

Aus dem Institut für Biochemie
der Deutschen Sporthochschule Köln
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**Untersuchungen zum Ernährungsstatus, Hydratationsstatus
und Nahrungsergänzungsmittelkonsum in ausgewählten
Bevölkerungsgruppen**

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Hierdurch erkläre ich, dass ich die „Leitlinien guter wissenschaftlicher Praxis“ der Deutschen Sporthochschule Köln eingehalten habe.

Ort, Datum

Hans Braun

To whom it may concern

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1 Zusammenfassender Überblick

1.1 Einleitung und Zielsetzung

Essen und Trinken hat für Menschen vielfältige Bedeutung, aus physiologischer Sicht jedoch eine essenzielle Relevanz. Eine bedarfsgerechte Energie- und Nährstoffzufuhr ist notwendig, um Gesundheit und Leistungsfähigkeit langfristig aufrecht zu erhalten. Dabei muss berücksichtigt werden, dass die Kenntnisse zum Nährstoffbedarf des Menschen nicht vollständig sind, jedoch durch Entwicklungen im Bereich der Ernährungs- und Lebensmittelwissenschaften ständig weiterentwickelt werden [1]. In den Referenzwerten zur Nährstoffzufuhr der Deutschen Gesellschaft für Ernährung, Österreichischen Gesellschaft für Ernährung, Schweizerischen Gesellschaft für Ernährungsforschung und Schweizerischen Vereinigung für Ernährung (DACH) werden Empfehlungen zu Nährstoffmengen und Energierichtwerten für Bevölkerungsgruppen in Abhängigkeit von Geschlecht und Alter sowie speziellen Lebenssituationen (z.B. Schwangerschaft und Stillzeit) formuliert [1]. Dies soll die Umsetzung einer vollwertigen und damit bedarfsgerechten Ernährung unterstützen und nährstoffspezifische Mangelerscheinungen, aber auch Nährstoffübersicherungen vermeiden [1]. Dabei ist zu berücksichtigen, dass eine den Referenzwerten entsprechende Nährstoffzufuhr eine unzureichende Versorgung sehr unwahrscheinlich macht, aber aufgrund individueller Nährstoffbedarfe diese nicht ausgeschlossen werden kann. Im Umkehrschluss ist jedoch auch eine Unterschreitung der empfohlenen Nährstoffzufuhr nicht mit einem Nährstoffdefizit gleichzusetzen, sondern erhöht nur die Wahrscheinlichkeit für eine potenzielle Unterversorgung, die sich möglicherweise auch erst langfristig einstellt. Darüber hinaus ist es bei der Beurteilung der Ernährungssituation von Bevölkerungsgruppen von wesentlicher Bedeutung, dass die exakte Beurteilung der Nährstoffversorgung von Einzelpersonen auf

Basis der Referenzwerte zur Nährstoffzufuhr nicht möglich ist, da der individuelle Bedarf nicht bekannt ist [1].

Hinsichtlich der Ernährung von sportlich aktiven Menschen gibt es innerhalb der DACH Referenzwerte für die Nährstoffzufuhr keine gesonderten Hinweise. Es wird davon ausgegangen, dass im Rahmen Breitensportlicher Aktivitäten der Energieverbrauch pro Woche um bis zu 2000 kcal ansteigt und der erhöhte Energiebedarf und ggf. daraus resultierende Nährstoffbedarf problemlos auf Basis einer vollwertigen Mischkost realisiert werden kann [1].

Im Bereich des Leistungssports muss aber berücksichtigt werden, dass sich Athlet*innen hinsichtlich anthropometrischer Merkmale (z.B. Körpergewicht, Körpergröße, Körperzusammensetzung) und Trainingsbelastungen (z.B. Trainingsinhalte, -dauer, -intensität) stark unterscheiden, was wiederum Einfluss auf den Energie- und Nährstoffbedarf haben kann [2]. Deutlich wird dies beispielsweise in der Sportart Leichtathletik, die eine Bandbreite verschiedener Belastungsformen in den Bereichen Ausdauer, Sprint, Sprung und Wurf beinhaltet. Entsprechend kann das Körpergewicht bei männlichen Werfern 100 kg überschreiten, hingegen im Ausdauerbereich unterhalb von 60 kg liegen [3, 4]. Erwachsene Elite-Ausdauerleistungssportler*innen berichten von Trainingsumfängen von 500 bis 1000 Stunden pro Jahr [5] oder einer Laufdistanz von >150 km pro Woche [5, 6]. Im Gegensatz dazu ergeben sich im Verlauf eines Trainingsjahres auch Phasen mit geringer körperlicher Aktivität, in der dann der tägliche Energiebedarf aufgrund einer potenziellen Trainingsdauer von weniger als 2 Stunden pro Woche auf einem geringen Niveau liegt und damit vergleichbar mit einer Person mit Breitensportlicher Belastung ist [5-7]. Auf Basis der anthropometrischen Merkmale sowie der variierenden Trainingsbelastung liegt der Energiebedarf bei den meisten Sportlern*innen wahrscheinlich zwischen 1500 kcal und

6000 kcal pro Tag und kann z. B. im Saisonverlauf für eine Person mit 70 kg auf 2000 kcal bis 5000 kcal geschätzt werden [7].

Daraus resultierend ergibt sich ein variierender Bedarf der Makronährstoffe Protein, Kohlenhydrate und Fett im Vergleich zur Allgemeinbevölkerung. Verschiedene Organisationen aus dem Bereich des Sports haben in den vergangenen Jahren auf Basis der verfügbaren wissenschaftlichen Literatur Konsensus- bzw. Positionspapiere zum Thema Sporternährung veröffentlicht und sportspezifische Ernährungsempfehlungen formuliert (Tabelle 1-1) [8-13].

Tabelle 1-1: Übersicht über sportspezifische Richtwerte zur Nährstoffzufuhr ausgewählter Organisationen im Vergleich zu den DACH Referenzwerten

	DACH [1]	IOC [8, 11]	ACSM [13]	DGE AG [9, 10, 12]
Protein	0,8 g/kgKG	1,3-1,8 g/kgKG	1,2-2,0 g/kgKG	1,2-2,0 g/kgKG
Kohlenhydrate	> 50 %E	3-12 g/kgKG	3-12 g/kgKG	3-12 g/kgKG
Fett	30 %E	NV	20-35 %E	20-30 %E

Anmerkung: Die sportspezifischen Richtwerte zur Nährstoffzufuhr sollten hinsichtlich anthropometrischer Merkmale, Trainingsziele, Trainingsbelastung und individuellen Fragestellungen angepasst werden. DACH (Deutsche Gesellschaft für Ernährung, Österreichische Gesellschaft für Ernährung, Schweizerische Gesellschaft für Ernährungsforschung und Schweizerische Vereinigung für Ernährung); IOC (International Olympic Committee); ACSM (American College of Sports Medicine); DGE AG (Arbeitsgruppe Sporternährung der Deutschen Gesellschaft für Ernährung); g/kgKG = Gramm pro Kilogramm Körpergewicht; %E = prozentualer Anteil der Energiezufuhr; NV = Nicht verfügbar

Dabei ist zu berücksichtigen, dass Richtwerte zur Nährstoffzufuhr für Sportler*innen differenziert in Abhängigkeit der oben beschriebenen anthropometrischen Merkmale, Trainingsziele, Trainingsbelastungen und individuellen Fragestellungen angewandt werden müssen.

Außerdem ist in der Sporternährung nicht nur die absolute Nährstoffzufuhr relevant. Die Verteilung über den Tag und der Zeitpunkt der Nährstoffzufuhr in Anlehnung an das Training scheinen für die Entwicklung von Anpassungsprozessen infolge des Trainingsreizes eine wichtige Rolle zu spielen [14-17].

Die sportspezifischen Nährstoffempfehlungen helfen einerseits den potenziellen Nährstoffbedarf von Athlet*innen zu formulieren, stellen jedoch auch eine wichtige Grundlage dar, um den Ernährungsstatus von Athlet*innen einordnen zu können. Generell ist die Beschreibung des Ernährungsstatus über Ernährungserhebungen ein weit verbreitetes und akzeptiertes Instrument bei der Erfassung der Ernährungssituation unterschiedlicher Bevölkerungsgruppen [18, 19]. Zur weiteren Beurteilung der Ernährungssituation von Einzelpersonen und Untergruppen innerhalb der Bevölkerung sollten nach Möglichkeit zusätzlich geeignete anthropometrische und klinische Parameter hinzugezogen werden [1, 18]. Ernährungserhebungen bei erwachsenen Sportler*innen sind im Rahmen von Studien oder Einzelberatungen etabliert, allerdings sind Untersuchungen bei Nachwuchsleistungssportler*innen dabei unterrepräsentiert [20, 21]. Daher sollte nach Möglichkeit diese Altersgruppe hinsichtlich des Ernährungsstatus, aber auch ausgewählter Parameter häufiger untersucht werden [20].

Eine Aufgabe für den Forschungs- und Servicebereich „Sporternährung“ im Deutschen Forschungszentrum für Leistungssport (momentum) war und ist es daher, systematisch die Ernährungssituation von Nachwuchsleistungssportler*innen in Nordrhein-Westfalen (NRW) zu untersuchen und Optimierungsmöglichkeiten abzuleiten. Eine Besonderheit der momentum Untersuchungen stellt das validierte Ernährungs- und Aktivitätsprotokoll dar [22]. Aufgrund der oben beschriebenen variablen Trainingsbelastungen innerhalb dieser Population ist es notwendig, neben dem Lebensmittelverzehr und Getränkekonsum, die Alltags- und Trainingsaktivitäten der Sportler*innen zu dokumentieren, um daraus den aktuellen Energiebedarf abschätzen zu können. Erst dadurch ist eine Bewertung der aktuellen Ernährungssituation in Anlehnung an sportspezifische Referenzwerte möglich. Darüber hinaus ist eine Kenntnis über den Energiebedarf notwendig, um mögliche Under- und Overreporter

zu identifizieren [23, 24] und eine Berechnung der Energieverfügbarkeit vornehmen zu können [25, 26]. Ergebnisse aus den momentum Daten wurden bereits in der Vergangenheit als Original-Publikation [27] oder Kongressbeiträge [28-34] publiziert.

Diese Dissertation hat zum Ziel, auf Basis unterschiedlicher Methoden (Ernährungserhebungen, Fragebögen, Messung von Blut- und Urinparametern) Untersuchungen zum Ernährungsstatus, Hydratationsstatus und Nahrungsergänzungsmittelkonsum in ausgewählten Bevölkerungsgruppen darzustellen, zu bewerten und zu diskutieren.

Die erste Publikation dieser Dissertation „Nutrition status of young elite female German football players“ ist eine sportartspezifische Zusammenfassung einer Subpopulation aus dem momentum Datenpool und stellt die Beschreibung des Ernährungsstatus von Nachwuchsfußballerinnen dar [35]. Auf Basis eines validierten Ernährungs- und Aktivitätenprotokolls [22] wurde die Ernährungssituation erfasst und in Anlehnung an sportspezifische Referenzwerte zur Nährstoffzufuhr bewertet. Ergänzend wurden ausgewählte anthropometrische und klinische Parameter hinzugezogen, um die Bewertung der Ernährungssituation umfassender zu beschreiben.

Eine beobachtete Besonderheit in der Ernährung von Leistungssportler*innen ist der weit verbreitete Konsum an Nahrungsergänzungsmitteln (NEM) [36-38]. Die Einnahme von NEM variiert jedoch zwischen den Sportarten und steigt mit zunehmendem Alter und Kaderstatus [37, 38]. Im Vordergrund steht der Konsum von Vitamin- und Mineralstoffpräparaten, um mögliche Nährstoffdefizite oder einen angenommenen höheren Bedarf auszugleichen [37, 38]. Insbesondere der unsachgemäße Konsum von Vitamin- und Mineralstoffpräparaten kann zu einem Hochkonsum mit potenziell negativen gesundheitlichen Konsequenzen und

Trainingsanpassungen führen [36, 39, 40]. Daher wird in den letzten Jahren verstärkt darauf hingewiesen, dass Sportler*innen zunächst über eine sportgerechte Basiskost versuchen sollten den aktuellen Nährstoffbedarf zu decken und erst im zweiten Schritt über eine individuelle Risiko-Nutzen-Abwägung den Konsum von NEM prüfen sollten [13, 37, 38, 41]. Darüber hinaus gilt für Nachwuchsleistungssportler*innen die Empfehlung, nach Möglichkeit auf NEM zu verzichten und zunächst zu lernen das Potenzial einer sportgerechten Ernährung und eines systematischen Trainings zu nutzen [13, 20, 21, 37].

Zu Beginn des Projekts momentum war insbesondere die Gruppe der Nachwuchsleistungssportler*innen hinsichtlich des Konsumverhaltens von NEM nicht ausreichend untersucht. Entsprechende Daten deutscher Nachwuchsleistungssportler*innen lagen unserer Kenntnis nach zum Zeitpunkt der Erhebung nicht vor. Ziel war es daher, im Rahmen des momentum Basischeck das Konsumverhalten der Nachwuchsathlet*innen zum Umgang mit NEM abzufragen. Die Ergebnisse dieser Befragung sind die Grundlage für die zweite Publikation dieser Dissertation [42].

Eine weitere Besonderheit der Gruppe der Leistungssportler*innen ist die belastungsbedingte Schweißbildungsrate und der dadurch bedingte Wasserverlust [43]. Die Schweißbildungsrate ist dabei von klimatischen Bedingungen aber auch individuellen Anpassungsmechanismen abhängig [44]. Entsprechend lassen sich für Sportler*innen keine einheitlichen Vorgaben für die tägliche Wasserzufuhr formulieren. Individuelle Messungen zum Schweißverlust in Training und Wettkampf werden empfohlen, um die zusätzliche Wasserzufuhrmenge für Athleten abschätzen zu können [13, 43, 44].

Auch für die „Normalbevölkerung“ kann hinsichtlich der täglichen Wasserzufuhr nur ein Orientierungswert formuliert werden. Unter der Annahme einheitlicher klimatischer und physiologischer Bedingungen wird für Erwachsene (19-65 Jahre) als Richtwert zur täglichen

Wasserzufuhr 35ml pro Kilogramm Körpergewicht ausgesprochen [1]. Dieser Wert beinhaltet Wasser aus festen Nahrungsmitteln und Getränken. Die europäische Behörde für Lebensmittelsicherheit [45] spricht sich hingegen für einen absoluten Richtwert zur täglichen Wasserzufuhr von 2,5 Liter für Männer und 2,0 Liter für Frauen aus. Dies können jedoch nur Orientierungswerte sein, da ein erhöhter Wasserbedarf bei hohem Energieumsatz, Hitze, trockener kalter Luft, aber auch hohem Kochsalz- und Proteinverzehr besteht. Aufgrund dessen ist die Wasserzufuhr als alleiniger Marker für die Bewertung des Flüssigkeitsstatus einer Gruppe oder Einzelperson nur begrenzt aussagekräftig und die Vergleichbarkeit von internationalen Untersuchungen zur Wasserzufuhr nur eingeschränkt möglich [46]. Zur unterstützenden Bewertung des Flüssigkeitsstatus haben sich nicht-invasive Parameter wie Urinosmolalität, Urinvolumen und Urindichte in der Alltagsdiagnostik und Forschung etabliert [13, 43, 45, 47]. Diese Marker wurden in den meisten Erhebungen zur Wasserzufuhr jedoch nicht berücksichtigt. Entsprechend gab es einen Bedarf an Untersuchungen, die einerseits Wasserzufuhr über Ernährungserhebungsinstrumente erfassen, darüber hinaus aber den Hydratationsstatus mit vorhandenen klinischen Markern untersuchen.

Im Rahmen eines Projekts des European Hydration Instituts war das Institut für Biochemie als Kooperationspartner an der „European Hydration Research Study“ (EHRS) beteiligt. Neben der Erfassung und Bewertung des Flüssigkeitsstatus war ein Ziel des Projekts, dies mit einer einheitlichen Methodik in verschiedenen europäischen Ländern (Spanien, Griechenland, Deutschland) durchzuführen und damit die Vergleichbarkeit der Daten zu verbessern. Verschiedene Ergebnisse aus diesem Forschungsprojekt (z.B. Gesamtwasserzufuhr, Urinosmolalität oder Urinvolumen im Ländervergleich, saisonal (Sommer/Winter) sowie geschlechtsspezifisch) sind bereits veröffentlicht [48, 49]. Die dritte Publikation dieser Dissertation „Differing Water Intake and Hydration Status in Three European Countries - A

Day-to-Day Analysis“ basiert auf Daten der EHRS und befasst sich mit der intra-individuellen Wasserzufuhr und Markern des Flüssigkeitsstatus im Erhebungszeitraum über 7 Tage [50].

1.2 Übersicht über den ersten Artikel – Nutrition Status of Young Elite Female German Football Players

Fußball gehört zu den beliebtesten Sportarten weltweit. In Anlehnung an eine Untersuchung der FIFA gibt es mehr als 30 Millionen Fußballerinnen, über 50% davon sind Jugendliche oder Kinder [51]. Diese große Zahl an aktiven Spielerinnen verdeutlicht die Notwendigkeit, sich mit dieser Zielgruppe zu beschäftigen und entsprechende Hinweise für eine sportgerechte Ernährungsweise zu formulieren. Untersuchungen zum Ernährungsverhalten dieser Gruppe sind jedoch nur vereinzelt verfügbar. Im Regelfall fehlt zudem eine Erfassung der Trainingsbelastungen, um eine Einordnung der Ernährungssituation in Anlehnung an sportspezifische Referenzwerte vornehmen zu können.

Ziel dieser Untersuchung war es, das Ernährungsverhalten von jungen Fußballerinnen (n=56, 14,8±0,7 Jahre) in Kombination mit der Dokumentation der Alltags- und Trainingsaktivitäten zu erfassen. Die Spielerinnen waren im Kader des entsprechenden Landesverbandes oder U-Nationalmannschaft.

Die Probandinnen kamen im Rahmen des momentum Basischeck um ca. 8:00 Uhr nüchtern zur Blutabnahme und Messung der Körperzusammensetzung (BA-418 MA, Tanita, Netherlands). Die Auswertung der Ernährungsprotokolle erfolgte mit EBIspro (version 7.0, 2005; Dr. Jürgen Erhardt, Willstätt-Legelshurst, Germany) auf Basis des Bundeslebensmittelschlüssel (BLS) Version 2.3. Als klinische Parameter wurden Hämoglobin, Hämatokrit, Ferritin und 25(OH)D bestimmt.

Ein weit verbreitetes Phänomen von Ernährungserhebungen ist das sogenannte „Underreporting“. Dabei kommt es aufgrund der Dokumentation des Ernährungsverhaltens zu einer geringeren Zufuhr an Lebensmitteln als üblicherweise oder es werden weniger Lebensmittel angegeben als verzehrt. In Anlehnung an Black [23] gilt ein Quotient aus

Energiezufuhr/Energiebedarf $<0,76$ als Underreporter und $>1,24$ als Overreporter. Die Anwendung dieser Klassifikation führte zu einem Ausschluß von 24 Probandinnen.

Die verbleibende Gruppe ($n=32$) zeigt eine mittlere Energiezufuhr (2262 kcal; 40,5 kcal/kgKG), die 141 kcal unterhalb des geschätzten Energiebedarfs liegt (2403 kcal; 43,1 kcal/kgKG). Dabei ist zu beachten, dass trotz Ausschluss von potenziellen Underreportern die Energieverfügbarkeit von 17 Spielerinnen unterhalb der kritischen Schwelle von 30 kcal/kg LBM (Lean Body Mass) liegt. Die Energieverfügbarkeit (EV) ist definiert als Energiezufuhr minus Energieverbrauch im Training. Ausgedrückt wird die EV als kcal pro kg LBM. Untersuchungen an Athletinnen zeigen, dass eine geringe Energieverfügbarkeit (<30 kcal pro kg LBM) ein erhöhtes Risiko für Müdigkeits- und Übertrainingserscheinungen, Immunschwäche, Menstruationsstörungen und Stressfrakturen bedeutet [25, 26].

Der Trainingsumfang der Spielerinnen lag bei durchschnittlich 85 Minuten pro Tag. In Anlehnung an die verfügbaren Empfehlungen zur Nährstoffzufuhr bei Sportler*innen ist ein täglicher Kohlenhydratbedarf von 5-7 g/kgKG an intensiven Trainingstagen bis zu 10 g/kgKG zu erwarten [8, 13]. Etwa ein Drittel der Spielerinnen ($n=10$) lagen mit der Kohlenhydratzufuhr unterhalb von 5 g/kgKG und erreichten diese Empfehlung nicht. Ein vergleichbares Ergebnis zeigt sich bei der Proteinzufuhr. Elf Spielerinnen (34%) liegen unterhalb der täglich empfohlenen Proteinzufuhr von 1,2-2,0 g/kgKG. Die Kohlenhydrat- und Proteinzufuhr ist zwar nicht mit einem Nährstoffmangel gleichzusetzen, entspricht jedoch teilweise nicht den Empfehlungen und kann als ungünstige Voraussetzung für eine sportspezifische Nährstoffversorgung betrachtet werden. Mögliche Verzerrungen aufgrund der bekannten Limitationen von Ernährungserhebungsinstrumenten [18, 19] sind möglich, wurden jedoch durch den Ausschluß von Underreportern und Overreportern reduziert.

Hinsichtlich Serum-Ferritin zeigt sich ein mittlerer Wert von 32,7 µg/L (n=29). Knapp zwei Drittel (59%) der untersuchten Spielerinnen lagen unterhalb von 35 µg/L. In Anlehnung an Peeling et al. (2008) zeigt dies reduzierte Eisenspeicher an [52]. Ein kritischer Wert unterhalb von <12 µg/L wird als Eisenarmut beschrieben und lag bei 5 (17%) Spielerinnen vor. Diese Ergebnisse zeigen einen unbefriedigenden Eisenstatus der jungen Fußballspielerinnen, sind aber vergleichbar mit früheren Untersuchungen bei Nachwuchsleistungssportlerinnen aus NRW [27].

Vitamin D nimmt unter den Vitaminen eine Sonderstellung ein, da es endogen hergestellt werden kann. Die alimentäre Zufuhr ist häufig unzureichend und auch beim untersuchten Kollektiv (mittlere Zufuhr, 1,3 µg/Tag) deutlich unterhalb der Empfehlung. Eine genauere Bewertung des Vitamin D Status kann über die Bestimmung von 25-Hydroxy-Vitamin D [25(OH)D] vorgenommen werden, wobei ein Wert >50 nmol/L angestrebt werden sollte [1, 53]. Es wurde ein mittlerer 25(OH)D Wert von 50,2 nmol/L gemessen (n=24). 9 Spielerinnen (38%) lagen in einem unzureichenden Bereich (30-50 nmol/L).

Die Untersuchung zum Ernährungsstatus junger Fußballerinnen zeigt trotz möglicher Limitationen im Bereich der Ernährungserhebungen und Kalkulation des Energiebedarfs in manchen Bereichen eine unbefriedigende Ernährungssituation. Bei nahezu täglichem Training spielt die Ernährung und damit die Versorgung des Organismus mit Nährstoffen eine zentrale Rolle. So sollten junge Sportlerinnen, aber auch deren Umfeld, zukünftig intensiver über eine sportgerechte Ernährung aufgeklärt werden, um eine ausreichende Grundlage für Gesundheit und Leistungsfähigkeit zu legen.

1.3 Übersicht über den zweiten Artikel – Dietary Supplement Use Among Elite Young German Athletes.

Schon vor einigen Jahren konnte aufgezeigt werden, dass der Konsum von Nahrungsergänzungsmitteln (NEM) bei Sportler*innen weit verbreitet ist und deutlich höher liegt als in der Normalbevölkerung [54, 55]. Im Rahmen der Nationalen Verzehrsstudie II (NVS) gaben ca. ein Sechstel der befragten Jugendlichen an, NEM zu konsumieren [56]. Hingegen lagen zum damaligen Zeitpunkt solche Daten für Nachwuchsleistungssportler*innen in Deutschland nicht vor.

Zentrales Ziel dieser Untersuchung war es daher das Konsumverhalten zu NEM bei Nachwuchsleistungssportler*innen zu erfassen. Im Zeitraum 09/2006 bis 12/2007 nahmen 228 Athlet*innen an der momentum Ernährungsberatung teil. Im Vorfeld des momentum Basischeck Termin wurden den Sportler*innen ein 5-seitiger geschlossener Fragebogen zum generellen und aktuellen (in den letzten 4 Wochen) Konsum von NEM mit den Materialien zum Ernährungsprotokoll geschickt. Es wurde spezifisch nach dem Konsum von Vitamin-, Mineralstoff-, Kohlenhydrat- und Proteinpräparaten, Sportgetränken, ergogenen Substanzen und Pflanzenextrakten gefragt. Darüber hinaus wurden Fragen zum Motiv, Informations- und Bezugsquellen, aber auch dem Wissen um die Kontaminationsproblematik bei NEM gestellt. Von 181 Athlet*innen konnten die Unterlagen wieder eingesammelt werden. Aufgrund unvollständiger Daten oder überschreiten einer Altersgrenze (>25 Jahre) wurden 17 Fragebögen ausgeschlossen. Die verbleibenden 164 Teilnehmer*innen wurden 4 Altersgruppen (10-14, 15-16, 17-18, 19-25) zugeordnet.

Von den 164 Sportler*innen gaben 80% (n= 131) an, bereits NEM konsumiert zu haben, 68% (n=111) bestätigten einen Konsum in den 4 Wochen vor der Befragung. Der Konsum war bei

den Athlete*innen >18 Jahre höher als bei den Jüngeren ($p < 0,05$). Ein sportartspezifischer Unterschied konnte nicht festgestellt werden.

Bei den 131 NEM Konsument*innen waren Mineralstoffe (87%), Vitamine (76%), Sportgetränke (69%) und Kohlenhydratprodukte (64%) am populärsten. Sportler*innen, die in der aktuellen Phase NEM genommen haben ($n=111$), gaben an, 3 (Median) verschiedene Präparate genommen zu haben. Dabei lag die Spannweite bei 1 bis 17 verschiedenen Präparaten.

Hinsichtlich der Motivlage waren „gesundheitliche Gründe“ mit 63% am häufigsten genannt, gefolgt von leistungsbezogenen Gründen (43%). Etwa ein Fünftel gab an, NEM aufgrund der Empfehlung Anderer zu konsumieren. Als Informationsquellen zum Konsum von NEM wurden Eltern (34%), Trainer*innen (26%) sowie Ärzt*innen (24%) am häufigsten genannt. Entsprechend gaben 39% der Sportler*innen an, die Produkte von den Eltern erhalten zu haben oder sich selbst zu besorgen (32%). Hinsichtlich eines möglichen Kontaminationsrisiko von NEM mit unerlaubten Substanzen gaben 36% an, dass Ihnen das Problem bekannt sei.

Die Untersuchung konnte für Nachwuchsathlet*innen aus Deutschland erstmal aufzeigen, dass der Konsum von NEM deutlich höher liegt als bei den bisher bekannten Befragungen in der „Normalbevölkerung“ [56]. Das Konsumverhalten entspricht vielmehr den vergleichbaren sportlich aktiven Altersgruppen aus den bis zu diesem Zeitpunkt bekannten internationalen Studienergebnissen [54, 55, 57-59].

Auffällig ist der hohe Konsum an Vitamin- und Mineralstoffpräparaten, obwohl es aus physiologischer Sicht keine Hinweise auf einen zusätzlichen Nährstoffbedarf bei Nachwuchsleistungssportler*innen gibt [54] und mögliche gesundheitliche Risiken nicht ausgeschlossen werden können [60]. In Anlehnung an die WADA Verbotsliste besteht darüber

hinaus für Sportler*innen das Risiko des Konsums unerlaubter Substanzen durch NEM [61].

Diese Problematik war jedoch nur einem Drittel der befragten Athlet*innen bekannt.

Generell wird insbesondere bei Nachwuchssportler*innen darauf hingewiesen, dass sie zunächst eine vollwertige sportgerechte Ernährung etablieren sollten, bevor sie den Konsum von NEM in Betracht ziehen [54]. Ein Ziel der Ernährungsberatung innerhalb des momentum Projekts ist es, Nachwuchssportler*innen genau in diesem Bereich zu unterstützen. Aus den momentum Untersuchungen ist jedoch bekannt, dass nur ca. 16% der Athleten vor der momentum Ernährungsberatung Erfahrungen mit individueller Ernährungsberatung gemacht hatten.

Auf Basis der Ergebnisse dieser Untersuchung wurden abschließende Empfehlungen formuliert. So erscheint es zwingend notwendig, dass Nachwuchsleistungssportler*innen und Verantwortliche (u.a. Eltern, Trainer*innen, Ärzt*innen und weitere Teambetreuer*innen) im Umfeld intensiver über Risiken und Nutzen von NEM aufgeklärt werden müssen. Um Jugendliche in ihrer Ernährungskompetenz zu stärken wurde vorgeschlagen, dass Ernährungsbildung und -beratung noch mehr für Nachwuchsathlet*innen verfügbar gemacht werden sollte. Insbesondere junge Sportler*innen (<15 Jahre) sollten bereits in diese Prozesse integriert werden.

1.4 Übersicht über den dritten Artikel – Differing Water Intake and Hydration Status in Three European Countries—A Day-to-Day Analysis.

Ein ausgeglichener Wasserhaushalt ist von grundlegender Bedeutung für Gesundheit und Funktionalität des menschlichen Körpers [45, 62]. Ein langfristiges Wasserdefizit wird mit verschiedenen Erkrankungen in Verbindung gebracht [63]. Kurzfristig hat ein Wassermangel jedoch auch einen Einfluss auf Gemütslage, Müdigkeit, Aufmerksamkeit oder Konzentrationsfähigkeit [64-68]. Um die Konsequenzen einer Dehydratation zu vermeiden, empfiehlt die European Food Safety Authority (EFSA) für Männer eine tägliche Gesamtwasserzufuhr aus fester Nahrung und Getränken von 2,5 Liter (Frauen, 2,0 Liter). Dies gilt auch vor dem Hintergrund, dass eine Urinosmolalität von <500 mOsmol/L angestrebt werden sollte, um die Ausscheidung harnpflichtiger Substanzen zu erleichtern [45].

Erhebungen zur Wasserzufuhr der europäischen Bevölkerung zeigen sehr unterschiedliche Ergebnisse hinsichtlich des Erreichens dieser Empfehlungen [45, 46]. Dabei ist unklar, in welchem Maße die abweichenden Ergebnisse in unterschiedlichen Erhebungsmethoden begründet liegen. Ziel der „European Hydration Research Study (EHRS)“ war es daher, mit einer einheitlichen methodischen Vorgehensweise die Wasserzufuhr und den Hydratationsstatus in drei europäischen Ländern [(Spanien (ESP), Griechenland (GRE), Deutschland (GER)] zu erheben und zu vergleichen. In drei ausgewählten Metropolen (Toledo, Athen, Köln) wurden in den Jahren 2013 und 2014 insgesamt 573 Erwachsene zur Teilnahme gewonnen. Die Akquise erfolgte möglichst gleich verteilt hinsichtlich Geschlecht, Jahreszeit (Sommer/Winter) und Altersgruppen (20-30, 31-40, 41-50, 51-60 Jahre). Zur Erfassung der Gesamtwasserzufuhr dokumentierten die Teilnehmer*innen über 7 Tage ihren Lebensmittel- und Getränkekonsum. Parallel dazu wurden über den gesamten Zeitraum alle Urinabgaben gesammelt.

Ergebnisse zur Wasserzufuhr und zum Flüssigkeitsstatus wurden im Ländervergleich [48], sowie in Abhängigkeit der körperlichen Aktivität und Umgebungstemperatur [49] bereits publiziert. Der dritte Artikel zu diesem Projekt und innerhalb dieser Dissertation beschäftigt sich tiefergehend mit der individuellen Bewertung der Wasserzufuhr und Markern des Flüssigkeitsstatus im Erhebungszeitraum über 7 Tage.

Die mittlere tägliche Gesamtwasserzufuhr lag bei $2,76 \pm 1,2$ L/Tag, wobei Männer ($2,94 \pm 1,1$ L) eine signifikant höhere ($p < 0,01$) tägliche Wasserzufuhr aufweisen als Frauen ($2,57 \pm 0,89$ L). Etwas mehr als ein Drittel (37%) der Männer und knapp ein Viertel (22%) der Frauen haben über den Erhebungszeitraum hinweg eine Gesamtwasserzufuhr, die unterhalb der EFSA Empfehlungen von 2,5 Liter für Männer und 2,0 Liter für Frauen liegt. Dabei zeigt sich eine sehr unterschiedliche Verteilung zwischen den Ländern (ESP: 55% Männer, 39% Frauen; GRE: 50% Männer, 24% Frauen; GER: 6% Männer, 7% Frauen). Die EFSA Empfehlungen zur täglichen Gesamtwasserzufuhr erreichen 60% der deutschen Teilnehmer*innen (ESP: 24%; GRE 21%), hingegen liegen 49% der griechischen Teilnehmer*innen (ESP: 41%, GER 11%) an mindestens 4 Tagen und sogar 20% (ESP: 11%, GER 1%) an allen Einzeltagen unterhalb der EFSA Empfehlungen.

Die Osmolalität der 24h-Urine lag im Mittel bei 638 ± 254 mOsmol/kg (Frauen: 595 ± 261 mOsmol/kg; Männer: 681 ± 237 mOsmol/kg) und war an allen Wochentagen bei den Frauen signifikant niedriger ($p < 0,01$) als bei den Männern. Im Erhebungszeitraum lag die mittlere Urinosmolalität der 24h-Urine bei 26% der Männer (Frauen 44%) < 500 mOsmol/kg. Nur 11% der untersuchten Teilnehmer*innen erreichten an allen Tagen eine Urinosmolalität < 500 mOsmol/kg. Im Gegensatz dazu zeigt fast die Hälfte (46%) der spanischen Teilnehmer*innen eine Urinosmolalität ≥ 800 mOsmol/kg an mindestens 4 Tagen des Untersuchungszeitraums

(GRE: 29%; GER: 11%) und knapp ein Zehntel der Proband*innen aus Spanien (9%) und Griechenland (8%) an allen Tagen.

Unserer Kenntnis nach war dies die erste Untersuchung, die mit einer einheitlichen Methodik sowohl Wasserzufuhr als auch Marker des Flüssigkeitsstatus in verschiedenen europäischen Ländern parallel erfasst hat. Die Untersuchung präsentiert eine zufriedenstellende mittlere Gesamtwasserzufuhr in Anlehnung an die Empfehlungen der EFSA. Ein Blick auf die Einzelwerte zeigt jedoch eine intra-individuelle Varianz mit einer unbefriedigenden Situation vor allem in Griechenland und Spanien, insbesondere bei den Männern. Die Abweichungen zwischen den Ländern konnten im Rahmen der Untersuchung nicht geklärt werden. Ein Misreporting bei Ernährungserhebungen ist zwar bekannt [45], ob dies jedoch länderspezifisch auftritt ist bisher nicht beschrieben. Aufgrund der schwankenden Gesamtwasserzufuhr zwischen den einzelnen Tagen wird empfohlen, dies bei weiteren Untersuchungen zur Gesamtwasser- oder auch Getränkezufuhr zu berücksichtigen, insbesondere wenn 24h-Ernährungsprotokolle verwendet werden sollen [69]. Da der tägliche Wasserbedarf unter anderem von den Schweißverlusten und dem produzierten Urinvolumen abhängt, ist die Erhebung der Gesamtwasserzufuhr kein ausreichender Parameter für die Bewertung der Hydratationsstatus. Vielmehr hat sich die Messung der Urinosmolalität im 24h Urin als Marker etabliert, wobei ein Wert <500 mOsmol/kg angestrebt werden soll [45] und >800 mOsmol/kg eine milde Hypohydratation anzeigt [70-73], die Symptome wie Schwindel, Kopfschmerzen, Müdigkeit und Konzentrationsvermögen hervorrufen kann [64-68, 74-79].

Abschließend erscheint es bedenklich, dass nur 11% der Proband*innen eine Urinosmolalität <500 mOsmol/kg an allen Untersuchungstagen erreichen und ein hoher Anteil der Männer (40%) eine Urinosmolalität >800 mOsmol/kg an mindestens 4 Tagen im Erhebungszeitraum aufweist. Welche individuellen Konsequenzen sich dadurch für die Teilnehmer*innen dieser

Studie ergeben haben ist unklar. Eine Steigerung der täglichen Gesamtwasserzufuhr erscheint jedoch notwendig, um Auswirkungen einer chronischen Hypohydratation zu vermeiden [64-68, 74-81]. Bei zukünftigen Untersuchungen sollten die intra-individuellen Schwankungen der Gesamtwasserzufuhr und 24h-Urinosmolalität berücksichtigt und die Auswirkungen auf Gesundheit und Wohlbefinden genauer untersucht werden.

1.5 Zusammenfassung und Ausblick

Diese Dissertation hat zum Ziel, Ergebnisse zum Ernährungsstatus, Hydratationsstatus und Nahrungsergänzungsmittelkonsum in ausgewählten Bevölkerungsgruppen darzustellen, zu bewerten und zu diskutieren. Die Publikationen zu diesem Themenfeld sind auf Grundlage verschiedener Forschungsprojekte der Abteilung Sporternährung im Institut für Biochemie der Deutschen Sporthochschule Köln entstanden.

Im Rahmen der Untersuchung zum Ernährungsstatus junger Fußballerinnen konnte aufgezeigt werden, dass die Ernährungssituation hinsichtlich Zufuhrempfehlungen aber auch unabhängiger klinischer Parameter nicht angemessen ist. Welche Konsequenzen für Gesundheit und Leistungsfähigkeit daraus zu erwarten sind, kann auf Basis dieser Studie nicht beurteilt werden. Weitere Publikationen aus dem momentum Datenpool zeigen für Ferritin [27] und Vitamin D [28] ähnliche Ergebnisse. Es erscheint also notwendig, Nachwuchssportlerinnen (und -sportler) noch intensiver über die Relevanz und Umsetzung einer sportgerechten Ernährung aufzuklären und das entsprechende persönliche und sportliche Umfeld in diesen Prozess zu integrieren.

Eine regelmäßige Erhebung der Ernährungssituation ist möglich und zumutbar. Zu klären bleibt die Qualität der Datenerhebung durch die Proband*innen. Hier sollten im Vorfeld die Bereitschaft und Motivation aber auch das Verständnis für die Bedeutung der Dokumentation vermittelt werden. Außerdem ist die regelmäßige Analytik ausgewählter Parameter kritischer Nährstoffe wünschenswert, jedoch aufgrund ethischer und praktischer Rahmenbedingungen nur eingeschränkt möglich. Eine neue Möglichkeit insbesondere im Nachwuchsbereich wäre der Einsatz von Dried Blood Spots (DBS) Methoden [82]. Hierzu werden mikroinvasiv je nach Methodik ca. 20 µL Kapillarblut benötigt und auf speziellen DBS Filterkarten gesammelt. Die

Blutabnahme kann selbstständig, dezentral und ohne ärztliche Aufsicht erfolgen und würde somit ein vereinfachtes Screening auch im Nachwuchsleistungssport gewährleisten.

In der zweiten Studie dieser Dissertation konnte aufgezeigt werden, dass der Konsum von NEM bei Nachwuchsleistungssportler*innen deutlich erhöht ist. Bevorzugt wurden von den Sportler*innen Vitamin- und Mineralstoffpräparate genutzt. In den letzten Jahren wurde bekannt, dass eine übermäßige Zufuhr an Mikronährstoffen kritisch hinsichtlich Gesunderhaltung und Leistungsentwicklung sein kann [36, 39, 40, 83-85]. Um auch die quantitative Zufuhr von Mikronährstoffen durch NEM bei den momentum Athlet*innen zu erfassen, wurde auf Basis der vorliegenden Ergebnisse die Befragung zum NEM Konsum angepasst. Die momentum Athlet*innen dokumentieren nun detailliert die konsumierten NEM (Hersteller, Dosierung, Zufuhrmenge pro Tag) parallel zum Ernährungsprotokoll. Erste Ergebnisse zeigen beispielsweise eine NEM bedingte übermäßige Zufuhr an Vitamin B6, Zink, Magnesium und Eisen [86]. Diese Mengen führen zu einer Überschreitung der sogenannten Upper Intake Level, mit denen sich das Risiko für Nebenwirkungen aufgrund der Hochdosierung erhöht [40]. Im Rahmen einer (sportspezifischen) Ernährungsberatung sollte daher die Erfassung und Bewertung des NEM Konsum unbedingt integriert werden. Erst dann ist ein zielgerichtetes Risiko-Nutzen Management im Bereich der NEM möglich, so wie es von verschiedenen Sportorganisationen mittlerweile gefordert wird [13, 37, 41, 87].

Zur methodisch einheitlichen Bewertung der Gesamtwasserzufuhr und des Hydratationsstatus von gesunden Erwachsenen in Europa wurde die „European Hydration Research Study (EHRS)“ unter Beteiligung des Instituts für Biochemie der Deutschen Sporthochschule Köln durchgeführt. Es konnte aufgezeigt werden, dass die mittlere Gesamtwasserzufuhr in Anlehnung an die EFSA Empfehlungen vor allem bei den deutschen Proband*innen zufriedenstellend ist, hingegen unbefriedigend bei zahlreichen Teilnehmer*innen aus Spanien

und Griechenland. Bestätigt wurde diese Tendenz durch die Messung des Hydratationsstatus auf Basis der Urinosmolalität von 24h-Urinen. Welche Konsequenzen sich daraus im Einzelfall hinsichtlich Gesundheit und Wohlbefinden ergeben, wurde im Rahmen der Studie nicht untersucht. Eine Dehydratation wird jedoch kurzfristig mit einem ungünstigen Einfluss auf Gemütslage, Müdigkeit, Aufmerksamkeit oder Konzentrationsfähigkeit [64-68, 78] und langfristig mit verschiedenen Erkrankungen in Verbindung gebracht [63]. Bei weiteren eigenen Untersuchungen mit Nachwuchsleistungssportler*innen zeigten Messungen des Hydratationsstatus ebenfalls unbefriedigende Ergebnisse [88, 89]. Intervention mit Schulung der Sportler*innen hinsichtlich der Relevanz eines ausgeglichenen Wasserhaushalts und dazu notwendiger Trinkmenge zeigte Verbesserungen des Hydratationsstatus [88, 89]. Die Erkenntnisse aus der europäischen Studie sowie den Projekten mit Nachwuchsleistungssportler*innen werden genutzt, um bei Fortbildungen mit Trainer*innen und Athlet*innen auf die Relevanz eines ausgeglichenen Wasserhaushalts im Sport hinzuweisen. Darüber hinaus werden im Rahmen der momentum Aktivitäten sogenannte Diagnostikcamps durchgeführt, in denen die Bewertung des individuellen Hydratationsstatus vorgenommen und eine Rückmeldung zur Optimierung der Situation gegeben wird.

Die Ergebnisse und Erkenntnisse aus den drei dargestellten Arbeiten werden bereits verwendet, um handelnden Personen im Sport (z.B. Sportler*innen, Trainer*innen und Eltern) sowie in der Normalbevölkerung (z.B. Polizeibeamt*innen in NRW) Hinweise zur Verbesserung der Ernährungssituation, Flüssigkeitsstatus und Reduzierung der Risiken durch unsachgemäßen NEM Konsum zu geben. Darüber hinaus konnten die Ergebnisse genutzt werden, um die Methodik der Datenerfassung weiterzuentwickeln und in neuen Projekten anzuwenden.

1.6 Literatur

1. Deutsche Gesellschaft für Ernährung, Österreichische Gesellschaft für Ernährung, Schweizerische Gesellschaft für Ernährung (Hrsg.): 2 ed. Referenzwerte für die Nährstoffzufuhr. 3. aktualisierte Auflage. 2017, Bonn.
2. Braun, H., et al., *Energiebedarf im Sport: Position der Arbeitsgruppe Sporternährung der Deutschen Gesellschaft für Ernährung e. V. (DGE)*. Ernährungs-Umschau, 2019. 66(12): p. 146-153.
3. Houtkooper, L., J.M. Abbot, and M. Nimmo, *Nutrition for throwers, jumpers, and combined events athletes*. Journal of Sports Sciences, 2007. 25(sup1): p. S39-S47.
4. O'Connor, H., T. Olds, and R.J. Maughan, *Physique and performance for track and field events*. J Sports Sci, 2007. 25 Suppl 1: p. S49-60.
5. Heydenreich, J., et al., *Total Energy Expenditure, Energy Intake, and Body Composition in Endurance Athletes Across the Training Season: A Systematic Review*. Sports Med Open, 2017. 3(1): p. 8.
6. Stellingwerff, T., M.K. Boit, and P.T. Res, *Nutritional strategies to optimize training and racing in middle-distance athletes*. J Sports Sci, 2007. 25 Suppl 1: p. S17-28.
7. Stellingwerff, T., R.J. Maughan, and L.M. Burke, *Nutrition for power sports: middle-distance running, track cycling, rowing, canoeing/kayaking, and swimming*. J Sports Sci, 2011. 29 Suppl 1: p. S79-89.
8. Burke, L.M., et al., *Carbohydrates for training and competition*. J Sports Sci, 2011. 29 Suppl 1: p. S17-27.
9. König, D., et al., *Position of the Working Group Sports Nutrition of the German Nutrition Society (DGE): Carbohydrates in Sports Nutrition*. Deutsche Zeitschrift für Sportmedizin, 2020. Volume 71(No. 7-8-9): p. 185-191.

10. König, D., et al., *Position of the Working Group Sports Nutrition of the German Nutrition Society (DGE): Protein Intake in Sports*. Deutsche Zeitschrift für Sportmedizin, 2020. Volume 71(No. 7-8-9): p. 192-198.
11. Phillips, S.M. and L.J. Van Loon, *Dietary protein for athletes: from requirements to optimum adaptation*. J Sports Sci, 2011. 29 Suppl 1: p. S29-38.
12. Schek, A., et al., *Position of the Working Group Sports Nutrition of the German Nutrition Society (DGE): Fats, Fat Loading, and Sports Performance*. Deutsche Zeitschrift für Sportmedizin, 2020. Volume 71(No. 7-8-9): p. 199-207.
13. Thomas, D.T., K.A. Erdman, and L.M. Burke, *American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance*. Med Sci Sports Exerc, 2016. 48(3): p. 543-68.
14. Burke, L.M., et al., *International Association of Athletics Federations Consensus Statement 2019: Nutrition for Athletics*. Int J Sport Nutr Exerc Metab, 2019. 29(2): p. 73-84.
15. Kerksick, C.M., et al., *International society of sports nutrition position stand: nutrient timing*. J Int Soc Sports Nutr, 2017. 14: p. 33.
16. Jeukendrup, A.E., *Periodized Nutrition for Athletes*. Sports Med, 2017. 47(Suppl 1): p. 51-63.
17. Stellingwerff, T., I.M. Bovim, and J. Whitfield, *Contemporary Nutrition Interventions to Optimize Performance in Middle-Distance Runners*. Int J Sport Nutr Exerc Metab, 2019. 29(2): p. 106-116.
18. Larson-Meyer, D.E., K. Woolf, and L. Burke, *Assessment of Nutrient Status in Athletes and the Need for Supplementation*. Int J Sport Nutr Exerc Metab, 2018. 28(2): p. 139-158.

19. Magkos, F. and M. Yannakoulia, *Methodology of dietary assessment in athletes: concepts and pitfalls*. *Curr Opin Clin Nutr Metab Care*, 2003. 6(5): p. 539-49.
20. Desbrow, B., et al., *Nutrition for Special Populations: Young, Female, and Masters Athletes*. *Int J Sport Nutr Exerc Metab*, 2019. 29(2): p. 220-227.
21. Desbrow, B., et al., *Sports Dietitians Australia position statement: Sports nutrition for the adolescent athlete*. *International Journal of Sport Nutrition and Exercise Metabolism*, 2014. 24(5): p. 570-584.
22. Koehler, K., et al., *Parallel assessment of nutrition and activity in athletes: validation against doubly labelled water, 24-h urea excretion, and indirect calorimetry*. *J Sports Sci*, 2010. 28(13): p. 1435-49.
23. Black, A.E., *The sensitivity and specificity of the Goldberg cut-off for EI:BMR for identifying diet reports of poor validity*. *Eur J Clin Nutr*, 2000. 54(5): p. 395-404.
24. Goldberg, G.R., et al., *Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording*. *Eur J Clin Nutr*, 1991. 45(12): p. 569-81.
25. Loucks, A.B., *Energy balance and body composition in sports and exercise*. *J Sports Sci*, 2004. 22(1): p. 1-14.
26. Slater, J., et al., *Low Energy Availability in Exercising Women: Historical Perspectives and Future Directions*. *Sports Med*, 2017. 47(2): p. 207-220.
27. Koehler, K., et al., *Iron status in elite young athletes: gender-dependent influences of diet and exercise*. *Eur J Appl Physiol*, 2012. 112(2): p. 513-23.
28. Braun, H., et al., *Vitamin D status of young elite German athletes*. In: *Abstracts from the December 2013 International Sports and Exercise Nutrition Conference in Newcastle upon Tyne*. *Int J Sport Nutr Exerc Metab*, 2014. 24(s1): p. S1.

-
29. Braun, H., et al. *Magnesium – dietary intake, supplement use and serum concentration in elite young German athletes.* in *14th annual congress of the European College of Sport Sciences: Book of abstracts.* 2009. Oslo.
 30. Braun, H., et al. *Use of nutritional supplements by german elite junior athletes.* In: *Sport science by the sea : book of abstracts; 13th Annual Congress of the European College of Sport Science, 9-12 July 08, Estoril-Portugal.* in *13th Annual Congress of the European College of Sport Science, 9-12 July 08, Estoril-Portugal.* 2008. Lissabon: European College of Sport Science.
 31. Braun, H., et al. *Dietary supplement use of elite German athletes and knowledge about the contamination problem.* in *14th annual congress of the European College of Sport Sciences: Book of abstracts.* 2009. Oslo.
 32. Braun, H., et al. *Nutrition status and physical activity of german elite junior athletes: preliminary results.* In: *Sport science by the sea : book of abstracts; 13th Annual Congress of the European College of Sport Science, 9-12 July 08, Estoril-Portugal.* in *13th Annual Congress of the European College of Sport Science, 9-12 July 08, Estoril-Portugal.* 2008. Lissabon: European College of Sport Science.
 33. Braun, H., et al. *Micronutrient intake of young elite German athletes.* in *16th annual congress of the European College of Sport Sciences, 6.-9. July 2011, Liverpool, ECSS : Book of abstracts.* 2011. Liverpool.
 34. von Andrian-Werburg, J., et al. *Nutrition status and carbohydrate intake in relation to training volume of 421 young elite German athletes.* in *23rd annual congress of the European College of Sport Sciences: Book of abstracts.* 2018. Dublin.
 35. Braun, H., et al., *Nutrition Status of Young Elite Female German Football Players.* *Pediatr Exerc Sci*, 2018. 30(1): p. 157-167.

36. Knapik, J.J., et al., *Prevalence of Dietary Supplement Use by Athletes: Systematic Review and Meta-Analysis*. Sports Med, 2016. 46(1): p. 103-123.
37. Maughan, R.J., et al., *IOC Consensus Statement: Dietary Supplements and the High-Performance Athlete*. Int J Sport Nutr Exerc Metab, 2018. 28(2): p. 104-125.
38. Garthe, I. and R.J. Maughan, *Athletes and Supplements: Prevalence and Perspectives*. Int J Sport Nutr Exerc Metab, 2018. 28(2): p. 126-138.
39. Carlsohn, A., et al., *Position of the Working Group Sports Nutrition of the German Nutrition Society (DGE): Minerals and Vitamins in Sports Nutrition*. Deutsche Zeitschrift für Sportmedizin, 2020. Volume 71(No. 7-8-9): p. 208-215.
40. Ziegenhagen, R., et al., *Position of the Working Group Sports Nutrition of the German Nutrition Society (DGE): Safety Aspects of Dietary Supplements in Sports*. Deutsche Zeitschrift für Sportmedizin, 2020. Volume 71(No. 7-8-9): p. 216-224.
41. Peeling, P., et al., *Sports Foods and Dietary Supplements for Optimal Function and Performance Enhancement in Track-and-Field Athletes*. Int J Sport Nutr Exerc Metab, 2019. 29(2): p. 198-209.
42. Braun, H., et al., *Dietary supplement use among elite young German athletes*. Int J Sport Nutr Exerc Metab, 2009. 19(1): p. 97-109.
43. Sawka, M.N., et al., *American College of Sports Medicine position stand. Exercise and fluid replacement*. Med Sci Sports Exerc, 2007. 39(2): p. 377-90.
44. McCubbin, A.J., et al., *Sports Dietitians Australia Position Statement: Nutrition for Exercise in Hot Environments*. Int J Sport Nutr Exerc Metab, 2020: p. 1-16.
45. EFSA, *Scientific opinion on dietary reference values for water*. EFSA Journal, 2010(8): p. 1459–1507.

-
46. Elmadfa, I. and A.L. Meyer, *Patterns of drinking and eating across the European Union: implications for hydration status*. Nutr Rev, 2015. 73 Suppl 2: p. 141-7.
 47. Baron, S., et al., *Assessment of hydration status in a large population*. Br J Nutr, 2015. 113(1): p. 147-58.
 48. Malisova, O., et al., *Water Intake and Hydration Indices in Healthy European Adults: The European Hydration Research Study (EHRS)*. Nutrients, 2016. 8(4): p. 204.
 49. Mora-Rodriguez, R., et al., *Influence of Physical Activity and Ambient Temperature on Hydration: The European Hydration Research Study (EHRS)*. Nutrients, 2016. 8(5).
 50. Braun, H., et al., *Differing Water Intake and Hydration Status in Three European Countries-A Day-to-Day Analysis*. Nutrients, 2019. 11(4).
 51. FIFA. *Women's Football Survey*. 2014 [cited 2017 July 20]; Available from: <https://resources.fifa.com/image/upload/fifa-women-s-football-survey-2522649.pdf?cloudid=emtgxvp0ibnebltvi3b>.
 52. Peeling, P., et al., *Athletic induced iron deficiency: new insights into the role of inflammation, cytokines and hormones*. Eur J Appl Physiol, 2008. 103(4): p. 381-91.
 53. Owens, D.J., W.D. Fraser, and G.L. Close, *Vitamin D and the athlete: emerging insights*. Eur J Sport Sci, 2015. 15(1): p. 73-84.
 54. Maughan, R.J., F. Depiesse, and H. Geyer, *The use of dietary supplements by athletes*. J Sports Sci, 2007. 25 Suppl 1: p. S103-13.
 55. Maughan, R.J., D.S. King, and T. Lea, *Dietary supplements*. J Sports Sci, 2004. 22(1): p. 95-113.
 56. NVS II, *Nationale Verzehrs Studie II, Ergebnisbericht, Teil 2*. 2008 [cited 2008 May 31]; Available from: http://www.was-esse-ich.de/uploads/media/NVS_II_Ergebnisbericht_Teil_2.pdf.

57. Nieper, A., *Nutritional supplement practices in UK junior national track and field athletes*. Br J Sports Med, 2005. 39(9): p. 645-9.
58. Slater, G., B. Tan, and K.C. Teh, *Dietary supplementation practices of Singaporean athletes*. Int J Sport Nutr Exerc Metab, 2003. 13(3): p. 320-32.
59. Sobal, J. and L.F. Marquart, *Vitamin/mineral supplement use among athletes: a review of the literature*. Int J Sport Nutr, 1994. 4(4): p. 320-34.
60. Lawson, K.A., et al., *Multivitamin use and risk of prostate cancer in the National Institutes of Health-AARP Diet and Health Study*. J Natl Cancer Inst, 2007. 99(10): p. 754-64.
61. Geyer, H., et al., *Analysis of non-hormonal nutritional supplements for anabolic-androgenic steroids - results of an international study*. Int J Sports Med, 2004. 25(2): p. 124-9.
62. Suhayda, R. and J.C. Walton, *Preventing and managing dehydration*. Medsurg Nurs, 2002. 11(6): p. 267-78.
63. El-Sharkawy, A.M., O. Sahota, and D.N. Lobo, *Acute and chronic effects of hydration status on health*. Nutrition Reviews, 2015. 73(suppl_2): p. 97-109.
64. Armstrong, L.E., et al., *Mild Dehydration Affects Mood in Healthy Young Women*. The Journal of Nutrition, 2011. 142(2): p. 382-388.
65. Cian, C., et al., *Effects of fluid ingestion on cognitive function after heat stress or exercise-induced dehydration*. International Journal of Psychophysiology, 2001. 42(3): p. 243-251.
66. D'Anci, K.E., et al., *Voluntary Dehydration and Cognitive Performance in Trained College Athletes*. Perceptual and Motor Skills, 2009. 109(1): p. 251-269.

-
67. Ganio, M.S., et al., *Mild dehydration impairs cognitive performance and mood of men*. British Journal of Nutrition, 2011. 106(10): p. 1535-1543.
 68. Pross, N., et al., *Influence of progressive fluid restriction on mood and physiological markers of dehydration in women*. British Journal of Nutrition, 2012. 109(2): p. 313-321.
 69. Gibson, S. and S.M. Shirreffs, *Beverage consumption habits "24/7" among British adults: association with total water intake and energy intake*. Nutr J, 2013. 12: p. 9.
 70. Armstrong, L.E., et al., *An empirical method to determine inadequacy of dietary water*. Nutrition, 2016. 32(1): p. 79-82.
 71. Chevront, S.N., et al., *Biological variation and diagnostic accuracy of dehydration assessment markers*. Am J Clin Nutr, 2010. 92(3): p. 565-73.
 72. Manz, F. and A. Wentz, *24-h hydration status: parameters, epidemiology and recommendations*. Eur J Clin Nutr, 2003. 57 Suppl 2: p. S10-8.
 73. Perrier, E.T., et al., *Twenty-four-hour urine osmolality as a physiological index of adequate water intake*. Dis Markers, 2015. 2015: p. 231063.
 74. Armstrong, L.E., et al., *Hydration biomarkers and dietary fluid consumption of women*. J Acad Nutr Diet, 2012. 112(7): p. 1056-61.
 75. Benton, D. and H.A. Young, *Do small differences in hydration status affect mood and mental performance?* Nutr Rev, 2015. 73 Suppl 2: p. 83-96.
 76. Gopinathan, P.M., G. Pichan, and V.M. Sharma, *Role of dehydration in heat stress-induced variations in mental performance*. Arch Environ Health, 1988. 43(1): p. 15-7.
 77. Sharma, V.M., et al., *Influence of heat-stress induced dehydration on mental functions*. Ergonomics, 1986. 29(6): p. 791-799.

78. Shirreffs, S.M., et al., *The effects of fluid restriction on hydration status and subjective feelings in man*. British Journal of Nutrition, 2007. 91(6): p. 951-958.
79. Suhr, J.A., et al., *The relation of hydration status to cognitive performance in healthy older adults*. International Journal of Psychophysiology, 2004. 53(2): p. 121-125.
80. Benelam, B. and L. Wyness, *Hydration and health: a review*. Nutrition Bulletin, 2010. 35(1): p. 3-25.
81. Watson, P., et al., *Mild hypohydration increases the frequency of driver errors during a prolonged, monotonous driving task*. Physiol Behav, 2015. 147: p. 313-8.
82. Holen, T., et al., *Biomarkers for nutrient intake with focus on alternative sampling techniques*. Genes Nutr, 2016. 11: p. 12.
83. Gomez-Cabrera, M.C., et al., *Oral administration of vitamin C decreases muscle mitochondrial biogenesis and hampers training-induced adaptations in endurance performance*. Am J Clin Nutr, 2008. 87(1): p. 142-9.
84. Mettler, S. and M.B. Zimmermann, *Iron excess in recreational marathon runners*. Eur J Clin Nutr, 2010. 64(5): p. 490-4.
85. Ristow, M., et al., *Antioxidants prevent health-promoting effects of physical exercise in humans*. Proc Natl Acad Sci U S A, 2009. 106(21): p. 8665-70.
86. Braun, H., et al. *Dietary supplement use, impact on micronutrient intake of young elite German athletes*. in *22nd annual congress of the European College of Sport Sciences: Book of abstracts*. 2017. Rhein-Ruhr: Westdeutscher Universitätsverlag.
87. Collins, J., et al., *UEFA expert group statement on nutrition in elite football. Current evidence to inform practical recommendations and guide future research*. Br J Sports Med, 2020: p. Epub ahead of print.

88. Domnik, K., et al. *Evaluation of fluid status and effect of an individual intervention in female soccer players before match play.* in *18th annual congress of the European College of Sport Science : 26th - 29th June 2013, Barcelona - Spain ; book of abstracts.* 2013. Barcelona: European College of Sport Science.
89. Mattausch, N.R., et al., *Case Study: Hydration Intervention Improves Pre-game Hydration Status in Female Collegiate Soccer Players.* *Int J Sport Nutr Exerc Metab*, 2017. 27(5): p. 475-481.

2 Nutrition Status of Young Elite Female German Football Players

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2.1 Abstract

Purpose: To investigate energy intake, energy expenditure and the nutritional status of young female elite football players using a 7-day food and activity record and blood parameters.

Methods: A total of 56 female elite football players (14.8 ± 0.68 yrs) completed the requested food and activity protocols. Misreporting was assessed by the ratio of energy intake to energy expenditure. The food records were analyzed concerning energy, macronutrient and micronutrient intake and energy expenditure was calculated using predictive equations. Hematological data and 25-hydroxy-vitamin-D (25(OH)D) serum concentrations were determined. *Results:* Mean energy intake was 2226 ± 368 kcal/d (40.5 ± 7.0 kcal/kg/d) and estimated energy expenditure averaged 2403 ± 195 kcal/d. 53% of the players exhibited an energy availability <30 kcal/kg lean body mass. 31% of the athletes consumed <5 g/kg carbohydrates and 34% consumed less than 1.2 g/kg protein. A large proportion of players (%) had intakes below the RDA of folate (75%), vitamin D (100%), iron (69%) and calcium (59%). Ferritin and 25(OH)D serum levels were below recommendations of 59% and 38%,

respectively. *Conclusion:* A remarkable number of players failed to meet energy balance and suggested recommended carbohydrate and protein intakes. Low iron and 25(OH)D serum levels were observed elucidating a suboptimal nutrition status of some young female football players. As a consequence, strategies have to be developed for a better information and application of sport nutrition practice among young female football players.

2.2 Introduction

Football is one of the world's most famous sports, meanwhile played by over 30 million females worldwide. 54% of all registered female football players are youth players [1]. In Germany football is, after gymnastics, the most common sport for girls between the age of 7 and 18 years, played by a total of 314,602 young female athletes [2]. The large number of young female football players outlines the need of appropriate training and nutrition guidelines for athletic performance, growth and development [3, 4]. Currently, specific nutrient recommendations for youth athletes are insufficiently studied, forcing the potentially not adequate use of adult recommendations.

When training and competing female athletes tend to eat less than required [5, 6], which can lead to a low energy and carbohydrate intake and an insufficient supply of some nutrients such as vitamin E, vitamin D, calcium, iron and magnesium [3, 7, 8]. Suitable fueling and nutrition plays an important role for a team sport, such as football, considering its metabolic demands including running, sprinting, stopping, turning, and jumping. Football is physiologically described as a high-intensity, intermittent sport with a relatively large amount of running distance. The average total distance covered during a game of female elite football players lies between 10 and 11 km of which approx. 2.500 m (24%) are covered at high speed (> 19.8 km/h) [9, 10]. A reduction in physical strength and sprint performance during the second half,

especially in the last 15 min by 26% up to 57% indicates that some female elite players are unable to maintain the required speed for the duration of the whole match. This can be attributed to muscular fatigue and/ or an insufficient training capacity, but the question arises whether this might also be partly attributed to an insufficient fueling before and during a football match. Previous studies have shown that the majority of female football players fail to meet the increased energy demands caused by training and competition [3, 8, 11-13]. Thereby, the minimum needs of carbohydrate intake for adequate glycogen synthesis are often not met, as it has been shown in previous studies investigating the nutritional behavior of female junior elite football players [3, 11, 13, 14]. Carbohydrates are the main energy source during the high-intensity parts of a football match, such as sprints and jumps. Thus, sufficient carbohydrate and protein intake is required in order to replenish glycogen stores as well as maintain body weight and synthesize muscle tissue [15].

For the development of appropriate dietary recommendations for young female elite athletes, the *status quo* needs to be defined regarding the respective demands. The two main challenges during this process are choosing the right assessment tool for the quantification of nutrient intake to minimize misreporting as well as determining the energy expenditure as precise as possible. In most previous studies the nutritional intake was gathered either using a 3-day food record or a 24-hour-recall [3, 11, 12, 14]. Both methods lower the burden of the subjects, but for an increased reliability a 7-day food record is unequivocally recommended [16]. Only Martin et al. (2006) used a 7-day food record for the nutrient intake of national female football players. However, the calculation for energy expenditure was performed using the software Diet Organizer 2.0 (MulberrySoft 2014), leaving uncertainties about the formulas used and the respective reliability of the calculations. It is suggested, that the most accurate method for estimating energy expenditure of young athletes in the field is the use of the *Metabolic*

Equivalent of Task (MET), expressing the energy costs of different physical activities by multiplying the MET factor with the basal metabolic rate (BMR) [15, 17].

A major source of error during the assessment of the nutrition status is misreporting in the dietary records. Poslusna et al. (2009) evaluated misreporting of energy intake in 69 studies and identified 7.6 – 49.0% (median: 32.5%) of all female subjects in the studies to be ‘under-reporters’ [18]. A similar number was found by Black (2000), who identified 37% of all women participating in 21 different studies to be under-reporters [19]. This large proportion of underreported protocols connotes a much lower average energy and nutrient intake than actually consumed, leading to wrong conclusions about the nutrition status. For that reason, under- as well as over-reporters need to be excluded from analysis. Hitherto, only one study excluded under-reporters, not considering over-reporters though [14]. For the development of solid sports nutrition recommendations for young female athlete’s defective protocols must be excluded.

The purpose of the present study was to perform an extensive analysis of the nutritional status, blood parameters, energy intake and expenditure of young elite female football players with the exclusion of misreported protocols.

2.3 Methods

2.3.1 Study Design

Data from young female football players, who visited the German Research Centre of Elite Sports in Cologne between March 2008 and August 2014, was analyzed retrospectively. All athletes participated in a routine examination including an extensive medical check-up, biomechanical and performance testing, psychological consultation, and a nutritional

assessment. Data of the food record, activity protocol and blood parameters were used for this study.

2.3.2 Subjects

All athletes eligible for this study were chosen by the football sports federation. At the time of the study they were playing for the age-related national team or regional representative team and can be considered to be among the (national) elite with respect to their age.

The study was approved by the German Sports University's local ethics committee and written informed consent was obtained from a legal representative of each subject.

Only athletes for whom all necessary data (nutrition, physical activity data and hematological profiles) was available, were included in this present study. 56 data sets were complete and used for the analysis of the nutrition status.

2.3.3 Study Protocol

At the time of the evaluation, athletes were asked to complete a detailed 7-day food record paralleled with a 7-day activity protocol prior to the testing day. After an overnight fast, the subjects reported to the lab at 08:00 am and body weight and body composition were assessed by bioimpedance using a BA-418 MA (Tanita, The Netherlands). Body height was measured using a calibrated scale and a venous blood sample was drawn from the antecubal vein.

2.3.4 Dietary Assessment

Dietary intake was assessed using a standardized 7-day food record. The applied food record had been validated against doubly labelled water (DLW) and 24-h urea excretion [20]. The standardized record comprised a list of frequently used food items. Standard portion sizes

were included to the choice of each food item to reduce misjudgment of portion sizes by the subjects and to minimize the respondents' burden. Detailed instructions for completing the food record were provided and a sample page of an accurately completed food record was included. All athletes were strongly encouraged to add foods and to change portion sizes if needed. Nutrient data from the diet logs was analyzed using the EBISpro software (version 7.0, 2005), based on the German Nutrient Data Base (Federal Research Centre for Nutrition and Food 2004). The recommended daily allowances (RDA) released by D-A-CH [21], a cooperation of the German, Austrian and Swiss Nutrition Societies, were used for the evaluation of the intake of minerals, vitamins and trace elements. Micro-Nutrients coming from dietary supplements were not included in the analysis.

2.3.5 Energy Expenditure

The participants' energy expenditure (EE) was estimated using a self-reported 7-day activity protocol, which had to be completed parallel to the food record. The activity protocol contained 25 activities, which were categorized into general activities (sleep, work, school, etc.), leisure activities (locomotion, leisure sports) and sports-related activities (training, competition, strength training, etc.). All athletes received written instruction for its completion and were asked to list the duration of all activities as precise as possible. The activity protocol had been validated against indirect calorimetry and doubly labelled water [20].

EE was calculated using the compendium of physical activities to determine the appropriate metabolic equivalent (MET) values for each activity performed [22]. The MET values are multiplication factors of the basal metabolic rate (BMR). In the present study BMR was calculated using the 'Harris-Benedict-Formula', which considers age as an individual parameter. The daily total energy expenditure (TEE) comprised the BMR, leisure activity

energy expenditure (LEE) and the energy expenditure of all sports-related activities (ExEE) and was calculated as the sum of the EE of all recorded activities.

Further, the energy availability (EA), which is defined as *(energy intake (kcal) – exercise energy expenditure (kcal)) / lean body mass (kg)*, was calculated. EA is categorized as insufficient when <30 kcal/kg lean body mass (LBM) are consumed [5, 6].

2.3.6 Identifying Records of Poor Validity: Under- and Over-Reporter

Subjects were classified as under-reporter (UR), average-reporter (AR) and over-reporter (OR), from their individual ratio of reported energy intake (EI) to TEE according to Black [19]. According to this, ARs were identified by representing an EI/TEE ratio in the range of 0.76 – 1.24, URs by EI/TEE <0.76 and OR by EI/TEE >1.24. 19 athletes were identified as URs (0.56 ± 0.14), 32 athletes were classified as ARs (0.94 ± 0.14) and 5 athletes showed a mean ratio greater than 1.24 (1.72 ± 0.57) whereby being categorized as ORs. For the analysis of the nutritional intake and status of the young female athletes only the 32 ARs were considered unless stated differently.

2.3.7 Hematological Data

Measurements of the venous blood samples were conducted using a Sysmex KX-21N blood analyzer (Sysmex, Nordersted, Germany) regarding: hemoglobin and hematocrit. Serum iron concentrations were measured using a Cobas 400 (Roche, Mannheim, Germany) and for ferritin levels the immunoassay analyzer Elecsys 2010 (Roche, Mannheim, Germany) was used. Serum ferritin levels were considered low at concentrations below 35 µg/L and critical below 12 µg/L [23]. Female athletes detecting serum ferritin levels below 12 µg/L were

considered 'iron deficient'. Hemoglobin and hematocrit values were classified in females as abnormal below 12 g/dL and 36% respectively, showing an iron deficiency anemia [24].

The analysis and interpretation of the vitamin D status is referring to 24 subjects. Blood samples were analyzed for 25-hydroxy-vitamin-D (25(OH)D) by a one-step immunoassay (ADVIA Centaur VitD-test) using the ADVIA Centaur (Siemens Healthcare, Germany). The 25(OH)D concentrations of the athletes were classified as 'severely deficient' (<12 nmol/L), 'deficient' (12–30 nmol/L), 'inadequate' (30–50 nmol/L) and 'adequate >50' (>50 nmol/L) [25, 26]. In addition, data was considered 'adequate >75' with respect to Heaney et al. (2010) who defined 25(OH)D status >75 nmol/l as adequate [27].

2.3.8 Statistical Analysis

All data was tested for normal distribution using Kolmogoroff-Smirnov-test. Depending on the normality of these data, the Student-t-test (parametric data) or the Mann-Whitney U-test (non-parametric data) was used. Differences were statistically significant at a probability of error below 5% ($p < 0.05$). If not stated otherwise, values were expressed as mean±standard deviation (SD). All statistical comparisons were conducted using the SPSS software (SPSS Inc., version 24.0).

2.4 Results

2.4.1 Physical Characteristics

The physical characteristics of the participants are presented in Table 2-1. The subjects' characteristics are subdivided in UR, AR and OR. Significant differences for the body mass index (BMI) were found between UR and OR as well as AR and OR ($p < 0.05$). A significant difference in body weight was shown between the the UR and OR ($p < 0.05$). No significant

difference in the percentage of body fat was found between those groups ($p = 0.08$). For all other anthropometric parameters and training time no significant results were observed.

Table 2-1: Anthropometric characteristics and training duration during study period

	Total (n = 56)	UR (n = 19)	AR (n = 32)	OR (n = 5)
	Mean (SD) (min; max)	Mean (SD) (min; max)	Mean (SD) (min; max)	Mean (SD) (min; max)
Age, y	14.8 (0.7) (13; 17)	14.8 (1.0) (13; 17)	14.8 (0.5) (13; 15)	14.6 (0.5) (14; 15)
Weight, kg	56.8 (6.1) (43.5; 74.9)	58.7 (6.1) (50.7; 74.9)*	56.3 (6.2) (43.5; 71.1)	53.1 (2.8) (49.9; 57.1)*
Height, cm	166 (5) (155; 180)	167 (5) (158; 176)	166 (6) (155; 180)	166 (6) (158; 172)
BMI, kg/m ²	20.6 (1.5) (17.5; 24.2)	21.1 (1.5) (18.7; 24.2)*	20.5 (1.5) (17.5; 23.2)**	19.4 (0.7) (18.2; 20.3)***
LBM, kg	46.9 (4.3) (37.2; 57.0)	47.8 (4.3) (41.2; 57.0)	46.6 (4.2) (37.2; 55.5)	45.6 (3.7) (40.2; 49.7)
Body fat, %	17.2 (3.9) (8.3; 24.9)	18.3 (3.3) (11.2; 24.9)	16.9 (4.0) (8.3; 24.8)	14.2 (3.6) (9.8; 19.4)
Training, min/d	85 (31) (26; 205)	89 (40) (26; 205)	85 (26) (31; 150)	68 (22) (41; 104)

Note: UR = under-reporter, AR = average reporter, OR = over-reporter. * shows a significant difference ($p < 0.05$) between under-reporter (UR) and over-reporter (OR); + shows a significant difference ($p < 0.05$) between average reporter (AR) and OR

2.4.2 Energy Balance and Energy Availability

Mean energy intake, energy expenditure and energy availability of the AR is shown in Table 2-2. Statistical analysis revealed no significant difference between EI and TEE ($p < 0.05$),

Table 2-2: Daily Energy Intake, Expenditure, Energy Availability, and the Percentage of Players Below Recommendations

Energy	Intake, mean (SD)	Range	Athletes consuming < recommendations, % (n)	Recommendations
Intake				
total, kcal	2262 (368)	1702 to 3194		
body weight, kcal/kg	40.5 (7.0)	28.5 to 57.4		
Expenditure				
total, kcal	2403 (195)	1946 to 2753		
body weight, kcal/kg	43.1 (4.8)	34.8 to 56.3		
Energy balance				
total, kcal	-141 (327)	-549 to +509	75 (24)	Energy balance
Energy availability				
lean body mass, kcal/kg	30.0 (7.3)	20.3 to 51.0	53 (17)	>30 kcal/kg lean body mass ^a

Note: ^a Loucks [28]

suggesting that energy balance was achieved in the group of AR. 53% of the players did not meet the minimum recommendation of 30 kcal/ kg LBM [5, 6]. Daily mean training time amounted to 85 ± 26 min (including 45 ± 11 min football specific training), which represents $24.7\pm 6.4\%$ of the daily TEE.

2.4.3 Macronutrient intake

Total and relative macronutrient intake are shown in Table 2-3. Compared with sport nutrition recommendations 10 athletes (31%) stayed below the recommended intake of 5-10 g/kg/d for moderate to high exercise programs lasting 1-3 hours [29]. 11 subjects (34%) didn't meet the current suggestion of dietary protein intake in the general range from 1.2-2.0 g/kg/d [15, 30].

Table 2-3: Daily Macronutrient Intake and the Percentage of Player Not Meeting DRIs and Sport Nutrition Recommendations

Macronutrient	Intake, mean (SD)	Range	Athletes consuming < RDA or recommendations, % (n) ^a	RDA or sport nutrition recommendation
Carbohydrate				
total, g	303 (62)	191–466	–	–
body weight, g/kg	5.4 (1.1)	3.2–8.4	31 (10)	5–10 g/kg/d ^b
total EI, %	54.9 (5.4)	45.0–66.0	–	–
Protein				
total, g	77 (11)	55–103	–	–
body weight, g/kg	1.4 (0.3)	1.0–2.0	34 (11)	1.2–2.0 g/kg/d ^{c,d}
total EI, %	14.1 (2.3)	10.0–19.0	–	–
Fat				
total, g	78 (19)	47–121	–	–
saturated fatty acids, %	13.0 (2.4)	9.0–18.3	84 (27)	<10% total energy ^{d,e}
monounsaturated fatty acids, %	10.8 (2.0)	7.5–14.2	59 (19)	10%–15% total energy ^e
polyunsaturated fatty acids, %	8.8 (1.3)	4.0–9.6	81 (26)	7%–10% total energy ^e
body weight, g/kg	1.4 (0.4)	0.9–2.2	–	–
total EI, %	30.7 (5.0)	22.0–40.0	50 (16)	30%–35% total energy ^{d,e}

Note: ^{*}except: % saturated fat (> DRI). ^aBurke et al. [29], ^bDesbrow et al. [31], ^cThomas et al. [15], ^dRDA = Recommended Daily Allowance. For females 13 – 19 years old [21].

2.4.4 Micronutrient and fluid intake

Micronutrient and fluid intakes compared with the respective RDA values [21] are presented in Table 2-4. No player met the RDA for vitamin D and a considerable group of participants stayed under the RDAs for vitamin B₁₂ (53%), Folate (75%), vitamin A (53%), calcium (59%), phosphorus (38%) and iron (69%).

Subjects showed a high inter-individual variability of mean total daily fluid intake.

Table 2-4: Daily Micronutrient^a and Fluid Intake Compared With the Respective RDA Values

Micronutrient/Fluid	Intake, mean (SD)	Range	Intake, % of RDA	Athletes consuming < RDA, % (n)	RDA ^b
Thiamin, mg/d	1.5 (0.3)	0.9–2.2	150	6 (2)	1.0
Riboflavin, mg/d	1.4 (0.2)	1.0–1.8	127	9 (3)	1.1
Niacin, mg/d	27.7 (4.4)	19.4–36.6	213	0 (0)	13
Vitamin B6, mg/d	1.9 (0.3)	1.3–2.6	136	3 (1)	1.4
Vitamin B12	2.9 (1.0)	1.0–4.8	97	53 (17)	3.0
Folate, µg/d	256 (61)	144–395	85	75 (24)	300
Vitamin A, µg/d	1228 (1088)	383–6762	123	53 (17)	1000
Vitamin D, µg/d	1.3 (0.9)	0.3–3.7	7	100 (32)	20
Vitamin E, mg/d	13.8 (2.8)	9.0–20.4	115	25 (8)	12
Vitamin C, mg/d	169 (59)	79–333	199	3 (1)	85
Calcium, mg/d	1107 (382)	459–1972	92	59 (19)	1200
Phosphorus, mg/d	1314 (202)	936–1692	105	38 (12)	1250
Magnesium, mg/d	446 (131)	265–707	144	22 (7)	310
Iron, mg/d	14.0 (2.7)	9.2–22.1	93	69 (22)	15
Zinc, mg/d	11.1 (6.1)	8.0–14.9	159	0 (0)	7.0
Potassium, mg/d	3412 (575)	2355–4457	180	0 (0)	1900
Sodium, mg/d	2791 (643)	1808–4444	507	0 (0)	550
Fluid intake					
total, mL	2456 (905)	976–4557			
body weight, mL/kg	43.8 (15.1)	17.1–79.1	110	44 (14)	40

Note: RDA, recommended daily allowance. ^aData show micronutrient intake from food only, micronutrients from dietary supplements are not included. ^bFor females 13–19 years old [21].

2.4.5 Biochemical data

Ferritin, hemoglobin and hematocrit values are shown in Table 2-5. Low ferritin values (<35 µg/L) suggestive for iron depletion were measured in 17 (59%) female football players. The high prevalence of critical ferritin values (<12 µg/L) classified 5 players (17%) as *iron depleted*.

A small proportion of the subjects had measures below the reference values for hemoglobin (n=2; 7%) and hematocrit (n=2; 7%). As both players were identical for the low hemoglobin and hematocrit values. 9 Players (38%) demonstrated inadequate vitamin D values below 50 nmol/L. As the blood samples were collected during the whole year, the lowest average serum concentrations were identified in March (47.6 ± 5.0 nmol/L).

Table 2-5: Biochemical Data, Prevalence of Abnormal Values for Iron-Related Indices (n = 29) and Vitamin D (n=24)

Parameter	Mean (SD)	Range	Players below defined parameter range, % (n)
Ferritin, $\mu\text{g/L}^{\text{a}}$	32.7 (19.4)	5.1–86.3	
low (<35)			59 (17)
critical (<12)			17 (5)
Hemoglobin, g/dL ^b	13.2 (0.7)	11.4–14.6	
abnormal (<12)			7 (2)
Hematocrit, %	39.0 (1.8)	34.8–42.1	
abnormal (<36)			7 (2)
25-hydroxyvitamin D, nmol/L	50.2 (16.6)	33.0–88.5	
adequate (>75) ^c			21 (5)
adequate (>50) ^d			42 (10)
inadequate (30–50) ^d			38 (9)
deficient (12 to <30) ^d			0 (0)
severely deficient (<12) ^d			0 (0)

Note: ^a Peeling et al. [23], ^b Deakin [24], ^c Heaney et al. [27], ^d Close et al. [25], Owens et al. [26]

2.5 Discussion

This retrospective study assessed the nutritional status of young elite female football players via a nutritional analysis combined with an individual calculation for energy expenditure and an analysis and interpretation of nutritional related blood parameters. The main outcome of this study was that despite excluding misreported protocols, the average relative EI (40.5 ± 7.0 kcal/kg) and EA (30.0 ± 7.3 kcal/kg) just met the minimum requirements for female athletes, leaving a considerable number of players below the minimum energy requirements. Therefore, the average CHO intake is comparatively low (5.4 ± 1.1 g/kg; 69% < 5g/kg), which in turn may

limit some players' energy supply for playing football at elite level. Another striking finding is the occurrence of a significant difference in the BMI and body weight between the group of UR and OR as well as between the ARs and ORs (BMI only). Hence, this indicates a relation between body weight and misreporting among young female athletes.

2.5.1 Energy balance and energy availability

A low energy availability among young female athletes can have severe negative health outcomes, such as menstrual dysfunction, stress fractures, reduction of the BMR and decreased reproductive hormone concentrations as well as a decline in performance [5, 28, 32, 33]. Athletes show increased occurrence of disordered eating patterns compared to their not-active peers, although this occurs mainly in older athletes who compete on a high performance level [32]. However, the age group of 14 – 18 year old female athletes exhibits a trend towards a lower energy intake and an impaired diet quality [3, 14]. In the present study, a mean energy deficit of 141 kcal/ day was identified after the exclusion of 19 (34%) underreported diet protocols. The mean relative EI of 40.5 ± 7.0 kcal/kg BW implies an insufficient energy intake compared to their relative EE of 43.1 ± 4.8 kcal/ kg BW. Similar findings of inadequate energy intake of female elite football players in this age group and older have been published elsewhere [3, 8, 11, 12, 14]. The recommended relative EI for adult female athletes training with a workload of >90 min is reported as 45-50 kcal/ kg body weight (BW) [34], which is slightly higher than the energy expenditure calculated in this study. Even if the EI is not significantly different from TEE, a tendency for low EI is shown.

The current cut-off criteria for a low EA is 30 kcal/kg LBM/day which was just accomplished by the young football players in the present study [28, 32]. 17 athletes (53%), did not meet the minimum requirement, with the lowest EA being 20.3 kcal/ kg LBM. Long-term effects of low

EA can be health-damaging and are potentially irreversible [32]. However, if diagnosed in an early state the impairments caused by a low EA are reversible emphasizing the need to correctly identify young female athletes with low EA.

2.5.2 Diet records of poor validity: Under- and Over-reporter

One important fact in the discussion of a low EA and a low EI is the right estimation and calculation of the caloric intake per day. It is well described that a high prevalence of misreported dietary intake with various assessment methods exists [16, 18, 19, 35]. The review of Magkos and Yannakoulia [16] identified an underestimation of the actual EI by 20–50% using estimated food records, which is the most applied assessment tool in research. Reasons for under-reporting can be a misjudgment of portion sizes or incomplete listing of snacks or drinks with caloric value, which is considered intentional or unintentional ‘underrecording’. Under-reporting can also be caused by an intentional or unintentional ‘undereating’, underlying an acute reduction of food intake during the study period [16]. A review of published studies using DLW revealed that under-reporting amounted to 10 – 45% of TEE and was primarily related to under-recording rather than under-eating [16].

In comparable studies the possible occurrence of under-reporters is mentioned in the limitations, thus such protocols have not been excluded [3, 8, 11, 13]. The challenge of identifying misreported protocols entails to distinguish different cut-off criteria, however the Goldberg cut-off [36] is the most common one in literature [18]. This cut-off criteria has been restated and the applied factors have been revised by Black [19], making it the most plausible cut-off value in current publications [18]. There are limitations to a cut-off criteria as there is a risk of excluding athletes with an actual low energy intake, however this source of error seems to be lower than the falsely accepted misreported protocols. The mean reported energy intake

of [8] of 1904 kcal/ day was below the calculated Goldberg cut-off value of 1911, which would have led to an exclusion of the majority of protocols. Considering the subjects' steady weight before and after that study, under-reporting has presumably taken place.

Taking this into account, 19 out of 56 protocols were excluded using the cut-off criteria of Black [19] due to a potential under-reporting in the present study. In addition to that, further 5 protocols were excluded due to over-reporting. Under-reporting is found among all age groups and genders, however it is more common among females who are overweight or rather discontent with their body weight [37]. This phenomenon is consistent with the results of the present study. The BMI and body weight of the UR is significantly higher than the BMI of the OR ($p < 0.05$). A significant difference was also found between the AR and OR ($p < 0.05$) with the OR having the lowest BMI of 19.4 ± 3.7 kg/m². Social desirability, discontentment with the own body weight or meeting the demands of the athletic environment (coaches, advisers, etc.) might have played a role during the evaluation of dietary intake.

Notwithstanding, even after the exclusion of 19 protocols (34%), the EI and EA still barely met the requirements, pointing out that a low EI among some of the young athletes exists.

2.5.3 Macronutrient intake

Carbohydrates are the primary energy source for the high-intensity bouts in football [4, 38, 39]. It is inevitable that the glycogen stores in the liver and muscles are replenished sufficiently to deliver performance in training and competition. Current adult sports nutrition recommendations range from 5-7 g/kg/d for a moderate exercise program for about 1 h/d up to 6–10 g/kg/d for moderate to high intensity exercise for 1-3 h training per day [15, 29]. The average training time in the present study was 85 ± 26 min including all intensities, estimating the range for carbohydrate requirements to be about 5–10 g/kg/d. In the position statement of

sports nutrition for adolescent athletes [31] no different carbohydrate requirements of adolescents compared to adult athletes were stated. The average CHO intake of 5.4 ± 1.1 g/kg/d is in the lower range of the aforementioned recommendations. Considering that 31% (10 players) who trained 77 ± 20 min/d did not meet the minimum requirement of 5 g/kg/d leads to the assumption that some players were not able to adequately replenish muscle glycogen stores. Similar low mean CHO intakes of young female football players were detected in previous studies [3, 8, 11, 13, 14]. Zehnder et al. found deficits of about 10% in glycogen replenishment for average amounts of CHO intake at 4.8 g/kg/d [39]. Cumulative deficits of 10% might result in a decrease of physical performance [39]. For that reason, young female football players should pay attention to their habitual diet and add more CHO to prevent deficits, especially on long and/ or intensive training days.

Protein recommendations for adult athletes range from 1.2-2.0 g/kg/day. Sufficient dietary protein intake is necessary for maximum muscle protein synthesis and repair mechanisms after strenuous exercise [30, 40]. For adolescent athletes, it is also a critical macronutrient for growth and development. Nevertheless, protein recommendations for youth athletes seem to be consistent with adult recommendations [31]. In the plurality of studies about young male football players, protein is no macronutrient of special interest as the recommended intake is sufficiently complied or exceeded. The average intake for male football players ranges from 1.5 to 2.4 g/kg/d [14, 35, 41-44]. In contrast, young female football players do not meet the minimum recommendations with an average protein intake of 1.0 g/kg/d in the post-season [11, 13] or show a low to moderate average protein intake of 1.2-1.4 g/kg/d in season [3, 8]. In the present study, the mean protein intake was 1.4 ± 0.3 g/kg/d including 34% (11 players), who did not meet the minimum sport nutrition recommendation of 1.2 g/kg/d. Female athletes need to ensure a sufficient protein intake through a variety of food.

Mean dietary fat intake was $30.7 \pm 5.0\%$, which is in the range of the recommendations for girls between 13–15 years [21]. Fat is an important component of a healthy diet, as it provides energy and assists the absorption of fat-soluble vitamins [15]. Athletes should avoid a chronic fat intake of less than 20% of total daily energy intake as a concomitant deficit of other nutrients may occur. Here, the average intake ranged from 22–40% leaving no athlete below the 20% limit. However, 15% exceeded the recommendations exhibiting a too high dietary fat intake. Some young football players may benefit from consuming fewer calories from fat and an increasing caloric intake from carbohydrates. The quality of fats also has to be considered as 84% exceeded the maximum of 10% of total energy coming out of saturated fats [15, 21]. The consumption of less saturated fats should be administered in favor of a greater intake of mono- and polyunsaturated fatty acids.

2.5.4 Micronutrient intake and hematological data

Athletes with a low energy intake often consume suboptimal amounts of micronutrients, affecting mostly the intake of iron, vitamin D, calcium and some antioxidants [45, 46]. Iron is considered as one of the most critical micronutrients for female athletes due to menstrual iron losses, via sweat, gastrointestinal bleeding and foot-strike hemolysis [7, 23]. Lowered iron status may reduce exercise capacity and impair sports performance [47, 48]. In the diagnosis of iron status disorders it is important to differentiate between 'reduced iron stores' (ferritin $<35 \mu\text{g/L}$), 'iron depleted' (ferritin $<12 \mu\text{g/L}$) and 'iron deficiency anemia' (hematocrit $<36\%$, hemoglobin $<12 \text{g/dL}$) [7, 31]. In the present study 59% of the female football players showed ferritin concentrations below $35 \mu\text{g/L}$ and 17% were below $12 \mu\text{g/L}$, therefore being categorized as *iron depleted*. 7% (2 players) were diagnosed with *iron deficiency anemia* due to abnormal hemoglobin and hematocrit values. In view of the dietary iron intake of female football players,

the results are consistent with the hematological data as the mean iron intake was 14.0 ± 2.7 including 69% of the players below the RDA of 15 mg/d. Comparable results have been published in previous studies analyzing the iron intake of young female football players [3, 8, 11]. No significant differences in dietary iron intake between *depleted* and *not-depleted* athletes were found, indicating that depleted iron stores can occur even if the intake meets the RDA [42]. Kang und Matsuo studied a 4-week iron supplementation on hematological status in 25 elite female football players [49]. The results showed increased body iron stores and a prevention of decreased hemoglobin levels induced by football training. Hence, it is important to examine the iron status of young elite football players regularly and ensure an iron-rich diet or, if necessary, include iron supplements.

None of the athletes in this study met the DRI for vitamin D. Mean dietary vitamin D intake was 1.3 ± 0.9 $\mu\text{g/d}$ with a range of 0.3–3.7 $\mu\text{g/d}$. Recommendations by the German Nutrition Society are 20 μg per day, if endogenous vitamin D synthesis through the exposure to sunlight (UV-B rays) is missing [21]. Dietary recommendations for vitamin D are challenging as the exposure and consequently the endogenous vitamin D synthesis differs between populations and seasons during the year [26]. Between October and April UV-B radiation is minor at latitudes of $>50^\circ\text{N}$ [50], minimizing the endogenous production. The data in the present study was retrieved over the course of all seasons, whereby it is evident that the nutritional intake was not sufficient for some players. The analysis of the 25(OH)D serum concentrations revealed, that 38% of the female football players had inadequate 25(OH)D levels below 50 nmol/ L. No *deficient* or *severely deficient* vitamin D statuses were observed. Chronic low 25(OH)D levels increase the risk of stress fractures, musculoskeletal dysfunction and impairs the development and maintenance of bone mineral density [26, 51]. Very low dietary vitamin D intakes were shown in comparable studies [3, 8, 11, 14], underlining the necessity of a seasonal screening

of vitamin D of young female football players. Corrections of a vitamin D deficiency through supplementation may be essential to maintain bone health and ensure optimal performance in adolescent athletes.

2.5.5 Fluid intake

Mean relative fluid intake of the female football players met the RDA of 40 ml/kg/d [21], anyhow, the large standard deviation demonstrates large intra-individual differences. 44% of the young football players did not meet the RDA, in which sweat losses during physical exercise are not included. These results are coherent with other studies examining the fluid intake and status of young female football players [52-54]. Chapelle et al. found 44-78% of 18 female youth players to be at least minimally hypohydrated before an official 4-day tournament [52]. Being euhydrated is crucial for physical exercise as dehydration can adversely affect on-field performance, aerobic capacity, concentration and mental performance [55-57]. Water and beverage consumption is difficult to quantify as drinks consumed outside of meals are prone to under-reporting [16]. Apart from this source of error, urine specific gravity, weight loss during training and urine color were not measured, therefore limiting the significance of these values. However, it is noticeable that 44% of the players did not meet the recommended 40 ml/kg/d [21]. Considering the variability in sweat rates during adolescence [31], the fluid needs of young athletes should be monitored regularly. Young athletes should be encouraged to be sufficiently hydrated before training and matches, especially in hot environments.

2.5.6 Methodological considerations and limitations

Self-reported dietary intake protocols are frequently biased towards underestimation and the assessment accuracy relies on the participant's ability to judge portions sizes and food

composition precisely. We cannot exclude that errors in estimation of the right portion sizes occurred, even if detailed instructions were provided. The incidence of misreporting was limited by using the cut-off criteria of Black [19].

For the calculation of TEE all activities during the day were summed up separately with the corresponding MET values. Different intensities during training and different types of training could be chosen for a preferably high accuracy of the ExEE. However, much variation between subjects comes from differences in time spent sleeping, sitting, standing and moving about different activities during the day [18]. Misestimation of the exact times of the above mentioned activities might have occurred as no activity tracker was used simultaneously.

The use of dietary supplements containing micronutrients was not assessed in this study, which alters the level of supply of micronutrients. However, the missing data of supplement intake has no consequences on the reported abnormal values of the iron related blood parameters and the vitamin D status.

2.6 Conclusion

Despite the limitations, our investigation represents a retrospective study with a homogeneous group of young female elite German football players. The findings of the present study are consistent with the results of previous literature [3, 8, 11, 12] and show that the nutrition status of young female football players is in need of improvement. A caloric deficit, low carbohydrate and fluid intakes were observed, wherefore sports drinks containing carbohydrates and electrolytes during/ after training and games are recommended to increase fluid and CHO intake and approach energy balance. Furthermore CHO and protein intakes should be monitored throughout the day to be sufficient for daily training energy expenditure, growth and regeneration processes.

A large proportion of players showed insufficient 25-hydroxyvitamin-D and iron/ferritin serum levels. A repeated screening program of those blood parameters should be implemented and, if necessary, a supplementation under physician supervision needs to be provided.

When working with young female athletes, coaches and medical staff need to create more favourable framework conditions for the implementation of an adequate and healthy sport nutrition. This includes regular screening dates alongside with the provision of information of healthy and appropriate nutrition guidelines for the athletes as well as their parents. Longitudinal studies are required to monitor the effectiveness of nutritional interventions among young female football players and other comparable groups of athletes.

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Conflict of interest

The authors declare that they have no conflict of interest. The founding sponsors had no role in the collection, analysis or interpretation of data; in the writing of the manuscript and in the decision to publish the results.

2.8 References

1. FIFA. *Women's Football Survey*. 2014 [cited 2017 July 20]; Available from: <https://resources.fifa.com/image/upload/fifa-women-s-football-survey-2522649.pdf?cloudid=emtgxvp0ibnebltvi3b>.
2. DOSB. *German Olympic Sports Federation Survey 2015 (Bestandserhebung 2015)*. [cited 2017 March 9]; Available from: https://www.dosb.de/fileadmin/sharepoint/Materialien%20%7B82A97D74-2687-4A29-9C16-4232BAC7DC73%7D/Bestandserhebung_2015.pdf.
3. Gibson, J.C., et al., *Nutrition status of junior elite Canadian female soccer athletes*. Int J Sport Nutr Exerc Metab, 2011. 21(6): p. 507-14.
4. Rosenbloom, C.A., A.B. Loucks, and B. Ekblom, *Special populations: the female player and the youth player*. J Sports Sci, 2006. 24(7): p. 783-93.
5. Nattiv, A., et al., *American College of Sports Medicine position stand. The female athlete triad*. Med Sci Sports Exerc, 2007. 39(10): p. 1867-82.
6. Slater, J., et al., *Low Energy Availability in Exercising Women: Historical Perspectives and Future Directions*. Sports Med, 2017. 47(2): p. 207-220.
7. Koehler, K., et al., *Iron status in elite young athletes: gender-dependent influences of diet and exercise*. Eur J Appl Physiol, 2012. 112(2): p. 513-23.
8. Martin, L., A. Lambeth, and D. Scott, *Nutritional practices of national female soccer players: analysis and recommendations*. J Sports Sci Med, 2006. 5(1): p. 130-7.
9. Bradley, P.S., et al., *Gender differences in match performance characteristics of soccer players competing in the UEFA Champions League*. Hum Mov Sci, 2014. 33: p. 159-71.

10. Datson, N., et al., *Match Physical Performance of Elite Female Soccer Players During International Competition*. The Journal of Strength & Conditioning Research, 2017. 31(9): p. 2379-2387.
11. Clark, M., et al., *Pre- and post-season dietary intake, body composition, and performance indices of NCAA division I female soccer players*. Int J Sport Nutr Exerc Metab, 2003. 13(3): p. 303-19.
12. Mullinix, M.C., et al., *Dietary intake of female U.S. soccer players*. Nutrition Research, 2003. 23(5): p. 585-593.
13. Reed, J.L., et al., *Nutritional practices associated with low energy availability in Division I female soccer players*. J Sports Sci, 2014. 32(16): p. 1499-509.
14. Parnell, J.A., K.P. Wiens, and K.A. Erdman, *Dietary Intakes and Supplement Use in Pre-Adolescent and Adolescent Canadian Athletes*. Nutrients, 2016. 8(9).
15. Thomas, D.T., K.A. Erdman, and L.M. Burke, *American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance*. Med Sci Sports Exerc, 2016. 48(3): p. 543-68.
16. Magkos, F. and M. Yannakoulia, *Methodology of dietary assessment in athletes: concepts and pitfalls*. Curr Opin Clin Nutr Metab Care, 2003. 6(5): p. 539-49.
17. Ridley, K. and T.S. Olds, *Assigning energy costs to activities in children: a review and synthesis*. Med Sci Sports Exerc, 2008. 40(8): p. 1439-46.
18. Poslusna, K., et al., *Misreporting of energy and micronutrient intake estimated by food records and 24 hour recalls, control and adjustment methods in practice*. Br J Nutr, 2009. 101 Suppl 2: p. S73-85.
19. Black, A.E., *The sensitivity and specificity of the Goldberg cut-off for EI:BMR for identifying diet reports of poor validity*. Eur J Clin Nutr, 2000. 54(5): p. 395-404.

20. Koehler, K., et al., *Parallel assessment of nutrition and activity in athletes: validation against doubly labelled water, 24-h urea excretion, and indirect calorimetry*. J Sports Sci, 2010. 28(13): p. 1435-49.
21. Deutsche Gesellschaft für Ernährung, Ö.G.f.E., Schweizerische Gesellschaft für Ernährung (Hrsg.):. 2 ed. Referenzwerte für die Nährstoffzufuhr. Vol. 3. aktualisierte Auflage. 2017, Bonn.
22. Ainsworth, B.E., et al., *2011 Compendium of Physical Activities: a second update of codes and MET values*. Med Sci Sports Exerc, 2011. 43(8): p. 1575-81.
23. Peeling, P., et al., *Athletic induced iron deficiency: new insights into the role of inflammation, cytokines and hormones*. Eur J Appl Physiol, 2008. 103(4): p. 381-91.
24. Deakin, V., *Prevention, detection and treatment of iron depletion and deficiency in athletes*, in *Clinical Sports Nutrition*, L. Burke and V. Deakin, Editors. 2010, McGraw Hill: Australia. p. 222–267.
25. Close, G.L., et al., *The effects of vitamin D(3) supplementation on serum total 25[OH]D concentration and physical performance: a randomised dose-response study*. Br J Sports Med, 2013. 47(11): p. 692-6.
26. Owens, D.J., W.D. Fraser, and G.L. Close, *Vitamin D and the athlete: emerging insights*. Eur J Sport Sci, 2015. 15(1): p. 73-84.
27. Heaney, S., et al., *Comparison of strategies for assessing nutritional adequacy in elite female athletes' dietary intake*. Int J Sport Nutr Exerc Metab, 2010. 20(3): p. 245-56.
28. Loucks, A.B., *Energy balance and body composition in sports and exercise*. J Sports Sci, 2004. 22(1): p. 1-14.
29. Burke, L.M., et al., *Carbohydrates for training and competition*. J Sports Sci, 2011. 29 Suppl 1: p. S17-27.

30. Phillips, S.M. and L.J. Van Loon, *Dietary protein for athletes: from requirements to optimum adaptation*. J Sports Sci, 2011. 29 Suppl 1: p. S29-38.
31. Desbrow, B., et al., *Sports Dietitians Australia position statement: Sports nutrition for the adolescent athlete*. International Journal of Sport Nutrition and Exercise Metabolism, 2014. 24(5): p. 570-584.
32. Joy, E., A. Kussman, and A. Nattiv, *2016 update on eating disorders in athletes: A comprehensive narrative review with a focus on clinical assessment and management*. Br J Sports Med, 2016. 50(3): p. 154-62.
33. Sundgot-Borgen, J. and M.K. Torstveit, *The female football player, disordered eating, menstrual function and bone health*. Br J Sports Med, 2007. 41 Suppl 1(Suppl 1): p. i68-72.
34. Economos, C., S. Bortz, and M. Nelson, *Nutritional practices of elite athletes. Practical recommendations*. Sports Med, 1993. 16(6): p. 381-99.
35. Caccialanza, R., B. Cameletti, and G. Cavallaro, *Nutritional Intake of Young Italian High-Level Soccer Players: Under-Reporting is the Essential Outcome*. J Sports Sci Med, 2007. 6(4): p. 538-42.
36. Goldberg, G.R., et al., *Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-reporting*. Eur J Clin Nutr, 1991. 45(12): p. 569-81.
37. Macdiarmid, J. and J. Blundell, *Assessing dietary intake: Who, what and why of under-reporting*. Nutr Res Rev, 1998. 11(2): p. 231-53.
38. Hargreaves, M., *Carbohydrate and lipid requirements of soccer*. J Sports Sci, 1994. 12 Spec No: p. S13-6.

39. Zehnder, M., et al., *Resynthesis of muscle glycogen after soccer specific performance examined by ¹³C-magnetic resonance spectroscopy in elite players*. European Journal of Applied Physiology, 2001. 84(5): p. 443-447.
40. Tipton, K.D. and R.R. Wolfe, *Protein and amino acids for athletes*. J Sports Sci, 2004. 22(1): p. 65-79.
41. Garrido, G., A.L. Webster, and M. Chamorro, *Nutritional adequacy of different menu settings in elite Spanish adolescent soccer players*. Int J Sport Nutr Exerc Metab, 2007. 17(5): p. 421-32.
42. Iglesias-Gutiérrez, E., et al., *Is there a relationship between the playing position of soccer players and their food and macronutrient intake?* Appl Physiol Nutr Metab, 2012. 37(2): p. 225-32.
43. Ruiz, F., et al., *Nutritional intake in soccer players of different ages*. J Sports Sci, 2005. 23(3): p. 235-42.
44. Russell, M. and A. Pennock, *Dietary analysis of young professional soccer players for 1 week during the competitive season*. J Strength Cond Res, 2011. 25(7): p. 1816-23.
45. Lukaski, H.C., *Vitamin and mineral status: effects on physical performance*. Nutrition, 2004. 20(7-8): p. 632-44.
46. Woolf, K. and M.M. Manore, *B-vitamins and exercise: does exercise alter requirements?* Int J Sport Nutr Exerc Metab, 2006. 16(5): p. 453-84.
47. Rodenberg, R.E. and S. Gustafson, *Iron as an ergogenic aid: ironclad evidence?* Curr Sports Med Rep, 2007. 6(4): p. 258-64.
48. Zoller, H. and W. Vogel, *Iron supplementation in athletes--first do no harm*. Nutrition, 2004. 20(7-8): p. 615-9.

49. Kang, H.S. and T. Matsuo, *Effects of 4 weeks iron supplementation on haematological and immunological status in elite female soccer players*. Asia Pac J Clin Nutr, 2004. 13(4): p. 353-8.
50. Zittermann, A., *The estimated benefits of vitamin D for Germany*. Mol Nutr Food Res, 2010. 54(8): p. 1164-71.
51. MacKelvie, K.J., K.M. Khan, and H.A. McKay, *Is there a critical period for bone response to weight-bearing exercise in children and adolescents? a systematic review*. Br J Sports Med, 2002. 36(4): p. 250-7; discussion 257.
52. Chapelle, L., et al., *The hydration status of young female elite soccer players during an official tournament*. J Sports Med Phys Fitness, 2017. 57(9): p. 1186-1194.
53. Ersoy, N., G. Ersoy, and M. Kutlu, *Assessment of hydration status of elite young male soccer players with different methods and new approach method of substitute urine strip*. J Int Soc Sports Nutr, 2016. 13(1): p. 34.
54. Gibson, J.C., et al., *Hydration status and fluid and sodium balance in elite Canadian junior women's soccer players in a cool environment*. Appl Physiol Nutr Metab, 2012. 37(5): p. 931-7.
55. Casa, D.J., P.M. Clarkson, and W.O. Roberts, *American College of Sports Medicine roundtable on hydration and physical activity: consensus statements*. Curr Sports Med Rep, 2005. 4(3): p. 115-27.
56. Edwards, A.M., et al., *Influence of moderate dehydration on soccer performance: physiological responses to 45 min of outdoor match-play and the immediate subsequent performance of sport-specific and mental concentration tests*. Br J Sports Med, 2007. 41(6): p. 385-91.

57. Logan-Sprenger, H.M., et al., *Effects of dehydration during cycling on skeletal muscle metabolism in females*. Med Sci Sports Exerc, 2012. 44(10): p. 1949-57.

3 Dietary Supplement Use Among Elite Young German Athletes

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3.1 Abstract

Little is known about the prevalence and motives of supplement use among elite young athletes, who compete on national and international level. Therefore, the present survey was performed in order to assess information regarding the past and present use of dietary supplements among 164 elite young athletes (16.6 ± 3.0 years of age).

A five-page questionnaire was designed to assess the past and present (last 4 weeks) use of vitamins, minerals, carbohydrate-, protein-, and fat supplements, sport drinks and other ergogenic aids. Furthermore information about motives, sources of advice, supplement sources and supplement contaminations was assessed.

Eighty percent of all athletes reported the use of at least one supplement and the prevalence of use was significantly higher in older athletes ($p < 0.05$). Among supplement users, minerals, vitamins, sport drink, energy drinks and carbohydrates were most frequently consumed. Only a minority of the athletes declared to use protein/amino acids, creatine or other ergogenic aids. Major motives for supplement use were health related, whereas performance enhancement and recommendations by others were less frequently reported. Supplements were mainly obtained from parents or by athletes themselves and were mostly purchased in pharmacies, supermarkets and health food stores.

Among all athletes, only 36% were aware of the problem of supplement contaminations.

The survey shows that supplement use is common and widespread among German elite young athletes. This stands strongly in contrast to recommendations by leading sport organizations against supplement use by minor athletes.

3.2 Introduction

In the past years many studies have shown that the use of dietary supplement (DS) is widespread among the group of athletes [1, 2]. It should be noted, that the term “dietary supplement” is not used consistently among scientific publications, as terms such as nutritional supplements, nutritional ergogenic aids or sports supplements have also been used by authors in the same context. Apparently, no clear definition exists for supplements, which are explicitly used by athletes [3]. According to the US Food and Drug Administration (FDA), a DS is a product (other than tobacco) that is intended to supplement the diet that bears or contains one or more of the following dietary ingredients: a vitamin, a mineral, an herb or other botanical, an amino acid, a dietary substance for use by man to supplement the diet by increasing the total

daily intake, or a concentrate, metabolite, constituent, extract, or combinations of these ingredients [4].

Despite the heterogeneous definition of the term supplement, it is indisputable that the prevalence of use is far greater in athletes than in the general (sedentary) population [2, 5]. Figures for elite athletes lie in the range of 44 and 100% use, strongly depending on age, sport and level of competition [2, 3, 6, 7].

Generally, there is good evidence that DS use increases with age both in elite athletes [3] and in the general population. Recently published data of the German National Nutrition Survey II showed that 16 to 19% of German adolescents (age 14 to 18) reported the use of supplements, whereas use among 18 to 24 year old Germans was more common (21%) and increased further with age [8].

To our knowledge, the supplementation practices of young German athletes have not been described in the literature so far. In young United States figure skaters (mean age: males 16.9 y, females 15.2 y) DS use was reported to be 65% for male and 76% for female athletes [9]. For British junior national track and field athletes the use of DS was documented to be 62% [10]. Even though a generalization of these results upon other sports and other levels of competition might be critical, this study indicates that supplement use by young athletes seems to be lower than in adult athletes, as a prevalence of 85% was reported for elite senior track and field athletes competing at international championships [3].

When considering the supplement use in adolescent athletes, high school and college athletes have been studied to a far greater extent than elite athletes. Percentages of use have been reported to lie between 13 and 76% [11]. However, this group is not comparable to elite young athletes, who compete on national and international levels, as the level of competition is considered to be a major indicator for supplement use [6].

In general, performance enhancement, prevention of illness, behavior of teammates or opponents and recommendations by influential individuals (such as coaches, friends, or family members) have been identified as the most important motives for supplement use in athletes [2].

To our knowledge, data on DS use among the unique group of elite young athletes is lacking. Understanding of the supplement use pattern and motives is an important aspect for proper nutritional and medical education in potential future elite athletes.

Therefore, the major goal of the study was to assess the prevalence of DS use among a wide spectrum of German elite young athletes with respect to age, gender and type of sport. Further objective of the study were the identification of the supplements used most frequently by the athletes and the assessment of motives and sources of recommendations, information, and products. Additionally, the athletes' education about the problem of contaminated supplements was asked for.

3.3 Methods

3.3.1 Study Population

A total of 228 athletes, who participated in the monitoring program of the German Research Centre of Elite Sport between September 2006 and December 2007, were provided a questionnaire regarding their use of dietary supplements. The questionnaires were sent to the athletes by mail, along with other information material, prior to a routine examination at the centre. The monitoring program includes multidisciplinary testing and consulting of prospective athletes with the aim to improve the individual performance in the area of psychology, aerobic and power performance, medicine, biomechanics and nutrition.

Questionnaires were voluntarily returned by 181 athletes (79%). Due to incomplete data, 13 data sets were excluded before analysis. Additionally, four questionnaires from athletes older than 25 years of age were omitted from the present analysis, resulting in a study group size of 164 athletes. In order to describe age related findings athletes were assigned to the following age groups (<15 y, 15-16 y, 17-18 y & 19-25 y). Since there is no clear definition for young athlete, the age group 19-25 y was included due to the fact that in some sports athletes are eligible for junior championships up to the age of 25. Written consent was obtained from all athletes participating in the program.

Body weight and body fat percentage were assessed by bioelectric impedance weighing after an overnight fast when athletes reported to the centre for a medical examination. Daily practice was self-recorded by athletes in the week prior to the examination. Due to the large number of sports, athletes were divided into the following sport categories: Endurance sports, racquet sports, ball sports, combat sports and other sports. Subject characteristics and the distribution of sports can be found in tables 3-1 and 3-2.

The performance level of each athlete was defined according the classification by the corresponding sport federation, which is based on guidelines by the German Olympic Sports Confederation [12]. According to these guidelines, A-level athletes have achieved top level positions at Olympic Games or world championships, B-level athletes display a considerable development of performance and are prospective candidates for A-level. C-level refers to the highest national level for prospective young athletes who exhibit a perspective to perform on international top level or who participate successfully at international junior competitions. D/C- and D-level athletes are long-term prospective young athletes, usually under 17 years of age, who are organized at national (D/C) or regional level (D) but train at regional level. Among the 164 participating athletes, the vast majority was D- (n = 47), D/C- (39) and C-level (28) athletes.

Only a small number of B- (16) and A-level (7) athletes were included into the analysis. Twenty-seven athletes were not categorized into the above mentioned performance levels by their sport federation.

3.3.2 Questionnaire

A closed-ended five-page questionnaire was designed to assess the past and present use of dietary supplements, sport drinks and foods and other ergogenic aids.

If a specific supplement had been used within four weeks prior to filling out the survey, the athletes were asked to additionally record the frequency of use (ranging from one to two times per month up to daily).

The listed supplements included vitamins (specific vitamins and multi-vitamin combinations), minerals (specific minerals and multi-mineral combinations), carbohydrate preparations, protein/amino acid preparations, specific fatty acid preparations, sport beverages, other ergogenic aids, isolated compounds and plant extracts. Additionally, athletes were provided space to list supplements which they could not classify. When necessary, assignment of these supplements was performed by experienced nutritionists during data digitalization. In a separate question, athletes were specifically asked whether they had ever consumed supplements.

Furthermore, information about motives, advices, supplement sources and supplement contaminations was assessed using closed-ended questions. Within these questions, athletes were allowed to choose multiple options.

In order to test for understandability and applicability of the questionnaire, a draft version was given out to 32 students of the German Sport University prior to distributing the questionnaire to athletes.

Table 3-1: Anthropometric characteristics and average training of the subjects

Age group	Gender	n	Age (years)	Weight (kg)	Height (cm)	Body-mass index (kg/m ²)	Body fat (%)	Practice (min/day)
10-14	male	17	13.3 ± 0.9	59.9 ± 17.3	170.8 ± 11.2	20.2 ± 4.1	10.3 ± 5.3	82.3 ± 42.3
	female	19	13.3 ± 0.9	57.1 ± 11.4	167.8 ± 10.1	20.0 ± 2.2	17.9 ± 5.1	134.8 ± 86.4
15-16	male	31	15.6 ± 0.5	72.5 ± 14.3	181.3 ± 9.2	21.9 ± 3.4	10.3 ± 6.0	97.3 ± 52.1
	female	31	15.4 ± 0.5	58.1 ± 6.5	167.5 ± 6.9	20.7 ± 2.2	17.1 ± 5.3	93.3 ± 55.2
17-18	male	16	17.2 ± 0.4	74.6 ± 8.8	184.6 ± 7.5	21.9 ± 1.9	8.7 ± 2.9	86.1 ± 37.0
	female	16	17.3 ± 0.5	64.2 ± 9.1	173.1 ± 5.9	21.3 ± 1.9	18.2 ± 5.1	83.8 ± 40.1
>18	male	13	21.4 ± 2.1	73.8 ± 11.2	182.3 ± 7.0	22.1 ± 2.0	10.1 ± 4.8	97.0 ± 51.3
	female	21	21.7 ± 2.0	67.0 ± 7.2	176.2 ± 8.2	21.5 ± 1.4	19.0 ± 3.1	92.4 ± 48.6
Overall		164	16.6 ± 3.0	65.5 ± 12.8	175.0 ± 10.4	21.1 ± 2.6	14.2 ± 6.3	96.3 ± 55.1

Table 3-2: Distribution of sports among the sport categories

	Endurance sports	47	Racquet sports	32	Ball sports	33	Combat sports	23	Other sports	29
Canoeing	15	Tennis	15	Handball	11	Judo	11	Track and field	7	
Swimming	9	Badminton	12	Basketball	10	Taekwondo	6	Fencing	6	
Nordic combined	8	Table tennis	5	Football/Soccer	10	Boxing	3	Luge	6	
Biathlon	7			Volleyball	2	Wrestling	3	Archery	3	
Triathlon	4							Horse riding	3	
Rowing	3							Skeleton	2	
Mountain biking	1							Diving	1	
								Pentathlon	1	

3.3.3 Statistical analysis

After digitalization of the data, statistical analysis was performed with R software (version 2.5.1). Analyses were calculated for all subjects, for age groups, sport categories, and both genders separately. Associations between age, gender, sport group and motives and supplement use were assessed by chi-square (χ^2) test. Anthropometric differences between users and non-users were assessed with by one-way analysis of variance (ANOVA). Associations and differences were considered to be statistically significant if the probability of error was smaller than 0.05. All data is presented as frequency (in per cent) or as mean \pm standard deviation.

3.4 Results

In total, 131 subjects (i.e. 80% of all athletes who filled out the questionnaire) reported to use or to have used dietary supplements. Supplement use did significantly differ between age groups ($p < 0.05$) and was highest in athletes older than 18 years of age (Figure 3-1 top). Since the athlete's level of performance strongly depends on the athlete's age, the prevalence of NS use was highest in A- and B-level athletes (100%) and lower for C- (72%), D/C- (79%) and D-level athletes (81%).

There was no significant difference between sports groups ($p = 0.53$; Figure 3-1 bottom) even though prevalence was lowest in racquet sports (70%). However, athletes from racquet sports tended to be younger than other athletes ($p = 0.1$). There were no significant differences in body composition and average practice time between users and non-users (data not shown).

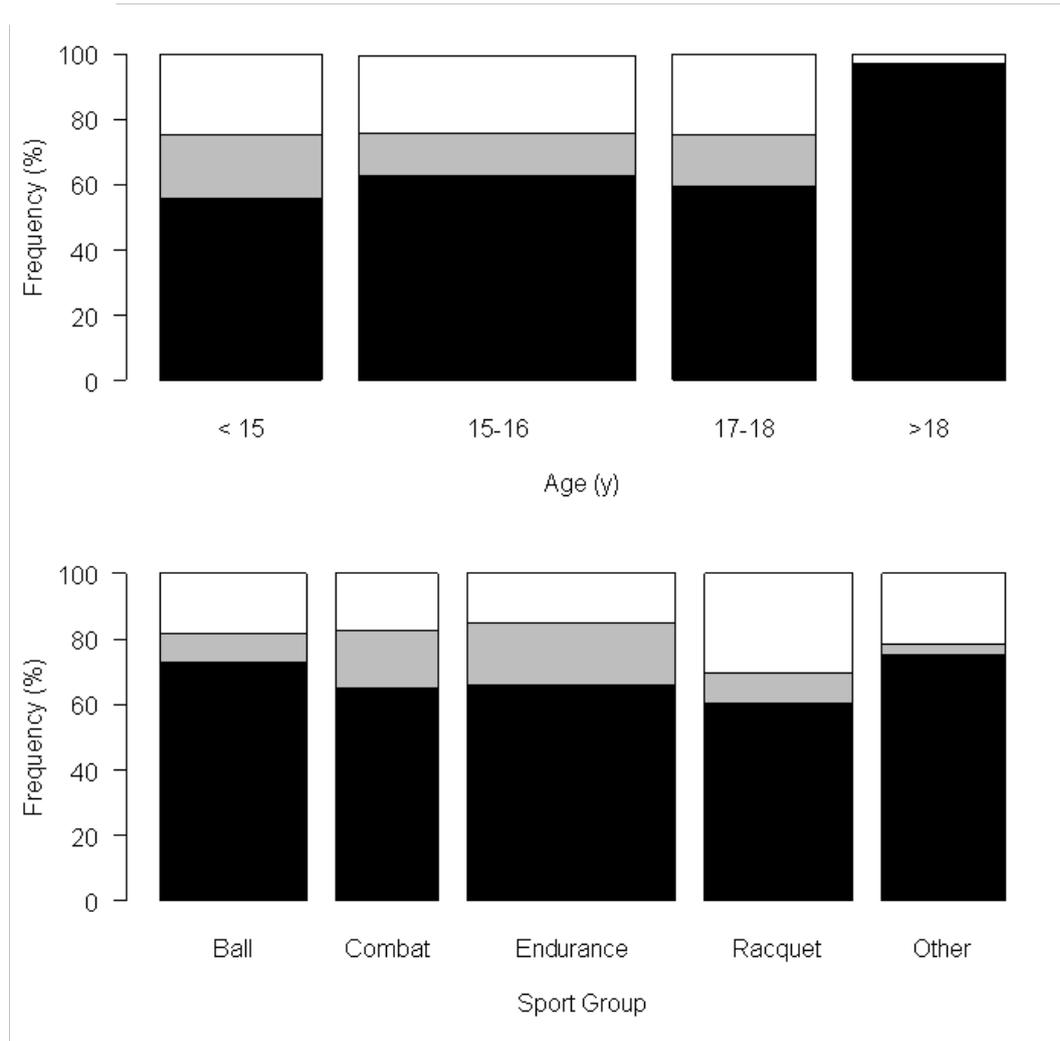


Figure 3-1: Prevalence of nutritional supplement use among German elite young athletes by age (top) and sport group (bottom)

Note: Black areas indicate supplement use at the time of the questionnaire, grey areas refer to athletes who reported to use supplements generally but did not at the time of the questionnaire and white areas represent athletes using no supplements; width of the boxes refers to the relative group size.

Minerals (87%), vitamins (76%), sport beverages (69%), and carbohydrate preparations (64%) were most frequently taken by DS users, whereas the usage of protein/amino acid products (30%), ergogenic aids (24%), fatty acid preparations (6%) and other supplements (27%) was less widespread. For detailed distribution of specific substances, please refer to table 3-3.

Table 3-3: Distribution of supplements used by German elite young athletes (n = 164)

Minerals	114	Vitamins	100	Sport beverages	90	Carbohydrates	84
Magnesium	85	Vitamin C	77	Sport drinks	87	Glucose/Grape sugar	68
Iron	56	Multivitamins	67	Energy drinks	41	Bars	28
Calcium	55	Mineral-vitamin combinations	42	Other drinks	7	Powders	19
Mineral-vitamin combinations	42	Vitamin E	20			Fructose	16
Selenium	15	Folic Acid	15			Gels	14
Multiminerals	13	Vitamin B12	18			Carbohydrate-protein combinations	10
Iodine	9	Vitamin B1	15			Other carbohydrates	3
Other minerals	3	Vitamin B6	14				
		Vitamin A	13				
		Other vitamins	4				
Proteins/Amino acids	39	Ergogenic aids	31	Fatty acids	8	Other supplements	35
Protein drinks	31	Caffeine	22	Omega-3 fatty acids	7	Concentrates (fruits/vegetables)	22
Protein bars	13	Carnithine	8	Other fatty acids	2	Gelatin	9
Carbohydrate-protein combinations	10	Creatine	8	Medium-chain triglycerides	1	Secondary plant sterols	5
Specific amino acids	4	Acid-base preparations	7			Ubiquinone (Q10)	3
						Extracts (fruits/vegetables)	2
						Other (not specified)	4

The use of protein products was greater in male than in female athletes (42% vs. 20% of male/female athletes using DS) but failed to reach statistical significance ($p = 0.07$).

Regarding the use of all other supplements, there were no significant differences between genders (data not shown).

Only a small number of athletes (12%) reported to generally use supplements but did not at the time of the questionnaire, so total of 111 athletes (68%) admitted to have consumed at least one DS within the last four weeks. At an average, those athletes were taking 3 (median) different supplements (range: 1-17). The number of different supplements used at the time of the questionnaire increased significantly with age ($p < 0.05$).

Among athletes having used or using supplements, 63% stated to do so for health related reasons ("maintenance of health": 44%, "improvement of immune functions": 34%, "prevention": 27%). Performance related reasons were cited by only 43% of all users ("regeneration": 35%, "improving performance: 27%"). 21% of the athletes reported to use supplements because it was recommended by others.

Those athletes who cited performance related reasons have been using significantly more protein ($p < 0.001$) and carbohydrate ($p < 0.05$) products. Athletes stating health related reasons tended to use vitamins more frequently ($p < 0.05$).

Major sources of recommendations and information were family (34%), coaches (26%), physicians (24%), physical therapists (11%) and pharmacists (9%). Only 9 young athletes (7%) documented to use DS based on self-acquainted information.

Consequently, products were acquired from parents (39%) or by the athletes themselves (32%), whereas other sources such as physicians (14%), coaches (11%) and others were used

only by a small group of athletes. The supplements were purchased mainly in pharmacies (56%), super markets (17%) and health food stores (15%).

Among all athletes who filled out the questionnaire, only 36% were aware of the problem of supplement contaminations. However, awareness of this problem significantly increased with age ($p < 0.05$). Only 34% of the athletes unaware of the problem stated that they would like to receive information regarding this subject.

3.5 Discussion

To our knowledge, this was the first study designed to systematically assess DS use among the unique group of young athletes, who compete at national and international level and who can therefore be considered to be among the elite athletes of their age group. The present data demonstrate that supplement use is very common among German elite young athletes, even at ages of 11-14 years.

As expected, the prevalence of use (80% of all athletes have already been using DS, 67% were using DS at the time of the questionnaire) was much greater in athletes than in the general German population (16 – 24% for 14 to 24 years of age) [8]. In American high school athletes, prevalence of supplement use was only 22% [11]. Most likely this remarkable difference is due to the higher level of competition of the athletes in the present study, as previous reports identified the level of competition to be a major determining factor of supplement use [6].

With respect to the high performance level, the present figures are partly comparable to results from 32 British junior track and field athletes (prevalence: 62%;[10]) and Singaporean athletes (prevalence: 77%;[13]). In contrast to the latter study, which did not find an association of DS

use with age [13], our data clearly show that both the prevalence of use and the number of supplements taken increase with age.

The high prevalence of DS use might be attributed to the very unconstrained definition of the term “dietary supplement”. Even though the inclusion of sport drinks, energy bars, and meal replacements is in agreement with other authors [3], special items such as energy drinks and grape sugar are not necessarily sport specific products. On the other hand, despite of the inclusion of these products, supplements most frequently used were minerals and vitamins, which have been reported to be very popular among athletes also by others investigators [2, 14].

In the present study, it occurred that male athletes were more likely to use protein preparations. Even though this effect failed to reach statistical significance, this is in agreement with other studies [5, 13]. However, there were no associations between gender and usage of other supplements such as iron and creatine, which have been reported previously [13, 15].

When regarding the athletes stating to use caffeine (17% among DS users), it has to be considered that there was no apparent discrimination between caffeine supplements and caffeine-containing foods (coffee, tea, cola beverages etc.) in the questionnaire. Therefore, this number might not be representative of the actual caffeine supplement consumption.

The high prevalence rate among our athletes is not in agreement with scientific evidence on positive effects of DS, which is lacking for most supplements with respect to exercise performance [3]. Even though it has been established that there is limited congruency between

supplement use and motives in athletes [16], our data is consistent with other studies identifying health concerns as a major motive for supplement use in athletes [2, 10, 13].

Despite the fact that there is some evidence in the general population that supplement users may display more favorable levels of disease-related biomarkers [17], it should be considered that other health-related factors such as lifestyle, dietary habits and exercise might be strongly associated with supplement use. Among athletes, available data indicate that dietary supplementation does not generally affect the hematological status of well-nourished subjects [18].

Besides the lack of positive effects, there are also potential risks associated with the use of DS, especially to young athletes. For most substances, the general safety of supplementation has not been evaluated in adolescents to a satisfying extend [3, 19]. More importantly, data from the NIH-AARP Diet & Health Study show that under some circumstances multivitamin use might have potential harmful consequences [20]. Additionally, the problem of supplement contaminations has been well described [21]. However, only a minority of the athletes participating in our survey (36%) were aware of this problem. This result leads to the assumption that also coaches, physicians and parents, as main source of information for young athletes, are also not adequately informed about this topic.

Major motives for supplement use among German elite young athletes were health and performance related. This might indicate that the athlete's diet is not believed to serve as an appropriate source of nutrients in order to maintain health and exercise performance even at young ages.

The generally high prevalence as well as the motives for supplement use stand in strong contrast to recommendations by leading sport organizations [22-24]. According to a consensus

statement by the International Association of Athletics Federation, supplements should not be used by underage athletes or when the dietary nutrient intake is sufficient [3].

In this context, it should also be considered that young elite athletes are apparently not well elucidated about nutrition. Among a comparable group of subjects visiting our center, only 18% of the athletes have had experience with individual nutritional consulting (Braun et al., unpublished). This is in contrast to the recommendation that “athletes should ensure they have a good diet before contemplating supplement use” [3].

With respect to usage of DS, family, coaches, and physicians were identified as the most influential individual for elite young athletes. For nutritional and health-oriented education of athletes, this group has to be accounted for.

Based on the present results and with respect to recent recommendations we suggest that

- athletes should be better educated about risks (and benefits) of supplements,
- parents, coaches, physicians and other staff members should be elucidated about the usage of supplements,
- nutritional education and consulting should be made available to more athletes and
- that these aspects should be considered specifically for athletes 10 – 14 years of age, as our study showed a high prevalence of DS use (75%) even in this group.

In conclusion, the present study gives informative insight into supplement use by young elite athletes. Both the very high prevalence of use among all age groups and the rationale for supplement use strongly contradict scientifically based recommendations. Even though present data indicate that young elite athletes use DS to a similar extend as senior elite athletes, future research is needed to assess supplement use in combination with the athletes' nutrition status in a larger group of athletes.

3.6 References

1. Maughan, R.J., D.S. King, and T. Lea, *Dietary supplements*. J Sports Sci, 2004. 22(1): p. 95-113.
2. Sobal, J. and L.F. Marquart, *Vitamin/mineral supplement use among athletes: a review of the literature*. Int J Sport Nutr, 1994. 4(4): p. 320-34.
3. Maughan, R.J., F. Depiesse, and H. Geyer, *The use of dietary supplements by athletes*. J Sports Sci, 2007. 25 Suppl 1: p. S103-13.
4. FDA, *Dietary Supplement Health and Education Act 1994*. 1995; Available from: <http://www.cfsan.fda.gov/~dms/supplmnt.html>.
5. Sundgot-Borgen, J., B. Berglund, and M.K. Torstveit, *Nutritional supplements in Norwegian elite athletes--impact of international ranking and advisors*. Scand J Med Sci Sports, 2003. 13(2): p. 138-44.
6. Erdman, K.A., T.S. Fung, and R.A. Reimer, *Influence of performance level on dietary supplementation in elite Canadian athletes*. Med Sci Sports Exerc, 2006. 38(2): p. 349-56.
7. Striegel, H., et al., *The use of nutritional supplements among master athletes*. Int J Sports Med, 2006. 27(3): p. 236-41.
8. NVS II, *Nationale Verzehrs Studie II, Ergebnisbericht, Teil 2*. 2008 [cited 2008 May 31]; Available from: http://www.was-esse-ich.de/uploads/media/NVS_II_Ergebnisbericht_Teil_2.pdf.
9. Ziegler, P.J., J.A. Nelson, and S.S. Jonnalagadda, *Use of dietary supplements by elite figure skaters*. Int J Sport Nutr Exerc Metab, 2003. 13(3): p. 266-76.
10. Nieper, A., *Nutritional supplement practices in UK junior national track and field athletes*. Br J Sports Med, 2005. 39(9): p. 645-9.

11. Scofield, D.E. and S. Unruh, *Dietary supplement use among adolescent athletes in central Nebraska and their sources of information*. J Strength Cond Res, 2006. 20(2): p. 452-5.
12. Deutscher Sportbund, *Nachwuchsleistungssport—Konzept 2012. Leitlinien zur Weiterentwicklung des Nachwuchsleistungssports*. 2006 [cited 2008 May 31]; Available from: http://www.dosb.de/fileadmin/fm-dsb/arbeitsfelder/leistungssport/Konzepte/Nachwuchsleistungssport-Konzept2012_ENDFASSUNG.pdf.
13. Slater, G., B. Tan, and K.C. Teh, *Dietary supplementation practices of Singaporean athletes*. Int J Sport Nutr Exerc Metab, 2003. 13(3): p. 320-32.
14. Corrigan, B. and R. Kazlauskas, *Medication use in athletes selected for doping control at the Sydney Olympics (2000)*. Clin J Sport Med, 2003. 13(1): p. 33-40.
15. Petroczi, A. and D.P. Naughton, *The age-gender-status profile of high performing athletes in the UK taking nutritional supplements: lessons for the future*. J Int Soc Sports Nutr, 2008. 5: p. 2.
16. Petróczy, A., et al., *Limited agreement exists between rationale and practice in athletes' supplement use for maintenance of health: a retrospective study*. Nutr J, 2007. 6: p. 34.
17. Block, G., et al., *Usage patterns, health, and nutritional status of long-term multiple dietary supplement users: a cross-sectional study*. Nutr J, 2007. 6: p. 30.
18. Bazzarre, T.L., et al., *Vitamin-mineral supplement use and nutritional status of athletes*. J Am Coll Nutr, 1993. 12(2): p. 162-9.
19. Metz, J.D., et al., *Creatine use among young athletes*. Pediatrics, 2001. 108(2): p. 421-5.

20. Lawson, K.A., et al., *Multivitamin use and risk of prostate cancer in the National Institutes of Health-AARP Diet and Health Study*. *J Natl Cancer Inst*, 2007. 99(10): p. 754-64.
21. Geyer, H., et al., *Analysis of non-hormonal nutritional supplements for anabolic-androgenic steroids - results of an international study*. *Int J Sports Med*, 2004. 25(2): p. 124-9.
22. American College of Sports Medicine, A.D.A., & Dietitians of Canada, *Joint Position Statement: nutrition and athletic performance*. *American College of Sports Medicine, American Dietetic Association, and Dietitians of Canada*. *Med Sci Sports Exerc*, 2000. 32(12): p. 2130-45.
23. FIFA, *Nutrition for football: the FIFA/F-MARC Consensus Conference*. *J Sports Sci*, 2006. 24(7): p. 663-4.
24. IOC, *IOC consensus statement on sports nutrition 2003*. 2003 [cited 2008 May 32]; Available from: http://multimedia.olympic.org/pdf/en_report_723.pdf.

4 Differing Water Intake and Hydration Status in Three European Countries—A Day-to-Day Analysis

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4.1 Abstract

Adequate hydration is essential for maintaining health and functionality of the human body. Studies assessing both daily water intake and hydration status are lacking. This study explored data from the European Hydration Research Study (EHRS) and focused on total water intake

(TWI), 24 h hydration status, and day-to-day variations in a sample of 573 healthy adults. TWI was assessed by food records and hydration status (urine osmolality and urine volume) was measured from 24 urine samples collected over seven consecutive days. On all weekdays, mean TWI was higher ($p < 0.001$ for all days) for the German subjects compared to the Greek and Spanish participants. In 37% of the male and 22% of the female subjects, the individual mean TWI was below the European Food Safety Authority (EFSA) recommendation, with 16% men (4% women) being below the EFSA recommendation on every testing day. Twenty-four hour urine osmolality was lower in women compared to men (595 ± 261 vs. 681 ± 237 mOsmol/kg; $p < 0.001$). More men (40%) showed a urine osmolality ≥ 800 mOsmol/kg at least on four days of the study period compared to women (26%) and more participants from Spain (46%) compared to Greece (29%) and Germany (11%). A large number of individuals showed an inadequate hydration status on several days per week, which may have a negative health and cognitive impact on daily life.

4.2 Introduction

Water is the main component of the human body and total body water averages about 60% of the body mass in adult males and 50–55% in females [1]. Water is involved in many functions within the human body, such as cellular metabolism, temperature regulation, nerve transmission, cardiovascular transport of oxygen and nutrients [2], as well as the removal of waste products [3]. Optimal physiological function is given in a state of water and electrolyte balance [4, 5]. Therefore, adequate hydration and electrolyte homeostasis are essential for maintaining health and functionality of the human body [5].

EI-Sharkawy et al. [6] summarized that dehydration has been linked with urological, gastrointestinal, circulatory, and neurological disorders while fluid overload might have an

impact on cardiopulmonary disorders, hyponatremia, edema, gastrointestinal dysfunction, and postoperative complications. Studies, which investigated consequences of acute dehydration showed a link between physiological and psychological functions. Predominant alterations concerning physiological sensations that occurred during dehydration were an increased feeling of thirst and dryness of the mouth [7, 8], worsened mood [7, 9], increasing fatigue [8, 10-12], and incidences of headaches [7, 9, 13]. In addition, the short-term memory was affected by dehydration [10, 11, 14, 15], alertness was reduced [8-12, 15], and the ability to concentrate decreased [8, 9, 14, 16].

To avoid short and long-term consequences of dehydration, but also overhydration, the European Food Safety Authority (EFSA) recommends a daily total water intake (water from food and beverages) of 2.5 L for men and 2.0 L for women to maintain urinary osmolality of 500 mOsmol/L [1]. Although European Nutrition Surveys show an average fluid intake within this recommended range, low intakes are described for Hungary, Italy, Poland, France, and Slovakia [1, 17]. In contrast, mean total water intake is recorded to be well within the EFSA recommendation for Sweden, Netherlands, Germany, Austria, or Ireland. It is unclear if this wide range of water intake data result from different methods used for assessing water intake or if it is based on diet, culture, tradition, availability of drinks, and other factors. However, obviously differences in total water intake between European countries exist. Furthermore, fluid intake and beverage choices vary among individuals in general, but also over the course of a day [17-19]. People live, work, and do physical activities in various environments and climatic conditions, which might affect daily water needs. In addition, availability of fluids might differ across a day and therefore hydration status might be suboptimal for some individuals at certain times of a day.

In this context it should be noted that water intake does not automatically describe hydration status. Markers (e.g., serum osmolality, urine osmolality, and urine volume) to assess hydration status in groups or individuals are missing in most dietary surveys [17]. There seems to be a need of studies showing both water intake and hydration status across the European population.

Therefore, the aim of the European Hydration Research Project (EHRS) was to assess water intake and hydration status using a uniform procedure in a sample of healthy adults in three European countries. First results from the EHRS on hydration indices and water intake as well as influence of physical activity and temperature on hydration status have been published recently [20, 21]. To our knowledge, data that describe the intra-individual variability in hydration status or total water intake within a selected period are not available. Therefore, this paper will focus on daily total water intake and 24 h hydration status on weekdays with respect to gender and country, but also on intra-individual data on day-to-day variations within the study period.

4.3 Materials and Methods

4.3.1 Study Protocol

This cross-sectional multi-center study was conducted on free-living adults in the metropolitan areas of Cologne (GER), Athens (GRE), and Toledo (SPA) in parallel and following identical protocols during winter (January–March 2013, December 2013, January–February 2014) and summer (June–August 2013, June–July 2014). Subject recruitment was oriented to reach a quota of 25 subjects, balanced for gender (e.g., 12 men and 13 women), in each of the following age groups: 20–30, 31–40, 41–50, and 51–60 years old, in each country. This subject recruitment scheme (100 per country) was repeated in winter and summer with a goal of 200

subjects tested per country (for details please see references [20, 21]). Five hundred and seventy three subjects aged 39 ± 12 years (51.1% males) with a BMI 25.5 ± 4.2 kg/m² for males and 24.5 ± 4.9 kg/m² for females were included in the study. Volunteers were recruited via several access channels (e.g., social media, local newspapers, and local companies). Exclusion criteria were diseases like diabetes insipidus, renal disease, liver disease, gastrointestinal disorders or diseases, cardiac or pulmonary diseases, diseases that limit mobility, and orthopaedic issues. Further exclusion criteria were pregnancy, lactation, hypertensive under severe salt restriction, the intake of drugs that are or contain diuretics, such as phenytoin, lithium, demeclocycline, or amphotericin B, or following a high-protein and/or hypocaloric diet. Demographic factors such as ethnic origin, living conditions, and marital status did not represent exclusion criteria. Subjects were rescheduled or omitted if they had a cold or fever, vomiting, and/or diarrhoea, or if they menstruated during the data collection period. The study protocol was approved by each local Research Ethics Committee (1/26-11-2012 for German Sport University, Germany, 197/27-02-2012 for Agricultural University of Athens, Greece, 4/02/2013-18 for University of Castilla-La Mancha, Spain). Written informed consent was obtained from all subjects.

4.3.2 Study Procedure

The study details were explained in detail to the volunteers during a preliminary talk. All subjects entering the study received a small backpack containing the instruction sheet for the study protocol and material for collecting urine samples and dietary data. For the 24 h urine collection, a diary for recording time of urination and urine volume, a kitchen scale readable to 1 g, a urine collection container, and eight plastic bags containing urine sampling vessels (days 1–7: ten urine sampling vessels, labelled with an individual code, day and number; day 8: one

urine sampling vessel for morning urine) were allotted. Furthermore, each subject received a seven-day food record to report in detail time and amount of food and beverages consumed, including wake-up time and bed time. Subjects entered the study on different days of the week in order to achieve a reasonable distribution of starting days over the week.

On study day 1, subjects arrived fasted at the study center between 7:00–9:30 am bringing a sample of their first morning urine void. Upon arrival, participants' body height was measured with calibrated mechanical sliding scales and weight was measured with electronic digital scales (± 0.05 kg) in underwear and no shoes. Subjects were instructed to sit for approximately 15–20 min while filling in study questionnaires. Subsequently, a blood sample (5 mL) from a forearm vein was collected without stasis. During the study period (days 1–7) subjects were asked to record all food and beverages consumed at the point of intake, following their normal daily routine. The recording was based on measurements with the kitchen scale, or, if that was not possible, portion sizes were estimated based on package information or usual household measures. Participants also collected and recorded the mass of each urination and time of collection and retained a sample in a numbered tube, as instructed. Subjects were asked to store the urine tubes under cool conditions (e.g., refrigerator or in the styrofoam box using fresh ice packs). On day 8, following an overnight fast, subjects visited the laboratory and returned urine samples and the food record; a blood sample was taken and body mass was measured as on day 1.

Urine collection of each day was from 00:00 to 24:00. A 24 h urine sample was reconstituted from all 24 h recorded and collected urine samples on each day. If subjects reported missing urine samples, 24 h urine was not reconstructed. Urine osmolality was measured with a freezing-point osmometer (GER: Osmomat 3000, Gonotec; GRE: Osmomat 030, Gonotec; SPA: Osmometer 3250, Advanced Instruments Inc). Urine volume was measured with an

electronic digital scale (Soehnle Fiesta 65106) and 1 gram of urine rated as 1 mL. Finally, seven-day food records were analyzed for total water intake (TWI) coming from food and beverages using specific softwares and country specific food databases (GER: Ebispro 2011 includes the German Food Database version 3.1, J. Erhardt University of Hohenheim, Stuttgart, Germany; GRE: Diet Analysis plus version 6.1, ESHA Research, Wadsworth Publishing Co. Inc., Salem, OR, USA; SPA: PCN 1.0, CESNID-University of Barcelona, Spain).

4.3.3 Data Processing and Statistical Analysis

Total water intake (TWI) was compared to the EFSA TWI recommendation of 2.5 L for men and 2.0 L for women [1]. Urine osmolality was classified in three groups regarding recommendations to achieve a mean urine osmolality <500 mOsmo/L [1,22], supplemented by suggestions of urine osmolality as a possible sign for hypohydration (>800 mOsmol/L) [22,23]. Finally, daily urine volume was grouped into <1 L/day or ≥ 1 L/day.

Data entry was performed using Microsoft Excel 2013, Statistical analysis was performed using SPSS (SPSS Statistics 23, IBM, Chicago, IL, USA). Descriptive analysis of variables was conducted indicating data as mean \pm standard deviation. Data were tested for normal distribution (Kolmogorov–Smirnov test), plausibility, and consistency. Depending on the existence of normal distribution, parametric tests (T-test or analysis of variance (ANOVA) or non-parametric tests (Mann–Whitney–U test or Kruskal–Wallis test) were used to analyze group differences. Post hoc comparisons were performed using the Tukey–Kramer test. Significance was accepted at the levels 0.001, 0.01, or 0.05, depending on the analysis. The coefficient of variation (CV) is calculated as the ratio of the standard deviation to the mean.

4.4 Results

4.4.1 Total Water Intake

Overall mean TWI of all days was 2.76 ± 1.2 L/day, with a higher TWI intake for men ($p < 0.001$) (Table 4-1). Mean TWI was similar for most days except Sundays, which showed a significantly lower TWI ($p < 0.05$) compared to Wednesday, Thursday, Friday and Saturday.

Table 4-1: Mean total water intake (TWI) on all weekdays and percentage of subjects with TWI below European Food Safety Authority (EFSA) recommendation.

Weekday	Total Water Intake (Mean \pm SD in L/day)				TWI < EFSA (in %)		
	All	Men	Women	<i>p</i> -Value *	All	Men #	Women #
Monday	2.74 \pm 1.2	2.92 \pm 1.26	2.55 \pm 1.08	=0.001	35	41	30
Tuesday	2.78 \pm 1.2	2.94 \pm 1.41	2.62 \pm 1.04	=0.012	32	38	25
Wednesday	2.80 \pm 1.3	3.00 \pm 1.38	2.59 \pm 1.13	<0.001	35	39	30
Thursday	2.80 \pm 1.1	2.97 \pm 1.21	2.64 \pm 1.03	=0.002	32	38	25
Friday	2.85 \pm 1.2	3.02 \pm 1.32	2.69 \pm 1.08	=0.004	35	41	28
Saturday	2.78 \pm 1.2	2.98 \pm 1.29	2.59 \pm 0.99	=0.001	35	41	28
Sunday	2.57 \pm 1.1	2.76 \pm 1.19	2.38 \pm 0.98	<0.001	37	41	36
All days	2.76 \pm 1.2	2.94 \pm 1.10	2.57 \pm 0.89	<0.001	35	40	29

Note: * *p*-values derived through Student's *t*-test for differences between genders; # EFSA recommendation for men 2.5 L/day and women 2.0 L/day. TWI: Total water intake; EFSA: European Food Safety Authority recommendation.

TWI was different between countries, with an average TWI of 3.29 ± 0.98 L/day for the German subjects, 2.56 ± 1.01 L/day for the Spanish subjects and 2.34 ± 0.77 L/day for the Greek subjects. With respect to each weekday mean TWI was higher ($p < 0.001$ for all days) for the German subjects compared to the Greek and Spanish participants (Figure 4-1). On Mondays and Wednesdays TWI intake was higher for the Spanish subjects compared to the Greek ($p < 0.05$).

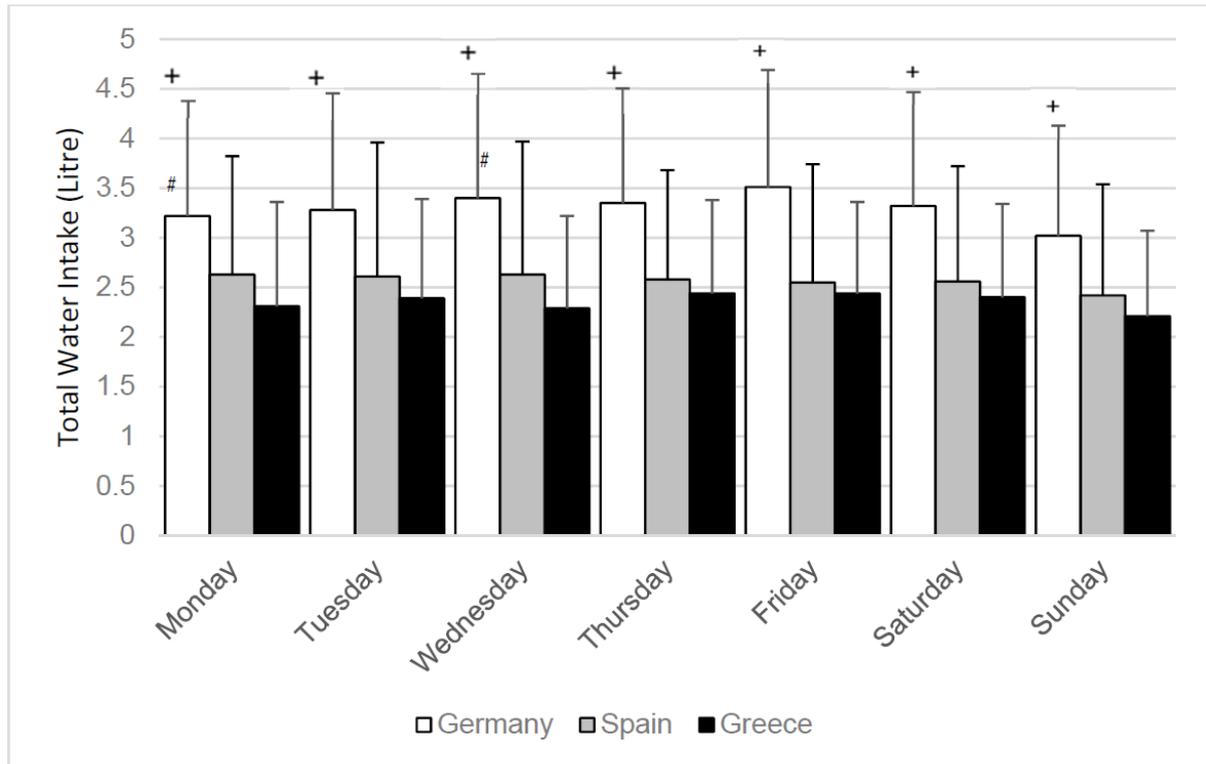
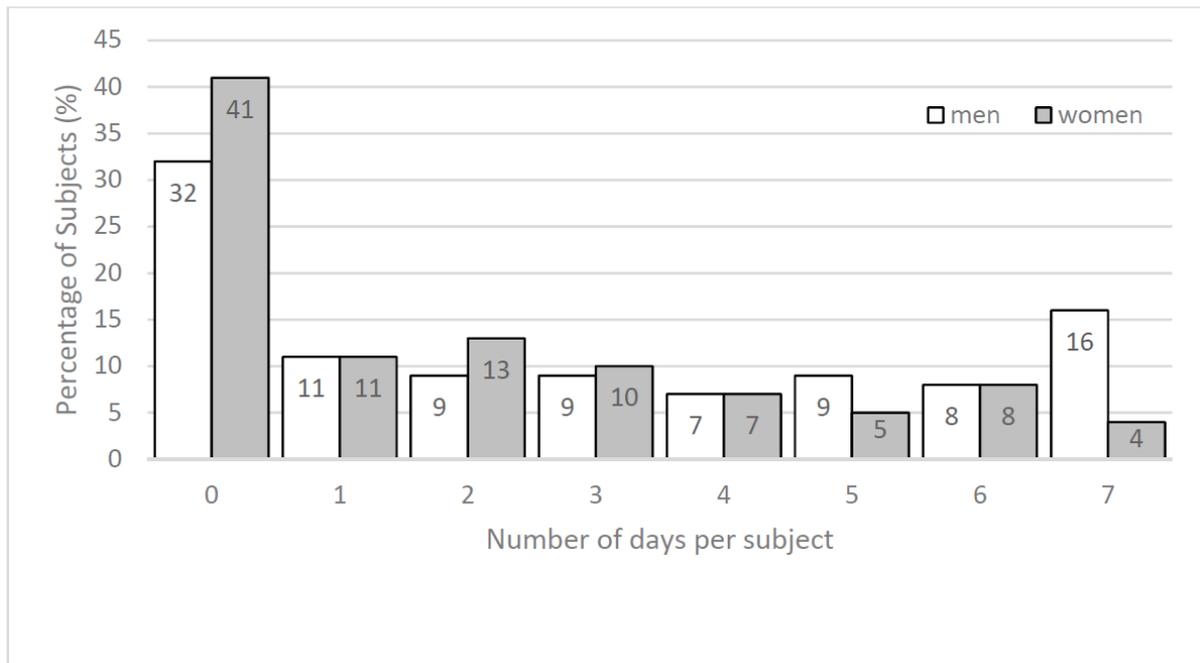


Figure 4-1: Mean total water intake (L/day) among weekdays with respect to country.

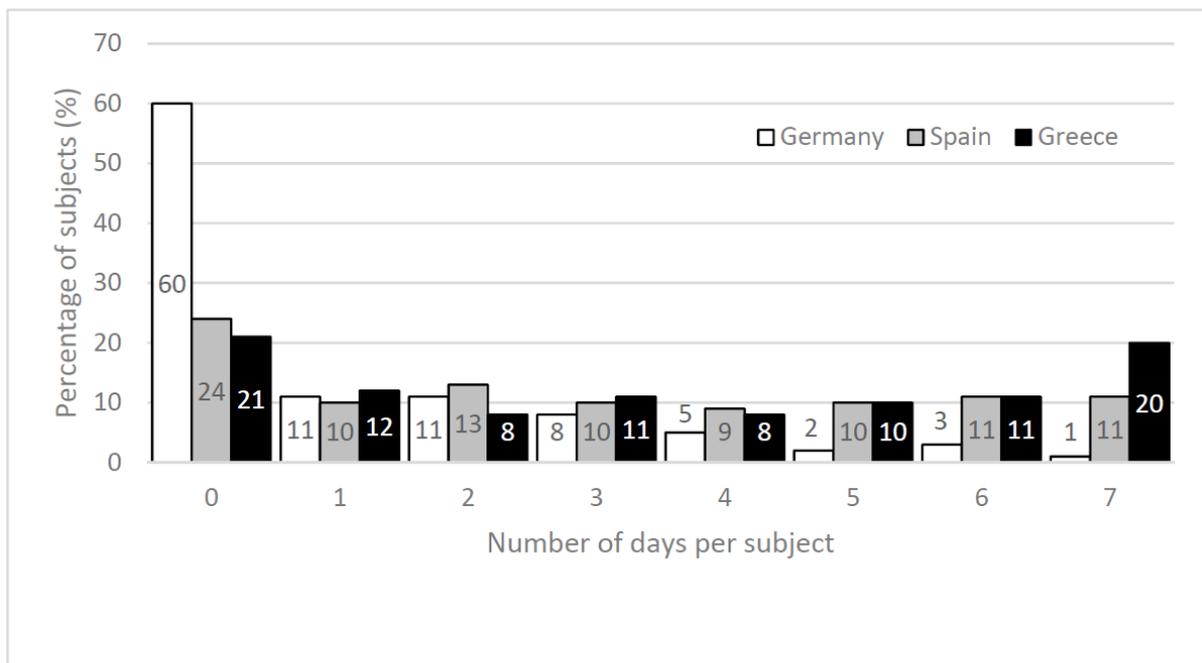
Note: p-values derived through Tukey–Kramer test for comparison between countries. + significantly different on all weekdays for the German subjects compared to the Greek and Spanish ($p < 0.001$). # significant different for the Spanish subjects compared to the Greek on Mondays and Wednesdays ($p < 0.05$).

Mean individual TWI over the seven-day study period below EFSA recommendation was found in 37% males and 22% females. This result varies between countries with a lower rate for Germany (6% males and 7% females) compared to Greece (50% males and 24% females) and Spain (55% males and 39% females). With respect to each single day, 40% of all days from males and 29% from females were $<$ EFSA recommendation (Table 4-1).

Considering the number of days per subjects below EFSA recommendation, 40% of males and 24% of females had at least four days in which TWI was below EFSA recommendation during the seven-day study period (Figure 4-2a). Furthermore, 16% of all males showed a TWI below 2.5 L/day on every day within the study period. A country-specific analysis demonstrates that 60% of the German subjects (24% of the Spanish and 21% of the Greek subjects) had zero days with a TWI below the EFSA recommendations (Figure 4-2b). 49% of



(a)



(b)

Figure 4-2: (a) Number of days per subject in the seven-day study period with TWI below the EFSA recommendation for men and women; (b) number of days per subject in the seven-day study period with TWI below the EFSA recommendation with respect to the country.

Greek participants (41% of Spanish and 11% of German participants) showed TWI lower than the EFSA recommendation on at least four days of the study week (Figure 4-2b). To describe the intra-individual difference of TWI consumption, the individual highest TWI minus the lowest TWI within the seven-day period was calculated. The overall mean intra-individual difference was found to be 1.67 ± 0.94 L. The coefficient of variation (CV) for TWI was $20.5\% \pm 9.2\%$.

4.4.2 Urine Osmolality

On each weekday, 24 h urine osmolality is lower ($p < 0.01$ for each day) in females compared to males (Table 4-2).

Table 4-2: Mean 24 h urine osmolality (mOsmol/kg) on weekdays for men and women.

Weekday	24 h Urine Osmolality (Mean \pm SD in mOsmol/kg)			
	All	Men	Women	<i>p</i> -Value *
Monday	642 \pm 252	680 \pm 238	605 \pm 259	<0.001
Tuesday	639 \pm 256	687 \pm 238	593 \pm 265	<0.001
Wednesday	620 \pm 255	670 \pm 242	568 \pm 257	<0.001
Thursday	639 \pm 265	685 \pm 250	590 \pm 270	<0.001
Friday	634 \pm 254	669 \pm 234	595 \pm 267	<0.001
Saturday	637 \pm 250	686 \pm 239	588 \pm 252	<0.001
Sunday	656 \pm 241	687 \pm 216	624 \pm 260	=0.002
All 24 h samples	638 \pm 254	681 \pm 237	595 \pm 261	<0.001

Note: * *p*-values derived through Mann–Whitney–U test for differences between genders.

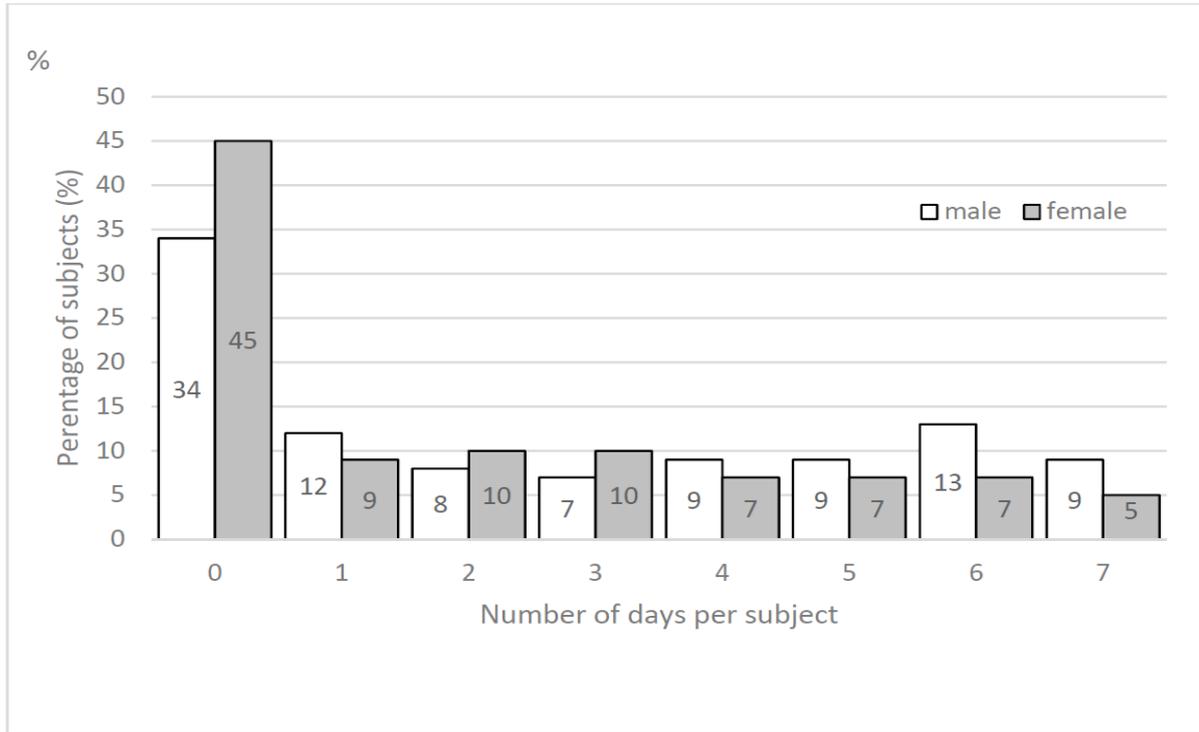
We observed more 24 h urine samples with an osmolality <500 mOsmol/kg in women (44%) compared to men (26%). Twenty-four hour urine samples with an osmolality ≥ 800 mOsmol/kg occurred more often in males than in females (32% vs. 24%). This trend exists on all weekdays (Table 4-3).

Table 4-3: Percentage of 24 h urine osmolality within selected categories on weekdays for men and women.

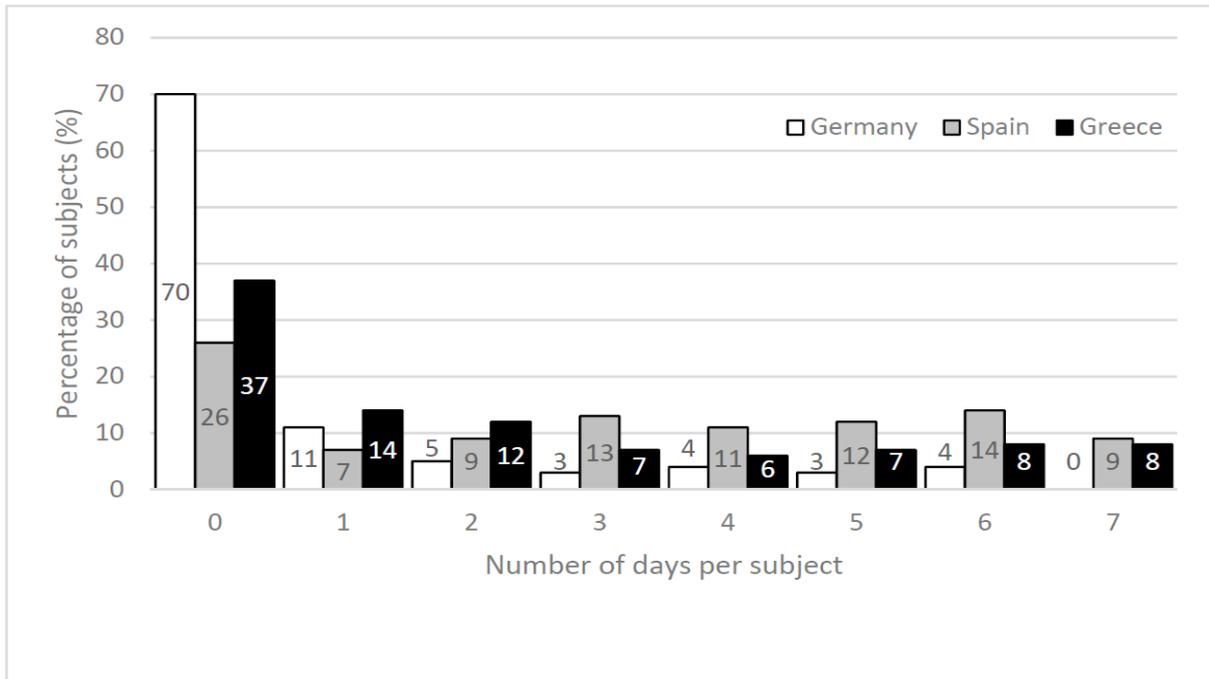
Weekday	<500 mOsmol/kg (%)			500–799 mOsmol/kg (%)			≥800 mOsmol/kg (%)		
	All	Men	Women	All	Men	Women	All	Men	Women
Monday	34	27	41	36	39	33	30	34	26
Tuesday	33	23	43	38	42	34	29	35	23
Wednesday	38	29	47	36	39	33	26	32	20
Thursday	35	25	45	36	41	32	29	34	23
Friday	36	28	46	35	40	30	28	32	24
Saturday	35	26	45	39	43	34	26	31	21
Sunday	30	22	39	40	47	32	30	31	29
All 24 h samples	34	26	44	37	42	33	28	32	24

Overall, 11% of the study population (6% men; 15% women) showed a 24 h urine osmolality on all days of the study period <500 mOsmol/kg. In contrast, 9% of all men (5% women) showed a urine osmolality ≥800 mOsmol/kg on all seven days. Almost half (40%) of the male participants and 26% of the female participants had a urine osmolality ≥800 mOsmol/kg on at least four days within the study week (Figure 4-3a).

A country specific analysis illustrates that 70% of the German subjects (26% SPA, 37% GRE) had zero days with urine osmolality ≥800 mOsmol/kg during the study period. In contrast, 46% of the Spanish participants (29% GRE, 11% GER) showed a urine osmolality ≥800 mOsmol/kg on at least four days of the study week (Figure 4-3b) including almost 10% of the subjects in Greece and Spain with a 24 h urine osmolality ≥800 mOsmol/kg on every day of the study period. The CV for urine osmolality was 17.9% ± 8.6%.



(a)



(b)

Figure 4-3: (a) Number of days per subject in the seven-day study period with a 24 h urine osmolality >800 mOsmol/kg for men and women; (b) number of days per subject in the seven-day study period with a 24 h urine osmolality >800 mOsmol/kg with respect to the country.

4.4.3 Urine Volume

Mean daily urine volume was found to be 1.68 ± 0.85 L/day with no difference between weekdays and gender. However, 19% of the men and 24% of the women had a urine volume <1 L/day (Table 4-4). The CV for urine volume was $23.2\% \pm 11.2\%$.

Table 4-4: Mean 24 h urine volume (L/day) on weekdays and percentage of subjects with a urine volume <1 L/day, for men and women.

Weekday	24 h Urine Volume (Mean \pm SD in L/day)				Urine Volume <1 L/day (%)		
	All	Men	Women	<i>p</i> -Value *	All	Men	Women
Monday	1.69 ± 0.87	1.69 ± 0.83	1.69 ± 0.91	=0.615	21	18	24
Tuesday	1.66 ± 0.86	1.64 ± 0.80	1.69 ± 0.91	=0.907	24	24	24
Wednesday	1.70 ± 0.89	1.68 ± 0.86	1.73 ± 0.91	=0.683	22	22	22
Thursday	1.66 ± 0.80	1.68 ± 0.78	1.66 ± 0.83	=0.418	22	17	26
Friday	1.70 ± 0.88	1.69 ± 0.81	1.73 ± 0.95	=0.785	20	17	23
Saturday	1.68 ± 0.85	1.65 ± 0.79	1.71 ± 0.92	=0.911	21	19	23
Sunday	1.65 ± 0.82	1.68 ± 0.79	1.63 ± 0.85	=0.198	22	17	26
All 24 h samples	1.68 ± 0.85	1.67 ± 0.81	1.69 ± 0.90	=0.881	22	19	24

Note: * *p*-values derived through Mann–Whitney–U test for differences between genders.

4.5 Discussion

The European Hydration Research Study (EHRS) is the first study to examine total water intake and selected hydration markers over a period of seven consecutive days in healthy adults. While studies in this field are quite often not comparable due to different collecting methods and survey dates [18], we conducted the study following a normalized experimental protocol and methods in all three countries. In this study, we found differences in TWI and 24 h urine osmolality with respect to country and gender. While mean group results are within the recommended levels, individual data show an intra-individual variation in daily TWI and 24 h urine osmolality.

4.5.1 Total Water Intake

Overall mean TWI of the study population is in the range of the suggested EFSA adequate intake [1] for both men and women. The country-specific difference in our study is comparable to the variance in TWI among European countries described by others already [1, 17, 19]. Individual mean TWI of the seven-day study period was below the EFSA recommendation for 37% men and 22% women. This overall result is analogous to data from the UK [19]. Sunday was found to be the day with the lowest TWI in all countries (Figure 4-1); this should not be misinterpreted as particularly low, as TWI on Sunday is only about 200 mL below the overall mean TWI intake. However, while this observation is similar for females from a UK population, it is different from UK males who reported lowest beverage consumption on Monday [19].

Deeper analysis of the daily data reveals that a substantial amount of all subjects (men 40%; women 24%) had TWI below EFSA on ≥ 4 days and almost every fourth male below EFSA on ≥ 6 days per week (Figure 4-2a). These results emphasize that although the overall mean TWI is within the recommended values, an intra-individual variance regarding TWI within a seven-day period exists. Such a day-to-day difference in beverage consumption habits is already described [18] and supported by our findings.

Based on previous results, the German subjects showed a higher water intake from beverages and a higher water intake from food [20]. However, at this stage, we are unable to explain why we found more men compared to women and more people from Greece and Spain being unable to meet the EFSA recommendation compared to the German subjects. While misreporting/underreporting in dietary surveys is common [1], the extent of beverage misreporting is not known for the sedentary population [18], and to our knowledge country-specific underreporting has not been described so far. However, the day-to-day variety of TWI

might have implications on short-term surveys (e.g., 24 h recalls) and should be kept in mind when planning surveys on TWI and hydration status [18].

In addition, it remains unclear what consequences the day-to-day variety has in each individual of our study. Water requirements and TWI vary highly between individuals with respect to daily activities, diet, climate, and environment. Therefore, based on TWI data solely, it is difficult to determine how many subjects were hypohydrated during the study period or on selected days.

4.5.2 Urine Osmolality

Although no single biomarker represents hydration status in humans in all situations and persons, 24 h urine osmolality is regarded as an excellent indicator, as it represents the sum of all behavioral and neuroendocrine responses and the whole body hydration status more accurately than single spot samples [22-25]. Urine osmolality varies within 50 and 1200 mOsmol/L with a theoretical maximum of 1400 mOsmol/L [1]. However, a maximum urine osmolality in adults has been determined to be 900–1400 [1]. A 24 h urine osmolality <500 mOsmol/kg is suggested to be desirable to excrete the daily solute load [1, 25] and urine osmolality >800 mOsmol/kg is suggested to represent mild hypohydration [23, 25-27].

Individual water requirement is based on respiratory and sweat losses but is also dependent on the diet and its osmotic solute content and the concentrating capacity of the kidneys [1]. For safety concerns regarding kidney health, daily water intake recommendation is connected with a urine osmolality of about 500 mOsmol/kg [1, 25]. In this study the female subjects showed a significantly lower 24 h urine osmolality compared to males. However, the mean values were above the suggested 500 mOsmol/kg for both males and females on each weekday. With respect to the EFSA recommendation to achieve a daily 24 h urine osmolality <500 mOsmol/kg [1], we found only 11% of our subjects reached this value on a daily basis.

This appears alarming following the suggestion that a urine osmolality <500 mOsmol/kg is a relevant physiological index of hydration for the general population [25]. Furthermore, in 40% of all males we observed a 24 h urine osmolality ≥ 800 mOsmol/kg on ≥ 4 days in the seven-day study period with enormous difference between the three countries. This can be interpreted as a large number of days in which our subjects might have had inadequate water consumption [22]. Even though we don't know if our results describe a long-term behaviour and what consequences 24 h urine osmolality ≥ 800 mOsmol/kg has on each individual, an increased TWI for those subjects seems to be necessary. Attention should be paid to specific groups to reduce possible risks on chronic kidney disease [28-31], although well-designed prospective studies are needed before such a recommendation can be justified [32].

Assuming this describes a typical behavior of our subjects, detrimental effects on wellbeing, mood, or health are possible [6, 33]. Mild hypohydration can cause symptoms like dizziness, headache, or fatigue with lower self-reported ratings of alertness and ability to concentrate [7-16, 33]. Depending on the work to be done on such days, this possibly has a negative impact on several situations during daily life. Recently, an increased number of driving errors during a prolonged, monotonous drive were reported when subjects were hypohydrated [34].

4.5.3 Urine Volume

Using urine volume as a marker for hydration status, it should be kept in mind that physical activity and heat decrease urine output, while cold and hypoxia increase it [1]. Urine volume, TWI, and urine osmolality are closely related [1, 24], and urine volume varies inversely with the body hydration status [35]. Average urine volumes in adults are described to be 1–2 L/day with extremes in both directions [1, 35]. An average urine output of approximately 100 mL/h in healthy people is possibly a sign of being well hydrated. In contrast, if urine output decreases

to an average of 30 mL/h the person is probably dehydrated [35]. However, an agreement on a urine volume to describe hypohydration does not exist. Suggestions exist that the minimum volume that must be excreted generally amounts to 20 to 50 mL/h [36], which results in a basal urine volume in the range of 480 to 1200 mL/day. Within our study we found a mean urine volume on all weekdays for males and females within the described values. However, 24% of the female 24 h urine samples and 19% of the male were below 1 L/day. While we found no gender specific difference on urine volume, previous results from the EHRS project showed that urine volume of the German subjects was significantly higher compared to the Greek and Spanish participants [20]. This is likely due to the higher TWI intake, which also explains the lower urine osmolality of the German subjects [20, 21].

4.6 Conclusion

In Summary, we highlighted TWI, 24 h urine osmolality, and urine volume in a group of 573 adults from three different European countries. We found differences in TWI and 24 h urine osmolality between countries and between males and females. Mean group results from a seven-day data collection are within the recommended levels. However, individual data show an intra-individual day-to-day variation in TWI and urine osmolality. Individuals were identified with low TWI and high 24 h urine osmolality on several days per week or even daily. While it is unclear what the consequences are for the individual subject currently tested, chronic hypohydration may have detrimental effects on wellbeing, mood, or health [7-16, 33, 34]. Future studies need to consider the intra-individual day-to-day variation and show if this might have consequences on health and wellbeing.

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4.8 References

1. EFSA, *Scientific opinion on dietary reference values for water*. EFSA Journal, 2010(8): p. 1459–1507.
2. Thomas, D.R., et al., *Understanding clinical dehydration and its treatment*. J Am Med Dir Assoc, 2008. 9(5): p. 292-301.
3. Benelam, B. and L. Wyness, *Hydration and health: a review*. Nutrition Bulletin, 2010. 35(1): p. 3-25.
4. Chevront, S.N., et al., *Physiologic basis for understanding quantitative dehydration assessment*. Am J Clin Nutr, 2013. 97(3): p. 455-62.
5. Suhayda, R. and J.C. Walton, *Preventing and managing dehydration*. Medsurg Nurs, 2002. 11(6): p. 267-78.
6. El-Sharkawy, A.M., O. Sahota, and D.N. Lobo, *Acute and chronic effects of hydration status on health*. Nutrition Reviews, 2015. 73(suppl_2): p. 97-109.
7. D'Anci, K.E., et al., *Voluntary Dehydration and Cognitive Performance in Trained College Athletes*. Perceptual and Motor Skills, 2009. 109(1): p. 251-269.
8. Shirreffs, S.M., et al., *The effects of fluid restriction on hydration status and subjective feelings in man*. British Journal of Nutrition, 2007. 91(6): p. 951-958.
9. Armstrong, L.E., et al., *Mild Dehydration Affects Mood in Healthy Young Women*. The Journal of Nutrition, 2011. 142(2): p. 382-388.
10. Cian, C., et al., *Effects of fluid ingestion on cognitive function after heat stress or exercise-induced dehydration*. International Journal of Psychophysiology, 2001. 42(3): p. 243-251.
11. Ganio, M.S., et al., *Mild dehydration impairs cognitive performance and mood of men*. British Journal of Nutrition, 2011. 106(10): p. 1535-1543.

12. Pross, N., et al., *Influence of progressive fluid restriction on mood and physiological markers of dehydration in women*. British Journal of Nutrition, 2012. 109(2): p. 313-321.
13. Armstrong, L.E., et al., *Hydration biomarkers and dietary fluid consumption of women*. J Acad Nutr Diet, 2012. 112(7): p. 1056-61.
14. Gopinathan, P.M., G. Pichan, and V.M. Sharma, *Role of dehydration in heat stress-induced variations in mental performance*. Arch Environ Health, 1988. 43(1): p. 15-7.
15. Suhr, J.A., et al., *The relation of hydration status to cognitive performance in healthy older adults*. International Journal of Psychophysiology, 2004. 53(2): p. 121-125.
16. Sharma, V.M., et al., *Influence of heat-stress induced dehydration on mental functions*. Ergonomics, 1986. 29(6): p. 791-799.
17. Elmadfa, I. and A.L. Meyer, *Patterns of drinking and eating across the European Union: implications for hydration status*. Nutr Rev, 2015. 73 Suppl 2: p. 141-7.
18. Gibson, S., P. Gunn, and R.J. Maughan, *Hydration, water intake and beverage consumption habits among adults*. Nutrition Bulletin, 2012. 37(3): p. 182-192.
19. Gibson, S. and S.M. Shirreffs, *Beverage consumption habits "24/7" among British adults: association with total water intake and energy intake*. Nutr J, 2013. 12: p. 9.
20. Malisova, O., et al., *Water Intake and Hydration Indices in Healthy European Adults: The European Hydration Research Study (EHRS)*. Nutrients, 2016. 8(4): p. 204.
21. Mora-Rodriguez, R., et al., *Influence of Physical Activity and Ambient Temperature on Hydration: The European Hydration Research Study (EHRS)*. Nutrients, 2016. 8(5).
22. Armstrong, L.E., et al., *Interpreting common hydration biomarkers on the basis of solute and water excretion*. Eur J Clin Nutr, 2013. 67(3): p. 249-53.

23. Armstrong, L.E., et al., *An empirical method to determine inadequacy of dietary water*. Nutrition, 2016. 32(1): p. 79-82.
24. Perrier, E., et al., *Relation between urinary hydration biomarkers and total fluid intake in healthy adults*. Eur J Clin Nutr, 2013. 67(9): p. 939-43.
25. Perrier, E.T., et al., *Twenty-four-hour urine osmolality as a physiological index of adequate water intake*. Dis Markers, 2015. 2015: p. 231063.
26. Chevront, S.N., et al., *Biological variation and diagnostic accuracy of dehydration assessment markers*. Am J Clin Nutr, 2010. 92(3): p. 565-73.
27. Manz, F. and A. Wentz, *24-h hydration status: parameters, epidemiology and recommendations*. Eur J Clin Nutr, 2003. 57 Suppl 2: p. S10-8.
28. Clark, W.F., et al., *Urine Volume and Change in Estimated GFR in a Community-Based Cohort Study*. Clinical Journal of the American Society of Nephrology, 2011. 6(11): p. 2634.
29. Perrier, E., et al., *Hydration biomarkers in free-living adults with different levels of habitual fluid consumption*. Br J Nutr, 2013. 109(9): p. 1678-87.
30. Sontrop, J.M., et al., *Association between Water Intake, Chronic Kidney Disease, and Cardiovascular Disease: A Cross-Sectional Analysis of NHANES Data*. American Journal of Nephrology, 2013. 37(5): p. 434-442.
31. Strippoli, G.F., et al., *Fluid and nutrient intake and risk of chronic kidney disease*. Nephrology, 2011. 16(3): p. 326-334.
32. Feehally, J. and M. Khosravi, *Effects of acute and chronic hypohydration on kidney health and function*. Nutr Rev, 2015. 73 Suppl 2: p. 110-9.
33. Benton, D. and H.A. Young, *Do small differences in hydration status affect mood and mental performance?* Nutr Rev, 2015. 73 Suppl 2: p. 83-96.

34. Watson, P., et al., *Mild hypohydration increases the frequency of driver errors during a prolonged, monotonous driving task*. *Physiol Behav*, 2015. 147: p. 313-8.
35. Institute of Medicine, *Dietary Reference Intakes for Water Potassium, Sodium, Chloride, and Sulfate*, I.o.M. (IoM), Editor. 2004, National Academies Press: Washington DC, USA.
36. Shirreffs, S.M. and R.J. Maughan, *Urine osmolality and conductivity as indices of hydration status in athletes in the heat*. *Med Sci Sports Exerc*, 1998. 30(11): p. 1598-602.

5 Zusammenfassung

Eine bedarfsgerechte Energie- und Nährstoffzufuhr ist notwendig, um Gesundheit und Leistungsfähigkeit des Menschen langfristig aufrecht zu erhalten. Die Beschreibung der Nährstoffzufuhr über Instrumente der Ernährungserhebungen ist trotz bekannter Limitationen ein weit verbreitetes und akzeptiertes Instrument. Ergänzend sollten nach Möglichkeit bei der Beurteilung der Ernährungssituation geeignete anthropometrische und klinische Parameter integriert werden.

Ziel dieser Dissertation ist es, den Ernährungsstatus, Hydratationsstatus und Nahrungsergänzungsmittelkonsum in ausgewählten Bevölkerungsgruppen mittels unterschiedlicher etablierter Methoden darzustellen, zu bewerten und zu diskutieren.

Trotz zahlreicher Publikationen zum Ernährungsverhalten gibt es noch Bevölkerungsgruppen, die bisher nicht ausreichend untersucht und beschrieben sind. Nach Angaben des Fußball Weltverband FIFA sind mehr als 30 Millionen Fußballspielerinnen aktiv. Untersuchungen zum Ernährungsverhalten dieser Gruppe sind nur vereinzelt verfügbar. Im Rahmen dieser Dissertation konnte aufgezeigt werden, dass der Ernährungsstatus junger deutscher Fußballerinnen hinsichtlich sportspezifischer Empfehlungen zur Nährstoffzufuhr aber auch unabhängiger klinischer Parameter, nicht angemessen ist.

Von verschiedenen internationalen Organisationen wird verstärkt darauf hingewiesen, dass Sportler*innen eine mögliche unzureichende Nährstoffzufuhr über eine sportgerechte Basiskost ausgleichen und erst im zweiten Schritt über eine individuelle Risiko-Nutzen-Abwägung den Konsum von Nahrungsergänzungsmitteln (NEM) prüfen sollten. Bei einer Befragung von deutschen Nachwuchsleistungssportler*innen wurde deutlich, dass der Konsum von NEM gegenüber der Normalbevölkerung deutlich erhöht ist. Bevorzugt werden von den Sportler*innen Vitamin- und Mineralstoffpräparate genutzt. Es kann dabei nicht

ausgeschlossen werden, dass es dadurch zu einer NEM bedingten übermäßigen Zufuhr an Mikronährstoffen kommt, die infolge einer Überschreitung der Upper Intake Level zu einem Risiko für Nebenwirkungen hinsichtlich Gesunderhaltung und Leistungsentwicklung werden kann. Im Rahmen einer (sportspezifischen) Ernährungsberatung sollte daher die Erfassung und Bewertung des NEM-Konsums integriert werden. Auf Basis dieser Ergebnisse erscheint es generell notwendig, im Bereich des Nachwuchsleistungssports noch intensiver über die Relevanz und Umsetzung einer sportgerechten Ernährung aufzuklären und das entsprechende persönliche und sportliche Umfeld der Athlet*innen in diesen Prozess zu integrieren.

Eine weitere Besonderheit der Gruppe der Leistungssportler*innen ist die belastungsbedingte Schweißbildungsrate und der daraus resultierende erhöhte Wasserbedarf. Der tägliche Wasserbedarf ist allerdings keine fixe Größe, sondern variiert aufgrund verschiedener Faktoren auch bei der Normalbevölkerung. Daher ist die Wasserzufuhr als alleiniger Parameter bei der Bewertung des Hydratationsstatus nicht ausreichend und sollte mit nicht-invasiven Parametern wie Urinosmolalität und Urinvolumen ergänzt werden. Untersuchungen zum Hydratationsstatus sind aufgrund unterschiedlicher Methoden häufig nicht vergleichbar. Ziel der European Hydration Research Study (EHRS) war es daher, mit einer einheitlichen methodischen Vorgehensweise die Wasserzufuhr und den Hydratationsstatus in drei europäischen Ländern zu erheben und zu vergleichen. Dies war die erste Untersuchung, die mit einer einheitlichen Methodik sowohl Wasserzufuhr als auch Marker des Flüssigkeitsstatus in verschiedenen europäischen Ländern parallel erfasst hat. Die Untersuchung präsentiert eine zufriedenstellende mittlere Gesamtwasserzufuhr in Anlehnung an die Empfehlungen der Europäischen Behörde für Lebensmittelsicherheit (EFSA). Ein Blick auf die Einzelwerte zeigt

jedoch eine individuelle Varianz mit einer unbefriedigenden Situation vor allem in Griechenland und Spanien, insbesondere bei den Männern.

Ergebnisse und Erkenntnisse aus den in dieser Dissertation dargestellten Arbeiten wurden bereits verwendet, um handelnden Personen im Sport (z.B. Sportler*innen, Trainer*innen und Eltern) sowie in der Normalbevölkerung (z.B. Polizeibeamt*innen) Hinweise zur Verbesserung der Ernährungssituation, Flüssigkeitsstatus und Reduzierung der Risiken durch unsachgemäßen NEM-Konsum zu geben. Darüber hinaus werden die Ergebnisse genutzt, um die Methodik der Datenerfassung weiterzuentwickeln und in neuen Projekten anzuwenden.

6 Abstract

A needs-based energy and nutrient supply is necessary to maintain human health and performance in the long term. Despite known limitations, the description of nutrient intake via nutrition survey instruments is a widely used and accepted tool. Where possible, appropriate anthropometric and clinical parameters should be integrated, in the assessment of the nutritional situation.

The aim of this dissertation is to present, evaluate and discuss the nutritional status, hydration status and dietary supplement use in selected population groups via different established methods.

Despite numerous publications on dietary behaviour, there are still population groups that have not been sufficiently studied and described. According to the world football association (FIFA), more than 30 million women footballers are active. Studies on the dietary behaviour of this group are only available rarely. In the course of this dissertation, it was shown that the nutritional status of young female German footballers is not adequate with regard to sport-specific recommendations on nutrient intake as well as independent clinical parameters.

Various international organisations are pointing out that athletes should compensate for a possible insufficient nutrient intake via a basic diet suitable for sport. Only in the second step, athletes should examine the consumption of dietary supplements (DS) based on an individual risk-benefit assessment. A survey of young German athletes showed that DS consumption is higher compared to the normal population. Vitamin and mineral preparations are preferably used by the athletes. It cannot be ruled out that this leads to a DS related excessive intake of micronutrients, which can become a risk of side effects in terms of health and performance development as a result of exceeding the Upper Intake levels. The recording and evaluation of DS consumption should therefore be integrated within the framework of (sport-specific)

nutrition advice. Based on these results, it generally seems necessary to educate young athletes even more intensively about the relevance and implementation of a sport-appropriate diet and to integrate the appropriate personal and sporting environment of the athletes into this process.

Another special characteristic of the group of competitive athletes is the sports-related sweat rate resulting in increased water needs. The daily water requirement is not a fixed quantity but varies due to various factors also in the normal population. Therefore, the water supply as the solely parameter in the evaluation of the hydration status is not sufficient and should be supplemented with non-invasive parameters such as urine osmolality and urine volume. Studies on hydration status are often not comparable due to different methods. Therefore, the aim of the European Hydration Research Study (EHRS) was to use a uniform methodological approach to collect and compare water intake and hydration status in three European countries. This was the first study to have recorded both water intake and markers of hydration status in various European countries in parallel with a uniform methodology. The study presents a satisfactory mean total water intake in line with the recommendation of the European Food Safety Authority (EFSA). However, a look at the individual values shows an individual variance with an unsatisfactory situation, especially in Greece and Spain, especially for men.

Results and findings from the work presented in this dissertation have already been used to provide information on improving the nutritional situation, hydration status and reducing the risks of improper DS use to active persons in sports (e.g., athletes, coaches and parents) as well as in the normal population (e.g., police officers). In addition, the results will be used to further develop the methodology of data collection and to apply them in new projects.

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7.3 Abkürzungsverzeichnis

Abkürzung	Erläuterung
%	Prozent
%E	Prozentualer Anteil der Energiezufuhr
µg	Mikrogramm
µg/L	Mikrogramm pro Liter
µL	Microliter
25(OH)D	25-Hydroxy-Vitamin D
ACSM	American College of Sports Medicine
AR	Average-reporter
BMI	Body Mass Index
BMR	Basal metabolic rate
CV	Coefficient of variation
DACH	Deutsche Gesellschaft für Ernährung, Österreichische Gesellschaft für Ernährung, Schweizerische Gesellschaft für Ernährungsforschung und Schweizerische Vereinigung für Ernährung
DBS	Dried blood spot
DGE	Deutsche Gesellschaft für Ernährung
DGE AG	Arbeitsgruppe Sporternährung der Deutschen Gesellschaft für Ernährung
dL	Deziliter
DLW	Doubly labelled water
DOSB	Deutscher Olympischer Sportbund
DRI	Dietary Reference Intake
DS	Dietary supplement
e.g.	exempli gratia / zum Beispiel
EA	Energy availability
EE	Energy expenditure
EFSA	European Food Safety Authority
EHRS	European Hydration Research Study
EI	Energy intake
ESP	Spanien
etc.	et cetera
EV	Energieverfügbarkeit

ExEE	Exercise energy expenditure
FIFA	Fédération Internationale de Football Association
g	Gramm
g/kgKG	Gramm pro Kilogramm Körpergewicht
GER	Deutschland
GRE	Griechenland
h	Hour
IAAF	International Association of Athletics Federations
IOC	International Olympic Committee
kcal	Kilokalorien
kg	Kilogramm
KG	Körpergewicht
km	Kilometer
L	Liter
LBM	Lean body mass
LEE	Leisure activity energy expenditure
m	Meter
MET	Metabolic Equivalent of Task
min	Minute
ml	Milliliter
mOsmol/kg	milliosmol pro Kilogramm
mOsmol/L	milliosmol pro Liter
n	Anzahl
NEM	Nahrungsergänzungsmittel
nmol	Nanomol
nmol/L	Nanomol pro Liter
NRW	Nordrhein-Westfalen
NV	Nicht verfügbar
NVS	Nationale Verzehrsstudie
OR	Over-reporter
p	p-value, Irrtumswahrscheinlichkeit
RDA	Recommended Dietary Allowance
SD	Standard deviation
TEE	Total energy expenditure

TWI	Total water intake
u.a.	unter anderem
UK	United Kingdom
UR	Under-reporter
WADA	World Anti-Doping Agency
y	Year
yrs	Years
z.B.	zum Beispiel

8 Publikationsliste

Wissenschaftliche Publikationen in absteigender chronologischer Reihenfolge

2021

Zwingmann, L., Below, T., Braun, H., Wahl, P., & Goldmann, J-P. (2021). Consequences of police-related personal protective equipment and physical training status on thermoregulation and exercise energy expenditure. *The Journal of sports medicine and physical fitness*. <https://doi.org/10.23736/S0022-4707.21.12196-6>

2020

König, D., Braun, H., Carlsohn, A., Großhauser, M., Lampen, A., Mosler, S. C., Nieß, A., Oberitter, H., Schäbenthal, K., Schek, A., Stehle, P., Virmani, K., Ziegenhagen, R., & Hesecker, H. (2020). Position of the Working Group Sports Nutrition of the German Nutrition Society (DGE): Carbohydrates in Sports Nutrition. *German Journal of Sports Medicine*, 71(7-8-9), 185-190. <https://doi.org/10.5960/dzsm.2020.456>

Braun, H., Carlsohn, A., Großhauser, M., König, D., Lampen, A., Mosler, S. C., Nieß, A., Oberitter, H., Schäbenthal, K., Schek, A., Stehle, P., Virmani, K., Ziegenhagen, R., & Hesecker, H. (2020). Position of the Working Group Sports Nutrition of the German Nutrition Society

(DGE): Energy Needs in Sports. German Journal of Sports Medicine, 71(7-8-9), 171-176.

<https://doi.org/doi:10.5960/dzsm.2020.451>

Schek, A., Braun, H., Carlsohn, A., Grosshauser, M., Koenig, D., Lampen, A., Mosler, S., Niess, A., Oberritter, H., Schaebethal, K., Stehle, P., Virmani, K., Ziegenhagen, R., & Hesecker, H. (2020). Position of the Working Group Sports Nutrition of the German Nutrition Society

(DGE): Fats, Fat Loading, and Sports Performance. German Journal of Sports Medicine, 71(7-8-9), 199-206. <https://doi.org/10.5960/dzsm.2020.448>

Mosler, S., Braun, H., Carlsohn, A., Grosshauser, M., Koenig, D., Lampen, A., Niess, A., Oberritter, H., Schaebethal, K., Schek, A., Stehle, P., Virmani, K., Ziegenhagen, R., & Hesecker, H. (2020). Position of the Working Group Sports Nutrition of the German Nutrition Society (DGE): Fluid Replacement in Sports. German Journal of Sports Medicine, 71(7-8-9), 178-183.

<https://doi.org/doi:10.5960/dzsm.2020.453>

Carlsohn, A., Braun, H., Grosshauser, M., Koenig, D., Lampen, A., Mosler, S. C., Niess, A., Oberritter, H., Schaebethal, K., Schek, A., Stehle, P., Virmani, K., Ziegenhagen, R., & Hesecker, H. (2020). Position of the Working Group Sports Nutrition of the German Nutrition Society (DGE) Minerals and Vitamins in Sports Nutrition. German Journal of Sports Medicine, 71(7-8-9), 208-214. <https://doi.org/10.5960/dzsm.2020.454>

König, D., Carlsohn, A., Braun, H., Großhauser, M., Lampen, A., Mosler, S., Nieß, A., Schäbethal, K., Schek, A., Stehle, P., Virmani, K., Ziegenhagen, R., & Hesecker, H. (2020). Position of the Working Group Sports Nutrition of the German Nutrition Society (DGE): Protein

Intake in Sports. German Journal of Sports Medicine, 71(7-8-9), 192-197.
<https://doi.org/10.5960/dzsm.2020.450>

Ziegenhagen, R., Braun, H., Carlsohn, A., Großhauser, M., Hesecker, H., König, D., Mosler, S., Nieß, A., Oberritter, H., Schäbenthal, K., Schek, A., Stehle, P., Virmani, K., & Lampen, A. (2020). Position of the working group sports nutrition of the German Nutrition Society (DGE): safety aspects of dietary supplements in sports. German Journal of Sports Medicine, 71(7-8-9), 216-223. <https://doi.org/10.5960/dzsm.2020.455>

König, D., Carlsohn, A., Braun, H., Großhauser, M., Lampen, A., Mosler, S., Nieß, A., Schäbenthal, K., Schek, A., Virmani, K., Ziegenhagen, R., & Hesecker, H. (2020). Proteinzufuhr im Sport: Position der Arbeitsgruppe Sporternährung der Deutschen Gesellschaft für Ernährung e. V. (DGE). Ernährungs-Umschau, 67(7), M406-M413. <https://doi.org/10.4455/eu.2020.039>

Osterkamp-Baerens, C., Stensitzky-Thielemans, A., Braun, H., Brüning, K., & Carlsohn, A. (2020). Interne Kühlmethode im Überblick. Leistungssport, 50(2), 28-29.

Ziegenhagen, R., Braun, H., Carlsohn, A., Großhauser, M., Hesecker, H., König, D., Mosler, S. C., Nieß, A., Oberritter, H., Schäbenthal, K., Schek, A., Stehle, P., Virmani, K., & Lampen, A. (2020). Sicherheitsaspekte bei Nahrungsergänzungsmitteln im Sport: Position der Arbeitsgruppe Sporternährung der Deutschen Gesellschaft für Ernährung e. V. (DGE). Ernährungs-Umschau, 67(2), 42-50.

Bauhaus, H., Vassiliadis, A., Braun, H., Predel, H-G., & Thevis, M. (2020). Comparison of Selected Spirometric Systems for Measuring the Resting Metabolic Rate. *International Journal of Sport Nutrition Exercise Metabolism*, 30(S1), S1-3 - S1-4. <https://doi.org/10.1123/ijsnem.2020-0065>

2019

Carlsohn, A., Braun, H., Großhauser, M., König, D., Lampen, A., Mosler, S., Nieß, A., Oberritter, H., Schäbenthal, K., Schek, A., Stehle, P., Virmani, K., Ziegenhagen, R., & Hesecker, H. (2019). Mineralstoffe und Vitamine im Sport: Position der Arbeitsgruppe Sporternährung der Deutschen Gesellschaft für Ernährung e. V. (DGE). *Ernährungs-Umschau*, 12(12), M712-M719. <https://doi.org/10.4455/eu.2019.050>

König, D., Braun, H., Carlsohn, A., Großhauser, M., Lampen, A., Mosler, S. C., Nieß, A., Oberritter, H., Schäbenthal, K., Schek, A., Stehle, P., Virmani, K., Ziegenhagen, R., & Hesecker, H. (2019). Carbohydrates in Sports Nutrition Position of the Working Group Sports Nutrition of the German Nutrition Society e. V. (DGE): Position der Arbeitsgruppe Sporternährung der Deutschen Gesellschaft für Ernährung e. V. (DGE). *Ernährungs-Umschau*, 66(11), M660-M667. <https://doi.org/10.4455/eu.2019.044>

Schek, A., Braun, H., Carlsohn, A., Grosshauser, M., Koenig, D., Lampen, A., Mosler, S., Niess, A., Oberritter, H., Schaabenthal, K., Stehle, P., Virmani, K., Ziegenhagen, R., & Hesecker, H. (2019). Fats in sports nutrition. Position of the working group sports nutrition of the German Nutrition Society (DGE): Position der Arbeitsgruppe Sporternährung der Deutschen

Gesellschaft für Ernährung e. V. (DGE). Ernährungs-Umschau, 66(9), 181-188.

<https://doi.org/10.4455/eu.2019.042>

Braun, H., Carlsohn, A., Großhauser, M., König, D., Lampen, A., Mosler, S. C., Nieß, A., Oberritter, H., Schäbenthal, K., Schek, A., Stehle, P., Virmani, K., Ziegenhagen, R., & Hesecker, H. (2019). Energiebedarf im Sport: Position der Arbeitsgruppe Sporternährung der Deutschen

Gesellschaft für Ernährung e. V. (DGE). Ernährungs-Umschau, 66(8), 146-153.

<https://doi.org/10.4455/eu.2019.040>

Bauhaus, H., von Andrian-Werburg, J. U., & Braun, H. (2019). Ernährungsstrategien für Langstreckenläufer. *Leichtathletiktraining*, 30(6), 32-37.

Braun, H., von Andrian-Werburg, J., Malisova, O., Athanasatou, A., Kapsokefalou, M., Ortega, J. F., Mora-Rodriguez, R., & Thevis, M. (2019). Differing Water Intake and Hydration Status in

Three European Countries: A Day-to-Day Analysis. *NUTRIENTS*, 11(4), [773].

<https://doi.org/10.3390/nu11040773>

Mosler, S. C., Braun, H., Carlsohn, A., Großhauser, M., König, D., Lampen, A., Nieß, A., Oberritter, H., Schäbenthal, K., Schek, A., Stehle, P., Virmani, K., Ziegenhagen, R., & Hesecker, H. (2019). Flüssigkeitsmanagement im Sport: Position der Arbeitsgruppe Sporternährung der

Deutschen Gesellschaft für Ernährung e.V. (DGE). Ernährungs-Umschau, 66(3), 52-59.

<https://doi.org/10.4455/eu.2019.011>

2018

Bauhaus, H., von Andrian-Werburg, J., Braun, H., & Thevis, M. (2018). Examination of the timing of carbohydrate and protein intake among young elite female football players. in M. Murphy, C. Boreham, G. De Vito, & E. Tsolakidis (Hrsg.), Book of abstracts: 23rd Annual Congress of the European College of Sport Science, 4th-7th July 2018, Dublin, Ireland : Sport science at the cutting edge (S. 113-114). ECSS.

von Andrian-Werburg, J., Braun, H., Bauhaus, H., & Thevis, M. (2018). Nutrition status and carbohydrate intake in relation to training volume of 421 young elite German athletes. in M. Murphy, C. Boreham, G. De Vito, & E. . Tsolakidis (Hrsg.), Book of abstracts: 23rd Annual Congress of the European College of Sport Science, 4th-7th July 2018, Dublin, Ireland : Sport science at the cutting edge (S. 57-58). ECSS.

von Andrian-Werburg, J., Braun, H., & Thevis, M. (2018). Evaluation of different protein supplements regarding their amino acid profile using the Digestible Indispensible Amino Acid Score (Dias). Deutsche Zeitschrift für Sportmedizin, 69(2, Suppl.), S5.

Bauhaus, H., von Andrian-Werburg, J., Thevis, M., & Braun, H. (2018). Evaluation of the Indispensable Amino Acids (IAA) Intake among German Athletes. Deutsche Zeitschrift für Sportmedizin, 69(2, Suppl.), S5.

von Andrian-Werburg, J. U., & Braun, H. (2018). Ernährung jugendlicher Leistungssportler. Leichtathletiktraining, 29(2+3), 32-35.

Braunstein, B., Wendeler, L., Weiss, K., Braun, H., Müller, D., Niehoff, A., & Albracht, K. (2018). Evaluation of an MRI method to determine hydration states of tendons. in P. A. Hume, J. A. Alderson, & B. D. Wilson (Hrsg.), Proceedings of the International Society of Biomechanics in Sports (ISBS) (S. 534-537). International Society of Biomechanics in Sports.

Braun, H., von Andrian-Werburg, J., Schänzer, W., & Thevis, M. (2018). Nutrition Status of Young Elite Female German Football Players. *Pediatric exercise science*, 30(1), 159-169. <https://doi.org/10.1123/pes.2017-0072>

Bauhaus, H., von Andrian-Werburg, J. U., & Braun, H. (2018). Periodisierung der Ernährung bei Läufern. *Leichtathletiktraining*, 30(8), 28-33.

2017

Mattausch, N. R., Domnik, K., Koehler, K., Schaenzer, W., & Braun, H. (2017). Case Study: Hydration Intervention Improves Pre-game Hydration Status in Female Collegiate Soccer Players. *International Journal of Sport Nutrition Exercise Metabolism*, 27(5), 475-481. <https://doi.org/10.1123/ijsnem.2016-0209>

Hülsemann, F., Koehler, K., Wittsiepe, J., Wilhelm, M., Hilbig, A., Kersting, M., Braun, H., Flenker, U., & Schänzer, W. (2017). Prediction of human dietary $\delta(15)\text{N}$ intake from standardised food records: validity and precision of single meal and 24-h diet data. *Isotopes in environmental and health studies*, 1-12. <https://doi.org/10.1080/10256016.2017.1302447>

Braun, H., von Andrian-Werburg, J. U., May, S., Geyer, H., Schänzer, W., & Thevis, M. (2017). Dietary supplement use, impact on micronutrient intake of young elite German athletes. in A. Ferrauti, P. Platen, E. Grimminger-Seidensticker, T. Jaitner, U. Bartmus, L. Becher, M. De Marées, T. Mühlbauer, A. Schauerte, T. Wiewelhove, & E. Tsolakidis (Hrsg.), 22nd Annual Congress of the European College of Sport Sciences: Book of abstracts (S. 453). Westdeutscher Universitätsverlag.

von Andrian-Werburg, J. U., Braun, H., Schänzer, W., & Thevis, M. (2017). Nutrition status of Young Female Elite German Football Players. in A. Ferrauti, P. Platen, E. Grimminger-Seidensticker, T. Jaitner, U. Bartmus, L. Becher, M. De Marées, T. Mühlbauer, A. Schauerte, T. Wiewelhove, & E. Tsolakidis (Hrsg.), 22nd Annual Congress of the European College of Sport Sciences: Book of abstracts (S. 454). Westdeutscher Universitätsverlag.

2016

Andres, S., Ziegenhagen, R., Trefflich, I., Pevny, S., Schultrich, K., Braun, H., Schänzer, W., Hirsch-Ernst, K. I., Schäfer, B., & Lampen, A. (2016). Creatine and creatine forms intended for sports nutrition. *Molecular Nutrition & Food Research*. <https://doi.org/10.1002/mnfr.201600772>

Koehler, K., Hoerner, N. R., Gibbs, J. C., Zinner, C., Braun, H., De Souza, M. J., & Schänzer, W. (2016). Low energy availability in exercising men is associated with reduced leptin and insulin but not with changes in other metabolic hormones. *Journal of sports sciences*, 34(20), 1921-1929. <https://doi.org/10.1080/02640414.2016.1142109>

Braun, H. (2016). Die Besonderheiten der Ernährung im Leistungssport – von Freizeit- bis zu Hochleistungsaktivitäten. *Sportverletzung-Sportschaden*, 30(3), 149-153.
<https://doi.org/10.1055/s-0042-110450>

Mora-Rodriguez, R., Ortega, J. F., Fernandez-Elias, V. E., Kapsokefalou, M., Malisova, O., Athanasatou, A., Husemann, M., Domnik, K., & Braun, H. (2016). Influence of Physical Activity and Ambient Temperature on Hydration: The European Hydration Research Study (EHRS). *NUTRIENTS*, 8(5). <https://doi.org/10.3390/nu8050252>

Malisova, O., Athanasatou, A., Pepa, A., Husemann, M., Domnik, K., Braun, H., Mora-Rodriguez, R., Ortega, J. F., Fernandez-Elias, V. E., & Kapsokefalou, M. (2016). Water Intake and Hydration Indices in Healthy European Adults: The European Hydration Research Study (EHRS). *NUTRIENTS*, 8(4). <https://doi.org/10.3390/nu8040204>

2015

Braun, H., Marées, M. D. (Hrsg.), Mester, J. (Hrsg.), & Schänzer, W. (Hrsg.) (2015). Erfassung des Vitamin-D-Status und Knochen-Stoffwechsel relevanter Parameter bei Nachwuchsleistungssportlerinnen und -sportlern. *BISp-Jahrbuch : Forschungsförderung ...*, (2013/2014), S. 19-25. <http://my.page2flip.de/2895682/3868707/3868810/html5.html#/20>

Geyer, H., & Braun, H. (2015). Inadvertent doping. in LM. Castell, SJ. Stear, & LM. Burke (Hrsg.), *Nutritional supplements in sport, exercise and health: An A-Z Guide* (S. 15-19). Routledge.

Stear, S. J., Braun, H., & Currell, K. (2015). Introduction. in LM. Castell, SJ. Stear, & LM. Burke (Hrsg.), *Nutritional supplements in sport, exercise and health: An A-Z Guide* (S. 1-39). Routledge.

Flenker, U., Riemann, P., Hülsemann, F., Gougoulidis, V., Haenelt, N., Braun, H., Köhler, K., Mester, J., & Schänzer, W. (2015). Still more physiological Effects on stable Isotope Ratios of endogenous Steroids. in W. Schänzer, M. Thevis, H. Geyer, & U. Mareck (Hrsg.), *Recent advances in doping analysis* (23) (Band 23, S. 249). Sportverlag Strauß.

Kapsokefalou, M., Malisova, O., Pepa, A., Athanasatou, A., Husemann, M., Domnik, K., Braun, H., Mora-Rodríguez, R., Ortega, J. F., & Fernandez-Elias, V. E. (2015). Water intake and hydration indices in healthy adults; the European Hydration Research Study (EHRS). *Nutrición hospitalaria*, 32 Suppl 2, 10265. <https://doi.org/10.3305/nh.2015.32.sup2.10265>

2014

Köhler, K., Braun, H., Marées, de, M., Geyer, H., Thevis, M., Mester, J., & Schänzer, W. (2014). Glycerol administration before endurance exercise: metabolism, urinary glycerol excretion and effects on doping-relevant blood parameters. *Drug testing and analysis*, 6(3), 202-209. <https://doi.org/10.1002/dta.1446>

Braun, H., de Marées, M., Mester, J., Thevis, M., & Schänzer, W. (2014). Vitamin D status of young elite German athletes. Abstracts from the December 2013 International Sports and

Exercise Nutrition Conference in Newcastle upon Tyne. *International Journal of Sport Nutrition Exercise Metabolism*, 24(s1), S1-S10. <https://doi.org/10.1123/ijsnem.24.s1.s1>

2013

Koehler, K., Achtzehn, S., Braun, H., Mester, J., & Schänzer, W. (2013). Comparison of self-reported energy availability and metabolic hormones to assess adequacy of dietary energy intake in young elite athletes. *Applied physiology, nutrition, and metabolism = Physiologie appliquée, nutrition et métabolisme*, 38(7), 725-33. <https://doi.org/10.1139/apnm-2012-0373>

Flenker, U., Riemann, P., Gougoulidis, V., Haenelt, N., Köhler, K., Braun, H., Engelmeyer, E., Predel, H-G., & Mester, J. (2013). 13C/12C Ratios of Endogenous Urinary Steroids from a Population of Young Elite Athletes. in W. Schänzer, M. Thevis, H. Geyer, & U. Mareck (Hrsg.), *Recent advances in doping analysis (21) (Band 21, S. 66)*. Sportverlag Strauß.

Franzki, R., Braun, H., Schänzer, W., & Köhler, K. (2013). Essstörungen im Sport: Vergleich von Sportstudenten und Studenten weiterer Studiengänge mittels Eating Disorder Inventory-2. *Aktuelle Ernährungsmedizin*, 38(4), 283-289.

Domnik, K., Braun, H., Köhler, K., Mester, J., & Schänzer, W. (2013). Evaluation of fluid status and effect of an individual intervention in female soccer players before match play. in N. Balagué, C. Torrents, A. Vilanova, J. Cadefau, R. Tarragó, & E. Tsolakidis (Hrsg.), *18th annual congress of the European College of Sport Sciences: Book of abstracts (S. 571-572)*

Köhler, K., Marées, de, M., Braun, H., & Schänzer, W. (2013). Evaluation of two portable sensors for energy expenditure assessment during high-intensity running. *European Journal of Sport Science*, 13(1), 31-41. <https://doi.org/10.1080/17461391.2011.586439>

Hülsemann, F., Koehler, K., Braun, H., Schänzer, W., & Flenker, U. (2013). Human dietary 15N intake: Representative data for principle food items. *American Journal of Physical Anthropology*, 152(1), 58-66. <https://doi.org/10.1002/ajpa.22328>

Hoerner, N., Braun, H., Schänzer, W., & Köhler, K. (2013). The effect of energy restriction on exercise-induced release of hormone and metabolites. in *Proceedings of the German Nutrition Society (Band 18, S. 82)*

Braun, H., Werkner, J., Köhler, K., Mester, J., Thevis, M., & Schänzer, W. (2013). Weight loss practices of German athletes in Olympic weight class sports. in N. Balagué , C. Torrents , A. Vilanova, J. Cadefau, R. Tarragó, & E. Tsolakidis (Hrsg.), *18th annual congress of the European College of Sport Sciences: Book of abstracts (S. 357)*

2012

Koehler, K., Braun, H., Achtzehn, S., Hildebrand, U., Predel, H-G., Mester, J., & Schänzer, W. (2012). Iron status in elite young athletes: gender-dependent influences of diet and exercise. *European journal of applied physiology*, 112(2), 513-523. <https://doi.org/10.1007/s00421-011-2002-4>

Köhler, K., Settner, K., Braun, H., Achtzehn, S., Mester, J., & Schänzer, W. (2012). Association Between Energy Availability And Serum IGF1, T3, Leptin And Insulin In Young Female Athletes. *Medicine and science in sports and exercise*, 44, 189-190.

Guddat, S., Fußhöller, G., Geyer, H., Thomas, A., Braun, H., Haenelt, N., Schwenke, A., Klose, C., Thevis, M., & Schänzer, W. (2012). Clenbuterol: regional food contamination a possible source for inadvertent doping in sports. *Drug testing and analysis*, 4, 534-538.

Braun, H., Köhler, K., Geyer, H., Mester, J., Thevis, M., & Schänzer, W. (2012). Dietary supplement use, impact on micronutrient intake of young German athletes. in R. Meeusen, J. Duchateau, B. Roelands, M. Klaas, B. de Geus, S. Baudry, & E. Tsolakidis (Hrsg.), 17th annual Congress of the European College of Sport Science, 4.-7. July 2012, Bruges, Belgium: Book of abstracts (S. 237)

Köhler, K., Pilger, N., Zinner, C. J., Braun, H., Kleinert, J., Mester, J., & Schänzer, W. (2012). Effects of short-term energy restriction with and without training on physiological and psychological measures of performance. in R. Meeusen, J. Duchateau, B. Roelands, M. Klaas, B. de Geus, S. Baudry, & E. Tsolakidis (Hrsg.), 17th annual Congress of the European College of Sport Science, 4.-7. July 2012, Bruges, Belgium: Book of abstracts (S. 90)

Köhler, K., Pilger, N., Zinner, C. J., Braun, H., Mester, J., & Schänzer, W. (2012). Einfluss einer Energierestriktion und Training auf ausgewählte Parameter der Leistungsfähigkeit. *Deutsche Zeitschrift für Sportmedizin*, 63(7-8), 234.

Koehler, K., Braun, H., Thevis, M., & Schänzer, W. (2012). Glycerol as prohibited substance: meta-analysis on the effects of glycerol administration on haemoglobin, haematocrit and plasma volume. in W. Schänzer, M. Thevis, H. Geyer, & U. Mareck (Hrsg.), Recent advances in doping analysis (20) : Proceedings of the Manfred-Donike-Workshop, 30th Cologne Workshop on Dope Analysis : 26th February to 2nd March 2012 2. Variante (S. 250). (Recent advances in doping analysis; Band 20). Sportverlag Strauß.

Braun, H., Köhler, K., Geyer, H., Mester, J., Thevis, M., & Schänzer, W. (2012). Nahrungsergänzungsmittelkonsum, Einfluß auf die Mikronährstoffzufuhr bei Nachwuchsleistungssportlern. Deutsche Zeitschrift für Sportmedizin, 63(7-8), 237.

Köhler, K., Achtzehn, S., Braun, H., Settner, K., Mester, J., & Schänzer, W. (2012). Serum-Leptin bei jungen Leistungssportlern: Einfluss von Sportart, Energieverfügbarkeit und Gewichtsentwicklung. Proceedings of the German Nutrition Society, 17, 6.

2011

Köhler, K., Hülsemann, F., Marées, de, M., Braunstein, B., Braun, H., & Schänzer, W. (2011). Case study: Simulated and real-life energy expenditure during a 3-week expedition. International Journal of Sport Nutrition Exercise Metabolism, 21(6), 520-526.

Köhler, K., Braun, H., Marées, de, M., Fusch, G., Fusch, C., & Schänzer, W. (2011). Assessing energy expenditure in male endurance athletes : validity of the Sensewear Armband. Medicine and science in sports and exercise, 43(7), 1328-1333.

Geyer, H., Braun, H., Burke, L. M., Stear, S. J., & Castell, L. M. (2011). A-Z of nutritional supplements: dietary supplements, sports nutrition foods and ergogenic aids for health and performance-Part 22. *British journal of sports medicine*, 45(9), 752-754. <https://doi.org/10.1136/bjsports-2011-090180>

Braun, H., Köhler, K., Mester, J., Thevis, M., & Schänzer, W. (2011). Micronutrient intake of young elite German athletes. in T. Cable, & K. George (Hrsg.), 16th annual Congress of the European College of Sport Science, 6.-9. July 2011, Liverpool, ECSS (S. 295-296)

Braun, H., Köhler, K., Geyer, H., & Schänzer, W. (2011). Nahrungsergänzungsmittel: Doping- und Gesundheitsgefahren. *Ernährung und Medizin*, 26, 174-178.

Köhler, K., Braun, H., Marées, de, M., Geyer, H., Thevis, M., Mester, J., & Schänzer, W. (2011). Urinary excretion of exogenous glycerol administration at rest. *Drug testing and analysis*, 3(11-12), 877-882. <https://doi.org/10.1002/dta.355>

2010

Köhler, K., Braun, H., Marées, de, M., Fusch, G., Fusch, C., Mester, J., & Schänzer, W. (2010). Parallel assessment of nutrition and activity in athletes: validation against doubly labelled water, 24-h urea excretion, and indirect calorimetry. *Journal of sports sciences*, 28(13), 1435-1449. <https://doi.org/10.1080/02640414.2010.513482>

Braun, H. (2010). Besonderheiten der Ernährung in Sportarten mit Gewichtsklassen. Aktuelle Ernährungsmedizin, 35, 178-182.

Köhler, K., Marées, de, M., Braun, H., & Schänzer, W. (2010). Comparison Of Two Portable Devices For Assessing Energy Expenditure During High-intensity Running. Medicine and science in sports and exercise, 42(5), 304-305.

Braun, H. (2010). Dietary supplements. in A. Jeukendrup (Hrsg.), Sports Nutrition: From Lab to Kitchen (S. 86-91). Meyer & Meyer Sport.

Braun, H., Köhler, K., & Geyer, H. (2010). Verunreinigungen von Nahrungssupplementen- Eine Quelle verbotener Substanzen ? Schweizer Zeitschrift für Ernährungsmedizin, 4, 18-21.

2009

Braun, H., Koehler, K., Geyer, H., Kleiner, J., Mester, J., & Schanzer, W. (2009). Dietary supplement use among elite young German athletes. International Journal of Sport Nutrition Exercise Metabolism, 19(1), 97-109.

Braun, H. (2009). Dietary supplements – risk and benefits. in A. Jeukendrup, & B. Wolfarth (Hrsg.), Proceedings of the Sport nutrition conference, Munich 2009 (S. 15-19)

Braun, H., Köhler, K., Geyer, H., Thevis, M., & Schänzer, W. (2009). Dietary supplement use of elite German athletes and knowledge about the contamination problem. in S. Loland, K. Bø, K. Fasting, J. Hallén, Y. Ommundsen, G. Roberts, & E. Tsolakidis (Hrsg.), 14th annual congress of the European College of Sport Sciences: Book of abstracts (S. 378)

Köhler, K., Braun, H., Marées, de, M., Mester, J., & Schänzer, W. (2009). Einsatz eines Armbands zur Beschreibung des Energieumsatzes und der körperlichen Aktivität bei Läufern und Radfahrern. in E. Engelmeyer, & J. Mester (Hrsg.), Schriftenreihe des Deutschen Forschungszentrums für Leistungssport (Band 1, S. 44). Das Deutsche Forschungszentrum für Leistungssport.

Köhler, K., Braun, H., Achtzehn, S., Predel, H-G., Mester, J., & Schänzer, W. (2009). Iron Status in Young Elite Athletes: Influence of Diet, Exercise and Gender. in S. Loland, K. Bo, K. Fasting, J. Hallen, Y. Ommundsen, G. Roberts, & E. Tsolakidis (Hrsg.), 14th Annual Congress of the European College of Sport Science, Oslo, Norway: Book of Abstracts (S. 259)

Braun, H., Köhler, K., Achtzehn, S., Predel, H-G., Thevis, M., & Mester, J. (2009). Magnesium – dietary intake, supplement use and serum concentration in elite young German athletes. in S. Loland, K. Bø, K. Fasting, J. Hallén, Y. Ommundsen, G. Roberts, & E. Tsolakidis (Hrsg.), 14th annual congress of the European College of Sport Sciences: Book of abstracts (S. 130)

Köhler, K., & Braun, H. (2009). Nahrungsergänzungsmittel im Sport: Sinn, Unsinn und Gefahren. Sportmedizin in Nordrhein, 2, 4-6.

Köhler, K., Hülsemann, F., Marées, de, M., Braun, H., Mester, J., & Schänzer, W. (2009). Nutrition strategies for a 3-week solo dessert crossing: a case study. in S. Loland, K. Bø, K. Fasting, J. Hallén, Y. Ommundsen, G. Roberts, & E. Tsolakidis (Hrsg.), 14th annual congress of the European College of Sport Sciences: Book of abstracts (S. 576)

2008

Köhler, K., Braun, H., & Geyer, H. (2008). Ernährung und Aktivität jugendlicher Kaderathleten. in A. Ferrauti, P. Platen, & J. Müller (Hrsg.), Sport ist Spitze; Nachwuchsleistungssport in Nordrhein-Westfalen auf dem Prüfstand (S. 168-172). (Sport ist Spitze; Band 22). Meyer & Meyer.

Braun, H., Geyer, H., & Köhler, K. (2008). Meat products as potential doping traps? International Journal of Sport Nutrition Exercise Metabolism, 18, 539-542.

Braun, H., Köhler, K., Mester, J., & Schänzer, W. (2008). Nutrition status and physical activity of german elite junior athletes: preliminary results. in 13th Annual Congress of the European College of Sport Science in Estoril, Portugal from 9-12 July 2008: Book of abstracts

Hülsemann, F., Flenker, U., Köhler, K., Braun, H., & Schänzer, W. (2008). Retrospective analysis of metabolic activity by nitrogen isotope ratio analysis of hair. in 13th Annual Congress of the European College of Sport Science in Estoril, Portugal from 9-12 July 2008

Braun, H., Köhler, K., Geyer, H., Kleinert, J. M., Mester, J., & Schänzer, W. (2008). Use of nutritional supplements by german elite junior athletes. in 13th Annual Congress of the European College of Sport Science in Estoril, Portugal from 9-12 July 2008: Book of abstracts

Köhler, K., Braun, H., Marées, de, M., Mester, J., & Schänzer, W. (2008). Utilisation of an armband device for monitoring of energy expenditure and activity in running and cycling athletes. in 13th Annual Congress of the European College of Sport Science in Estoril, Portugal from 9-12 July 2008: Book of abstracts

Köhler, K., Braun, H., Marées, de, M., Fusch, G., Mester, J., & Schänzer, W. (2008). Validation of the cologne nutrition and activity protocol using double-labelled water, indirect calorimetry and 24h urea excretion. in 13th Annual Congress of the European College of Sport Science in Estoril, Portugal from 9-12 July 2008: Book of abstracts

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