results

Results show that while male wheelchair players were significantly older, taller, and heavier than the females, the BMI did not differ between males and females (Table 4.1). The number of training minutes completed during the training camp and the years in high performance sport were significantly greater in males than in females (Table 4.1).

Table 4.1. Participant characteristics

Parameter	Men (n = 12)	Women (n = 10)	p-Value	Hedges' g
Age (years)	29.4 $\pm$ 6.8	22.1 $\pm$ 6.3	0.017	1.22
Height (cm)	180.7 $\pm$ 5.1	154.3 $\pm$ 18.5	<0.001	2.22
Weight (kg)	78.2 $\pm$ 16.7	57.9 $\pm$ 16.2	0.009	1.35
BMI (kg/m ²)	23.9 $\pm$ 4.7	24.4 $\pm$ 5.5	0.832	-
Years in wheelchair	11.9 $\pm$ 5.9	14.2 $\pm$ 5.3	0.470	-
Training (min/day)	249 $\pm$ 26	174 $\pm$ 22	<0.001	3.39
Years in elite sport	8.5 $\pm$ 3.4	4.8 $\pm$ 3.8	0.034	1.14

BMI, body mass index

The skinfold thickness of the triceps and the thigh was significantly greater in the female participants relative to the males (Figure 4.1 and Table 4.2). The remaining skinfold thickness and the sums of the four and eight skinfolds were not significantly different (Table 4.2).

Table 4.2. Skinfold thickness and sum of skinfolds of male and female wheelchair basketball players

Skinfold	Men (n = 12)	Women (n = 10)	p-Value	Hedges' g
Triceps (mm)	11.1±3.9	17.2±9.2	0.046	1.00
Subscapular (mm)	15.0±6.4	16.1±8.7	0.507	-
Biceps (mm)	5.9±4.0	9.0±5.7	0.275	-
Iliac crest (mm)	21.4±10.9	22.4±10.3	0.815	-
Supraspinale (mm)	19.8±10.6	15.5±8.9	0.325	-
Abdominal (mm)	24.1±9.7	18.7±9.8	0.212	-
Thigh (mm)	21.5±9.7	30.3±7.2	0.026	1.13
Medial calf (mm)	17.2±8.5	24.5±9.9	0.077	-
ΣSK_{41} (mm)	53.4±22.8	64.9±31.6	0.334	-
ΣSK_{42} (mm)	69.9±29.2	67.6±33.7	0.861	-
ΣSK_8 (mm)	135.9±51.3	153.9±62.1	0.466	-

ΣSK_{41} , sum of biceps, triceps, subscapular, and iliac crest skinfolds; ΣSK_{42} , sum of triceps, subscapular, iliac crest, and abdominal skinfolds; ΣSK_8 , sum of all eight skinfolds

Figure 4.1. Skinfolds map of male and female wheelchair basketball players. Values are represented as means $\pm$ SD and expressed in millimeters

Compared to normative data from able-bodied basketball players, the skinfolds sum of the trunk ΣSK_{Trunk} showed no difference from normal (median, 50th percentile) in the male participants and were slightly greater for females (Table 4.3).

Table 4.3. Percentiles of the skinfolds sum of the trunk and of the legs

Parameter	Men (n = 12)	Women (n = 10)	p-Value	Hedges' g
ΣSK_{Trunk}	47.8 $\pm$ 34.2	60.0 $\pm$ 34.1	0.411	-
ΣSK_{Legs}	83.8 $\pm$ 31.7	70.3 $\pm$ 32.3	0.067	-

ΣSK_{Trunk} , sum of subscapular, abdominal, and iliac crest skinfolds; ΣSK_{Legs} , sum of thigh and calf skinfolds

The skinfolds sum of the legs ΣSK_{Legs} was greater than for the able-bodied basketball players in both male and female wheelchair participants, and a trend toward statistical significance was observed (p=0.067).

Diet analysis revealed a significantly higher total energy intake for the males relative to the females (Table 4.4). This difference disappeared when the total energy intake was expressed per bodyweight. When macronutrients were calculated per body mass, carbohydrate and fat intake did not significantly differ between males and females (Table 4.4). The distribution of macronutrients showed higher carbohydrate and lower fat intake for males than for females (Table 4.4). Thereby, the female players derived half of their energy from fat alone. The dietary intake of cholesterol was over the recommendation of 300 mg/day in both groups, with greater amounts in male athletes (Table 4.4).

Table 4.4. Dietary intake of male and female wheelchair basketball players

Parameter	Men (n = 12)	Women (n = 10)	p-Value	Hedges' g
Energy intake (kcal)	3194±504	1916±404	< 0.001	3.03
Energy intake (kcal/kg)	42.3±10.3	36.2±15.3	0.277	-
EE (kcal)	4084±1073	2496±648	0.001	1.92
ΔEE-EI (kcal)	890±1029	581±803	0.449	
ΔEE-EI (% of EE)	16.6±26.2	18.5±28.6	0.875	
Carbohydrate (%)	37.1±4.8	32.5±3.6	0.020	1.18
Protein (%)	19.1±1.1	17.4±2.5	0.066	-
Fat (%)	43.6±4.9	50.1±4.0	0.003	1.59
Carbohydrate (g/kg)	3.8±1.2	2.9±1.4	0.109	-
Protein (g/kg)	2.0±0.5	1.5±0.6	0.047	0.99
Fat (g/kg)	2.0±0.4	2.0±0.8	0.928	-
Cholesterol (mg)	671±171	389±86	< 0.001	2.22

EE, energy expenditure; EI, energy intake

The overall quality index of participants' dietary intake was higher in male athletes than in females. In addition, a better number of portions of cereals and vegetables was evident for males compared to females (Table 4.5). Although both males and females reached the maximum value of 10 for meat, they exceeded the recommended portions of meat by 2.4 times and 1.7 times, respectively ($p<0.001$; $g=1.93$). The males consumed more portions of cereals ($p<0.001$; $g=2.57$) and vegetables ($p<0.001$; $g=2.59$) than the women (Figure 4.2).

Figure 4.2. Portion of food group intake for male and female wheelchair basketball players

Table 4.5. Diet quality and portions of intake by food group

Diet quality	Men (n = 12)	Women (n = 10)	p-Value	Hedges' g
Overall (0 to 100)	52.4±9.1	44.5±6.0	0.018	1.10
Fat (%)	43.6±4.9	50.1±4.0	0.003	1.59
Fat Index	1.7±1.9	0.0±0.1	0.001	1.32
Saturated fatty acids (%/kcal)	13.0±1.9	15.3±1.3	0.005	1.50
Saturated fatty acids Index	4.0±2.9	1.0±1.5	0.007	1.38
Variety	13.2±2.4	8.0±2.3	< 0.001	2.42
Variety Index	7.0±2.1	2.2±2.0	< 0.001	2.56
Cereals and legumes	7.4±1.7	4.7±1.2	< 0.001	2.00
Vegetables	7.1±2.0	4.0±1.8	0.001	1.77
Fruits	4.7±3.3	3.2±2.8	0.274	-
Dairies	7.1±2.1	5.9±2.3	0.205	-
Meat, fish, eggs	10.0±0.0 ^a	10.0±0.0 ^b	-	-

^a Male players, with 7.1±1.5, exceeded the maximum portions (2.9±0.2).

^b Female players, with 3.8±0.9, exceeded the maximum portions (2.3±0.3).

The sum of four skinfolds, ΣSK_{41} , was negatively correlated with the percentage of energy intake derived from carbohydrates ($r=0.45$; $p=0.036$), but positively correlated with the percentage of energy derived by fat ($r=0.45$; $p=0.035$).

4.4 Discussion

The present study reports reference values for the skinfold thickness body composition measurement method that was standardized according to the ISAK protocol in male and female elite wheelchair basketball athletes.

This investigation found that the percentages of carbohydrate and fat intake were inversely related to regional body composition in wheelchair basketball athletes, with a higher percentage of carbohydrates leading to a lower sum of upper body skinfolds.

One consequence of SCI is a deterioration of body composition as well as segmental differences between the upper and lower body. Studies found, that paraplegic non-athletes had generally lower lean and higher fat mass in the whole and lower body, but no difference in arm lean and fat mass compared to able-bodied controls (Beck et al. 2014, Dionyssiotis et al. 2008). Other studies have reported even higher lean mass in the arms for both male and female wheelchair athletes relative to able-bodied athletes and lower values in the whole and lower body (Miyahara et al. 2008, Sutton et al. 2009). Reasons for this are lower muscle mass below the lesion levels in athletes with SCI as a result of paralysis (Glaser 1985), which causes reduced sympathetic nervous system activity (Leicht et al. 2012).

Measurement of skinfold thickness is the most frequently used field-based method of determining body composition and could be used to determine whole and segmental body composition (Meyer et al. 2013); however, equations needed for converting skinfolds into whole body fat have been developed only for able-bodied athletes and showed poor agreement with DXA in wheelchair athletes (Mojtahedi et al. 2009, Sutton et al. 2009, Willems et al. 2015). Regarding the segmental body composition in wheelchair and able-bodied athletes this was predictable and highlights the use of the raw data of skinfold thickness, which could be used separately as an indicator of fat contents for different body parts or as a sum of certain skinfolds for body segments or the whole body, rather than equations.

The results of this study showed differences for the upper body only for the triceps, with higher skinfold thickness in females relative to males. Compared to a mixed gender group

(males $n=15$, females $n=5$) of non-athletes with SCI the triceps skinfold thickness (16.3 ± 8.1 mm) was lower in the male wheelchair athletes of the present study and equal in the female (Desport et al. 2000). Because of the higher prevalence of male non-athletes in the mixed group in the study of Desport et al. (2000), the results of skinfold thickness may have been greater, when data would have been displayed for the female non-athletes separately. For the male participants, the single skinfold thickness of the upper body was in line with Bulbulian et al. (1987) and Iturricastillo et al. (2015). In comparison to younger (18.1 ± 4.1 years) or male wheelchair basketball players with lower athletic status (Spanish first- and third-division teams) their skinfolds and the skinfolds sum ΣSK_{42} were approximately 12% to 56% lower (Granados et al. 2015, Cavedon et al. 2015, Gil et al. 2015). In this regard, Inukai et al. (2006) reported that training load and athletic history had a significant influence on the DXA-measured body fat percentage in male athletes with SCI. The skinfolds sum ΣSK_{41} was approximately 15% higher in males compared to British wheelchair athletes (Goosey-Tolfrey et al. 2003, Goosey-Tolfrey 2005) and comparable to Canadian wheelchair athletes (Krempien and Barr 2012).

Until now, no study had reported single skinfold thickness values for female wheelchair basketball players, so the results of the female participants could not be compared. In contrast to the male participants, females showed an approximately 13% higher skinfold sum ΣSK_{41} compared with that of Canadian female wheelchair athletes (Krempien and Barr 2012). However, these athletes were older (31 ± 5 years) and probably more experienced. It is quite possible that the observations from Inukai et al. (2006) regarding training load and athletic history could also be applied to female wheelchair athletes. The female wheelchair basketball players participated significantly fewer years in high performance basketball than the male players.

Regarding the thickness of the lower-body skinfolds, female participants had significantly higher thigh skinfold thickness compared to males, which is not surprisingly due to their vital circle. Only Bulbulian et al. (1987) reported lower-body skinfold thickness in male wheelchair basketball players, and the skinfold thicknesses of the thigh and calf reported in their study were comparable to those of the males in our study.

Because no reference values for skinfold thickness in male and female wheelchair basketball players currently exist, we compared them with percentiles for able-bodied basketball players (Santos et al. 2014). The skinfolds sum of the trunk ΣSK_{Trunk} showed no deviation from normal (50th percentile) in males and was slightly greater for females. In contrast, the

skinfolds sum of the legs ΣSK_{Legs} was greater than normal for male and females. DXA measurements also showed this segmental difference (Miyahara et al. 2008, Sutton et al. 2009), indicating why equations developed for able-bodied athletes to convert skinfold thickness into percentage of body fat could not be transferred to wheelchair athletes (Mojtahedi et al. 2009, Sutton et al. 2009, Willems et al. 2015).

When analyzing the relationship between body composition and nutrition, significant correlations between the upper body skinfolds sum ΣSK_{41} and percentage of carbohydrate, respectively fat intake were found. The results revealed similar but contrary values, which is understandable given the relationship of carbohydrates to fat intake. The participants with higher carbohydrate intake showed lower sums of upper body skinfolds. The same but reciprocal relationships were shown recently by Gorgey et al. (2015) between carbohydrate and fat intake and lean mass, as measured by DXA in male non-athletes with SCI.

Regarding nutrition, the male participants had a higher caloric intake compared to the females. These results are not surprising, and such gender differences have been found elsewhere (Goosey-Tolfrey and Crosland 2010, Stellingwerff et al. 2011). However, when referring to their body mass, we observed no differences by gender, although the values were higher in both males and females than previously reported (Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2011). Compared to a mixed gender sample of non-athletes with SCI the caloric intake was higher both absolute and normalized to body mass in the participants (Bertoli et al. 2006).

The distribution of macronutrients to energy intake showed a lower percentage of carbohydrates and a higher percentage of fat in females relative to the males. This could be explained by the males' longer participation in elite sports. In both groups, the percentage of fat was higher, as noted in British and Canadian wheelchair athletes (Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2012). The results in g/kg revealed a carbohydrate intake below the ACSM recommendations of 5-10 g/kg, which appears common among elite wheelchair athletes but bares the risk of insufficient energy for performance and inadequate micronutrient intake (Erdmann et al. 2013, Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2011, Rodriguez et al. 2009, Thomas et al. 2016). In contrast to the low carbohydrate, the protein intake of both male and female participants was in the ACSM recommended range of 1.2-2.0 g/kg (Rodriguez et al. 2009, Thomas et al. 2016).

Some of these discrepancies could be explained by the absence of specific recommendations for athletes with SCI. Regarding the previously described altered body composition in

comparison to able-bodied athletes, such as lower muscle mass, the energy expenditure and requirements for athletes with SCIs are lower and influenced by lesion level.

The other explanation could be the poor diet quality of the participants. Their main source of protein was meat, but all participants exceeded the recommended portions, leading to cholesterol intakes well above the recommendations of 300 mg/day. All other portions of food groups were below recommendations of Dapcich et al. (2004), with higher cereals, legumes and vegetables intake for males. Raising the intake of vegetable protein would have led to a lower fat intake. Furthermore, yogurt might induce positive aspects in the regulation of mouth to caecum transit time due to changes in the fecal bacteria flora (Ortega 2002), which is a very sensible and important topic among athletes with SCI. With regard to dairy products, Ortega et al. (2006) emphasized their importance in the Mediterranean diet, because the lactic acid bacteria confer probiotic benefits, better gastrointestinal health, and immune response.

Fruits are recommended eaten at least 3 times per day, but only 1.9 ± 1.2 in males and 1.4 ± 0.5 in females did so. Because the fruits are important sources of fiber, vitamins, minerals, flavonoids, and terpenes, which help protect the body against oxidative stress (Serra-Majem et al. 2004), often occurring through high intensity training, the participants should be encouraged to increase their fruit intake, especially as snacks. Fruits additionally are a source of water, which can be crucial in wheelchair athletes, because fluid intake can be difficult.

It seemed that the absence of a buffet style, as personal dislikes or discomforts of certain food groups or meals could not be addressed because plate meals were offered to the participants, which limited the variation tremendously, had have an influence of the diet quality. Hence, the males could choose from a mixed salad during lunch and showed a higher variety index than the females. If a menu style is unavoidable, it seems necessary to give additional nutritional advice and to emphasize fruit intake. One way to increase fruit intake, for instance, would have been to serve them in sliced form or as fruit salad in the main dishes. Another possible way would have been to offer them as snacks, during the training breaks, while still at the training hall.

The female athletes of this study were less experienced as shown by less years in sport and showed a lower athletic status in wheelchair basketball compared to the male athletes, which could be an explanation for some differences in body composition and nutrition habits. Their training time was additionally significantly lower than for the male athletes, which could

explain the lower energy expenditure. As energy expenditure was only calculated from activity protocols, the results must be interpreted with caution.

4.5 Limitations

The small sample size did not allow the calculation of representative percentiles for skinfold thickness measurements for elite wheelchair athletes. However, this is the first study that reported the raw data of all eight skinfold thickness measurements, standardized according to the ISAK for male and female wheelchair athletes.

Regarding nutrition, one limitation of this study was the absence of a control group with a buffet style diet, but the small sample size together with no influence on the chosen hotels prevented this. Additionally, the participants estimated their nutritional intake themselves, and no direct measurements were taken. In fact, they received previous detailed instructions, e.g., regarding portion sizes, but errors might have occurred. The quality index calculated by the nutrition software DIAL used in this study to assess the diet quality is based on the normal population, and therefore, must be interpreted with caution. Even though choosing a diet quality index is complicated and probably not suitable for special populations, we used it to integrate quantitative and qualitative data pertaining to diet. However, it could be used to assess the food variety, which is recommended by the ACSM (Rodriguez et al. 2009, Thomas et al. 2016). Finally, it has to be mentioned that results cannot be generalized to the athletes' daily lives because data were collected during high intensity training camps, and plate meals were offered.

4.6 Conclusion

Body composition assessment can be used to monitor both training and nutrition interventions in the long term. Standardized skinfold thickness measurements are easy to perform and applicable in wheelchair athletes. Use of the raw data allows the monitoring of intra-individual, longitudinal changes in body composition, even regarding the segmental differences in wheelchair athletes. However, to classify the inter-individual standing within the population of wheelchair athletes, normative values for the raw data of standardized skinfold thickness measurements are required.

The relationship between body composition and nutrition shows lower skinfold thickness for athletes, with higher percentage of carbohydrate and lower percentage of fat intake.

Therefore, nutritional knowledge is necessary to improve dietary intake and to support training programs that can enhance body composition. Additionally, our results show that meals offered as plates instead of a buffet may lead to poor results. If plate meals are unavoidable, emphasizing fruit and vegetable intake should be encouraged to assure a balanced diet.

4.7 Future lines

Future studies should further investigate the different phases over one year, taking high intensity training days and periods as well as off seasons into account regarding changes in body composition and nutrition.

Chapter Five

Dietary Intake and Mediterranean Diet Quality in High-Performance Wheelchair Basketball Players in Two European Nations

5.1 Introduction

Achieving the best possible outcome in training and competition is the primary objective of every athlete regardless of competitive level. Therefore, every athlete seeks to enhance all aspects of performance and also high-performance Paralympic athletes participate in training programs similar to the programs of their able-bodied counterparts (Broad and Burke 2014). The principles of sports nutrition not only support training effectiveness and enhance competitive performance during training and competition but following these principles may also represent the difference between success and failure (Kreider et al. 2010, Thomas et al. 2016).

Hence, monitoring and supervising individual dietary intake should lead to an optimized and well-balanced diet, which compensates the high energy expenditure of athletes and supplies the athletes with the essential macro- and micronutrients (Kreider et al. 2010, Thomas et al. 2016). Although no specific nutrient recommendations for Paralympic sports yet exist, the recommendations based on able-bodied athletes from the ACSM and the ISSN for nutrient intake in relation to exercise intensity can be transferred to Paralympic athletes (Jeukendrup 2013, Kreider et al. 2010, Rodriguez et al. 2009, Thomas et al. 2016). However, some anatomical and physiological consequences resulting of their impairment such as lower active muscle mass due to limb amputation or paralysis because of SCI together with less activity or even immobility, must be considered (Croft et al. 2010, Price 2010).

In this regard, previous studies have reported relatively low energy intake in wheelchair athletes compared with their abled-bodies counterparts (Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2011, Krempien and Barr 2012). In fact, low energy intake often lacks dietary variety (Grams et al. 2016), which results in inadequate micronutrient intake and a weaker immune system, risking players being absent from training and competitions (Derman et al. 2014, Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2011). Therefore, a healthy and nutrient-dense diet is particularly important for wheelchair athletes with low

energy intake consisting of carbohydrate-based food groups (e.g., bread, cereals and grains, legumes, milk, vegetables, and fruits) as emphasized by the ACSM and ISSN (Kreider et al. 2010, Rodriguez et al. 2009). Following a typical Western diet, which is rich in refined sugars, alcohol, salt, fatty domestic meats, and processed foods, but poor in grains, legumes, vegetables, and fruits, can make it difficult to achieve the appropriate intake of macro- and micronutrients without supplements (Cordain et al. 2005, Thomas et al. 2016). A more promising diet is the Mediterranean diet, which is characterized by high amounts of cereals and whole grains, legumes, vegetables, and fruits besides high intakes of olive oil, fish, and nuts (Sanchez-Benito et al. 2009). Although the Mediterranean diet is traditionally being consumed in the Mediterranean region such as Spain (Ortega 2006), the Mediterranean-style eating pattern is currently being widely disseminated and has found its way into dietary guidelines around the world, such as in the US (U.S. Department of Health and Human Services and U.S. Department of Agriculture 2015).

Together with the fact that there is scarcely any knowledge available regarding food intake in Paralympic or wheelchair athletes in general (Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2011, Krempien and Barr 2012) or data comparing nutrition during training camps in two different nations, the goals of this investigation are to 1) compare the diet composition of high performance German and Spanish male wheelchair basketball athletes during precompetitive training camps and 2) evaluate the quality of their diets with particular focus on whether the teams followed the Mediterranean diet.

5.2 Methods

5.2.1 Participants

Two groups of male athletes belonging to the Spanish and German national teams of wheelchair basketball participated in the study. Evaluations were completed during the precompetitive phase in 2015 during a five day training camp.

The Ethics Committee of the Technical University of Madrid (Spain) approved the study, which was conducted in accordance with the Helsinki Declaration for research on humans (Williams 2008). The volunteer participants were informed of the purpose of the study and gave their written consent before participating.

5.2.2 Anthropometrics

Body weight was determined using a calibrated scale (Kern, Twister Medical, Spain) to the nearest 0.1 kg with athletes wearing minimal clothing. Height was measured using a stadiometer (DKSH Switzerland Ltd, Switzerland) to the nearest 0.1 cm in a standing position, and for athletes who were unable to stand, the formula recommended by Canda (2009) was applied to estimate height based on arm span and seated height.

5.2.3 Diet composition

Diet composition was determined by food intake protocols over the entire period, and all players previously received written and oral information in personal interviews explaining how to complete the nutritional protocol. Players were also encouraged to take a photo of their meals if they were not confident regarding how to properly describe the meal.

Both teams were served breakfast from a continental buffet, and players could carry away snacks such as fruit or cereal bars. The rest of the meals for the Spanish team were plated meals, comprising an appetizer, main dish and dessert, which could be chosen from a menu. The German athletes were able to choose from a buffet for all meals during the training camp. All nutritional data from the Spanish team were analyzed using the DIAL version 2 program (Alce Ingeniería, Madrid, Spain). For the German players, the software from the German Federation for Nutrition DGE-PC version 5.1.0.048 (GOE mbH, Linden, Germany) was applied. The factors used for the conversion of the energy values from the macronutrients of both programs are comparable and the country-specific food databases take e.g. different ways of enriching foods, different recipes, or different growth rates of plants due to the climatic conditions, into account. The researchers undertaking the analysis were familiar with the respective program.

5.2.4 Diet quality

Adherence to the Mediterranean diet was evaluated with the Mediterranean Adequacy Index (MAI) (Alberti et al. 2009, Sanchez-Benito et al. 2009). The level of adherence was calculated by dividing the sum of the percentages of dietary energy from food groups typical of a healthy Mediterranean diet (cereals + legumes + potatoes + vegetables + fresh and dried fruit + fish) by the sum of the percentages of the dietary energy of food groups atypical of a Mediterranean diet (meat + eggs + cookies + processed dishes). Consistent with Sanchez-

Benito et al. (2009), the consumption of dairy milk was excluded from the calculation of the MAI because the athletes consumed whole cow's milk instead of typical Mediterranean goat's milk. The researchers classified the food into the appropriate food groups, before the energy of each food group was calculated. Additionally, the fat intake profile was calculated as the quotient of the sum of mono- and polyunsaturated fatty acids divided by saturated fatty acids.

To evaluate diet quality in terms of micronutrient adequacy, five micronutrients with special interest for athletes (Thomas et al. 2016) were examined (calcium, iron, and vitamins A, C, and E) using the probability approach recommended by the American Dietetic Association, and the EAR cutpoint method with the latest United States and Canada DRI (Institute of Medicine 2000, Institute of Medicine 2001, Murphy and Barr 2011).

5.2.5 Statistical analysis

Normal distribution was tested with the Shapiro-Wilk test. For comparing the two teams, unpaired, two-sided Student's t-tests for parametric data and Mann-Whitney U-tests for non-parametric data were performed. Hedges' g was determined to estimate the effect size. The variability in nutrient intake values was calculated using the coefficient of variation (CV), which describes variability relative to the mean. To compare the adequacy of micronutrient intake for both teams, Fisher's exact tests were calculated. All data are presented as the mean±standard deviation. Significance was accepted at $p < 0.05$. All tests were performed with SPSS version 23 (IBM Corp., Armonk, NY, USA).

5.3 Results

Table 5.1 shows the German and Spanish athletes' characteristics. There were no differences between the teams in age, height, weight, or BMI.

Table 5.1. Participants' descriptive characteristics

Parameter	German (n = 12)	Spain (n = 13)	p-Value	Hedges' g
Age (years)	29.1±5.9	29.6±6.5	0.833	-
Height (cm)	176±15	180±5	0.335	-
Weight (kg)	69.4±16.4	78.2±16.0	0.188	-
BMI (kg/m ²)	22.3±3.5	24.0±4.5	0.296	-
BMI, body mass index.				

The nutrient intake of the German and Spanish teams is shown in Table 5.2. The energy intake was significantly lower in the German team with a higher variability (CV=32%) than in the Spanish team (CV=16%). The macronutrients' contribution to energy intake showed significantly higher amounts of carbohydrates and protein and lower amounts of fat for the German team than for the Spanish team. The differences in energy (kcal), carbohydrate (g/day) and protein (g/day) intakes disappeared when intakes were calculated based on body mass (kcal/kg or g/kg); however, the lower fat intake in the German team remained even considering body mass (g/kg). The German team showed slightly higher values in dietary fiber intake than the Spanish team although both teams' intakes were within the recommendations of 25-30 g/d (Table 5.2). The cholesterol intake was significantly lower in the German team than in the Spanish team (525 ± 331 mg compared with 680 ± 167 mg, respectively; $p < 0.001$, $g = 0.65$); however, both mean values were above the recommendations of 300 mg.

The German team had a higher snack contribution to energy intake ($18.7 \pm 8.3\%$) than the Spanish team ($4.4 \pm 3.4\%$, $p < 0.001$, $g = 2.49$). Thus, the protein contribution to snack energy was also higher in the German team ($14.3 \pm 11.7\%$) than in the Spanish team ($7.0 \pm 7.3\%$, $p < 0.001$, $g = 0.82$).

Table 5.2. Nutrient intake for the German and Spanish teams

Parameter	German (n = 12)	Spain (n = 13)	p-Value	Hedges' g
Energy intake				
Per day (kcal)	2473±786	3235±505	0.008	1.26
Per kg body mass (kcal/kg)	36.6±12.0	42.7±9.9	0.172	-
Carbohydrate				
Per day (g/day)	271.4±98.3	290.0±61.5	0.573	-
Contribution (%)	44.3±5.2	37.5±4.8	0.002	1.50
Per kg body mass (g/kg)	4.0±1.4	3.9±1.2	0.782	-
Protein				
Per day (g/day)	131.4±44.0	153.3±26.4	0.141	-
Contribution (%)	21.8±4.0	18.9±1.3	< 0.001	1.08
Per kg body mass (g/kg)	1.9±0.6	2.0±0.5	0.610	-
Fat				
Per day (g/day)	88.4±30.4	157.0±27.3	< 0.001	2.58
Contribution (%)	31.7±5.7	43.4±4.7	< 0.001	2.45
Per kg body mass (g/kg)	1.3±0.5	2.1±0.4	< 0.001	1.66
Fiber (g)	25.2±12.7	23.0±4.0	< 0.001	0.26

The fat intake profiles are displayed in Figure 5.1 and Table 5.3. The Spanish team derived significantly more energy from monounsaturated fatty acids than the German team. The quotient of the sum of mono- and polyunsaturated fatty acids divided by saturated fatty acids was significantly higher for the Spanish team (2.08 ± 0.26) than for the German team (1.54 ± 0.30 , $p < 0.001$, $g = 2.11$). No significant difference in the MAI was identified between the German (1.28 ± 0.50) and the Spanish teams (1.22 ± 0.41 , $p = 0.771$).

Table 5.3. Fat intake profiles for the German and Spanish teams

Parameter	German (n = 12)	Spain (n = 13)	p-Value	Hedges' g
Saturated fats (g)	32.7±12.0	46.9±9.0	< 0.001	1.46
Monounsaturated fats (g)	31.6±10.9	76.7±12.6	< 0.001	4.14
Polyunsaturated fats (g)	16.9±7.0	19.6±4.6	0.250	-

Figure 5.1. Energy derived from saturated and unsaturated fats

Figure 5.2 shows the adequacy of dietary intake of selected micronutrients for the German and Spanish teams. All players had intakes of iron above the RDA. The intake of vitamin A was significantly higher in the Spanish team, above both the EAR ($p<0.001$) and RDA ($p=0.015$). The Spanish team showed a higher adequacy of vitamin C although the difference was not significant ($p=0.096$).

Figure 5.2. Probability of adequate micronutrient intake (EAR, Estimated Average Requirements; RDA, Recommended Dietary Allowance)

5.4 Discussion

This study proposed to display and compare energy intake, diet composition and adherence to the Mediterranean diet in male Spanish and German high-performance wheelchair basketball players during a precompetitive season.

Experts agree that nutrition plays a key role in athletes' health and supports training effectiveness and enhances competitive performance during training and competition (Kreider et al. 2010, Rodriguez et al. 2009, Thomas et al. 2016). However, the existing recommendations of the ACSM or the ISSN are based on investigations of able-bodied athletes and no special recommendations for wheelchair athletes have been developed, so far (Kreider et al. 2010, Rodriguez et al. 2009, Thomas et al. 2016). But, because no strong evidence exists that the muscles of athletes with SCI respond differently from the muscles of able-bodied athletes, the principles of sports nutrition can be transferred to wheelchair athletes, considering their impairment (Knechtle et al. 2003, Leicht et al. 2012). In this regard, one major difference is a lower active muscle mass in disabled athletes because of limb amputation or paralysis together with less activity or even immobility (Croft et al. 2010, Price 2010). Hence, their energy expenditure and requirements are lower than for their able-bodied counterparts and are additionally influenced by the lesion level in athletes with SCI (Croft et

al. 2010). Therefore, the energy intake of a wheelchair basketball team, which comprises, according to the rules of the International Wheelchair Basketball Federation (International Wheelchair Basketball Federation 2016), players with different levels of impairment, will show great variability, as displayed by the participating German team (CV=32%) or in British (CV=44%) or Canadian (CV=26%) wheelchair athletes as shown by Goosey-Tolfrey and Crosland (2010) and Krempien and Barr (2011) respectively. The Spanish team, however, had less variability (CV=16%) and higher energy intake (3235 ± 505 kcal) than the German team (2473 ± 786 kcal) or the British (2060 ± 904 kcal) and Canadian (2028 ± 528 kcal) teams (Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2011). This may partially be explained by their plated meals, as previously observed by Krempien and Barr (2011), because the plated meals were served in identical sizes and therefore some Spanish players might have been tempted to eat more than required.

The macronutrients carbohydrate and fat are the primary sources of energy, and together with protein, each macronutrient plays a different role in sports nutrition (Thomas et al. 2016). A depletion of muscle glycogen stores is associated with reduced work rates, impaired skill, a lack of concentration and overall fatigue (Thomas et al. 2016). Therefore, according to the newest ACSM guidelines of 2016, able-bodied athletes should have had a carbohydrate intake of approximately 3-12 g/kg depending on training or competition intensity (Thomas et al. 2016). Based on these guidelines, the intake of both teams corresponded only to low-intensity activities (3-5 g/kg), with 4.0 ± 1.4 g/kg for the German and 3.9 ± 1.2 g/kg for the Spanish players. Identical low intakes were observed by Goosey-Tolfrey and Crosland (2010) and Krempien and Barr (2011) in British and Canadian wheelchair athletes. Because both the participating teams and these athletes were training at high intensity, the recommended intake for able-bodied athletes would be approximately 6-10 g/kg or even higher according to the ACSM Guidelines (Burke et al. 2011, Thomas et al. 2016). This divergence from the recommendations for able-bodied athletes may in part be explained by the lower muscle mass of athletes with SCI. In fact, the recommendations are based on body mass and not on muscle mass. Considering the liver and muscles' limited capacity to store glycogen, future research must determine the optimal amount for athletes with SCI (Goosey-Tolfrey et al. 2014).

The macronutrient protein is important because protein interacts with exercise and supports metabolic adaptation (Phillips 2012, Thomas et al. 2016). The German athletes had a protein intake of 1.9 ± 0.6 g/kg and the Spanish of 2.0 ± 0.5 g/kg, which were well within the ACSM recommendations of 1.2 to 2.0 g/kg. Higher intakes may be required during short, intensive

training periods (Phillips and van Loon 2011) and to support the healing of pressure ulcers or wounds, which can occur in wheelchair athletes (Lee et al. 2006). Spreading the protein intake over multiple meals per day can maximize muscle adaptation to training (Thomas et al. 2016), and the German team's snack intake was significantly higher both in terms of the number of snacks and the amount of protein per snack compared with the Spanish team.

The third macronutrient fat completes a healthy diet and provides essential fatty acids and fat-soluble vitamins and should compose 20% to 35% of energy intake (Institute of Medicine 2005, Thomas et al. 2016). Overall, fat contribution was significantly lower in the German team ($32\pm6\%$) than the Spanish team ($43\pm5\%$), who exceeded the recommendations. Such fat contents of approximately 30% were also observed in other publications (Goosey-Tolfrey and Crosland 2010, Krempien and Barr 2011); however, the Spanish team derived even more energy from fat ($43\pm5\%$) than from carbohydrates ($38\pm5\%$), which is not consistent with any nutritional recommendations for optimal sports performance.

When athletes are attempting to meet the recommendations of sports nutrition, differences between countries may appear because of their nutritional habits, which are based on their origins and might be influenced by the supposedly health-promoting Mediterranean diet for the Spanish team and the Western diet for the Germans, which is often associated with negative health outcomes (Mozaffarian et al. 2016). But contrary to our expectations, the MAI did not differ significantly between the teams (German: 1.28 ± 0.50 , Spanish: 1.22 ± 0.41). Compared to further studies, the German players reached higher results than expected, when comparing to German female adults that showed a MAI of 0.8 (Alberti et al. 2009). The results of the Spanish players were expected to be higher due to studies in young male Spanish cyclists who achieved 2.31 ± 0.70 (Sanchez-Benito et al. 2009), and healthy Spanish adults even had a MAI of approximately 1.7 (Mila-Villarroel et al. 2011). In addition to a generally lower adherence to the Mediterranean diet in the Spanish population (Leon-Munoz et al. 2012) and insufficient sports nutrition knowledge (Devlin and Belski 2015, Sanchez-Benito et al. 2009), the composition of the served plate meals as the main dishes, rich in fat and meat, may also explain the poor results of the Spanish team in this study.

These low MAIs were reflected in the poor adequacy of micronutrient intakes in both teams due to their low consumption of typical and nutrient-dense Mediterranean food groups. Thus calcium rich food groups (e.g., dairy, legumes, nuts, fish) represented approximately 10% of total energy intake for both teams and therefore the calcium intakes of only approximately

half of the players on each team exceeded the RDA, and approximately 40% of the German and 25% of Spanish players were below the EAR.

The Spanish players reached a higher amount of vitamin A. Although both teams reported an extremely low intake of typical vitamin A rich food sources, Serra-Majem et al. (2009) showed that adherence to a Mediterranean diet rather than a Western diet resulted in a greater adequacy of vitamin A. Pitsavos et al. (2005) observed a positive correlation between antioxidant capacity and the consumption of fruit, vegetables, and olive oil, but by contrast, the use of plant oils used for frying and cooking by the German team, having a high amount of vitamin E, may explain the higher levels of vitamin E in their diet. Vitamin C intake was adequate in all Spanish players and in 75% of the German team; however, the three German players with inadequate vitamin C levels consumed no fruit and only small amounts of vegetables. Because exhaustive exercise generates transient acute inflammation and oxidative stress (Bruunsgaard 2005), the positive effects of antioxidants on the immune system are particularly important for athletes (Gleeson et al. 2004, Marcos et al. 2003, Ristow et al. 2009), since illness can result in being absent from training and competitions (Derman et al. 2014, Goosey-Tolfrey and Crosland 2010). Therefore all players should try to reach at least the EAR for vitamin C and E.

Conversely, the second parameter of adherence to the Mediterranean diet, the quotient of the sum of mono- and polyunsaturated fatty acids divided by saturated fatty acids, was significantly higher in the Spanish team (2.08 ± 0.26) than in the German team (1.54 ± 0.30). The higher content of healthy fatty acids may partly be explained by the use of olive oil in the Spanish team (Soriguer et al. 2010). Although both teams consumed more unsaturated than saturated fatty acids, all athletes exceeded the recommendations by deriving more than 10% of their energy intake from saturated fatty acids and consuming more cholesterol than the recommended 300 mg, most likely because of high intakes of meat in the main dishes and cold cuts at breakfast.

5.5 Limitations

The major limitation is the use of two different programs for the analysis of diet composition. But modifying one database to analyze intakes for both teams with one program, may lead to miscalculations. However, some errors may have occurred because the athletes estimated the amount of each consumed food item according to detailed instructions, but did not weigh their food. In addition, the data were compiled during training camps, and the athletes may have

different nutritional patterns at home. In the case of micronutrient intake, values should be confirmed with further tests such as blood analyses.

5.6 Conclusion

German and Spanish high performance wheelchair basketball players showed inadequate dietary intake in terms of sports nutrition, barely adhering to the traditional Mediterranean diet, with an even lower index in the Spanish players than in the German players. Nevertheless, another component of the Mediterranean diet, the consumption of olive oil, led to a healthier fat intake profile in the Spanish players. Although fat is an important dietary component, high fat intake is contradictory to the recommendations for sports nutrition, which emphasize the roles of carbohydrates and protein in performance, and the Spanish team derived more energy from fat than from carbohydrates. The unbalanced diet of the Spanish team showed that plated meals with an unfavorable ratio of fat and carbohydrates during training camps should be avoided, or at least that a selection of fruits and vegetables should be offered with each meal. This would give the players the opportunity to make optimal food choices, such as replacing energy-dense⁸ with nutrient-dense foods. Additionally, because plated meals are normally all served in identical sizes, athletes should be aware of their energy demands and eat only as much as their bodies require. This caution is particularly important for wheelchair athletes, whose energy expenditures vary greatly depending on body size and composition, as well as the lesion level in case of SCI. But because athletes' food selection during training camps is limited due to the provided food by the kitchen staff, it is also necessary to discuss the principles of sports nutrition with the whole kitchen staff in advance to arrival. This should include the energy expenditure of the athletes and the need to provide at least two of each macronutrient sources, e.g. potatoes and pasta in the case of carbohydrates at lunch and dinner. This is especially important if plate meals are unavoidable. Besides, more nutritional knowledge for all athletes appears to be necessary to assure that athletes choose foods which are both nutrient-dense and which avoid any discomfort or digestion problems. Such nutritional advice may also be helpful if the players were able to choose their food freely from a buffet for each meal and when advice is given immediately before a training camp.

⁸ Energy-density: The amount of energy (or calories) per gram of food. Energy-dense foods are the opposite of nutrient-dense foods and provide a high amount of energy, but a low amount of micronutrients.

5.7 Future lines

Future research should investigate the nutrition of the players at home and, particularly for the Spanish athletes participating in this study, monitoring thereby their adherence to the Mediterranean diet, with particular emphasis on their excessive consumption of saturated fats and cholesterol. Body composition and its changes over the different training periods throughout one year should be evaluated in all athletes, paired with frequent nutritional advice.

Hence, changes in training load and intensity due to high or low season, as well as daily variations, can result in significant changes in energy expenditure, which in return have to be taken into account when giving nutritional advice.

Chapter Six

Conclusion

The conclusion section is separated into three parts, starting with the main conclusions (6.1) of the findings of all four studies (see Chapters Two to Five) that are part of this thesis, followed by, practical applications (6.2), and finally future research lines (6.3) are presented.

6.1 Main conclusion and limitations

One of the main findings of this thesis is high intra-individual variability in energy intake in all participating teams, which was lower when compared to able-bodied athletes (as outlined in Chapters Two to Five). Furthermore, the results showed, that energy derived from fat was elevated and at the upper end of the recommendations (20-35%) in all investigated teams, both in the Spanish (as outlined in Chapters Two to Five) and German (as outlined in Chapter Five) male national team, as well as in the female Spanish national team (as outlined in Chapter Four). The highest fat intake in the Spanish men's team has been detected during the fourth data collection (as outlined in Chapter Five), where food was offered as plated meals.

In contrast to the high fat intake, data showed that carbohydrate intake was at the lower end of the recommendations of the ACSM (Thomas et al. 2016) and the FNB in all four studies (as outlined in Chapters Two to Five). Protein intake was in line with recommended guidelines, but protein sources were often based on animal proteins, leading to high levels of cholesterol above recommendations of 300 mg/d (FNB) in all studies (as outlined in Chapters Two to Five).

One important aspect of diet quality is the distribution of the dietary intake over the day. The analysis of the meal frequencies showed, that the timing and amount of energy intake should be improved in the Spanish male teams (as outlined in Chapters Two and Five). High energy intakes during main dishes probably explains the low energy intake through snacks between main meals. Contrarily, the German team showed a better timing and higher energy intake through snacks between main meals (as outlined in Chapter Five).

Regarding micronutrient intake, the adequacy of vitamin A was overall high in the Spanish male teams (as outlined in Chapters Two and Five), because of the intake of vitamin A rich food sources such as fruits and olive oil. Results also revealed that fruit intake led to a high adequacy of vitamin C in the Spanish male players (as outlined in Chapters Two and Five).

These players also reached 100% of adequacy in iron intake (as outlined in Chapters Two and Five) and 80% in calcium intake, both of these micronutrients are highly important for athletes and the general population because of their biochemical (oxygen transport), mechanical (muscular and skeletal architecture) and physiological functions (e.g., muscle contraction, calcium channel, or second messenger function). However, vitamin D intakes were below EAR in study 2 and 4 (as outlined in Chapters Three and Five). However a supplementation should only be recommended after a blood analysis that proves inadequacies, because dietary intake of vitamin D compared to the endogenous synthesis of vitamin D is low.

When further looking at dietary patterns, the results of the second study displayed that in order to achieve adequacies of micronutrient intakes, it is necessary to consume a large variety of food groups (as outlined in Chapter Three). In that concern, high nutrient-dense food groups are associated with more micronutrients than lower nutrient-dense food groups (as outlined in Chapter Three). In contrast to energy-dense food, where density refers to energy (or calories), they provide smaller amounts of energy, due to their low fat, high fiber or high water contents, and high amounts of micronutrients. Fish for example additionally contains more unsaturated than saturated fatty acids.

The results of study 2 further revealed that fruits, cereals, and fish are beneficial for micronutrient adequacies (as outlined in Chapter Three). Following a Mediterranean diet should be favorable for athletes, especially with a restricted energy intake, such as athletes with SCI, because the three previously mentioned food groups are typical for Mediterranean diet (as outlined in Chapters Three and Five).

Contrary to the recommendations for sports nutrition might be the high intake of olive oil in the Mediterranean diet, because all Spanish teams showed high fat intakes (as outlined in Chapters Two to Five). The German team on the other hand consumed relatively low amounts of fats (as outlined in Chapter Five). However, various studies have proven health benefits of olive oil due to its high amount of monounsaturated fatty acids. In fact the quotient of unsaturated to saturated fats was higher in the Spanish male team compared to the German team (as outlined in Chapter Five). The high amounts of overall fat intake in relation to carbohydrate intake in the Spanish teams may additionally be explained by the high amount of animal food sources in their diet, which reached its peak in the results of the third study, because the offered plate meals contained a high percentage of meat (as outlined in Chapter Four).

Body composition, as one of the variables influencing an athletes' performance and health was the main topic in study 3 and the results clearly showed, that skinfold thickness measurements are very practical for intra-individual examination (as outlined in Chapter Four).

The energy intake throughout all studies showed a high inter-individual variability, which stresses the fact, that nutrition and nutritional advice must be individualized (as outlined in Chapters Two to Five). Additionally, because energy expenditure measurements are more challenging in disabled than in abled-bodied athletes and no valid energy expenditure estimation equation for disabled athletes yet exists, together with the fact that a team of wheelchair basketball players consists of athletes with different impairments, one has to deal with a wide variation of energy expenditure. Therefore, monitoring nutrition or evaluating nutrition and/or training interventions should be done together with body composition measurements, since energy balance is reflected in changes in body composition, e.g. gaining fat or as a result of muscle hypertrophy-training gaining lean mass.

Nevertheless, the studies of this thesis had some limitations, which have to be mentioned. Due to the fact, that all investigated participants were high-level athletes, the sample sizes were small. However in all studies the current national teams were investigated both in Spain and Germany but, because coaches and athletes always aim to enhance the performance of all players, it was impossible to recruit a control group. To evaluate energy balance the energy expenditure has been estimated as precise as possible, but no prediction equation existed, that takes all individual differences in disabled athletes into account. In case of micronutrients the probability of adequate intakes could only be estimated and not proven by analyzed blood samples. Neither existed the possibility to examine sedentary SCI control groups.

Despite these limitations several practical applications of the thesis' findings can be made and some future research lines arise.

6.2 Practical applications of the thesis' findings

In order to improve health and performance in wheelchair basketball players, the following aspects should be considered when evaluating their nutrition:

- Wheelchair athletes should be evaluated individually to get an idea about their macronutrients intake and food frequency. Lunch and dinner are more likely to exceed recommendations on energy intake compared to breakfast.

- Snacks between main meals play an important role in athletes' nutrition and should be evaluated and recommended, especially before and after training sessions.
- Overall fat contribution and an often-occurring low carbohydrate intake should be of special concern. Likewise, protein intake and sources should be analyzed.
- Wheelchair basketball players, just as their abled-bodied counterparts, who consume a well-balanced diet together with high overall energy intake, are more likely to have an adequate micronutrient intake.
- For wheelchair basketball players with restricted energy intake a broad variety of nutrient-dense food groups (such as fruits and vegetables) should be consumed to reach adequate micronutrient intakes and avoid inadequacies.
- Wheelchair athletes might have to deal with digestion problems that require individual advice regarding food choices and the way of consuming food in a different manner (e.g. as soups, or smoothies).
- Micronutrient supplementation may be necessary depending on various factors (e.g. sun exposure, season, indoor training). However, blood analysis should always be carried out before any supplements are consumed.
- Skinfolds measurements are a practical and reliable tool for a longitudinal individual observation to determine changes in body composition. Due to the characteristics of a wheelchair basketball team, only intra-individual comparisons seem possible.
- Wheelchair athletes, who participated in the current thesis, with a higher percentage of carbohydrate intake and lower percentage of fat intake are more likely to have a lower skinfolds thickness, hence lower body fat mass.
- The difference in energy demands of wheelchair athletes, due to their high variability in body size and composition, make plate meals not a recommendable form of providing food to this population. Each meal during training camps should be offered through a buffet with various food choices, especially containing low-energy nutrient-dense foods (e.g. fruits and vegetables).
- The Mediterranean diet seems to be a highly beneficial diet for athletes in general and also for wheelchair athletes. However neither the Spanish, nor the German athletes adhered to it sufficiently.
- Training camps independent of the team or country should offer a large variety of different foods.

- The athletes' education regarding nutritional knowledge is very important and highly necessary to take self- responsibility and understand the benefits of sports nutrition for health and performance.
- In order to correct imbalances and improve dietary habits and knowledge about sports nutrition, individual advice and long term work with the athletes is necessary. To achieve this, continuous advice and guidance should be given in short periods, favorably personally or over telephone and internet during the whole year to cover all periods with different training loads and intensities.
- Because athletes' food selection during training camps is limited due to the food provided by the kitchen staff, it seems to be necessary to discuss the principles of sports nutrition with the staff prior to the camp. Awareness should be given regarding the energy expenditure of the athletes, resulting in the need to provide at least two of each macronutrient sources, e.g. potatoes and pasta in the case of carbohydrates at lunch and dinner. This is especially important if plate meals are unavoidable.

6.3 Future research lines

Future studies should investigate dietary intake of wheelchair basketball players several times over the whole year, because seasonal changes of training load have to be taken into account. Additionally, their diet should be evaluated at home to assess both their habitual diet patterns and their adherence to a nutrient-dense dietary pattern with a large variety of foods (e.g. the Mediterranean diet) with special regard to reduce high amounts of fat and cholesterol. Besides macronutrient intake in relation to exercise likewise micronutrients adequacy should be monitored and deficiencies should be regularly controlled using blood analysis. Furthermore, favorable individual solutions concerning certain food choices should be investigated continuously over a long period, to help all athletes eating a well-balanced diet with concern to digestion and discomfort.

Because fluids are important for training and competition, sweat rates and fluid replacement strategies of wheelchair athletes should be examined under different environmental conditions.

Each of these evaluations should be accompanied by assessments of the players' nutritional knowledge and measurements of body composition to determine possible relations of improvements in dietary take with improvements in nutrition knowledge and body composition.

Furthermore, there is a lack of knowledge regarding calculating energy expenditure in wheelchair athletes. It is necessary that already existing compendiums such as from Collins et al. (2010) are being expanded. The improvement of methods to calculate total energy expenditure during training and competition, would precisely display the individual differences in energy expenditure in relation to physical activity, which would allow more advanced and differentiated recommendations on nutrition. The application of multi-sensor devices to measure energy expenditure especially for wheelchair athletes throughout activities of daily living and sports is another area yet not sufficiently known. With valid energy expenditure measurements, energy availability could be determined precisely and individualized nutritional advice would be optimized so that the influence of exercise and nutrition on body composition could be investigated sufficiently. Expanding these investigations to sedentary wheelchair users could improve their quality of life.

Besides wheelchair athletes with elite status, nutrition and body composition should also be examined in a broad range of wheelchair athletes with lower competitive levels, as well as in non-athletes to determine possible differences between both groups. Because of the high

individual variability regarding lesion levels and severity of SCI, international multicenter studies and projects should be established.

Finally, since less data is available about nutrition and body composition in female wheelchair basketball players compared to male athletes, further investigations on females are absolutely essential.

Chapter Seven

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