

An Assessment of the Validity of the Remote Food Photography Method (Termed Snap-N-Send) in Experienced and Inexperienced Sport Nutritionists

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The remote food photography method, often referred to as “Snap-N-Send” by sport nutritionists, has been reported as a valid method to assess energy intake in athletic populations. However, preliminary studies were not conducted in true free-living conditions, and dietary assessment was performed by one researcher only. The authors, therefore, assessed the validity of Snap-N-Send to assess the energy and macronutrient composition in experienced (EXP, $n = 23$) and inexperienced (INEXP, $n = 25$) sport nutritionists. The participants analyzed 2 days of dietary photographs, comprising eight meals. Day 1 consisted of “simple” meals based around easily distinguishable foods (i.e., chicken breast and rice), and Day 2 consisted of “complex” meals, containing “hidden” ingredients (i.e., chicken curry). The estimates of dietary intake were analyzed for validity using one-sample t tests and typical error of estimates (TEE). The INEXP and EXP nutritionists underestimated energy intake for the simple day (mean difference [MD] = -1.5 MJ, TEE = 10.1%; -1.2 MJ, TEE = 9.3%, respectively) and the complex day (MD = -1.2 MJ, TEE = 17.8%; MD = -0.6 MJ, 14.3%, respectively). Carbohydrate intake was underestimated by INEXP (MD = -65.5 g/day, TEE = 10.8% and MD = -28.7 g/day, TEE = 24.4%) and EXP (MD = -53.4 g/day, TEE = 10.1% and -19.9 g/day, TEE = 17.5%) for both the simple and complex days, respectively. Interpractitioner reliability was generally “poor” for energy and macronutrients. The data demonstrate that the remote food photography method/Snap-N-Send underestimates energy intake in simple and complex meals, and these errors are evident in the EXP and INEXP sport nutritionists.

Keywords: dietary intake, LEA, RED-S

A fundamental activity for sport nutritionists is to estimate the energy and macronutrient intake from an athlete’s self-reported food intake (Braakhuis et al., 2003). Such dietary assessments are important, given the role of energy and macronutrient intake in modulating training adaptation (Impey et al., 2018), body composition (Kasper et al., 2019; Morton et al., 2010; Wilson et al., 2015), and exercise performance (Burke & Hawley, 2018). In addition, nutrient availability can play a fundamental role in growth and maturation (Hannon et al., 2020), mental health (Wilson et al., 2014), and reducing the risk of illness and injury (Kasper et al., 2019; Walsh, 2019; Wilson et al., 2014). Despite the clear rationale to accurately assess an athlete’s energy intake, this remains a major methodological challenge that is fraught with sources of error on both the athlete’s and sport nutritionist’s part (Capling et al., 2017).

Broadly speaking, dietary assessment methods are classified as “retrospective” (including 24-hr recall, food frequency questionnaires, and diet histories) or “prospective” (including food diaries with/without weighed inventory). Inaccuracies are inherent with self-reported dietary assessments and include the misreporting of

food consumption alongside measurement error (Gemming et al., 2014; Rollo et al., 2016; Westerterp et al., 1986). Furthermore, most of the dietary assessment methods are logistically complicated, especially when assessing multiple athletes (e.g., sports teams) in free-living conditions (Martin et al., 2012). Validity and precision, in addition to practitioner and participant burden, are cited as some of the main causes of inaccuracies in dietary assessment (Livingstone & Black, 2003; Thompson et al., 2010). In addition to the bias associated with participant burden and self-reporting, the requirement of an accurate, unbiased interpretation by a nutritionist or dietitian has led to criticism within the sports nutrition community that systematic error in dietary analysis is neglected and somewhat overlooked (Kirkpatrick & Collins, 2016).

In an attempt to improve participant reporting accuracy in traditional pen-and-paper methods, Martin et al. (2009) developed the remote food photography method (RFPM), whereby participants record dietary intake in real-time via ecological momentary assessment. In this approach, participants take and transmit photographs (via camera-enabled cell phones with data transfer capability) of their food selection and plate waste to researchers for subsequent dietary analysis. In combining the principles of the RFPM with elements of behavioral change science to engage participants and all key stakeholders, Costello et al. (2017) subsequently developed the “Snap-N-Send” methodology, demonstrating that an athletic population was also capable of adhering to self-reporting of dietary intake via Smartphone technology. However,

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while this preliminary study concluded that Snap-N-Send was valid and reliable as a standalone dietary assessment method, there are several limitations that should be noted. First, the experimental conditions were not truly free-living, given that the participants were restricted to consuming foodstuffs that were provided by the researchers during the study period. In this way, the researcher had prior knowledge of the approximate portion sizes and macronutrient profile of the foods consumed, given that the foods were weighed by the research team before being distributed to the participants. Second, the subsequent dietary analysis was performed by one researcher only, an important methodological factor, considering the inherent variability that exists between experienced sports dietitians when coding food records for analysis (Braakhuis et al., 2003). Thus, the aim of the present study was to assess the validity of utilizing the RFPN/Snap-N-Send as a standalone method to assess energy and macronutrient composition in experienced and inexperienced sport nutritionists.

Methods

Participants

Forty-eight participants were recruited to take part in this study. The participants were nonrandomly allocated to two independent groups based upon the inclusion criteria: (a) recent Sport and Exercise Nutrition register (SENr) graduates with graduate accreditation status ($n = 25$; termed INEXPERIENCED) or (b) full SENr practitioner registrants with >3 years working within elite sport ($n = 23$; termed EXPERIENCED). All of the “inexperienced” sport nutritionists had received recent training in dietary assessment (including the RFPN) from experienced sport nutritionists, while all of the “experienced” sport nutritionists, as a criterion of their SENr registration, will have demonstrated evidence of competency in dietary assessment. This study was approved by Liverpool John Moores University ethics committee (M20_SPS_767) and was conducted in accordance to the Declaration of Helsinki.

Study Design

The participants were provided with the same 2 days of dietary images, comprising a total of eight meals (breakfast, morning snack, lunch, and evening meals). These foods, photographed remotely, had been compiled by the research team, with 1 day being classed as “simple” meals and the second day being “complex” meals and with the 2 days being similar in total energy content. Dietary images and short descriptions were then sent to each participant via e-mail or over a free cellular picture messaging Smartphone application (Whatsapp Inc., Menlo Park, CA) for analysis. The participants were asked to analyze each meal for its calorific and macronutrient content using Nutritics dietary analysis software and using the preset United Kingdom/Ireland database (Nutritics version 5.5; Swords, Ireland) and to return these data files to the primary researcher to assess the ability of experienced and inexperienced practitioners to estimate energy intake in comparison with food labels.

Control

To standardize the perceived portion size, all meals were placed on the same plate or bowl with cutlery on a 1 cm × 1 cm A3 reference grid placemat, as previously described (Costello et al., 2017). All images were taken by the researcher at a height of 60 cm and at a

90° angle. The images were later cropped so that the reference grid filled the image (15.01 cm × 21.34 cm) and added to a standard PowerPoint slide (19.05 cm × 25.4 cm), with a brief description of the food in the image (e.g., Weetabix cereal made with semi-skimmed milk).

Meal Design

Day 1 of the diet diary was designed in a simplistic manner whereby each individual food item could be easily identified and distinguished by the participant, for example, chicken breast and rice (termed SIMPLE). On this day, no extras were added to meals, such as butter on potatoes or condiments such as mayonnaise. The second day was designed to contain a number of complex meals whereby it was more difficult to ascertain a number of individual ingredients and definite quantities of each food item, for example, chicken curry and rice (termed COMPLEX). Again, no hidden extras were added. For the purpose of this study, it was presumed that all foods on the plate were consumed, with no need to attempt to calculate the leftover food items. An overview of the meals and energy content can be found in Figure 1.

Statistical Analysis

The data were assessed for normality using standard graphical procedures and Shapiro–Wilk’s tests. Values of minimally clinically important difference have not been used in this study because the use of hard anchors cannot be universally applied for each variable in multiple scenarios (Cook et al., 2014). For example, in an acute nutritional intervention, the differences in energy intake of 0.5 MJ/day would have little effect, but would likely be clinically important in a chronic setting. Likewise, a small change in the nutrient content of diets that have very low total energy may be important, but in an athlete with much higher energy needs and intake, it will not be. Therefore, the effect sizes of Cohen’s d (for t tests) and r values (for Wilcoxon signed-rank tests) were used to help to determine the magnitude of potential differences. These effect sizes were interpreted as small, medium, and large, using the values of 0.2, 0.5, 0.8, and 0.1 to <0.4, 0.4 to <0.6, ≥ 0.6 were used for d and r , respectively.

Consequently, the differences between the actual nutrient data (as obtained from food labels), the estimated energy intake, the macronutrient content of the simple and complex days, and the individual meals and daily snacks were assessed using one-sample t tests or Wilcoxon signed-rank tests, where the difference data were nonparametric. Differences in the observed dietary analysis data between the inexperienced and experienced groups were assessed using independent t tests for the energy and macronutrient content of both the simple and complex days.

The validity of the observed data compared with the known nutrient values was assessed using the coefficient of variation along with 95% limits of agreement, bias, and 95% confidence intervals (CI). The coefficient of variation was interpreted using the following thresholds: <2% (excellent), <5% (good), <10% (acceptable), >10% (poor), and >20% (very poor). Interrater reliability (termed “interpractitioner reliability” hereafter) was assessed using a two-way mixed-effects model for Cronbach’s alpha, intraclass correlations with 95% CI, and coefficient of variation. All inferential statistical tests and validity calculations were conducted using SPSS (version 25; Windows, SPSS Inc., Chicago, IL) and MS Excel (365 for Windows, Microsoft, Redmond, WA), respectively.

	Simple day	Complex day
Breakfast	 Weetabix cereal (made with semi-skimmed milk) [MJ=1.08; CHO=39.5 g; PRO=13.5 g; FAT=5.1 g]	 Scrambled eggs on toast (made with semi-skimmed milk) [MJ=2.50; CHO 41.3 g; PRO 45.3 g; FAT 28.2 g]
Morning snack	 Avocado on toast with poached eggs [MJ=3.19; CHO=44.0 g; PRO=25.6 g; FAT=53.7 g]	 Overnight oats (made with chocolate milk and whey protein) [MJ=1.56; CHO=55.0 g; PRO=26.7 g; FAT=4.8 g]
Lunch	 Poached salmon with baby new potatoes and broccoli [MJ= 2.49; CHO=34.7 g; PRO=47.8 g; FAT=26.0 g]	 Chicken tikka masala with pilau rice [MJ=2.48; CHO=62.1 g; PRO=35.6 g; FAT 20.4 g]
Evening meal	 Chicken breast fillet with basmati rice and mixed peppers [MJ=2.57; CHO=94.9 g; PRO=41.0 g; FAT=4.4 g]	 Chicken chow mein [MJ= 1.99; CHO=49.2 g; PRO=32.8 g; FAT=15.2 g]
Total	<i>MJ=9.33; CHO=213.1 g; PRO=127.9; FAT=89.2 g</i>	<i>MJ=8.53; CHO=207.6 g; PRO=140.4; FAT=68.6 g</i>

Figure 1 — Overview of diet diary provided for both simple and complex days. This includes an image and brief explanation provided to participants (nonitalic), alongside the calculated energy and macronutrient breakdowns for each meal and overall daily total (italics). MJ= megajoules; CHO = carbohydrate; PRO = protein; and FAT = fat.

Results

Estimated Dietary Intake

The inexperienced, experienced, and whole sample all underestimated energy intake (Figure 2a and Table 1) for the simple day (MD = -1.7 MJ, $w = 10.0$, $z = 4.1$, $p < .001$, $r = .58$; MD = MD -1.2 MJ, $p < .001$, CI = [-1.56, -0.81], $d = 1.36$ and MD = -1.4 MJ, $p < .001$, CI = [-64, -1.10], $d = 1.50$; respectively) and the complex day (MD = -1.2 MJ, $p = .001$, CI = [-1.80, -0.54],

$d = 0.76$; MD = -1.5 MJ, $w = 1,140$, $z = 5.7$, $p < .001$, $r = .58$; and, MD = -0.9 MJ, $p < .001$, CI = [-1.32, -0.50], $d = 0.65$; respectively). The estimated energy intake values were not different between the groups for either the simple (MD = 0.35 MJ, $p = .186$, CI = [-0.88, 0.18], $d = 0.59$) or complex days (MD = $p = .185$, CI = [-1.35, 0.27], $d = 0.39$).

Estimated carbohydrate (CHO) intake (Figure 2b) was underestimated by the inexperienced (MD = -67.5 g, $w = 324.0$, $z = 4.4$, $p < .001$, $r = .62$; and, MD = -26.9 g, $w = 217.0$, $z = 2.4$, $p = .016$, $r = .35$), the experienced (MD = -53.4 g, $p < .001$, CI = [-62.7,

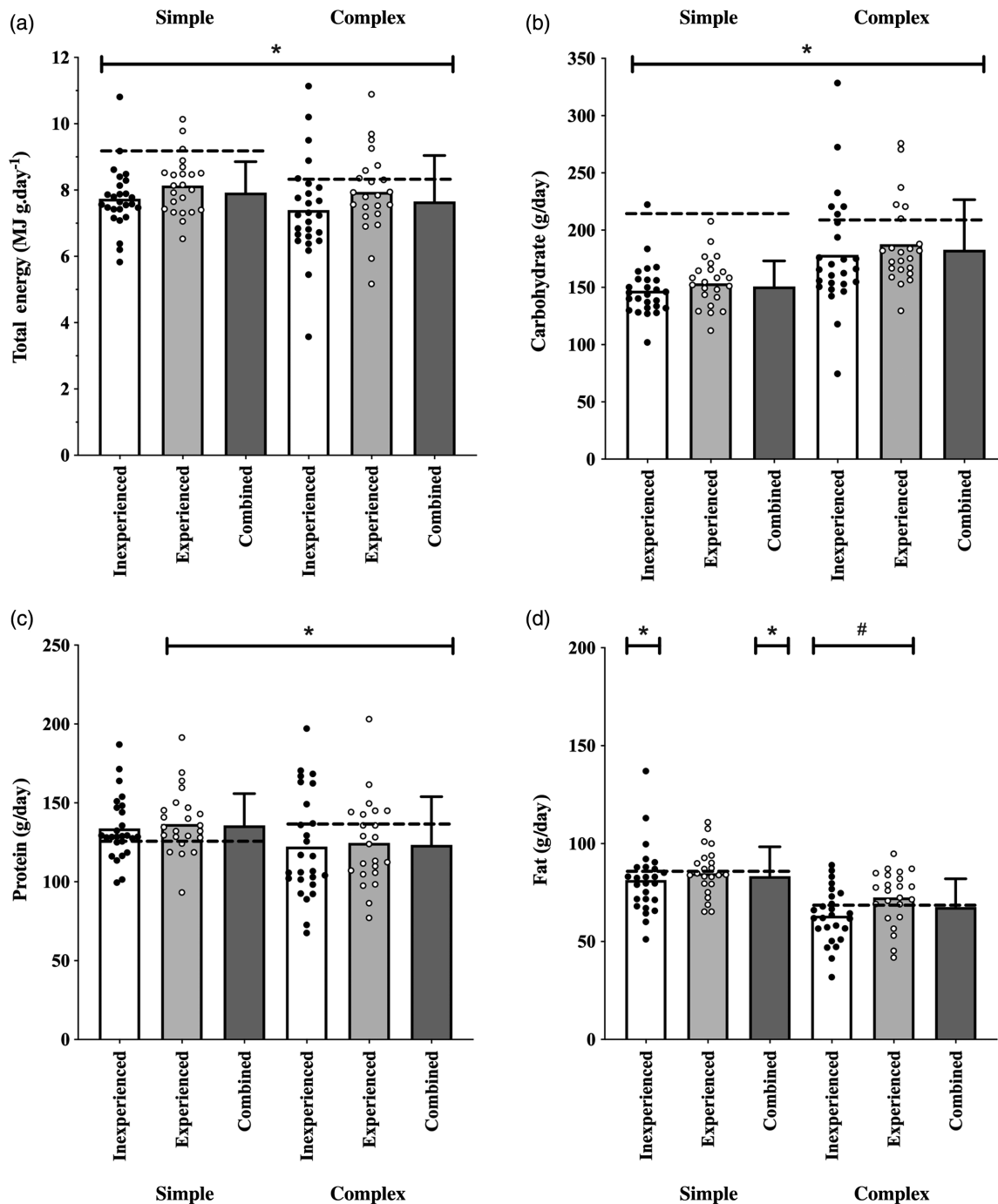


Figure 2 — (a) Total energy intake estimated by inexperienced (black circles) and experienced (white circles) accredited practitioners on the simple and complex days. Macronutrient intake estimated by practitioners for (b) carbohydrate, (c) protein, and (d) fat. Bars are representative of mean estimation, with the dashed line representing actual calculation of energy intake for energy. *Significant difference compared with actual calculated intake. #Significant differences between groups.

−44.0], $d = 2.73$ and $MD = -64.2$ g, $w = 1,174$, $z = 6.0$, $p < .001$, $r = .61$), and the whole sample ($MD = -62.3$ g, $p < .001$, $CI = [-68.8, -55.8]$, $d = 2.79$; and $MD = -24.5$ g, $p < .001$, $CI = [-37.3, -11.64]$, $d = 0.55$) for both the simple and complex days, respectively. There were again no differences in the CHO estimates between the groups for either the simple ($MD = 6.7$ g, $p = .308$, $CI = [-19.6, 6.3]$, $d = 0.30$) or complex ($MD = 8.8$ g, $p = .493$, $CI = [-34.7, 17.0]$, $d = 0.20$) days.

The estimates of fat intake (Figure 2d) made by the inexperienced group were lower than the actual fat content of the simple day ($MD = -6.7$ g, $w = 257.0$, $z = 2.5$, $p = .011$, $r = .36$), but this was not the case for the experienced group ($MD = -3.6$ g, $p = .173$, $CI = [-8.8, 1.7]$, $d = 0.29$), and there were no differences between the fat intake estimates of the two groups combined ($MD = -4.2$ g, $p = .331$, $CI = [-12.9, 4.4]$, $d = 0.24$). However, when the two groups were combined for the whole sample, the fat intake was

Table 1 Outcomes of the LoA and CV Validity Analysis

Dietary variable	Inexperienced		Experienced		All	
	Simple	Complex	Simple	Complex	Simple	Complex
Daily energy intake (MJ)						
Bias	-1.5	-1.2	-1.2	-0.6	-1.4	-0.9
95% CI	[-1.9, -1.2]	[-1.8, -0.5]	[-1.6, -0.8]	[-1.2, 0.1]	[-1.6, -1.1]	[-1.3, -0.5]
LoA (upper)	0.3	1.8	5.0	1.8	0.4	1.8
LoA (lower)	-3.4	-4.3	-0.5	-3.0	-3.2	-3.7
CV (%)	10.1	17.8	9.3	14.3	9.8	16.4
Interpretation	Poor	Poor	Acceptable	Poor	Poor	Poor
Carbohydrate (g/day)						
Bias	-65.5	-28.7	-53.4	-19.9	-62.6	-24.5
95% CI	[-75.0, -56.0]	[-49.7, -7.8]	[-62.7, -44.0]	[-35.6, -4.2]	[-68.8, -55.8]	[-37.3, -11.6]
LoA (upper)	-20.5	70.7	-7.5	51.7	-19.1	62.1
LoA (lower)	-110.5	-128.1	-110.2	-91.4	-106.1	-110.6
CV (%)	10.8	24.4	10.1	17.5	10.4	21.3
Interpretation	Poor	Very poor	Poor	Poor	Poor	Very poor
Fat (g/day)						
Bias	-7.1	-5.8	-3.6	4.0	-5.8	-1.1
95% CI	[-14.2, 0.0]	[-11.6, 0.0]	[-8.8, 1.7]	[-2.0, 9.9]	[-9.7, -1.1]	[-5.4, 3.1]
LoA (upper)	26.5	21.7	20.2	31.0	23.7	27.5
LoA (lower)	-40.8	-33.2	-27.3	-23.0	-35.2	-29.7
CV (%)	19.3	20.4	5.7	6.6	7.1	7.0
Interpretation	Poor	Very poor	Acceptable	Acceptable	Acceptable	Acceptable
Protein (g/day)						
Bias	7.3	-17.2	10.1	-15.7	7.9	-16.5
95% CI	[-0.6, 15.3]	[-31.2, -3.3]	[1.28, 18.9]	[-27.7, -3.7]	[2.9, 14.3]	[-25.4, -7.6]
LoA (upper)	45.2	49.0	49.9	38.5	47.4	43.7
LoA (lower)	-30.5	-83.5	-29.7	-69.9	-31.6	-76.7
CV (%)	9.1	16.3	9.5	13.3	9.5	14.8
Interpretation	Acceptable	Poor	Acceptable	Poor	Acceptable	Poor

Note. CI = confidence interval; LoA = limits of agreement; CV = coefficient of variation.

underestimated by a small amount (MD = -5.8 g, $p = .010$, CI = [-10.1, -1.48], $d = 0.39$).

The fat intake estimates for the complex day were not different from the actual value for either the inexperienced (MD = 5.38 g, $p = .059$, CI = [-10.9, 0.22], $d = 0.39$), experienced (MD = 3.95 g, $p = .183$, CI = [-2.0, 9.9], $d = 0.29$), or whole sample (MD = -1.0 g, $p = .630$, CI = [-5.2, 3.2], $d = 0.08$). However, the inexperienced group estimated the fat intake to be lower than that of the experienced group for the complex day (MD = -9.3 g, $p = .023$, CI = [-17.3, -1.4], $d = 0.69$).

The estimations of protein intake were not different between the two groups (Figure 2c), for either the simple or complex days (MD = 4.1 g, $p = .482$, CI = [-15.8, 7.6], $d = 0.14$ and MD = 2.4 g, $p = .791$, CI = [-19.9, 15.2], $d = 0.13$, respectively). Interestingly, the experienced group estimated the protein intake to be higher than the actual value for the simple day (MD = 10.1 g, $p = .027$, CI = [2.1, 16.7], $d = 0.50$), but the inexperienced group did not (MD = 5.4 g, $p = .070$, CI = [-2.2, 14.1], $d = 0.38$). When the whole sample was combined for the simple day, the protein intake was estimated to be higher than the actual value (MD = 7.9 g, $p = .009$, CI = [2.1, 13.7], $d = 0.44$). Conversely, for the complex day, the protein intake estimates were lower than the actual values for the

inexperienced (MD = -18.0 g, $p = .011$, CI = [-31.5, -4.6], $d = 0.51$), experienced (MD = -15.7 g, $p = .012$, CI = [-27.7, -3.7], $d = 0.57$), and whole sample (MD = -16.9 g, $p < .001$, CI = [-25.7, -8.2], $d = 0.54$).

Meal-by-Meal Estimates

The complex day breakfast (Figure 3a1-a4) was underestimated for energy (MD = -0.63 MJ, $p < .001$, CI = [-0.82, -0.45], $d = 1.40$, and MD = -0.50 MJ, $p < .001$, CI = [-0.67, -0.34], $d = 1.28$), CHO (MD = -11.5 g, $w = 325.0$, $z = 4.4$, $p < .001$, $r = .62$, and MD = -11.5 g, $w = 276.0$, $z = 4.2$, $p < .001$, $r = .62$), and protein (MD = -22.1 g, $p < .001$, CI = [-24.45, -19.79], $d = 3.90$, and MD = -18.5 g, $w = 276.0$, $z = 4.2$, $p < .001$, $r = .62$) by the inexperienced and experienced groups. Notably, the inexperienced group also underestimated the energy (MD = -0.18 MJ, $p = .005$, $w = 267.0$, $z = 2.8$, $r = .40$), protein (MD = -3.5 g, $w = 240.0$, $z = 3.7$, $p < .001$, $r = .52$), and fat content (MD = -1.5 g, $w = 236.0$, $z = 3.7$, $p < .001$, $r = .51$) of the simple breakfast, but this was not the case for the experienced group.

Typically, the simple snack energy (MD = -0.80 MJ, $w = 4.0$, $z = 4.4$, $p < .001$, $r = .62$, and MD = 0.96 MJ, $p < .001$,

Table 2 Outcomes of the Interrater Reliability Analysis

Dietary variable	Inexperienced		Experienced		All	
	Simple	Complex	Simple	Complex	Simple	Complex
Daily energy intake						
α	.985	.931	.977	.834	.991	.950
ICC	.73	.35	.65	.180	.69	.29
CI	[0.32, 1.00]	[0.06, 1.00]	[0.23, 1.00]	[0.001, 0.99]	[0.29, 1.00]	[0.06, 1.00]
CV (%)	12.1	20.6	10.7	15.4	11.5	18.3
Interpretation	Acceptable	Poor	Acceptable	Poor	Acceptable	Poor
Carbohydrate						
α	.995	.875	.994	.855	.997	.932
ICC	.89	.22	.88	.20	.89	.22
CI	[0.60, 1.00]	[0.02, 0.99]	[0.57, 1.00]	[0.12, 0.99]	[0.60, 1.00]	[0.04, 1.00]
CV (%)	15.6	28.6	14.0	19.3	14.8	24.1
Interpretation	Acceptable	Very poor	Acceptable	Poor	Acceptable	Poor
Fat						
α	.765	.765	.496	.472	.841	−2.562
ICC	.12	.12	.04	.04	.10	−.02
CI	[−0.01, 0.99]	[−0.01, 0.99]	[−0.03, 0.99]	[−0.03, 0.99]	[0.04, 0.99]	[−0.02, 0.85]
CV (%)	20.9	22.3	14.1	19.0	17.8	21.6
Interpretation	Very poor	Very poor	Poor	Very poor	Very poor	Very poor
Protein						
α	.722	.846	.823	.865	.892	.928
ICC	.09	.18	.17	.218	.15	.21
CI	[−0.01, 0.99]	[0.01, 1.00]	[0.002, 0.99]	[0.16, 0.99]	[0.02, 1.00]	[0.03, 1.00]
CV (%)	14.3	27.4	14.7	22.2	14.4	24.8
Interpretation	Very poor	Very poor	Very poor	Very poor	Very poor	Very poor

Note. ICC = intraclass correlation; CI = confidence interval; CV = coefficient of variation.

CI = [−1.11, −0.81], $d = 2.74$), CHO (MD = −12.6 g, $w = 324.0$, $z = 4.4$, $p < .001$, $r = .62$, and MD = −12.9 g, $w = 254.0$, $z = 3.5$, $p < .001$, $r = .52$), and fat (MD = 14.6 g, $w = 313.0$, $z = 4.1$, $p < .001$, $r = .57$, and MD = −15.8 g, $w = 276.0$, $z = 4.2$, $p < .001$, $r = .62$) content was underestimated by the inexperienced and experienced groups (Figure 3b1–b4). Conversely, the inexperienced and experienced groups overestimated energy (MD = 0.29 MJ, $p = .001$, CI = [0.13, 0.44], $d = 0.76$, and MD = 0.34 MJ, $w = 234.0$, $z = 2.9$, $p = .004$, $r = .43$), protein (MD = 7.9 g, $w = 295$, $z = 3.6$, $p < .001$, $r = .50$, and MD = 8.0 g, $w = 228.0$, $z = 2.7$, $p = .006$, $r = .40$), and fat (MD = 4.3 g, $w = 324.0$, $z = 4.3$, $p < .001$, $r = .62$, and MD = 4.4 g, $w = 272.0$, $z = 4.1$, $p < .001$, $r = .60$) for the complex snacks.

For the lunch meal, the CHO content was underestimated by the inexperienced (MD = 10.2 g, $w = 290.0$, $z = 3.4$, $p < .001$, $r = .49$ and MD = −20.1 g, $p < .001$, CI = [−28.9, −11.4], $d = 0.95$) and experienced (MD = 7.9 g, $p = .001$, CI = [12.4, −3.4], $d = 0.76$ and MD = 16.1 g, $p < .001$, CI = [−23.6, −8.6], $d = 0.93$) groups for both the simple and complex days, respectively (Figure 3c1–c4). The protein and fat content of the simple lunch were overestimated by the inexperienced (MD = 5.2 g, $w = 253.0$, $z = 2.4$, $p = .015$, $r = .35$ and MD = 11.5 g, $w = 307.0$, $z = 3.9$, $p < .001$, $r = .55$) and experienced (MD = 6.2 g, $w = 222.0$, $z = 2.6$, $p = .011$, $r = .38$, and MD = 21.1 g, $w = 271.0$, $z = 4.0$, $p < .001$, $r = .60$) groups, whereas the fat (MD = 4.3 g, $w = 324.0$, $z = 4.3$, $p < .001$, $r = .62$ and MD = 7.1 g, $w = 248.0$, $z = 3.4$, $p < .001$, $r = .49$) and energy content (MD = −0.8 MJ, $p < .001$, CI = [−1.1, −0.5], $d = 1.21$ and MD = −0.6 MJ,

$p < .001$, CI = [−0.8, −0.4], $d = 1.25$) of the complex lunch were underestimated by the inexperienced and experienced groups, respectively.

The energy (MD = 0.15 MJ, $p = .024$, CI = [0.02, 0.28], $d = 0.48$, and MD = 0.71 MJ, $w = 271.0$, $z = 4.1$, $p < .001$, $r = .60$), CHO (MD = 46.9 g, $w = 325.0$, $z = 4.4$, $p < .001$, $r = .62$, and MD = 45.9 g, $w = 276.0$, $z = 4.2$, $p < .001$, $r = .62$), and protein content (MD = 5.0 g, $p = .004$, CI = [1.8, 8.1], $d = 0.64$, and MD = 3.0 g, $w = 230.0$, $z = 2.8$, $p = .005$, $r = .41$) of the simple evening meal (Figure 3d1–d4) were overestimated by the inexperienced and experienced groups, respectively. In addition, the experienced group overestimated the fat content for the simple (MD = 4.5 g, $w = 256.0$, $z = 3.6$, $p < .001$, $r = .53$) and the complex evening meal (MD = 18.6 g, $w = 227.0$, $z = 2.7$, $p = .006$, $r = .40$).

Assessment of Interpractitioner Reliability

The interpractitioner reliability (Table 2 and Figure 2) was generally poor for the estimation of energy and nutrient intake. Specifically, the only acceptable interpractitioner reliability was observed for the simple dietary intake day in both groups of practitioners and the sample as a whole. All of the complex dietary intake day analysis resulted in poor or very poor interpractitioner reliability. The inexperienced group appeared to have worse interpractitioner reliability than their more experienced counterparts, but even the experienced practitioners displayed poor interpractitioner reliability for energy intake and CHO and very poor reliability for the

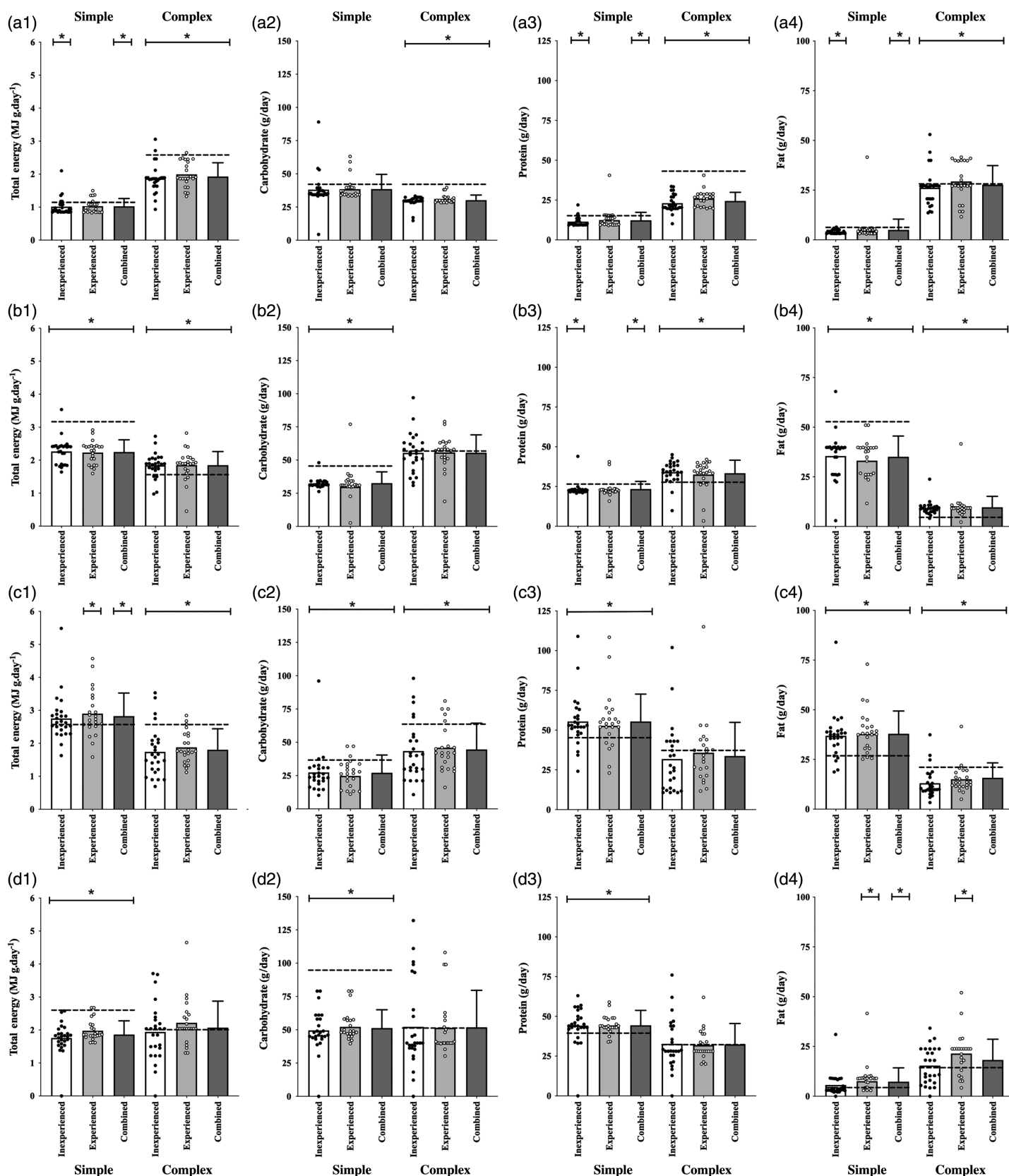


Figure 3 — Meal-by-meal overview of (a1–a4) breakfast, (b1–b4) snack, (c1–c4) lunch, and (d1–d4) evening meal regarding the total energy, carbohydrate, protein, and fat content (1–4, respectively) estimated by inexperienced (black circles) and experienced (white circles) accredited practitioners on the simple and complex days. *Significant difference compared with actual calculated intake.

fat and protein estimates. Furthermore, very poor interpractitioner reliability was observed in both groups and the sample as a whole for the estimates of fat and protein intake, with the exception of the experienced group's estimate of fat on the simple day, which was still poor.

Discussion

The aim of the present study was to assess the validity of utilizing the RFPM/Snap-N-Send as a standalone methodology to assess energy and macronutrient composition. To this end, we recruited 49 accredited sport nutritionists to analyze 2 days of dietary images comprising four "simple" meals or four "complex" meals. We reported that the RFPM/Snap-N-Send method has "poor" validity compared with the known values for both total energy intake and macronutrient composition. In addition, the interpractitioner reliability was qualified as "poor," even between the experienced sport nutritionists. Taken together, our data provide a reference point for practitioners when considering the typical error associated with these methods of dietary assessment.

The design of the present study allowed for 24 different assessments of validity (energy, CHO, fat, and protein; in complex and simple days; by experienced, inexperienced, combined nutritionists; $4 \times 2 \times 3$). We report that only 8/24 of the assessments were qualified as "adequate," with the remaining 16/24 categorized as "poor" or "very poor." Moreover, no assessments of validity were classed as "good" or "very good." Overall, the RFPM/Snap-N-Send method significantly underreported the total energy content by 13%, which is in line with previous research, which has reported 8.8%, 11.3%, and 13.1%, respectively (Martin et al., 2012; Kikunaga et al., 2007; Lassen et al., 2010). Importantly, there was an extreme variation observed in the reporting of energy intake which ranged from -47% to +18%. Indeed, "acceptable" validity for energy intake was only seen in the simple day when analysed by experienced practitioners and this still resulted in a TEE of -9.3%. These data are in contrast to the preliminary report assessing the validity of the Snap-N-Send methodology, where variability was reported as acceptable (<5%, Costello et al., 2017). It is noteworthy, however, that these researchers combined digital photography alongside a written food diary, and all food items were weighed by the researcher team pre- and postconsumption. This contrasts with the present methodology, where the individuals who performed the dietary assessments had no prior knowledge of the food being provided or the portion sizes. As such, the data presented herein likely represent a more ecologically valid assessment scenario in which both practitioners and researchers are likely to engage in dietary assessment activities. Indeed, in a further study from Costello et al. (2019), the researchers compared Snap-N-Send-derived estimates of energy intake obtained from free-living conditions (i.e., participants consumed their own food choices, with no prior researcher knowledge) with energy expenditure (using doubly labeled water) and reported large random error and reduced measurement accuracy at an individual level. In this instance, the authors suggested that the poor performance of Snap-N-Send was a consequence of low athlete adherence to submitting all of the food consumed. However, when considered with the present data, we suggest that it is likely due in part to the inability of practitioners to correctly identify foods and quantities from dietary photographs. Indeed, the limitation of using only one coder when performing dietary assessments is an important methodological factor, considering the inherent variability that exists between experienced sports dieticians when coding food

records for analysis (Braakhuis et al., 2003). Our data could also suggest that the RFPM/Snap-N-Send requires a high level of specialist and specific training prior to use in order to yield reliable data. We, therefore, suggest that, in free-living conditions, practitioners should take into consideration the limitations of this approach and interpret the data accordingly.

In addition to total energy intake, we also provide the first report of sport nutritionists using the RFPM/Snap-N-Send methodology to assess the validity of analyzing macronutrient composition. The validity of CHO intake was "poor" or "very poor" in the experienced and inexperienced practitioners in both the simple and complex days, with the range being as much as 75–329 g on 1 day. This "poor" validity of CHO intake is of particular concern given that the majority of the meals, even on the complex day, used easily recognized CHO sources, such as potatoes. Many sport nutritionists now look to periodize CHO intake based on the training of the athlete utilizing the "fuel for the work required" concept (Impey et al., 2018). The inability to accurately identify the amount of CHO from dietary photographs (even on simple days by experienced practitioners) suggests that practitioners must be cautious with regard to making CHO alterations to their athletes' diets based purely upon pictures sent from their athletes. Protein intake was "acceptable" with both inexperienced and experienced practitioners on the simple day; however, it was "poor" on the complex day, ranging from 68 to 203 g. On the simple day, protein was easily identified, with portion sizes easy to estimate through using foods such as poached eggs. However, on the more complex day, protein was in the form of scrambled eggs, a food harder to quantify via images alone. It is therefore crucial that, in free-living conditions, practitioners are aware that significant error may exist in protein intake estimated from complex meals, and advice should be tailored accordingly. Interestingly, the most valid macronutrient estimate was for fat, which was "acceptable" in the experienced practitioners on both the simple and complex days. This may be due to the food choices being low-fat meals typically eaten by athletes, and future studies may wish to assess this observation in meals with a higher fat content.

In addition to quantifying the total daily energy and macronutrient composition, we also performed an analysis on a meal-by-meal basis. From a practical perspective, such an analysis is highly important, given that nutritional periodization is performed on a meal-by-meal basis. In this regard, our data demonstrate extreme variability on a meal-by-meal basis, with no consistent pattern of error in terms of the experience of practitioners, complexity, or type of meals. It did appear that the snacks were a particular problem, with the complex snacks being overestimated for both energy and protein intake in experienced as well as inexperienced practitioners. Given the high reliance on snacks by athletes to achieve total caloric intake, as well as to achieve suggested protein distribution (Areta et al., 2013), this overestimation of energy and protein could be a particular problem in athletic groups who often consume three to four snacks per day.

The present study also assessed the interpractitioner reliability of RFPM/Snap-N-Send in both the experienced and inexperienced sport nutritionists on the complex and simple days. With regard to the total energy intake, despite "poor" validity, there was "acceptable" reliability in both the inexperienced and experienced nutritionists on the simple food day; however, this became "poor" on the complex food day. Indeed, a coefficient of variation of 20.2% and 15.4%, along with very low intraclass correlations, was reported on the complex day for the inexperienced and experienced

nutritionists, respectively. This pattern was also observed for CHO intakes. Taken together, these data suggest that, when assessing anything apart from simple meals that are atypical of many athletes in free-living conditions, the RFPM/Snap-N-Send methodology lacks interpractitioner reliability, even in experienced nutritionists. Given the lack of differences reported between the experienced and inexperienced sport nutritionists, our data suggest that experience in sport nutrition per se does not improve the accuracy of the RFPM/Snap-N-Send methodology. Rather, sport nutritionists looking to use this technique would benefit from enhanced specialist training, including targeted activities to address the components underpinning the accuracy in quantifying meal and individual food portions from pictures prior to use. It should be stressed, however, that taking pictures alongside traditional dietary intake methodologies could help to reduce participant burden, improve the accuracy of food diaries, and help with behavior change (Costello et al., 2019). It is therefore important not to dismiss the benefit of pictures to help with dietary assessment; rather, the present data highlight the limitation of this technique as a stand-alone methodology.

Despite presenting novel data, this study is not without limitations, many of which are directly related to the controls employed to improve internal validity. Only 2 days of meals were analyzed in an attempt to recruit high-performance nutritionists working in an elite environment. Initial conversations prior to testing suggested that the length of the food diary would be acceptable from a time perspective for applied practitioners. Future studies may wish to assess more days, with a wider range of energy intakes. Given that underreporting is further exacerbated in accordance with increases in total energy expenditure (Barnard et al., 2002), it is possible that, in sports with higher energy intakes (e.g., rugby, Bradley et al., 2015), the RFPM/Snap-N-Send could have higher variability than reported here. A second limitation is that the meals in the present study (despite some being classed as complex) were relatively plain, with things such as sauces and desserts being left to a minimum. Combined with the fact that it was not necessary to account for uneaten food, there is a high possibility that, when used by athletes in the field as an assessment tool, the variability could be more extreme than reported in the current data. Likewise, the present study was based upon the diet histories reporting 100% of the total food consumed. In the real world, it is likely that athletes will forget to take pictures (or fail to submit) of all of the food and drinks consumed, adding further error to this method. The present study used only one dietary assessment software (Nutritics), given that Nutritics is widely used in sport nutrition in the United Kingdom and Ireland (where all of the participants were based) and participants were familiar with the software, using it regularly in their daily jobs. To assess whether the error reported was purely related to the software, the lead researcher, with specific knowledge of the foods and weights, inputted all of the data into Nutritics and gained values within 1% of the total energy reported on the food labels, suggesting that the error was not within the software, but rather the interpretation of the food from the pictures. Finally, the aim of the present study was to assess the RFPM/Snap-N-Send within sport nutrition, and it, therefore, cannot be excluded that specialist-trained individuals who are highly experienced in picture-based diet assessments may achieve data differing from that reported in the present study.

In conclusion, we have provided the first report to assess the validity of the RFPM/Snap-N-Send as a standalone methodology to assess the energy and macronutrient composition of dietary photographs. Our data demonstrate “poor” validity and interpractitioner

reliability, even when dietary analysis was performed by experienced sport nutritionists. The present data, therefore, provide a reference point for practitioners when considering the typical error associated with these methods of dietary assessment. Such estimates of validity should therefore be taken into account when utilizing this method, alongside the requirement to use multiple coders when performing a dietary analysis of athletic populations.

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