# Snap-N-Send: A Valid and Reliable Method for Assessing the Energy Intake of Elite Adolescent Athletes

Running Head: 'Validating a Novel Assessment of Energy Intake for Elite Adolescent Athletes'

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## Abstract

To ensure that elite adolescent athletes meet their unique training, growth and maturation demands it is imperative to have access to valid measures of energy intake. Contemporary methods demand close attention-to-detail, meaning that athletes often do not fully adhere to real-time protocols. This study represents the first investigation of a real-time dietary assessment designed using a comprehensive behaviour change framework (COM-B). In a crossover design 12 elite adolescent male rugby players recorded their energy intake via an estimated food diary (est-FD) and photography-based mobile assessment ('Snap-n-Send'), combined with a 24-hour dietary recall interview. Two four-day assessment periods were divided into three separate recording environments: 96h free-living and researcher-observed; 72h free-living; and 10h researcher-observed. Assessment periods were one month apart. All foods and beverages were provided and weighed by the research team to quantify actual intakes. 'Snap-n-Send' reported a *small* mean bias for underreporting across 96h (-0.75 MJ·day$^{-1}$; 95% CI for bias= -5.7% to -2.2%, $p$<0.001), 72h (-0.76 MJ·day$^{-1}$; 95% CI for bias= -5.6% to -2.1%, $p$=0.004), and 10h (-0.72 MJ·day$^{-1}$; 95% CI for bias= -8.1% to -0.1%; $p$=0.067) environments. The est-FD reported a *moderate* mean bias for under-reporting across 96h (-2.89 MJ·day$^{-1}$; 95% CI for bias= -17.9% to -10.2%; $p$<0.001), 72h (-2.88 MJ·day$^{-1}$; 95% CI for bias= -17.9% to -10.1%; $p$<0.001), and 10h (-2.52 MJ·day$^{-1}$; -26.1% to -5.3%; $p$=0.023) environments. Results evidence the ability of 'Snap-n-Send' to accurately assess the diet of elite adolescent athletes, signalling the exciting promise of this comprehensive and theoretical behavioural approach within valid dietary assessment.



**Key words:** *Energy Intake, Validity, Behaviour Change, Ecological Momentary Assessment, Elite Adolescent Athlete, Rugby*

## Introduction

The unique training and competition demands of adolescent athletes require optimal dietary intakes for health, development and performance (Desbrow et al., 2014). Elite adolescent athletes risk inadequate energy intakes due to their significantly higher training loads, associated energy expenditures and clinically lower energy availability than their non-athletic peers (Muia, Wright, Onywera, & Kuria, 2016). Given such distinctive developmental requirements, their diets need to be equally distinctive to maintain physiological and psychological health, reduce injury and drive optimal performance (Mountjoy et al., 2015). To support such requirements, valid and reliable methods of assessing energy intake are urgently required so that practitioners and researchers can evaluate, and thus optimise, the diet of elite adolescent athletes.

Contemporary assessment of energy intake is fraught with long acknowledged limitation (Bingham, 1991); for example, contemporary retrospective and prospective dietary assessments are characterised by substantial random and systematic measurement error, apparent across universal populations (Freedman, Schatzkin, Midthune, & Kipnis, 2011). These measurement issues are further complicated by the distinctiveness of athletes' serving sizes, frequency of snacking, supplement use, weight-management practices and extensive training demands (Magkos & Yannakoulia, 2003). Additionally, given the challenges adolescents face in maintaining focus or motivation to adhere over long periods, their self-reported energy intakes are typically incomplete or inadequate (Livingstone, Robson & Wallace, 2004). Although this can be a reflection of poor methodological compliance (Hill & Davies, 2001), it may also signal that instruments have not been designed to reflect contemporary understanding of behaviour change science. In this understanding, persisting with the weaknesses of traditional dietary assessments is no longer acceptable; more accurate, valid and innovative dietary assessments are required (Thompson, Subar, Loria, Reedy, & Baranowski, 2010).

A new generation of electronic dietary intake assessments (e-DIA) operating across several platforms (Forster et al., 2016), provide promise for the rapid collection, management and storage of dietary information (Stumbo, 2013) as it occurs in participants' habitual environments (i.e., ecological

momentary assessment, EMA; Hand & Perzynski, 2016). Theoretically, EMA addresses memory-based measurement biases (Shiffman, Stone, & Hufford, 2008) that underpin any contemporary critique of epidemiological research (Archer, Pavela, & Lavie, 2015). However, the successful deployment of EMA relies upon participants having both the motivation and the capability (Patterson, Grenny, Maxfield, McMillan, & Switzler, 2007) to fully comply with prolonged real-time data collection protocols, highlighting the importance of intervening on the often overlooked behavioural component within, and integral to, valid dietary assessment.

This study investigated the combination of (i) a novel photography-based mobile dietary assessment (m-DIA; 'Snap-n-Send'), (ii) traditional prospective estimated food diary (est-FD), and (iii) 24-hour dietary recall interview, with a systematic and theory-based behaviour change intervention, targeting correct and habitual adherence to real-time dietary assessment (EMA). To the authors' knowledge, this study represents the first investigation of an EMA or photography-based dietary assessment within an elite adolescent athlete cohort and the first investigation of any dietary assessment method in combination with a comprehensive theory of behaviour change. We hypothesised that the combination of innovative smartphone technology ('Snap-n-Send') and active deployment of behaviour change techniques (BCT) would outperform a combined BCT and traditional pen-and-paper approach (est-FD), by increasing adherence to EMA principles and providing a more valid assessment of energy intake.

# Method

## Design

Participants recorded their energy intake across two four-day assessment periods separated by one month in a counterbalanced, crossover design. Participants were informed that the study assessed their energy intake rather than the validity of two dietary assessment methods. To determine method validity all food and drink items were provided by the research team and covertly weighed before and after *ad libitum* consumption. Each four-day assessment period housed three separate recording environments; 96-hour free-living and researcher-observed (Days 1-4); 72-hour free-living (Days 1-3); and 10-hour researcher-observed (within Day 4). To investigate any added benefit of combined dietary assessments a 24-hour dietary recall interview was completed on the fourth day of each assessment period. A schematic representation of the study design is provided in Figure 1. Prior to volunteering, all participants signed a written statement of consent. Parental consent was not required as all participants were over 16 years old. Ethical approval was granted by the Carnegie Faculty Research Ethics Committee (Leeds Beckett University, UK).

***INSERT FIGURE 1 HERE***

## Participants

Twelve healthy, elite adolescent (age range 16 to 18 years) male rugby league (RL) players (17.9 ± 0.5 years, 181.4 ± 6.1 cm, 91.2 ± 8.7 kg) were recruited for this study. All participants were selected from the same elite rugby academy and had personal access to a smart phone. The 'Dutch Behaviour Eating Questionnaire' classified all participants as unrestrained eaters (van Strien, Frijters, Bergers, & Defares, 1986).

**Experimental Protocol**

Throughout both assessment periods all food and drink items were provided by the research team (Table 1). On Days 1, 2 and 3 of both assessment periods, participants consumed items within a free-living environment. Pre-weighed food and drink items were collected every evening from Leeds Beckett University for *ad libitum* consumption the following day. All unconsumed items, packaging and leftovers were kept in separate waste disposal bags and returned the next day for covert re-weighing and disposal by the research team. Participants were told that returning these items was essential due to the waste prevention legislation of the university. No assistance was offered to participants regarding the recording of any food or fluid items.

On Day 4 of both assessment periods, researchers directly observed the energy intake of participants for a 10-hour period (10:00 – 20:00 h) within a university laboratory environment. All meals (breakfast, lunch, dinner, snacks and fluids) were available *ad libitum* throughout the day in a buffet style. Researchers covertly recorded all items consumed by the participants and weighed all food items before and after consumption. Following the laboratory environment (Day 4) participants were only allowed to consume 'Home Items' (Table 1) until the end of the assessment period (20:00-00:00).

**Behaviour Change Intervention**

An eight-step, theory-based, behaviour change framework was employed to optimise adherence to EMA principles across both dietary assessment methods. This approach utilised the Capability, Opportunity, Motivation-Behaviour (COM-B) model, the Theoretical Domains Framework, the Behaviour Change Technique Taxonomy version 1 (BCTTv1) and APEASE criteria within the Behaviour Change Wheel (Michie, 2014). Consistent with this approach, 47 BCTs (appendix 1) were identified and delivered across six intervention domains (Education, Persuasion, Incentivisation, Training, Environmental Restructuring, Enablement), five categories of policy (Communication, Guidelines, Regulation, Environmental/Social Planning, Service Provision) and

four modes of delivery (Face-to-Face; Group and Individual, Mobile Contact; Group and Individual; Michie, 2014), within the design and delivery of the preliminary workshop and both dietary assessment methods**.**

**Dietary Assessment Methods**

*Estimated Food Diary (est-FD, appendix 2)*

The est-FD was completed using conventional pen-and-paper reporting and returned to the lead researcher, a SENr nutritionist, at the end of the 4-day assessment period. To reduce participant burden the assessment of physical activity levels (PAL; Ainsworth et al., 2012) was omitted. Motivational quotes from highly respected former players of the club were included at the bottom of each page to increase interest and adherence. BCTs were used to supplement the est-FD wherever possible (appendix 1).

*** INSERT TABLE 1 HERE ***

*'Snap-n-Send'*

Using 'Snap-n-Send' on their smartphones, participants took two photographs of every food or fluid item consumed. The first picture was taken prior to consumption, while the second picture was taken post-consumption to identify what the participant actually ingested. Where an item was totally consumed, a picture was still required. To standardise food and drink portion sizes, participants were also provided with a personalised A3 1 x 1 cm grid placemat and a measurement shaker (Nyström et al., 2016).

In real-time pictures were sent immediately to the researcher (EMA; Stone & Shiffman, 1994) over a free cellular, picture messaging smartphone application (WhatsApp). Using text or voice

recording, participants also detailed brand labels, cooking methods and a clear description of the items contained in each picture. Once received, the lead researcher immediately checked that the picture and description were suitable for accurate analysis. For unsatisfactory contributions, participants were immediately contacted via WhatsApp, asking for clarification. At no point was picture quality an issue during assessment periods.

*24-hour Dietary Recall Interview*

All 24-hour dietary recalls were undertaken by the lead researcher (SENr nutritionist) on Day 4 of both assessment periods (10:00-12:00), reassessing self-reported energy intake for Day 3. The 24-hour dietary recall interview followed the multiple-pass approach (Guenther, DeMaio, Ingwersen, & Berlin, 1997).

**Preliminary Workshop**

All participants attended a preliminary workshop, which detailed the BCTs (appendix 1), and outlined the importance of nutrition for the health, development and performance of elite adolescent RL players. Full adherence to the dietary assessment method was clearly emphasised and heavily incentivised by regularly linking accurate dietary reporting to achieving participant's personal developmental goals. Participants were asked to individually outline the pros and cons of completing each dietary assessment method for four-days, which were shared and discussed amongst the group.

The lead researchers delivered a detailed verbal, visual and kinaesthetic explanation and demonstration of how to complete the two dietary assessment methods. The bespoke improvements in the conventional dietary assessment tools were highlighted and contrasted with methods the participants had previously used. Using both methods participants practised reporting a number of different food and drink items until they displayed complete mastery of this process. A detailed explanation of how to correctly comply with the dietary method during 'if-then' situations (e.g.

limited phone access for ‘Snap-n-Send’) was outlined. Participants were then asked to mentally rehearse themselves successfully adhering to the dietary method in a series of increasingly challenging situations until they were comfortable accurately using both methods.

With support from the researcher, a number of highly-regarded coaches attended to emphasise both the expectations that players will practice good nutritional habits and the benefits that would result. They also emphasised how accurate dietary recording was a behavioural expectation of these participants, reminding them of their social standing within the community and within the club. In a further part of the commitment-building approach, participants also committed to accurately following the dietary assessment method over the entirety of the recording period both verbally and in writing, and in the presence of significant club others. This shifted attention from ‘compliance’ to ‘adherence’ by inviting the participant’s autonomous decisions. After completing the preliminary workshop, all participants were provided with written and visual instructions. They were encouraged to contact the lead researcher directly if they required further support.

**Dietary Assessment Intervention**

Throughout the entire recording process participants were sent personalised messages over the cellular network (Martin et al., 2012). These reminded participants of the importance, expectations and rewards associated with adhering to the protocols. This was further reiterated by daily motivational quotes from highly regarded ex-club players, emphasising the importance of nutrition and professionalism. Messages ‘nudged’ participants to record around typical meal and snack times (Martin et al., 2012), with additional reminders sent for how to handle difficult potential ‘if-then’ situations (e.g., times of limited phone, wifi or food diary accessibility). During waking hours if participants made no recordings over two hours they were contacted and asked to explain their next intended time of consumption.

‘Snap-n-Send’ allowed for instant, real-time, methodological feedback tailored towards the individual. Such feedback reinforced using the correct dietary method both for individuals and across

each group. Participants were encouraged and verbally rewarded for precision, accuracy and adherence throughout; significant figures within the club used smartphone messages to congratulate participants who displayed especially impressive methodological commitment. Regular group messages created social competition between participants, by highlighting participants doing particularly well. Assigned 'team leaders' drove further adherence by reminding participants about behavioural expectations.

**Estimation of Energy Intake**

Energy intake (MJ $day^{-1}$) was determined by covertly weighing all available food and drink items before and after consumption using calibrated bench top scales (Salter Electronic Weighing Scales, Salter Precision). All item left-overs, packaging and natural waste was individually weighed and subtracted from the original weight of the item to calculate exact energy intakes. Food diaries and pictures were analysed by a SENr nutritionist with applied experience within the investigated population. To improve the accuracy of 'Snap-n-Send', portions of food were matched to pictures and weighed before being entered for analysis. Energy intake was determined from Nutritics dietary analysis software (Nutritics 3.06, Ireland), with items not available on the database manually entered from the packaging label.

**Statistical analyses**

Statistical analysis was performed on SPSS version 22 (IBM, Armonk, NY, USA) and Microsoft Excel (2016, Seattle, USA). Statistical significance was set at $p<0.05$. Agreement between the self-reported energy intake ('Snap-n-Send' and est-FD) and researcher-weighed criterion ($MJ \cdot day^{-1}$) was assessed across three different recording environments: 96-hour free-living and research-observed; 72-hour free-living; and 10-hour research-observed, within each four-day assessment period. The Bland and Altman method (Bland & Altman, 1986) established limits of agreement (LOA) to assess the relative bias (mean difference) and random error (1.96 SD of the

difference) between methods with 95% confidence intervals (CI). A one sample *t*-test investigated significant differences between methods. An Excel spreadsheet (Hopkins, 2015) calculated the standardised mean bias, typical error of the estimate (TEE) and correlation between method and criterion with 90% confidence limits.

The standardised mean bias was rated as *trivial* (<0.2), *small* (0.2-0.59), *medium* (0.6-1.19) or *large* (1.2-1.99) (Hopkins, 2015). The magnitude of the correlations was rated as *trivial* (<0.1), *small* (0.1-0.29), *medium* (0.3-0.49), *large* (0.5-0.69), *very large* (0.7-0.89), or *nearly perfect* (0.9-0.99) (Hopkins, 2015). A mixed model assessed differences in measurement bias across each four-day assessment period. The model included fixed effects accounting for the dietary assessment method (2 levels) and assessment day (4 levels), with a random effect for participant. The interaction effect between dietary assessment method and assessment day was included to test measurement bias across the assessment period.

# Results

### 96 Hour Free-Living and Researcher-Observed Recording Environment

In comparison with the researcher-weighed criterion self-reported energy intake across the 96-hour recording environment was significantly under-reported via both 'Snap-n-Send' (18.14 ± 2.42 vs. 18.92 ± 2.83 MJ·day$^{-1}$; 95% CI for bias -5.7 to -2.2%; $p$<0.001) and the est-FD (18.01 ± 3.23 vs. 20.88 ± 2.99 MJ·day$^{-1}$; 95% CI for bias -17.9 to -10.2%; $p$<0.001) (Figure 2a and 2d). 'Snap-n-Send' reported a *small* standardised mean bias and TEE for under-reporting of -3.9% and 3.5% respectively (Table 2). The est-FD reported a *moderate* standardised mean bias and TEE for under-reporting of -13.2% and 9.0% respectively (Table 2). Correlations with the researcher-weighed criterion were *nearly perfect* for 'Snap-n-Send' and *very large* for the est-FD (Table 2).

***INSERT TABLE 2 HERE***

### 72 Hour Free-Living Recording Environment

Compared with the researcher-weighed criterion self-reported energy intake across the 72-hour free-living environment was significantly under-reported via 'Snap-n-Send' (18.31 ± 3.01 vs. 19.07 ± 3.30 MJ·day$^{-1}$; 95% CI for bias = -5.6 to -2.1%; $p$=0.004) and the est-FD (18.22 ± 3.50 vs. 21.10 ± 3.30 MJ·day$^{-1}$; 95% CI for bias = -17.9 to -10.1%; $p$<0.001) (Figure 2b and 2e). 'Snap-n-Send' reported a *small* standardised mean bias and TEE for under-reporting of -3.8% and 3.7% respectively (Table 2). The est-FD reported a *moderate* standardised mean bias and TEE for under-reporting of -13.1% and 9.2% respectively (Table 2). Correlations with the researcher-weighed criterion were *nearly perfect* for 'Snap-n-Send' and *very large* for the est-FD (Table 2).

### 10 Hour Researcher-Observed Recording Environment

In comparison with the researcher-weighed criterion self-reported energy intake across the 10-hour researcher-observed environment was not significantly under-reported via 'Snap-n-Send' (16.44 ± 3.14 vs. 17.15 ± 3.31 MJ·day$^{-1}$; 95% CI for bias = -8.1% to -0.1%; $p$=0.067), but was significantly under-reported via the est-FD (13.35 ± 5.93 vs. 15.87 ± 5.89; -26.1% to -5.3%, $p$=0.023) (Figure 2c and 2f). 'Snap-n-Send' reported a *small* standardised mean bias and *moderate* TEE for under-reporting of -4.1% and 8.4% respectively (Table 2). The est-FD reported a *moderate* standardised mean bias and *large* TEE for under-reporting of -15.1% and 25.9% respectively (Table 2). Correlations with the researcher-weighed criterion were *nearly perfect* and *large* for 'Snap-n-Send' and the est-FD, respectively (Table 2).

***INSERT FIGURE 2 HERE***

**Combined Methods**

Completing an additional 24-h dietary recall interview did not change any of the dietary intake information provided via 'Snap-n-Send'. In contrast, combining a 24-h dietary recall with the est-FD significantly reduced measurement bias (0.43 ± 0.61 MJ·day$^{-1}$, 95% CI for improvement = 0.043 to 0.82 MJ·day$^{-1}$, $p$=0.032) compared with the est-FD in isolation. Although, combining the est-FD and 24-h dietary recall still resulted in a *moderate* standardised bias for under-reporting (-2.84 MJ·day$^{-1}$, -11.6%; 95% CI for bias = -18.3 to -4.9%) and TEE between measurements (16.2%; 95% CI for TEE = 12.4 to 27.6%).

## Discussion

This study represents the first investigation of a real-time (EMA) or innovative photography-based dietary assessment ('Snap-n-Send') within an elite adolescent athlete cohort. It is also the first investigation of the validity and reliability of conventional dietary assessment methods designed and

supplemented alongside a comprehensive framework of behaviour change (COM-B) across any population. There are two main findings. First, 'Snap-n-Send' is a valid and reliable stand-alone dietary assessment method across ecologically and internally valid environments. Second, an est-FD is an invalid and unreliable dietary assessment method when used in isolation, or combined with a 24-hour dietary recall interview. The validity and reliability of 'Snap-n-Send' confirm it as an accurate method for assessing the actual energy intakes of elite adolescent RL players. Results indicate that adopting a comprehensive behaviour change intervention substantially enhances the validity of conventional dietary assessment, outlining the exciting promise of this approach within future applied practise and dietary research.

'Snap-n-Send' displayed a *small* systematic bias for underreporting across all investigated ecologically (four-day; 72-hour free-living) and internally (10-hour researcher-observed) valid environments; displaying precise 95% confidence intervals (<10%; Basiotis, Welsh, Cronin, Kelsay, & Mertz, 1987), evidencing the accuracy of the method. Typical error of the estimate, a measure of method reliability, was acceptable (<5%; Hopkins, 2000) across all ecologically valid recording environments (four-day; 72-hour free-living). The accuracy of 'Snap-n-Send' was not improved with the addition of a 24-hour dietary recall interview, likely a consequence of real-time dietary analysis performed by the researcher over the cellular network. Results provide compelling evidence that 'Snap-n-Send' enhances the validity and reliability of energy intake assessment over isolated or combined traditional assessments, providing accurate assessment of energy intake for elite adolescent RL players.

The validity of 'Snap-n-Send' exceeds those of a range of approaches deployed within non-athletic and elite athlete populations (Wardenaar et al., 2015; Wood, 2014). These approaches include leading photography-based m-DIA (Gemming, Utter, & Ni Mhurchu, 2015; Henriksson et al., 2015), combined traditional and m-DIA assessments (Gemming et al., 2015), augmented reality m-DIA (Pouladzadeh, Shirmohammadi, & Yassine, 2016), wearable cameras (Gemming et al., 2015; Pettitt et al., 2016) and other innovative e-DIA (Rollo, Ash, Lyons-Wall, & Russell, 2015). Despite the exciting promise of many of the aforementioned methods, they require further development and

robust validation (Kirkpatrick et al., 2016) before valid dietary assessment can be realistically achieved (Rollo et al., 2016).

The strength of the current findings are enhanced by the extensive participant food choice and availability utilised within this study (Table 1), and research design which ensured robust and replicable validation, across internally and ecologically valid environments. This improves substantially upon the laboratory-only conditions (Briggs, Rumbold, Cockburn, Russell, & Stevenson, 2015), short assessment periods (single meal), and/or the limited food choice (Gemming et al., 2015) used to validate other methods. Consequently, current evidence confirms 'Snap-n-Send' as a leading photography-based m-DIA within published literature.

Findings also evidence the invalidity and unreliability of the est-FD, which reported a *moderate* systematic bias for under-reporting across all investigated environments, with imprecise 95% confidence intervals (>10%; Basiotis et al., 1987) and an unacceptable TEE (>5%; Hopkins, 2000). The addition of a 24-hour dietary recall interview significantly reduced measurement bias, as is commonly reported when traditional dietary assessments are combined (Shim, Oh, & Kim, 2014). Nevertheless, reported values were still invalid (>10%; Basiotis et al., 1987) and unreliable (>5%; Hopkins, 2000) and significantly worse than those reported via 'Snap-n-Send'.

Despite these substantial errors of validity and reliability, the est-FD reported an enhanced relative validity over previously investigated food diaries (Bandini, Schoeller, Cyr, & Dietz, 1990; Bratteby, Sandhagen, Fan, Enghardt, & Samuelson, 1998; Champagne, Baker, DeLany, Harsha, & Bray, 1998) and innovative photography-based m-DIA (Pouladzadeh et al., 2016), investigated across universal populations and adolescents (Livingstone, Robson, & Wallace, 2004). Of even greater relevance, the est-FD reported a considerably enhanced relative validity over an est-FD and combined 24-hour dietary recall interview used within a similar elite senior RL sample, despite the lead researcher providing participants with their daily supplements and lunch-time intakes (Morehen et al., 2016). Although such findings do not advocate the use of an est-FD or a combined 24-hour dietary recall interview, they evidence the supplementation of previously validated dietary assessment tools

with a comprehensive and over-deterministic approach to behaviour change (Michie, Atkins & West, 2014).

Our findings suggest that the continued use of unrefined, traditional, dietary assessments within elite adolescent athlete cohorts is now both inappropriate and scientifically unacceptable (Dhurandhar et al., 2015). The current data also justify approaching dietary values obtained using traditional methods with increased caution. Our data show that the inadequacies of these approaches can now be addressed using evidence from contemporary behaviour change science. Importantly, the strong evidence of enhanced dietary reliability and validity has been established within a robust design and population known to have difficulty accurately recording their diet (Livingstone, Robson & Wallace, 2004).

More widely, the Remote Food Photography Method (RFPM) and Tool for Energy Balance in Children (TECH) are photography-based m-DIA which utilise real-time dietary assessment principles (EMA) and have produced promising results across both free-living (Nyström et al., 2016; Henriksson et al., 2015; Martin et al., 2012) and laboratory conditions (Altazan et al., 2016; Duhé, Gilmore, Burton, Martin, & Redman, 2016; Martin et al., 2014). Unfortunately, neither method has been specifically designed for use within adolescent or athletic populations; variously, they rely on parental involvement, email contact, or semi-automated dietary analysis and as such, are unlikely to accurately assess the unique dietary requirements of elite adolescent athletes (Magkos & Yannakoulia, 2003). Moreover, both methods have only been validated in small pilot studies (Martin et al., 2009), under laboratory-only conditions and with limited food choices (Altazan et al., 2016). Nonetheless, both methods hold exciting promise of improving the accuracy of dietary assessment, however would most likely benefit from implementation of behaviour change science to further over-determine participant adherence to challenging real-time protocols.

Despite the exciting promise of ‘Snap-n-Send’, the method is not without limitation. Dietary analysis relies upon picture-based portion size estimation by the lead researcher. This has been shown to improve the accuracy of dietary assessment over traditional assessments (Boushey et al., 2016), however like any ‘estimation’, will inevitably introduce some degree of measurement error

(Braakhuis, Meredith, Cox, Hopkins, & Burke, 2003). To minimise this error it is essential that the primary researcher is appropriately qualified and experienced at performing dietary analysis, ideally within the target population, and weighs picture-replicated food portions when required. Furthermore, it is important to consider that the validity of 'Snap-n-Send' was determined against a research-weighed criterion, which in itself is unlikely to be completely free of measurement error, however remains the most appropriate method for energy intake validation (de Jonge, 2007). Finally, this study represents the first investigation of this specific approach to dietary assessment. Future investigations should focus upon refining the method, determining effective, rather than all-inclusive, BCTs to support adherence to demanding real-time protocols (EMA) and within other unique or challenging populations.

In conclusion, this study demonstrates the validity and reliability of 'Snap-n-Send' and the relative invalidity and unreliability of an est-FD, or combined 24-hour dietary recall interview, for accurately assessing the energy intakes of elite adolescent RL players. The findings, drawn from a counterbalanced design, strongly evidence the importance of deploying a comprehensive behaviour change approach alongside innovative technology to secure improved adherence to real-time protocols and thus more valid dietary assessment. Although further investigation is warranted, these results provide a clear and novel direction for future methodological design and dietary assessment. This signals the exciting promise of 'Snap-n-Send' as a dietary assessment tool and as a behavioural approach within future dietary assessment research.

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## Appendix 1.

| | Behaviour Change Technique (BCT) | Intervention Function | Policy Category | Mode of Delivery |
|---|---|---|---|---|
| **1** | Information about health consequences | Education | Communication | Face to Face- Group |
| **2** | Feedback on behaviour | Education | Communication | Individual; Personalised Cellular Contact |
| **3** | Feedback on behaviour; Social Reward | Education | Communication | Individual; Personalised Cellular Contact |
| **4** | Prompts/cues | Education | Communication | Individual; Personalised Cellular Contact |
| **5** | Prompts/cues; Action planning | Education | Communication & Regulation | Individual; Personalised Cellular Contact |
| **6** | Information about ancedents 'if-thens' | Education | Regulation | Face to Face- Group |
| **7** | Framing/Re-framing; Information about health consequences | Persuasion | Communication | Face to Face- Group |
| **8** | Framing/Re-framing; Information about emotional consequences | Persuasion | Communication | Face to Face- Group |
| **9** | Credible Source | Persuasion | Guidelines & Communication | Face to Face- Group & Print Out Media |
| **10** | Information about health consequences | Persuasion | Communication, Guidelines & Service Provision | Face to Face- Group & Individual; Personalised Cellular Contact |
| **11** | Feedback on behaviour | Persuasion | Communication | Individual; Personalised Cellular Contact |
| **12** | Verbal persuasion of capability | Persuasion | Communication | Face to Face- Group & Individual; Personalised Cellular Contact |
| **13** | Information of others approval | Persuasion | Communication | Face to Face- Group |
| **14** | Social Comparison | Persuasion | Communication | Individual; Personalised Cellular Contact |
| **15** | Salience of consequences; information about health & emotional consequences | Persuasion | Communication & Guidelines | Face to Face- Group & Individual; Personalised Cellular Contact |
| **16** | Identify self as role model | Persuasion | Communication | Face to Face- Group |
| **17** | Identity associated with changed behaviour | Persuasion | Communication | Face to Face- Group |
| **18** | Demonstration of behaviour | Training | Communication & Guidelines | Face to Face- Group & Individual |
| **19** | Instruction of how to perform behaviour | Training | Communication & Guidelines | Face to Face- Group & Individual |
| **20** | Feedback on behaviour | Training | Communication & Regulation | Individual; Personalised Cellular Contact |
| **21** | Behaviour practise rehearsal | Training | Regulation | Face to Face- Group |
| **22** | Habit formation | Training | Regulation | Face to Face- Group & Individual |
| **23** | Mental rehearsal of successful performance | Training | Regulation | Face to Face- Group |
| **24** | Restructuring physical environment | Environmental Restructuring | Environmental/Social Planning | Face to Face- Group & Individual; Personalised & Group Cellular Contact |

| | | | | |
|---|---|---|---|---|
| **25** | Adding objects to the environment; social support | Environmental Restructuring | Environmental/Social Planning & Communication | Individual; Personalised Cellular Contact |
| **26** | Prompts/ cues | Environmental Restructuring | Environmental/Social Planning & Communication | Individual; Personalised Cellular Contact |
| **27** | Restructuring social environment | Environmental Restructuring | Environmental/Social Planning & Communication | Individual; Personalised Cellular Contact |
| **28** | Social Support; Unspecified | Enablement | Environmental/Social Planning & Communication | Individual; Personalised Cellular Contact & Face to Face- Individual |
| **29** | Social Support; Emotional | Enablement | Environmental/Social Planning & Communication | Individual; Personalised Cellular Contact & Face to Face- Individual |
| **30** | Goal Setting (behaviour) | Enablement | Regulation | Face to Face- Individual |
| **31** | Goal Setting (outcome) | Enablement | Regulation | Face to Face- Individual |
| **32** | Restructuring the physical environment | Enablement | Regulation & Environmental/social planning | Individual; Personalised Cellular Contact |
| **33** | Action Planning; 'If-Then's' | Enablement | Regulation | Face to Face- Group & Individual; Personalised Cellular Contact |
| **34** | Reduce Negative Emotions; Problem Solving | Enablement | Environmental/Social Planning & Communication | Individual; Personalised Cellular Contact |
| **35** | Generalisation of Target Behaviour | Enablement | Regulation & Communication | Face to Face- Group & Individual; Personalised Cellular Contact |
| **36** | Restructuring the social environment | Enablement | Environmental/Social Planning & Communication | Face to Face- Group & Individual; Personalised Cellular Contact |
| **37** | Mental rehearsal of successful performance | Enablement | Regulation | Face to Face- Group |
| **38** | Verbal persuasion of capability | Enablement | Communication | Face to Face- Individual |
| **39** | Behavioural Contract | Enablement | Regulation | Face to Face- Individual |
| **40** | Commitment | Enablement | Regulation | Face to Face- Individual |
| **41** | Pros + Cons | Enablement | Communication | Face to Face- Individual |
| **42** | Comparative imagining of future outcomes | Enablement | Communication | Face to Face- Individual |
| **43** | Framing/Re-framing | Enablement | Communication | Face to Face- Group |
| **44** | Identity associated with changed behaviour | Enablement | Regulation & Communication | Face to Face- Group |
| **45** | Imaginary Reward/ Covert conditioning | Enablement | Regulation & Communication | Face to Face- Group |
| **46** | Salinance of consequences; information about health | Enablement | Communication | Face to Face- Individual |
| **47** | Reward/ Social reward / social incentive | Enablement | Regulation & Communication | Face to Face & Cellular Contact; Individual & Group |

**Appendix 2**

# Player Name 'x' – Player Position 'x'

| Example | TIME | DESCRIPTION OF FOOD OR FLUID | COOKING METHOD | BRAND | DID YOU FINISH THE MEAL/DRINK? |
|---|---|---|---|---|---|
| BREAKFAST | 8am | 4 Weetabix with Blue Milk (Large Bowl) | N/A | Sainsburys | Yes |
| | | 1 Banana (Large) | N/A | Sainsburys | Yes |
| | | 1 Mug of Tea (With Milk, No Sugar) | N/A | PG Tips | Yes |
| MID-MORNING | 11am | Packet of Biltong (200g) | N/A | Kings Elite Snacks | Only ate ½ the Pack |
| LUNCH | 1pm | 2 Chicken Breasts w Rice (Whole Pack) & Mixed Veg (1 Fist) | Fried Chicken & Microwave Rice/Veg | Uncle Bens Rice/ Sainsburys Veg & Chicken | Finished it all |
| | | Oasis Summer Fruits (300ml) | N/A | Oasis | Yes |
| PRE-TRAINING SNACK | 2.30pm | Apple | N/A | Braeburn | To core |
| | | Fruit Flapjack | N/A | Mcvities | Yes |
| | | | | | |
| DURING TRAINING | 4.00pm | Water (Full Shaker) | N/A | N/A | Had Half (500ml) |
| | | | | | |
| POST-TRAINING SUPPLEMENT | 5.30pm | X3 heaped scoops Mass Gainer- Full shake water | N/A | Multipower | Finished |
| | | | | | |
| DINNER | 7.30pm | X1 well done Steak, with x1 Large Sweet Jacket Potato, carrots (fist) | Fry steak, Boil potato & Carrots | Sainsburys | Finished except few carrots |
| | | Pint of Blue milk | N/A | Sainsburys | Yes |
| | | Yogurt (450g) | N/A | Yeovalley Strawberry | Half |
| | | | | | |
| | | | | | |
| PRE-BED | 9.00pm | Pint of blue milk | N/A | Sainsburys | Yes |
| | | 6 squares of chocolate (Milk)- Large bar | N/A | Galaxy | Yes |
| Questions | 1. **Have you filled in every column as accurately as possible?** Yes, I checked item weights on the back of packs.<br>2. **Have you forgotten to include anything?** No, this is everything I ate today. | | | | |

Club Logo

**"We Are What We Repeatedly Do. Excellence Then, Is Not An Act, But A Habit."**

Club Logo

**Table 1.** Available food and drink items across both assessment periods.

| |
|---|
| Breakfast; Weetabix, Quaker Original Porridge Oats (range), Free Range Eggs, Branflakes, Strawberry Jam, Bread, Butter, Crumpets |
| Lunch & Dinner; Penne Pasta, Rice (range), Pizza (range), Sweet Potato, Sandwiches (range), Super Noodles, Heinz Beans, Tuna, Cured Ham, Salmon Fillets, Turkey, Chicken Breast, Chicken Pieces, Lamb Chops, Ostrich Fillet Steak, Gold Standard Nutrition Pots of Gold (range) |
| Fruit & Vegetables; Fairtrade Bananas, Braeburn Apples, Oranges, Kiwis, White Onion, Cucumber, Iceburg Lettuce, Sweet Corn, Peppers, Mixed Vegetables (frozen) |
| Other; Fajita Kit, Bolognese Sauce, Heinz Tomato Ketchup, Cheese (range), Salt, Pepper, Mayonnaise, Sugar, BBQ Sauce, Fry Light Oil Spray (range) |
| Home Items (Day 4 Only) & Snacks; Cornish Pastry, Ready Meals (range), Fruit Flapjack, Arla High Protein Yogurt (range), Peanut Butter, Uncle Ben Rice Time (range), McCoy Crisps (range), Cadbury Brunch Bar, Kinder Chocolate, Ski Yogurt (range), Batch Tested Whey Protein (range), Biltong, Marybake Flapjacks (range), Dark Chocolate, Nutrigrains |
| Fluids; Milk (range), Tea Bags (range), Orange Juice, Oasis, Horlicks Light Chocolate, Nescafe Cappuccino, Robinsons Squash (range), Vimto, Lucozade Sport |

**Table 2**. Comparison of energy intake between the researcher-weighed criterion measure, 'Snap-n-Send' and est-FD across recording periods. Data are mean energy intake (± standard deviation (SD)) and mean bias, typical error of the estimate (TEE) and Pearson correlation coefficient, all with 90% confidence intervals.

| | **Criterion Measure (Research-weighed)** | **Practical Measure** | **Bias %** | **TEE%** | **Correlation** |
|---|---|---|---|---|---|
| 96 hour free-living and researcher-observed (Days 1-4) | 20.88 ± 2.99 | Estimated Food Diary | -13.2 [-10.2 to -17.9] | 7.9 [5.8 to 12.9] | 0.86 [0.63 to 0.95] |
| | | 18.01 ± 3.23 | (*moderate*) | (*moderate*) | (*very large*) |
| | 18.92 ± 2.83 | Snap-n-Send | -3.9 [-2.2 to -5.7] | 3.3 [2.4 to 5.5] | 0.98 [0.93 to 0.99] |
| | | 18.14 ± 2.42 | (*small*) | (*small*) | (*nearly perfect*) |
| 72 hour free-living (Days 1-3) | 21.10 ± 3.30 | Estimated Food Diary | -13.1 [-10.1 to -17.9] | 7.9 [5.8 to 12.9] | 0.88 [0.68 to 0.96] |
| | | 18.22 ± 3.50 | (*moderate*) | (*moderate*) | (*very large*) |
| | 19.07 ± 3.30 | Snap-n-Send | -3.8 [-2.1 to -5.6] | 3.8 [2.7 to 6.3] | 0.98 [0.94 to 0.99] |
| | | 18.31 ± 3.01 | (*small*) | (*small*) | (*nearly perfect*) |
| 10 hour researcher-observed (within Day 4) | 15.87 ± 5.89 | Estimated Food Diary | -15.1 [-5.3 to -26.1] | 16.8 [12.0 to 29.0] | 0.56 [0.04 to 0.84] |
| | | 13.35 ± 5.93 | (*moderate*) | (*large*) | (*large*) |
| | 17.15 ± 3.31 | Snap-n-Send | -4.1 [-0.1 to -8.1] | 8.7 [6.3 to 14.7] | 0.93 [0.78 to 0.98] |
| | | 16.44 ± 3.14 | (*small*) | (*moderate*) | (*nearly perfect*) |

## Figure Captions

**Figure 1.** Consort diagram illustrating the experimental protocol of the study.

**Figure 2.** Bland and Altman plot of the mean difference between participant self-reported energy intake (estimated food diary- A, B, C & 'Snap-n-Send' method- D, E, F) across 96-hour free-living and researcher-observed (Days 1-4), 72-hour free-living (Days 1-3) and 10-hour researcher-observed (within Day 4) recording environments, respectively.