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RESEARCH

Fuel-90: validation of a questionnaire to assess players' knowledge of carbohydrate guidelines for soccer

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Abstract

Purpose Professional soccer players typically under-consume carbohydrate in relation to contemporary guidelines, where their dietary behaviors may, in part, be underpinned by lack of knowledge. Accordingly, we aimed to develop and validate a novel and time-efficient questionnaire for use with professional soccer players to assess soccer players' knowledge of the current carbohydrate guidelines.

Method The Fuel-90 questionnaire was developed by research-active practitioners, based upon the 2021 Union of European Football Associations (UEFA) expert group statement on nutrition in elite soccer. The Fuel-90 questionnaire comprised 25 multiple choice questions divided into 5 sub-sections, assessing: (1) Fueling Fundamentals, (2) Match Day-1, (3) Pre-match Meal, (4) In-match fueling and (5) Post-match Recovery. The questionnaire was administered to 62 professionally Sport and Exercise Nutrition registered practitioners (SENR), 186 professional male adult soccer players from the English Premier League and Championship (PRO) and 145 recreational male adult soccer players (REC) ($n = 393$). Of the 186 professional soccer players, 31 completed a second questionnaire within 21 days of their first completion. *Results:* Construct validity was confirmed by significant differences in Fuel-90 score between the three groups (SENR: 24 ± 2; $96 \pm 6\% >$ PRO: 15 ± 4; $59 \pm 17\% >$ REC 13 ± 4; $51 \pm 14\%$; ($p < 0.005$). Fuel-90 demonstrated acceptable internal consistency (Cronbach's alpha = 0·86). Fuel-90 questionnaire was established ($r = 0.74$; $p < 0.001$), with no significant learning effect between test (17 ± 4) and re-test (18 ± 4; $p = 0.295$).

Conclusion The Fuel-90 questionnaire presents a valid, reliable, and practical tool for practitioners to assess professional soccer players' knowledge of current carbohydrate guidelines, thereby providing an initial framework to tailor subsequent education and nutrition interventions.

Keywords Soccer · Carbohydrate · Nutrition knowledge · Questionnaire

Introduction

Since the 1970s, it has become widely accepted that carbohydrate (CHO) is the primary fuel for muscle during soccer training and match play (1–4). Current evidence demonstrates the importance of CHO availability for both physical (5, 6) and technical skill (7–9) performance, with muscle glycogen depletion considered one of the key contributing factors toward fatigue and subsequent performance decrements in the latter stages of a match (10). Accordingly, a recent Union of European Football Associations (UEFA) expert group statement on nutrition in elite soccer highlighted the importance of consuming sufficient energy and CHO at different stages throughout the weekly microcycle. In particular, the consensus suggested that players should aim to consume 6–8 $g \cdot kg\ BM^{-1} \cdot day^{-1}$ of CHO the day before a match (i.e., MD-1) to elevate muscle and liver glycogen stores, 1–3 $g \cdot kg\ BM^{-1}$ of CHO in the 3–4 h prior to kick-off to promote liver glycogen stores, 30–60 $g \cdot h^{-1}$ of CHO during match play to maintain blood glucose concentrations and ~ 1 $g \cdot kg\ BM^{-1} \cdot h^{-1}$ in the first four hours

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post-match to replenish muscle and liver glycogen stores (11).

Over the past two decades, the physical demands of professional soccer match play have increased. In particular, there have been significant increases in high-intensity running and sprinting distances and also in the number of high-intensity runs and sprints (12, 13). Furthermore, the number of competitive matches is increasing, a trend that is expected to continue, with some professional players playing almost 80 matches per year (14–16). Professional soccer players typically expend around 2500–4500 kcal·day^{-1} (17, 18). These increasing demands on players further highlight the importance of players consuming adequate CHO at the right times to optimize health, performance and recovery. However, despite this, players often do not achieve the recommended CHO intakes. Professional players from the top English and Dutch leagues, typically consume ~ 4 g·kg BM^{-1} and ~ 5–6 g·kg BM^{-1} of CHO on training and match days, respectively, with sub-optimal intakes commonly observed on MD-1 (17–19). Recent data also indicate that English Premier League players only consume ~ 17 g·h^{-1} of CHO during match play (20), significantly lower than the recommended intake of 30–60 g·h^{-1} (11).

It is unclear why professional soccer players do not meet the recommended CHO requirements though one possibility may be a lack of knowledge and understanding of the current guidelines. Recent research has demonstrated that players lack knowledge and understanding on the role of nutrition's impact on performance, with players stating that a lack of nutrition knowledge is a barrier to adherence of nutritional guidelines (21, 22). While there are numerous contributing factors that influence an athlete's dietary intake and behavior (including physiological, lifestyle, beliefs, psychological, social and economic), higher nutrition knowledge has been positively associated with better dietary practices (23, 24). Currently, there are numerous sports nutrition knowledge questionnaires available, with some of these more generic in nature, designed for a broad range of athletes (25), while others are more sport- (26, 27) or nationality- (28, 29) specific. Sampson and colleagues recently validated the 'carbohydrate for endurance athletes in competition questionnaire' (CEAC-Q). The CEAC-Q, which comprises 25 multiple choice questions divided into 5 sub-sections, assesses knowledge of both scientific principles and practical application of contemporary CHO guidelines for endurance athletes. In this study, validation of the CEAC-Q was established following validity and reliability assessments among three different populations, general population, endurance athletes and accredited Sports Dieticians and Nutritionists (27). However, currently, there is no tool available to assess the nutrition knowledge of professional soccer players, specifically focused on fueling requirements (i.e., CHO intake), arguably one of the biggest performance priorities from a sports nutrition perspective (11).

By systematically assessing player's knowledge of the current CHO guidelines, practitioners working with this population could better design, facilitate, and evaluate specific education and coaching interventions to address gaps in knowledge to ultimately change behavior and improve performance. With this in mind, the aim of this study was to develop and validate a novel questionnaire to systematically and rapidly assess professional soccer player's knowledge of the 2021 UEFA CHO recommendations (11).

Materials and methods

Fuel-90 was developed by five performance nutritionists involved in applied soccer nutrition research and that also work as practitioners within professional soccer (considered the "expert panel"). The questionnaire was derived from original research and the guidelines outlined in the 2021 UEFA expert group statement on nutrition in elite soccer (11). The Fuel-90 validation process was similar to that of the CEAC-Q (27), with an overview shown in Fig. 1.

Defining the construct

Following initial concept and construct development discussions, the expert panel decided to focus the questionnaire on CHO recommendations for fueling performance and selected five sub-sections: (1) Fueling Fundamentals, (2) Match Day -1 (MD-1), (3) Pre-match Meal, (4) In-match Fueling, and (5) Post-match Recovery. Each sub-section comprised five questions, collectively totaling 25 questions, which aim to assess knowledge of both scientific principles (factual) and practical application (procedural) (27).

Recruitment of participants

For recruitment of participants in the content and face validity stages, a convenience sample of UK Sport and Exercise Nutrition registered (SENR) practitioners and professional players from the authors networks were contacted and invited to participate. For recruitment of participants in the construct validity stage, SENR practitioners in the authors networks and on the SENR email list were contacted and invited to participate. Professional players were invited to participate via a SENR practitioner at their respective club. A convenience sample of recreational players was invited via the authors' professional networks and by email. Sample size was estimated according to our primary outcome variable questionnaire total score, based upon a validation study of a similar carbohydrate knowledge questionnaire for endurance athletes (27). These data would provide an effect

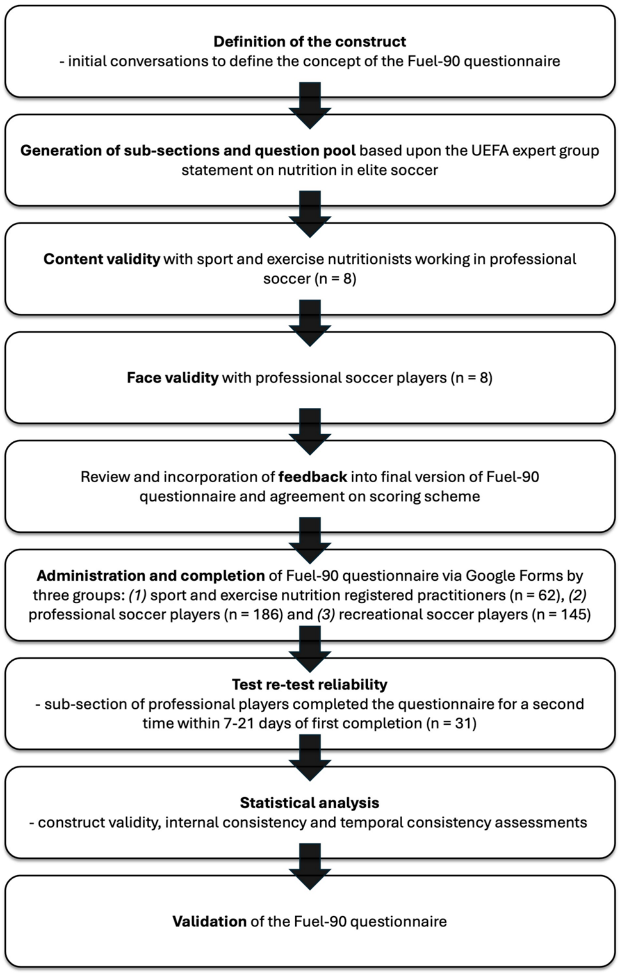

Fig. 1 A step-by-step overview of the Fuel-90 questionnaire development process

size of $f = 1.14$ where a sample size of 12 in each group would provide an alpha value of 0.05 and statistical power of 0.95 (G*Power, Version 3.1). Prior to completion of the questionnaire, all participants were informed of the purpose of the study and declared consent. Ethical approval was granted by the Ethics Committee of Birmingham City University, United Kingdom (approval reference: Carter/3540/R(B)/2019/Nov/HELS FAEC) and the study was conducted according to the Declaration of Helsinki.

Content and face validity assessments

Subsequently focus groups and pilot testing of the questionnaire was conducted with eight SENR practitioners and that worked in professional soccer, followed by eight professional soccer players competing in the English Premier League (February 2022). Practitioners provided feedback on the appropriateness, clarity, and accuracy of content and identified if there were any significant omissions (content validity), while players provided feedback on the questionnaire's clarity, comprehensibility, and appropriateness for soccer players (face validity) (30, 31). The qualitative feedback provided was reviewed by the research team and incorporated into the final version of the questionnaire endorsing content and face validity.

Fuel-90 questionnaire

The final questionnaire was written in English and consisted of 25 multiple choice questions (Table 1). Questions had one correct answer and for each question there was an "unsure" option to reduce the likelihood of guessing. Each question was assigned + 1 points for the correct answer and 0 for an incorrect or unsure answer (25). Participants could only select one answer. The maximum possible score was 5 for each sub-section and 25 for the entire questionnaire. The questionnaire was administered electronically via Google Forms (Google, USA), with questions randomly ordered for each participant to minimize the likelihood of order bias (32). Prior to completion of the questionnaire, participants were presented with the participant information sheet and required to provide consent electronically. Soccer players were required to confirm that they were either a "recreational" or "professional" player, while practitioners were required to confirm that they were a SENR practitioner.

Construct validity assessment

To assess construct validity, three distinct groups were recruited: (1) SENR practitioners, (2) professional soccer players (competing in the English Premier League and Championship at 1st team and U23 level), and (3) recreational soccer players (data collection May 2022–May 2024). It was considered that the SENR practitioners were "subject experts" and would therefore have high knowledge, while the two groups of footballers would have been expected to have received varying levels professional and accredited nutrition support. As such, it was hypothesized (a priori) that these three groups would have different levels of knowledge of the current CHO guidelines—SENR practitioners > professional soccer players > recreational soccer players (33).

Test–re-test reliability

Temporal consistency was assessed via a test–re-test protocol. Groups of professional soccer players were provided with the choice of completing the questionnaire for a second time, 7–21 days after initial completion (25, 27). These players were selected as this is the intended population for which this questionnaire is to be used with. A period of less than 21 days is considered long enough for the questions to be forgotten yet short enough to minimize any significant

Table 1 Fuel-90 questionnaire—questions and relevant scores

1. Fueling Fundamentals	Score: _/5
Q1. The daily energy (i.e., calorie) requirements for male professional footballers are likely to be between:	
(a) 1000 and 1500 kcal.day^{-1}	0
(b) 1500 and 2500 kcal.day^{-1}	0
(c) 2500 and 4500 kcal.day^{-1}	1
(d) More than 4500 kcal.day^{-1}	0
(e) Unsure	0
Q2. Consuming enough energy each day can:	
(a) Increase our ability to perform daily training, including physical (e.g., high-speed running and sprinting) and technical (e.g., passing, shooting and dribbling) actions	0
(b) Increase muscle growth	0
(c) Reduce the risk of illness and injury	0
(d) All of the above	1
(e) Unsure	0
Q3. The main energy source to fuel football training and matches is:	
(a) Fat	0
(b) Protein	0
(c) Carbohydrate	1
(d) Vitamins and minerals	0
(e) All of the above	0
(f) Unsure	0
Q4. The carbohydrate required to fuel football training and matches is provided from the:	
(a) Glycogen (stored carbohydrate) within our muscles	0
(b) Glycogen (stored carbohydrate) within our liver	0
(c) Glucose (sugar) within our blood	0
(d) All of the above	1
(e) Unsure	0
Q5. The daily carbohydrate requirements for male professional footballers are likely to be:	
(a) Always 1–3 g per kilogram of your body mass (e.g., 80–240 g for an 80 kg player)	0
(b) On a sliding scale from 3–8 g per kilogram of your body mass depending on the physical demands of training, fixture schedule and individual goals (e.g., 240–640 g for an 80 kg player)	1
(c) On a sliding scale from 8–12 g per kilogram of your body mass depending on the physical demands of training, fixture schedule and individual goals (e.g., 640–960 g for an 80 kg player)	0
(d) The same each day	0
(e) Unsure	0
2. Match Day -1 (MD-1)	Score: _/5
Q6. The most important nutritional goal the day before a match is to:	
(a) Consume enough carbohydrate to increase the amount of glycogen (stored carbohydrate) within our muscles and liver	1
(b) Consume enough protein to increase the amount of protein available for muscle growth	0
(c) Consume enough fat so that we have enough energy stored within our body	0
(d) Increase the amount of fiber that we consume so that we can better digest our food	0
(e) Unsure	
Q7. Starting a match with low glycogen (stored carbohydrate) stores is likely to decrease:	
(a) the total distance that we can cover during the match	0
(b) the distance covered at high-speed running and sprinting	0
(c) our ability to perform technical actions, such as passing, shooting and dribbling	0
(d) all of the above	1
(e) none of the above	0
(f) Unsure	0

Table 1 (continued)

2. Match Day -1 (MD-1)	Score: _/5
Q8. To help increase our muscle glycogen (stored carbohydrate) stores before a match, the carbohydrate requirements for male professional footballers on MD-1 (in a one match per week micro-cycle) is between:	
(a) Less than 3 g per kilogram of your body mass (e.g., less than 240 g of carbohydrate for an 80 kg player)	0
(b) 4–5 g per kilogram of your body mass (e.g., 320–400 g of carbohydrate for an 80 kg player)	0
(c) 6–8 g per kilogram of your body mass (e.g., 480–640 g of carbohydrate for an 80 kg player)	1
(d) 9–12 g per kilogram of your body mass (e.g., 720–960 g of carbohydrate for an 80 kg player)	0
(e) Unsure	0
Q9. The most appropriate examples of carbohydrate rich foods which could be consumed on MD-1 include:	
(a) Breads; cereals; pasta; rice pudding; fruit juices	1
(b) Steak; avocado; eggs; cheese; yoghurt	0
(c) Salad; chicken, couscous; yogurt; potatoes	0
(d) Butter; vegetables; legumes; milk; olive oil	0
(e) Unsure	0
Q10. Carbohydrate drinks are not as good at increasing muscle glycogen (stored carbohydrate) stores when compared with foods that contain an equal amount of carbohydrate:	
(a) True	0
(b) False	1
(c) Unsure	0
3. Pre-match Meal	Score: _/5
Q11. When should the pre-match meal be consumed:	
(a) Immediately before the warm-up	0
(b) In the 1–2 h before the match	0
(c) In the 3–4 h before the match	1
(d) Whenever you want	0
(e) Unsure	0
Q12. A pre-match meal should…	
(a) Increase liver glycogen (stored carbohydrate) stores	0
(b) Ensure a player feels comfortable and to prevent hunger	0
(c) Avoid foods high in both fat and fiber	0
(d) All of the above	1
(e) Unsure	0
Q13. It is recommended that carbohydrate intake in the pre-match meal contains:	
(a) Less than 1 g per kilogram of your body mass (e.g., less than 80 g of carbohydrate for an 80 kg player)	0
(b) 1–3 g per kilogram of your body mass (e.g., 80–240 g of carbohydrate for an 80 kg player)	1
(c) 4–5 g per kilogram of your body mass (e.g., 320–400 g of carbohydrate for an 80 kg player)	0
(d) More than 5 g per kilogram of your body mass (e.g., 240–400 g of carbohydrate for an 80 kg player)	0
(e) Unsure	0
Q14. For a 12:30 kick-off, which of the following would an optimal breakfast/pre-match on match day?	
(a) A large bowl of porridge with a banana and honey, a bagel with jam and a large glass of fruit juice	1
(b) Cheese & ham omelet with a slice of toast and a glass of water	0
(c) A cereal bar (35 g), a pot of natural yogurt and a small glass of milk	0
(d) Nothing	0
(e) Unsure	0
Q15. In terms of providing carbohydrate, which would be the most appropriate drink to consume as part of the pre-match meal?	
(a) Water (500 ml)	0
(b) Milk (500 ml)	0
(c) Fruit juice (500 ml)	1
(d) Coffee with milk (300 ml)	0
(e) Unsure	0

Table 1 (continued)

4. In-match Fueling	Score: _/5
Q16. Consuming carbohydrate during a match can improve performance by?	
(a) Maintaining blood glucose (sugar) levels	0
(b) Increasing the amount of glucose (sugar) available for the working muscles	0
(c) Stimulating the central nervous system (the brain)	0
(d) Sparing liver glycogen (stored carbohydrate) stores	0
(e) All of the above	1
(f) Unsure	0
Q17. How much carbohydrate should be consumed per hour of a match (this is considered from the start of the warm-up to the final whistle)?	
(a) None	0
(b) Less than 30 g per hour	0
(c) 30–60 g per hour	1
(d) 61–90 g per hour	0
(e) It depends on your body weight	0
(f) Unsure	0
Q18. Consuming carbohydrate during a match …	
(a) may improve both physical (e.g., high-speed running and sprinting) and technical (e.g., passing, shooting and dribbling) actions	1
(b) may improve physical (e.g., high-speed running and sprinting) but not technical (e.g., passing, shooting and dribbling) actions	0
(c) does not influence physical (e.g., high-speed running and sprinting) or technical (e.g., passing, shooting and dribbling) actions	0
(d) Unsure	0
Q19. Which of the following food/drink choices would be the most suitable throughout a match (this is considered from the start of the warm-up to the final whistle) to optimize fueling?	
(a) 4 slices of orange and a handful of nuts	0
(b) Electrolyte drink (500 ml), a sports drink (30 g carbohydrate, 500 ml) and a carbohydrate gel (20 g carbohydrate)	0
(c) 1 slice of banana bread and water (500 ml)	0
(d) A sports drink (30 g carbohydrate, 500 ml), 2 carbohydrate gels (50 g carbohydrate) and a banana (20 g carbohydrate)	1
(e) Water (1000 ml) and a carbohydrate gel (20 g carbohydrate)	0
(f) Unsure	0
Q20. When should you consume carbohydrate during a match (this is considered from the start of the warm-up to the final whistle)?	
(a) During the warm-up only	0
(b) At half time only	0
(c) During breaks in play and at half time	0
(d) During the warm-up, before kick-off, at half time and during breaks in play	1
(e) Only when you start to feel tired	0
(f) Unsure	1
5. Post-match Recovery	Score: _/5
Q21. To optimize recovery following a match, footballers should consume foods and drinks that are high in which of the following?	
(a) Carbohydrate, fat and protein	0
(b) Only protein	0
(c) Only carbohydrate	0
(d) Carbohydrate, protein and fluid	1
(e) Unsure	0
Q22. How long after you have finished training / a match should you consume food or drink to optimize recovery?	
(a) It doesn't make a difference when you first consume any food or drink	0
(b) Immediately after (within 1 h)	1
(c) Leave until 2–3 h after (before consuming any food or drink)	0
(d) Unsure	0

Table 1 (continued)

5. Post-match Recovery	Score: _/5
Q23. In the first 4 h after a match, how much carbohydrate should you eat to optimize the replacement of muscle glycogen (stored carbohydrate) stores?	
(a) Less than 0.5 g of carbohydrate per kg body mass per hour (e.g., less than 40 g of carbohydrate for an 80 kg player per hour)	0
(b) 0.5–1.0 g of carbohydrate per kg body mass per hour (e.g., 40–80 g of carbohydrate for an 80 kg player per hour)	0
(c) 1.0–1.5 g of carbohydrate per kg body mass per hour (e.g., 80–120 g of carbohydrate for an 80 kg player per hour)	1
(d) More than 1.5 g of carbohydrate per kg body mass per hour (e.g., more than 120 g of carbohydrate for an 80 kg player per hour)	0
(e) The amount of carbohydrate consumed does not influence the recovery rate at which glycogen stores are replaced	0
(f) Unsure	0
Q24. During a congested fixture period (i.e., two fixtures within 72 h), carbohydrate intake should be ….. between matches	
(a) High (i.e., 6–8 g of carbohydrate per kg body mass) for up to 24 h	0
(b) High (i.e., 6–8 g of carbohydrate per kg body mass) for up to 24–48 h	0
(c) High (i.e., 6–8 g of carbohydrate per kg body mass) for up to 48–72 h	1
(d) Moderate (i.e., 4–6 g of carbohydrate per kg body mass) for up to 24–48 h	0
(e) Unsure	0
Q25. Which of the following choices would be the most suitable for optimal nutrition after a match?	
(a) A whey protein shake with water (consumed within 60 min post-match)	0
(b) Chicken wings and a 500 ml electrolyte drink (consumed within 60 min post-match)	0
(c) A whey protein shake with water (consumed within 60 min post-match) and a medium portion of lasagne with salad (consumed within 60–120 min post-match)	0
(d) A smoothie (milk, whey protein, a banana and berries; consumed within 60 min post-match) followed by a large portion of chicken stir fry and noodles (consumed within 60–120 min post-match) and a medium portion of apple crumble (consumed within 120–180 min post-match)	1
(e) Unsure	0
	Total score: _/25

change in knowledge (34). Players that volunteered to complete the questionnaire a second time were sent a second Google Form link, 7 days after their first completion, and asked to complete the questionnaire again within the next 14 days. No formal nutrition education was advised or provided between tests.

Statistical analysis

All data were initially assessed for normality of distribution using the Shapiro–Wilk test. Statistical comparisons to compare total score and scores from each of the five sub-sections between groups were performed using a one-way analysis of variance (ANOVA). Where significant main effects were present, Scheffe post hoc analysis was conducted to locate specific differences due to unequal group sizes. Statistically significant differences between the three groups (total and sub-section scores) was seen as evidence of construct validity of the questionnaire (35). Internal consistency of the questionnaire was assessed using Cronbach's alpha, with a score of >0.7 (within a range of 0.0–1.0) indicating acceptable internal consistency (31, 36). Cronbach's alpha determines the extent to which all the questions in a questionnaire measure the same concept or construct and hence it is connected to the inter-relatedness of the questions within a questionnaire. The test–re-test reliability protocol used Pearson's correlation coefficient to compare questionnaire results from the first versus the second test, for total score and scores from each of the five sub-sections. All statistical analyses were completed using SPSS (Version 29; SPSS; Chicago, IL; USA) where $P<0.05$ is indicative of statistical significance and figures were created on Prism 10 (Version 10.4.1; GraphPad; Boston, MA; USA). Data are presented as mean ± SD.

Results

Participants. In total, 393 participants completed the questionnaire, comprising 62 SENR practitioners, 186 professional players (from 12 English Premier League teams and 1 English Championship team) and 145 recreational soccer players. Of the 186 professional players, 31 (17%) also completed the questionnaire a second time (test–re-test reliability).

Fuel-90 scores. Total score in the recreational (REC) group (12.7 ± 3.6; 50.7 ± 14.4%) was significantly lower than the professional (PRO) group (14.8 ± 4.2; 59.3 ± 16.7%; $p = 0.005$) and the SENR group (23.9 ± 1.5; 95.6 ± 5.9%; $p < 0.001$; Fig. 2A). Total score in the PRO group was significantly lower than the SENR group ($p < 0.001$).

For the first sub-section, Fueling Fundamentals, scores were similar between the REC (2.9 ± 1.3; 58.5 ± 25.1%) and PRO groups (2.9 ± 1.3; 58.0 ± 25.9%; $p = 0.980$), with both groups scoring significantly less than the SENR group (4.9 ± 0.4; 97.4 ± 7.7%; $p < 0.001$ for both comparisons; Fig. 2B).

Scores for MD-1 (sub-section two) were significantly lower in the REC group (2.6 ± 1.1; 52.1 ± 21.5%) than the PRO group (3.3 ± 1.1; 65.2 ± 22.0%; $p < 0.001$), with both groups scoring significantly less than the SENR group (4.8 ± 0.5; 96.1 ± 10.1%; $p < 0.001$ for both comparisons; Fig. 2C).

Scores for Pre-match Meal (sub-section three) were significantly lower in the REC group (2.9 ± 1.2; 57.1 ± 24.1%) than the PRO group (3.3 ± 1.1; 65.1 ± 21.3%; $p = 0.003$), with both groups scoring significantly less than the SENR group (4.9 ± 0.3; 97.4 ± 6.8%; $p < 0.001$ for both comparisons; Fig. 2D).

Scores for In-match Fueling (sub-section four) were significantly lower in the REC group (1.8 ± 1.3; 37.0 ± 25.9%) than the PRO group (2.5 ± 1.3; 49.4 ± 25.1%; $p < 0.001$), with both groups scoring significantly less than the SENR group (4.6 ± 0.7; 91.6 ± 14.3%; $p < 0.001$ for both comparisons; Fig. 2E).

Scores for Post-match Recovery (sub-section five) were significantly lower in the REC group (2.4 ± 1.1; 48.8 ± 21.7%) than the PRO group (2.9 ± 1.1; 58.7 ± 22.2%; $p < 0.001$), with both groups scoring significantly less than the SENR group (4.8 ± 0.5; 95.2 ± 10.7%; $p < 0.001$ for both comparisons; Fig. 2F).

Internal consistency. The Fuel-90 questionnaire demonstrated acceptable internal consistency with a Cronbach's alpha value of 0.86. Cronbach alpha values for sub-section's one, two, three, four and five were 0.53, 0.56, 0.44, 0.59 and 0.53, respectively.

Test–re-test reliability. There was no significant learning effect for total score between the test (i.e., first completion; 17 ± 4; 68 ± 14%) and the re-test (i.e., second completion; 18 ± 4; 70 ± 16%; $p = 0.295$; $d = 0.19$). Test–re-test reliability for the entire Fuel-90 questionnaire was established ($r = 0.74$; $p < 0.001$), but not for the individual subsections (Table 2).

Discussion

The aim of the current study was to develop and validate a novel questionnaire to assess professional soccer players' knowledge of current CHO guidelines based on the 2021 UEFA expert group statement on nutrition in elite soccer. The approach taken in this study establishes validation of the Fuel-90 questionnaire, providing a potentially useful tool for practitioners to quickly and easily assess players' knowledge of current CHO guidelines.

To our knowledge, Fuel-90 is the first questionnaire to assess professional soccer players' knowledge of the 2021 UEFA CHO guidelines. A sport- and nutrient-specific questionnaire was selected due to poor CHO-specific knowledge among many athletes (27, 37, 38) and because many professional soccer players consume suboptimal CHO intakes during training and match days (17–20). Recent qualitative research has also highlighted that players believe that a poor nutrition knowledge is a barrier to adherence of current nutritional guidelines (21, 22). The validated Fuel-90 questionnaire is a tool that practitioners working with professional soccer players can use to better design, facilitate, and evaluate bespoke education and coaching interventions to address gaps in knowledge to ultimately change dietary intake and behavior.

Knowledge scores were the greatest in the SENR group in all five sub-sections and total score compared to the PRO and the REC groups. Similarly, the PRO group demonstrated higher knowledge of the current CHO guidelines compared to the REC group in four of the five sub-sections and total score (Fig. 2). These data are consistent with similar nutrition knowledge questionnaire validation studies, which also report that sport and exercise nutritionists / dieticians (i.e., subject experts) consistently demonstrate greater knowledge scores compared to other athletic cohorts irrespective of sport or competitive level (27, 29, 39). Total knowledge score in the SENR group (~ 96%) was similar compared to those of other SENR practitioners from the UK and Ireland (~ 91%; 29) and Australian sports dieticians (~ 91%; 39) albeit for different sport nutrition knowledge questionnaires. Total knowledge scores in the PRO (59%) and REC (51%) groups fell within a similar range to those previously reported in other athletic populations (26, 40). A systematic review of general sports nutrition knowledge questionnaires reported that athletes had a mean knowledge score of ~ 50%, with athletic populations generally scoring equal to or greater than non-athletic comparison groups (40). In a similar design to the present study, Sampson and colleagues reported clear distinctions in total knowledge scores between general population (~ 17%), endurance athletes (~ 46%) and SENR practitioners (~ 76%) when validating the 'carbohydrate

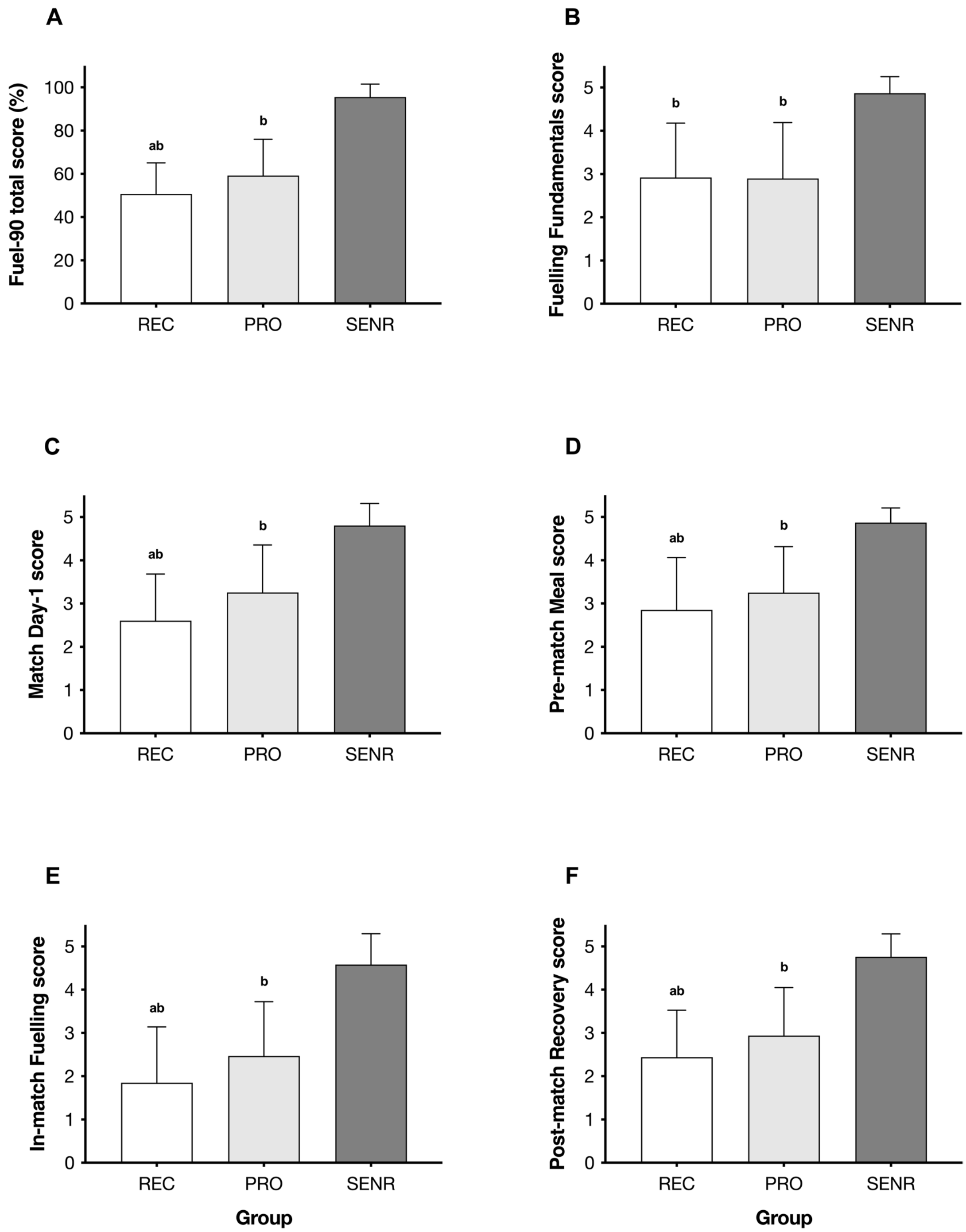

Fig. 2 Fuel-90 questionnaire scores of recreational soccer players (REC; $n = 145$; white bars), professional soccer players (PRO; $n = 186$; light gray bars) and sport and exercise registered nutritionists (SENR; $n = 62$; dark gray bars); **A** Total score (%), **B** sub-section one: Fueling Fundamentals, **C** sub-section two: Match Day-1, **D** sub-section three: Pre-match Meal, **E** sub-section four: In-match Fueling, and **F** sub-section five: Post-match Recovery. [a]denotes significant difference from professional players ($p < 0.05$). [b]denotes significant difference from registered sport and exercise nutritionists ($p < 0.005$)

for endurance athletes in competition questionnaire' (CEAC-Q; 27). Like the aforementioned studies, the distinct knowledge score differences between the three groups within the present study reveal varying levels of knowledge of the current CHO guidelines, demonstrating construct validity of the Fuel-90 questionnaire.

Reliability of the Fuel-90 questionnaire was supported in two ways via internal consistency and temporal consistency.

Table 2 Fuel-90 questionnaire test re-test reliability scores from professional soccer players ($n=31$; mean ± SD)

	1st score	2nd score	Pearson's correlation coefficient (r)	P value
Sub-section one Fueling Fundamentals	3.5 ± 1.3	3.6 ± 1.4	0.68	$P<0.001$
Sub-section two Match Day -1	3.7 ± 0.9	3.7 ± 1.1	0.44	$P=0.013$
Sub-section three Pre-match Meal	3.7 ± 1.0	3.9 ± 0.8	0.47	$P=0.008$
Sub-section four In-match Fueling	2.5 ± 1.1	2.9 ± 1.3	0.56	$P=0.001$
Sub-section five Post-match Recovery	3.5 ± 0.8	3.6 ± 1.0	0.29	$P=0.12$
Total Fuel-90 score	**17.0 ± 3.6**	**17.5 ± 3.9**	**0.74**	$\boldsymbol{P<0.001}$

The Fuel-90 questionnaire demonstrated acceptable internal consistency with a Cronbach's alpha value of 0.86. However, for individual sub-sections, Cronbach's alpha values were all < 0.7. The low number of questions (five) in each sub-section is likely to have been the cause as it is often shown that fewer questions can result in lower Cronbach's alpha values (39, 41). The temporal consistency of the Fuel-90 questionnaire was determined via a test–re-test protocol, with 7–21 days between tests, in line with other nutrition knowledge questionnaires, to minimize the effect of memory and upskilling / learning (25, 27). Overall test–re-test reliability was established through achieving the required 0.7 Pearson correlation coefficient value. One limitation of this approach is that motivated individuals may choose to upskill and increase knowledge between attempts. However, in the professional players that repeated the questionnaire, there was no significant learning effect between the first (~ 68%) and second (~ 70%) completion, suggesting that the Fuel-90 questionnaire would provide consistent scores between tests where there is no change in an individual's knowledge.

While an increase in nutrition knowledge alone may not necessarily result in improved dietary behaviors and intake among players, practitioners working with this population should use coaching interventions that enhance enablers and reduce barriers to facilitate change (42). According to Michie's "COM-B" model of behavior change, one of the key factors for a player to engage in a desired nutritional behavior is that they require the physical and psychological *capability* to perform the specific behavior (43). The Fuel-90 questionnaire incorporates elements of both theoretical knowledge and practical application from the 2021 UEFA guidelines, which can help players and practitioners alike, identify gaps in knowledge (i.e., *capability*), and subsequently bespoke education and coaching interventions. A recent review reported that sport nutrition questionnaires published between 2016 and 2021 were generic and lengthy in nature. The mean number of questions was 59 ± 18, with most questionnaires encompassing a broad range different nutrients and nutrition-related concepts (31). Research has shown that lengthy questionnaires may encourage respondents to respond carelessly (44). The Fuel-90 questionnaire is a 25-item questionnaire that is sport- (i.e., soccer) and nutrient- (i.e., CHO) specific. It has been designed to be administered online via a mobile device making it quick and easy for the player to complete. The practicality of this tool is particularly important considering the already high burden placed on professional soccer players, specifically from sports science and medicine monitoring perspective (45).

A limitation of this study is that we used convenience sampling for participant recruitment. This *may* have impacted the representativeness of the sample. However, considering the large sample size ($n=393$) including the high caliber of players (186 professional players from 12 English Premier League and 1 Championship teams) recruited, this *may* not be the case. We were also unable to calculate questionnaire completion rates as the questionnaire was distributed via numerous methods including group emails and messages, making total exposure unattainable. While the Fuel-90 questionnaire was based upon current UEFA guidelines for professional soccer players, it was developed and validated by UK-based practitioners and players and administered in the English language. Future research may wish to adapt the Fuel-90 questionnaire to ensure relevance to specific countries and cultures (including female players), and subsequently validate the adapted version with the intended population in their respective language as has been previously done with other sport nutrition knowledge questionnaires (28, 29). To better understand why professional players are not currently achieving the recommended CHO requirements, future research may wish to use the Fuel-90 questionnaire (i.e., knowledge assessment) alongside CHO intake data and player perspectives to further explore the relationship between knowledge and practice.

In conclusion, the present study resulted in the formation of a valid and reliable 25-item questionnaire for use with professional soccer players, to assess their knowledge of the current CHO guidelines. The Fuel-90 questionnaire demonstrated content and face validity, construct validity, and reliability. This questionnaire offers a useful tool for practitioners and players alike, to identify gaps in knowledge before subsequently developing bespoke education and coaching interventions to increase capability and ultimately improve dietary intake and behavior.

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Data availability All data related to this study is available at: doi:10.17632/5tf389cjnj.1

Declarations

Conflict of interests The authors have no relevant financial or non-financial interests to disclose.

Ethical approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Birmingham City University, United Kingdom (approval reference: Carter/3540/R(B)/2019/Nov/HELS FAEC).

Consent to participate Informed consent was obtained from all individual participants included in the study.

References

1. Saltin B. (1973) Metabolic fundamentals in exercise. Med Sci Sports [Internet] 5(3):137–46. http://www.ncbi.nlm.nih.gov/pubmed/4270581
2. Krustrup P, Mohr M, Steensberg A, Bencke J, Klær M, Bangsbo J (2006) Muscle and blood metabolites during a soccer game: Implications for sprint performance. Med Sci Sports Exerc 38(6):1165–1174
3. Krustrup P, Mohr M, Nybo L, Draganidis D, Randers MB, Ermidis G, et al (2022) Muscle metabolism and impaired sprint performance in an elite women's football game. Scand J Med Sci Sports [Internet]. 32 Suppl 1(S1):27–38. http://www.ncbi.nlm.nih.gov/pubmed/34171140
4. Gunnarsson TP, Bendiksen M, Bischoff R, Christensen PM, Lesivig B, Madsen K, et al (2013) Effect of whey protein- and carbohydrate-enriched diet on glycogen resynthesis during the first 48 h after a soccer game. Scand J Med Sci Sports [Internet]. 23(4):508–15. http://www.ncbi.nlm.nih.gov/pubmed/22107250
5. Rodriguez-Giustiniani P, Rollo I, Witard OC, Galloway SDR. 2019. Ingesting a 12% carbohydrate-electrolyte beverage before each half of a soccer match simulation facilitates retention of passing performance and improves high-intensity running capacity in academy players. Int J Sport Nutr Exerc Metab [Internet]. 1;29(4):397–405. http://www.ncbi.nlm.nih.gov/pubmed/30507267
6. Souglis AG, Chryssanthopoulos CI, Travlos AK, Zorzou AE, Gissis IT, Papadopoulos CN et al. (2013) The effect of high vs. low carbohydrate diets on distances covered in soccer. J strength Cond Res [Internet]. 27(8):2235–47. http://www.ncbi.nlm.nih.gov/pubmed/23168373
7. Currell K, Conway S, Jeukendrup AE (2009)Carbohydrate ingestion improves performance of a new reliable test of soccer performance. Int J Sport Nutr Exerc Metab [Internet]. 19(1):34–46. http://www.ncbi.nlm.nih.gov/pubmed/19403952
8. Harper LD, Stevenson EJ, Rollo I, Russell M (2017) The influence of a 12% carbohydrate-electrolyte beverage on self-paced soccer-specific exercise performance. J Sci Med Sport [Internet]. 20(12):1123–9. http://www.ncbi.nlm.nih.gov/pubmed/28483560
9. Russell M, Benton D, Kingsley M. (2012) Influence of carbohydrate supplementation on skill performance during a soccer match simulation. J Sci Med Sport [Internet]. 15(4):348–54. https://linkinghub.elsevier.com/retrieve/pii/S1440244011004804
10. Mohr M, Vigh-Larsen JF, Krustrup P. (2022) Muscle glycogen in elite soccer–A perspective on the implication for performance, fatigue, and recovery. front Sport Act Living [Internet]. 25;4:1–4. https://www.frontiersin.org/articles/https://doi.org/10.3389/fspor.2022.876534/full
11. Collins J, Maughan RJ, Gleeson M, Bilsborough J, Jeukendrup A, Morton JP, et al (2020) UEFA expert group statement on nutrition in elite football. Current evidence to inform practical recommendations and guide future research. Br J Sports Med [Internet] 1–27. http://www.ncbi.nlm.nih.gov/pubmed/33097528
12. Barnes C, Archer D, Hogg B, Bush M, Bradley P. 2014. The evolution of physical and technical performance parameters in the english premier league. Int J Sports Med [Internet]. 10;35(13):1095–100. http://www.thieme-connect.de/DOI/DOI?https://doi.org/10.1055/s-0034-1375695
13. Allen T, Taberner M, Zhilkin M, Rhodes D (2023) Running more than before? The evolution of running load demands in the English Premier League. Int J Sports Sci Coach [Internet]. 3;174795412311645. http://journals.sagepub.com/doi/https://doi.org/10.1177/17479541231164507
14. FIFPRO. At the limit - player workload in elite professional men's football. 2019.
15. FIFPRO. FIFPRO player workload monitoring. Men's Football Report. 2024.
16. Nassis GP, Massey A, Jacobsen P, Brito J, Randers MB, Castagna C, et al. (2020) Elite football of 2030 will not be the same as that of 2020: Preparing players, coaches, and support staff for the evolution. Scand J Med Sci Sports [Internet]. 30(6):962–4. http://www.ncbi.nlm.nih.gov/pubmed/32424904
17. Anderson L, Orme P, Naughton RJ, Close GL, Milsom J, Rydings D, et al. 2017. Energy intake and expenditure of professional soccer players of the english premier league: evidence of carbohydrate periodization. Int J Sport Nutr Exerc Metab [Internet].

27(3):228–38. http://journals.humankinetics.com/doi/https://doi.org/10.1123/ijsnem.2016-0259
18. Brinkmans NYJ, Iedema N, Plasqui G, Wouters L, Saris WHM, van Loon LJC, et al. (2019) Energy expenditure and dietary intake in professional football players in the Dutch Premier League: Implications for nutritional counselling. J Sports Sci [Internet]. 37(24):2759–67. https://www.tandfonline.com/doi/full/https://doi.org/10.1080/02640414.2019.1576256
19. Carter JL, Lee DJ, Perrin CG, Ranchordas MK, Cole M (2023) Significant changes in resting metabolic rate over a competitive match week are accompanied by an absence of nutritional periodization in male professional soccer players. Int J Sport Nutr Exerc Metab 33(6):349–359
20. Kasper AM, Allan J, Hodges D, Catterson P, Mason L, Fitzpatrick J, et al 2024 Nutritional habits of professional team sport athletes: an insight into the carbohydrate, fluid, and caffeine habits of english premier league football players during match play. J Sports Sci [Internet]. 42(17):1589–96. http://www.ncbi.nlm.nih.gov/pubmed/39323036
21. Carter JL, Lee DJ, Ranchordas MK, Cole M. (2023) Perspectives of the barriers and enablers to nutritional adherence in professional male academy football players. Sci Med Footb [Internet]. 7(4):394–405. http://www.ncbi.nlm.nih.gov/pubmed/36082957
22. Carney DJ, Hannon MP, Murphy RC, Close GL, Morton JP. (2024) Perspectives on the role of nutrition in influencing academy soccer player development and performance: A qualitative case study of key stakeholders from an English category one soccer academy. J Sports Sci [Internet]. 42(1):61–72. http://www.ncbi.nlm.nih.gov/pubmed/38394029
23. Birkenhead KL, Slater G. (2015) A review of factors influencing athletes' food choices. sport Med [Internet]. 5;45(11):1511–22. http://link.springer.com/https://doi.org/10.1007/s40279-015-0372-1
24. Janiczak A, Alcock R, Forsyth A, Trakman GL. (2024) A systematic review of interventions targeting modifiable factors that impact dietary intake in athletes. Br J Nutr [Internet]. 131(2):229–47. https://www.cambridge.org/core/product/identifier/S0007114523001769/type/journal_article
25. Trakman GL, Forsyth A, Hoye R, Belski R (2017) The nutrition for sport knowledge questionnaire (NSKQ): Development and validation using classical test theory and Rasch analysis. J Int Soc Sports Nutr 14(1):1–11
26. Furber MJW, Roberts JD, Roberts MG (2017) A valid and reliable nutrition knowledge questionnaire for track and field athletes. BMC Nutr [Internet]. 3(1):36. http://bmcnutr.biomedcentral.com/articles/https://doi.org/10.1186/s40795-017-0156-0
27. Sampson G, Pugh JN, Morton JP, Areta JL. (2022) Carbohydrate for endurance athletes in competition questionnaire (CEAC-Q): validation of a practical and time-efficient tool for knowledge assessment. Sport Sci Health [Internet]. 18(1):235–47. https://link.springer.com/https://doi.org/10.1007/s11332-021-00799-8
28. Bauhaus H, Jensen PM, Braun H, Thevis M. (2023). Evaluation of validity and reliability of a german general and sports nutrition knowledge questionnaire for athletes and coaches (GSNKQ-AC). Nutrients [Internet]. 15(22):4844. https://www.mdpi.com/2072-6643/15/22/4844
29. Edmonds C, Tam R, Madigan S, Gubb L, Beck KL, Gifford JA, et al. (2023) Validation of a sports nutrition knowledge questionnaire for athletes in the United Kingdom and Ireland. J Nutr Sci [Internet]. 12:e2. https://www.cambridge.org/core/product/identifier/S2048679022001094/type/journal_article
30. Trakman GL, Forsyth A, Hoye R, Belski R (2017) Developing and validating a nutrition knowledge questionnaire: key methods and considerations. Public Health Nutr [Internet]. 20(15):2670–9. https://www.cambridge.org/core/product/identifier/S1368980017001471/type/journal_article
31. Tam R, Gifford JA, Beck KL. (2022) Recent Developments in the Assessment of Nutrition Knowledge in Athletes. Curr Nutr Rep [Internet]. 11(2):241–52. http://www.ncbi.nlm.nih.gov/pubmed/35174474
32. Regmi PR, Waithaka E, Paudyal A, Simkhada P, van Teijlingen E. (2016) Guide to the design and application of online questionnaire surveys. Nepal J Epidemiol [Internet]. (4):640–4. http://www.ncbi.nlm.nih.gov/pubmed/28804676
33. Vázquez-Espino K, Rodas-Font G, Farran-Codina A (2022) Sport nutrition knowledge, attitudes, sources of information, and dietary habits of sport-team athletes. Nutrients [Internet]. 14(7):1345. https://www.mdpi.com/2072-6643/14/7/1345
34. Kline P (2000) The handbook of psychological testing, 2nd edn. Routledge, London
35. Blennerhassett C, McNaughton LR, Cronin L, Sparks SA. (2019) Development and implementation of a nutrition knowledge questionnaire for ultraendurance athletes. Int J Sport Nutr Exerc Metab [Internet]. 29(1):39–45. http://www.ncbi.nlm.nih.gov/pubmed/29757047
36. Tavakol M, Dennick R (2011) Making sense of Cronbach's alpha. Int J Med Educ [Internet] 2:53–5. http://www.ncbi.nlm.nih.gov/pubmed/28029643
37. Sampson G, Morton JP, Areta JL (2023) Mind the gap: limited knowledge of carbohydrate guidelines for competition in an international cohort of endurance athletes. J Nutr Sci [Internet]. 12:e68. http://www.ncbi.nlm.nih.gov/pubmed/37457680
38. Spendlove JK, Heaney SE, Gifford JA, Prvan T, Denyer GS, O'Connor HT (2012) Evaluation of general nutrition knowledge in elite Australian athletes. Br J Nutr [Internet]. 107(12):1871–80. http://www.ncbi.nlm.nih.gov/pubmed/22018024
39. Tam R, Beck K, Scanlan JN, Hamilton T, Prvan T, Flood V, et al (2021) The platform to evaluate athlete knowledge of sports nutrition questionnaire: a reliable and valid electronic sports nutrition knowledge questionnaire for athletes. Br J Nutr [Internet]. 28;126(4):561–71. https://www.cambridge.org/core/product/identifier/S0007114520004286/type/journal_article
40. Heaney S, O'Connor H, Michael S, Gifford J, Naughton G (2011) Nutrition knowledge in athletes: a systemic review. Int J Sport Nutr Exerc Metab 21:248–261
41. Streiner DL. (2003) Starting at the beginning: an introduction to coefficient alpha and internal consistency. J Pers Assess [Internet]. 80(1):99–103. http://www.tandfonline.com/doi/abs/https://doi.org/10.1207/S15327752JPA8001_18
42. Bentley MR, Mitchell N, Sutton L, Backhouse SH (2019) Sports nutritionists' perspectives on enablers and barriers to nutritional adherence in high performance sport: a qualitative analysis informed by the COM-B model and theoretical domains framework. J Sports Sci [Internet]. 37(18):2075–85. http://www.ncbi.nlm.nih.gov/pubmed/31124393
43. Michie S, van Stralen MM, West R (2011) The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci [Internet]. 23;6(1):42. http://www.implementationscience.com/content/6/1/42
44. Gibson AM, Bowling NA (2020) The effects of questionnaire length and behavioral consequences on careless responding. Eur J Psychol Assess. 36(2):410–20. https://econtent.hogrefe.com/doi/https://doi.org/10.1027/1015-5759/a000526
45. Drust B (2019) Applied science and soccer: a personal perspective on the past, present and future of a discipline. Sport Perform Sci Reports 57(1)

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