Are professional young rugby league players eating enough? Energy intake, expenditure and balance during a pre-season.

Running Head: 'Energy Balance of Professional Young Rugby League Players during a Pre-Season'

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Abstract

Due to the unique energetic demands of professional young collision sport athletes, accurate assessment of energy balance is required. Consequently, this is the first study to simultaneously investigate the energy intake, expenditure and balance of professional young rugby league players across a pre-season period.

The total energy expenditure of six professional young male rugby league players was measured via doubly labelled water over a fourteen-day assessment period. Resting metabolic rate was measured and physical activity level calculated. Dietary intake was reported via Snap-N-Send over a non-consecutive ten-day assessment period, alongside changes in fasted body mass and hydration status. Accordingly, energy balance was inferred.

The mean (standard deviation) difference between total energy intake (16.73 (1.32) MJ·day^{-1}) and total energy expenditure (18.36 (3.05) MJ·day^{-1}) measured over the non-consecutive ten-day period was *unclear* (-1.63 (1.73) MJ·day^{-1}; ES = 0.91 ±1.28; $p = 0.221$). This corresponded in a most likely *trivial* decrease in body mass (-0.65 (0.78) kg; ES = 0.04 ±0.03; $p = 0.097$). Resting metabolic rate and physical activity level across the fourteen-day pre-season period was 11.20 (2.16) MJ·day^{-1} and 1.7 (0.2), respectively.

For the first time, this study utilises gold standard assessment techniques to elucidate the distinctly large energy expenditures of professional young rugby league players across a pre-season period, emphasising a requirement for equally large energy intakes to achieve targeted body mass and composition adaptations. Accordingly, it is imperative that practitioners regularly assess the energy balance of professional young collision-sport athletes to ensure their unique energetic requirements are achieved.

Key words: Dietary intake, Energy expenditure, Doubly labelled water, Energy balance, Rugby

Highlights:

Professional young rugby league players displayed distinctly large energetic demands during a pre-season period, emphasising a requirement for equally large energy intakes to achieve targeted body mass and composition goals.

Despite consuming large average energy intakes, professional young rugby league players were still susceptible to an energy deficit and losing body mass, potentially negatively affecting targeted training adaptations across key developmental periods i.e. pre-season within a young athlete cohort.

Accordingly, it is imperative that practitioners and coaches operating within professional collision-based sports regularly assess and behaviourally support achievement of energy balance across pre-season periods to maximise the physical and anthropometric development of professional young collision-sport athletes.

Introduction

Professional young rugby league (RL) players require a sufficient energy intake and a high-quality diet to support optimal training adaptation and development across pre-season periods (Logue et al., 2018; Thomas, Erdman, & Burke, 2016). Rugby league is an intermittent team sport characterised by repeated collisions and high-intensity running efforts (Weaving et al., 2018), which results in considerable exercise- and collision-induced muscle damage(Naughton, Miller, & Slater, 2017), prolonged muscle soreness (Fletcher et al., 2016) and increased energy expenditure (Costello et al., 2018b) following training or match-play. A sufficient energy and macronutrient intake is required to fuel such demands (Logue et al., 2018; Thomas et al., 2016), while promoting targeted increases in fat-free and overall body mass (BM) required within professional collision sport cohorts (Brazier et al., 2018; Till, Scantlebury, & Jones, 2017). This is particularly true of elite young collision sport athletes, whose already distinct maturation (COMA, 1991) and home-based demands (e.g. academic and social stresses) (Desbrow et al., 2014) are combined with increased training loads to drive adaption across periods of pivotal physical development i.e pre-season (Brazier et al., 2018; Till, Scantlebury, & Jones, 2017). Evidently, excellent nutritional support is required across such periods to safeguard player well-being and health, while promoting maximal development.

Published literature investigating the dietary intakes of professional young RL players is limited (Smith, Jones, Sutton, King, & Duckworth, 2016), which makes accurate evaluation of current nutritional practise difficult. To date, four published studies have investigated the dietary intakes of professional RL players (Lundy, O'Connor, Pelly, & Caterson, 2006; MacKenzie, Slater, King, & Byrne, 2015; Smith et al., 2016; Tooley, Bitcon, Briggs, West, & Russell, 2015), however only one has specifically examined the energy and macronutrient intakes of professional young RL players during a pre-season period (Smith et al., 2016). Although informative, such research is confounded by the use of traditional dietary assessment tools (four-day food diary), which have not been robustly validated for use within athletic populations (Capling et al., 2017). Subsequently, traditional dietary assessment methods typically report substantial errors of both validity and reliability (Dhurandhar et al., 2014). For example, a combined food diary and 24-hour dietary recall interview resulted in physiologically implausible energy intakes within a professional senior RL population (2030 $kcal \cdot day^{-1}$ under-reporting error; Morehen et al., 2016), while reporting unacceptable measurement error within a professional young RL population (690 $kcal \cdot day^{-1}$ under-reporting error; Costello et al., 2017). Clearly, improved evaluation of dietary intakes utilising more accurate dietary assessment tools is warranted within professional young collision sports.

Current literature investigating the total energy expenditure (TEE) of professional young RL players is limited to one in-season assessment (Smith et al., 2018), which makes formulating precise, individualised dietary strategies during a pre-season difficult. To date, only four published studies have investigated the TEE of professional rugby players (Bradley et al., 2015; Morehen et al., 2016; Smith et al., 2018; Tooley et al., 2015). Such research is confounded by the use of invalid assessment tools, although the literature gold standard doubly labelled water (DLW)(Westerterp, 2017) has been utilised to accurately determine the TEE of professional senior (Morehen et al., 2016) and young RL players (Smith et al., 2018) during the season. Despite this, no study to date has specifically investigated the energetic demands of professional young RL players across a physically challenging pre-season period, where maximal physical adaptions are targeted (Brazier et al., 2018; Till, Scantlebury, & Jones, 2017). Subsequently, due to the unique energetic demands of adolescent athletes (COMA, 1991; Desbrow et al., 2014) and collision-based sports (Costello et al., 2018b), accurate assessment of energy balance is required across pre-season periods within a professional young RL population.

Therefore, this study utilised gold standard assessment techniques to investigate the energy intake, expenditure and balance of professional young RL players for the first time across a fourteen-day pre-season assessment period.

Methods

Participants

Six healthy, professional young (age range 16 to 18 years) male RL players (mean (SD) age; 17 (1) years, height; 178.2 (9.4) cm,BM; 87.4 (14.7) kg) were recruited. Participants were chosen from a range of playing positions including Loose Forward, Prop Forward (x2), Half Back, Hooker and Wing. All participants provided written informed consent, prior to volunteering. Ethics approval was granted by the Carnegie Faculty Research Ethics Committee (Leeds Beckett University, UK).

Design

Study data were collected over a fourteen-day assessment period, during the sixth and seventh week of a pre-season period. The period included ten resistance-training sessions, ten field sessions and four rest days (Table 1). Total energy expenditure was measured via DLW across the entire fourteen-day period, whereas dietary intake was reported via 'Snap-N-Send'(Costello et al., 2017; Costello et al., 2017b) across a shorter non-consecutive ten-day. A shorter dietary assessment period was specifically chosen to ensure high behavioural compliance to accurate dietary reporting amongst participants (Monday-Friday) (Costello et al., 2017; Costello et al., 2017b). Therefore, in order to determine energy balance, TEE was also calculated from DLW data collected during the corresponding non-consecutive ten-day dietary assessment period. The RMR of participants was measured one day prior to the start of each training week (Sunday) and averaged to obtain a mean value. This allowed for physical activity level (PAL) to be calculated. Changes in fasted BM and hydration status were assessed on Monday and Saturday of both assessment weeks, providing an objective assessment of energy balance. The training and home-based loads of participants were recorded via sessional ratings of perceived exertion (sRPE) (Foster et al., 2001), micro-technology units and SenseWear Armbands (SWA), respectively.

INSERT TABLE 1 HERE

Dietary Intake

Energy and macronutrient intakes were analysed via 'Snap-N-Send' across a non-consecutive ten-day assessment period. The combined non-consecutive period included Monday-Friday of both assessment weeks. Two non-consecutive five-day dietary assessment periods were specifically chosen so that participants received a break from dietary reporting over the weekend, enhancing the quality of analysis likely to be obtained (Costello et al., 2017b). Importantly, a shorter seven-day assessment period is considered accurate representation of habitual energy and macronutrient intakes (Braakhuis, Meredith, Cox, Hopkins, & Burke, 2003). Moreover, 'Snap-N-Send' is a dietary assessment tool specifically designed and validated for use within an elite adolescent athlete cohort, reporting enhanced validity and reliability over traditional dietary assessment tools (Costello et al., 2017) via novel addressment of both methodological and behavioural dietary assessment error (Costello et al., 2017b).

Prior to the study period, participants attended a preliminary workshop where they were verbally, visually and kinaesthetically taught how to use 'Snap-N-Send'. The method was explained in detail and demonstrated across a number of potentially difficult recording scenarios (‘if-then’ situations, i.e. periods with limited smartphone or Wi-Fi access). All participants had to individually demonstrate recording competence before the workshop was completed. Population-specific behaviour change techniques (BCTs), designed and implemented via the Behaviour Change Wheel (Michie et al., 2014), were applied across the preliminary workshop and assessment period to behaviourally adhere participants to accurate real-time ecological momentary assessment. For detailed explanation of ‘Snap-N-Send’ or the BCTs employed throughout the preliminary workshop or assessment period please see (Costello et al., 2017).

Dietary intakes were analysed by a SENr accredited nutritionist with applied experience within the investigated population. When required, portions of food were matched to pictures provided via ‘Snap-N-Send’ before being entered for analysis. Energy and macronutrient intakes were determined from Nutritics dietary analysis software (Nutritics 3.06, Ireland), with items not available on the database manually entered from label packaging.

Total Energy Expenditure measured by Doubly Labelled Water

DLW Stable Isotope Doses

Two bolus doses consisting of deuterium (^{2}H) and oxygen (^{18}O) stable isotopes were prepared for each participant, as has previously been described (Costello et al., 2018b). A spilt dose protocol was chosen to ensure tracer enrichment in body water remained above the minimum recommendation throughout the study (IAEA 2009). Doses were calculated relative to the largest BM of any participant (Schoeller et al., 1980). This included $^{2}H_2O$ (99 atom %) and $H_2{}^{18}O$ (10 atom %) based on 0.14 g·kg^{-1} and 0.90 g·kg^{-1} of BM, respectively.

DLW Administration, Urine Collections and IRMS Analyses of Urine Samples

Each dose was provided on Sunday, one day prior to the start of each training week. Dose administrations occurred after a morning RMR assessment. A baseline urine sample was provided before oral consumption of a single bolus of DLW ($^2H_2{}^{18}O$), made under close supervision. To ensure consumption of the whole bolus, the dose bottles were washed twice with additional water that participants also consumed. Baseline enrichment was determined from a later urine sample provided by participants at 22:00, allowing for total body water (TBW) equilibrium. This protocol was repeated exactly for the second dose seven days later.

Participants provided daily urine samples at 22:00 across the entire fourteen-day data collection period. The final urine sample was collected at 06:00 on Monday morning, after completion of the second training week. Samples were collected directly into two date, time and participant ID registered 5 mL cryovials and filtered in compliance with the Human Tissue Act. Analysis of urine samples for ^2H and ^{18}O abundance was performed following gas exchange using a HYDRA 20-22 IRMS (SerCon, Crewe UK), as has previously been described (Costello et al., 2018b). All data were imported into a Microsoft Excel template for the calculation of TBW, TEE and quality control parameters.

Total Body Water and Total Energy Expenditure Calculations

Participant TBW and TEE were calculated specifically for the fourteen-day assessment period and non-consecutive ten-day dietary assessment period, so that energy balance could be investigated. Participant TBW was calculated from stable isotope dilution spaces, based on the intercept of the elimination plot of deuterium. Whereas, TEE was determined from the stable isotope elimination rate constants and “pool space” (IAEA 2009). Specific TEE values were then calculated (Goran, Poehlman, & Danforth, 1994). The Pearson product moment correlation of the tracer elimination plots was greater than 0.99 in all cases. A respiratory quotient of 0.85 was assumed (Schoeller & van Santen, 1982).

Resting Metabolic Rate

Participants underwent an overnight fast and fifteen-minute enforced rest period before the beginning of a fifteen-minute assessment. The assessment occurred within a mildly lit and temperate room (21–23 °C) with participants lying quietly in a supine position (Compher et al. 2006). Expired gas was analysed using an online gas analyser (Metalyzer 3BR3, Cortex, Leipzig, Germany). The gas analyser was calibrated as per the manufacturer's guidelines using two known concentrations of each gas (ambient and 15% O_2 and ambient and 5% CO_2), daily barometric pressure and a 3-L volume syringe. Participants wore a facemask connected to a gas analyser for online breath-by-breath analysis. Data were subsequently averaged every 30 s to remove artefacts and exported to Microsoft Excel (2016, Seattle, USA), providing an accurate assessment of RMR with a coefficient of variation <10 % (Compher et al., 2006). The respiratory exchange ratio was determined from $\dot{V}O_2$ and $\dot{V}CO_2$ measurements (Frayn, 1983). Energy expenditure was estimated from substrate oxidation rates and expressed per 24 hours, using an energy value for carbohydrate and fat of 3.75 kcal and 9 kcal, respectively (Southgate & Durnin, 1970).

Body Mass

To determine change in fasted BM across the non-consecutive ten-day energy balance assessment period, participants were weighed to the nearest 0.1 kg on Monday and Saturday of both assessment weeks and change scores were combined. Body mass assessments occurred after an overnight fast, wearing shorts only, after urination (SECA, Birmingham, UK). Hydration status was assessed prior to each BM weigh-in, so that observed changes in BM could be attributed to energy balance rather than fluctuations in hydration status. Specifically, the second void of the day was collected and analysed for osmolality through freezing point depression (Gonotec, Berlin, Germany). Samples were analysed in triplicate for each participant and averaged to provide a final osmolality score.

Training and Home-Based Loads

Training and home-based loads are reported in the supplementary materials. Internal and external training loads were assessed across all training sessions via sRPE (Foster et al., 2001) and micro-technological units (Optimeye S5, Catapult Innovations, Melbourne, Australia; version 5.1.7, 15 (3); horizontal dilution of precision 0.8 (0.6)), respectively. Microtechnology units were turned on fifteen minutes prior to any session in a clear outdoor space to achieve a satisfactory satellite lock. Home-based loads were assessed outside of every training session via SWA (SenseWear Professional version 6.1; BodyMedia, USA), as has previously been described (Costello et al., 2018b).

Statistical Analyses

Raw data are presented as mean ± standard deviation (SD). Paired t-tests and magnitude-based inferences (MBI) were used to assess for differences in energy intake and TEE across the non-consecutive ten-day assessment period, alongside fasted BM and hydration status. Magnitude-based inferences were included to promote direct interpretation of observed changes and whether observed changes were meaningful (Hopkins, Marshall, Batterham, & Hanin, 2009). Paired t-tests and MBI analyses were run in R Studio (v 1.414).

For null-hypothesis significance testing, statistical significance was assumed at 5% ($P < 0.05$). For MBI, the threshold for a change to be considered practically important (the smallest worthwhile change) was set at 0.2 x between subject SD, based on Cohen's *d* effect size (ES) principle (Hopkins et al., 2009). Thresholds for ES were set as; <0.2 *trivial*; 0.2-0.6 *small*; 0.6-1.2 *moderate*; 1.2-2.0 *large* (Hopkins et al., 2009). The probability that the magnitude of change was greater than the practically important threshold (0.2 x between subject SD) was rated as <0.5%, *almost certainly not*; 0.5-4.9%, *very unlikely*; 5-24.9%, *unlikely*; 25-74.9%, *possibly*; 75-94.9%, *likely*; 95-99.5%, *very likely*; >99.5%, *almost certainly* (Hopkins et al., 2009). The magnitude of change was described as *unclear* when the 90% CI crossed both the upper and lower boundaries of the practically important threshold (ES ±0.2).

Results

Dietary Intake

Mean energy intake across the non-consecutive ten-day assessment period was 16.73 (2.40) $MJ·day^{-1}$. Absolute carbohydrate, protein, fat and alcohol intakes were 445 (64) $g·day^{-1}$; 224 (48) $g·day^{-1}$; 149 (25) $g·day^{-1}$ and 1.5 (3.7) $g·day^{-1}$, respectively. When expressed relative to BM, players consumed 5.2 (1.2) $g·kg^{-1}·day^{-1}$ of carbohydrate, 2.6 (0.8) $g·kg^{-1}·day^{-1}$ of protein and 1.8 (0.3) $g·kg^{-1}·day^{-1}$ of fat.

Energy Expenditure

Individual values for RMR, TEE and PAL are reported in Table 2. The mean RMR, TEE and PAL across the fourteen-day assessment pre-season period was 11.20 (2.16) $MJ·day^{-1}$, 18.36 (3.05) $MJ·day^{-1}$ and 1.6 (0.2), respectively.

INSERT TABLE 2 HERE

Energy Balance

Individual values for energy intake, expenditure, balance and fasted BM change across the non-consecutive ten-day dietary assessment period are reported in Table 3. The mean difference between energy intake (16.73 (1.32) MJ·day^{-1}) and TEE (18.36 (3.05) MJ·day^{-1}) was *unclear* (-1.63 (1.73) MJ·day^{-1}; ES = -0.56 ±0.83; p = 0.233). The mean observed BM change was a *most likely* trivial decrease (-0.65 (0.78) kg; ES = -0.03 ±0.02; p = 0.076). Directional changes in BM were consistent with inferred energy balance values in five out of the six participants (i.e., those with a positive energy balance gained weight and those with a negative energy balance lost weight). There was a *possibly* trivial decrease in urine osmolality before BM weigh-ins (0.027 (0.066) mOsmol·kg^{-1}; ES = -0.3 ±0.29; p = 0.367).

INSERT TABLE 3 HERE

Discussion

This is the first study to simultaneously investigate the energy intake, expenditure and balance of professional young RL players across a pre-season period. Gold standard assessment techniques elucidated the distinctly large expenditures of professional young RL players across a pre-season, emphasising a requirement for equally large energy intakes to achieve targeted physical and anthropometric developments. Despite consuming large average dietary intakes, players were in a self-reported negative energy balance that corresponded in a mean reduction in fasted BM. Accordingly, it is imperative that professional young RL players and collision-sport athletes consume a sufficient energy intake to support optimal training adaption across physically demanding pre-season periods, where optimal development is targeted. Ultimately, practitioners and coaches are encouraged to regularly assess and behaviourally support desired manipulation of energy balance within professional young collision sport cohorts to maximise player development across pivotal pre-season periods.

We present novel measured RMR and DLW assessed TEE for professional young RL players during a pre-season period, which further evidences the distinctly large energy expenditures of professional RL players and collision-sport athletes. Average TEEs reported in this study are 819 $kcal \cdot day^{-1}$ higher than in-season values reported for professional senior soccer players via DLW, despite soccer players competing in two competitive matches across the data collection period (Anderson et al., 2017). On the contrary, reported expenditures are similar to values stated in-season for professional young rugby players (Smith et al., 2018) and elite young basketball players (Silva et al., 2013), despite the investigated cohort not competing in match play across pre-season. Interestingly, such large TEEs are probably a result of the distinct RMR measured in this study, which are 789 kcal higher than those reported for professional senior RL players in-season (Morehen et al., 2006). Such large RMR are possibly a consequence of the substantial muscle damage sustained during high pre-season training loads prescribed to drive desired player development (Costello et al., 2018b; Naughton et al., 2017). Collectively, RMR from this study and TEEs previously reported for both professional young and senior rugby players (Morehen et al., 2016; Smith et al., 2018) evidence the unique energetic demands of professional collision sport athletes across the season. Such large and individually varied TEE appear to exceed the kinematic demands of similar, non-collision based team sports (Anderson et al., 2017), likely influenced by the large fat-free and overall BM of collision-sport athletes (Till, Scantlebury, & Jones, 2017).

Professional young RL players have distinctly large TEEs, therefore require equally large energy intakes to achieve energy balance and targeted adaptations across challenging developmental periods. Due to the strenuous physical demands of professional RL and collision-based sports, it is imperative that young players utilise developmental periods (i.e. pre-season) to increase fat-free and overall BM to maximise their career progression (Brazier et al., 2018; Till, Scantlebury, & Jones, 2017). To drive desired adaptation, players require a habitual positive energy balance and high-quality diet (Logue et al., 2018; Thomas et al., 2016). In this study professional young RL players displayed distinctly large expenditures as high as 5708 kcal·day^{-1}, emphasising a requirement for equally large energy intakes to achieve the required daily energy surplus needed to increase fat-free mass alongside BM (Longland, Oikawa, Mitchell, Devries, & Phillips, 2016). Accordingly, it imperative that practitioners and coaches are aware of the unique energetic demands placed upon professional young, collision-sport athletes during intensified training periods such as pre-season.

Despite consuming large energy intakes, professional young collision sport athletes might fail to consistently achieve energy balance across demanding pre-season periods, potentially affecting targeted physical and anthropometric developments. In this study professional young RL players consumed a large average energy intake of ~4000 kcal·day^{-1}, 634 kcal·day^{-1} higher than intakes previously reported for professional young rugby players during a pre-season (Smith et al., 2016) and ~653 kcal·day^{-1} greater than values reported for professional senior RL players in-season (Morehen et al., 2016). In spite of such intakes, players still reported consuming 389 kcal·day^{-1} less on average than they expended, resulting in an undesirable reduction in fasted BM. Although a negative energy balance combined with a high protein diet can result in desirable body composition changes (i.e. decreased fat mass)(Longland et al., 2016), consistent energy deficits have been shown to result in low energy availability and a myriad of health defects that greatly '*out-weigh*' benefits in a young athlete population (Logue et al., 2018). Consequently, professional young collision-sport athletes are encouraged to account for the energetic '*impact*' of collisions, by (re)fuelling appropriately for the "muscle damage caused" alongside the kinematic "work required" (Costello et al., 2018b). Whereas, practitioners and coaches operating within professional collision-based sports are encouraged to objectively assess the energy balance of professional young RL players via daily fasted BM weigh-ins, supporting desired manipulation of energy intake via comprehensive, systematic, and theoretical behaviour change science (Costello et al., 2018).

Beyond energetic demands, players seemed to consume appropriate macronutrient intakes for optimal training, adaptation and recovery (Thomas et al., 2016), most likely an inevitable consequence of such large overall dietary intakes. In this study, player carbohydrate consumption was comparative to values reported for professional young and senior rugby players across pre- (4.7 $g \cdot kg^{-1} \cdot day^{-1}$)(Smith et al., 2016) and in-season periods (4.9-6.0 $g \cdot kg^{-1} \cdot day^{-1}$)(Lundy et al., 2006; Tooley et al., 2015). Interestingly, intakes aligned with current carbohydrate recommendations for moderately trained athletes (5-7 $g \cdot kg^{-1} \cdot day^{-1}$)(Desbrow et al., 2014) and more specifically with values advised prior to competitive RL match-play (6 $g \cdot kg^{-1} \cdot day^{-1}$)(Bradley et al., 2017). Likewise, protein intakes seemed appropriate within a young resistance trained population, subject to substantial exercise- and collision-induced muscle damage (Naughton et al., 2017), struggling to consistently attain energy balance (Costello et al., 2018). Therefore, due to the large dietary intakes reported it seems likely that players will inevitably consume a sufficient macronutrient profile, further evidencing a requirement for practitioners to prioritise a sufficient energy intake within professional collision-based sports.

Future research should seek to progress study findings by investigating the energy balance of professional young RL players during the season, while also examining intakes within other professional young and senior collision-sport cohorts (i.e. American football, Australian rules football, rugby union, rugby sevens and Gaelic football). Such research warrants dietary assessment over longer periods inclusive of a weekend, while also determining participant maturity status due to potential effects on expenditure (COMA, 1991). Future research should also confirm the reliability of dietary outputs via secondary analysis and prioritise a larger population size (Hopkins et al., 2009); although, the value of a low powered study that is otherwise well-designed and executed cannot be understated, especially within future meta-analyses or systematic reviews. For example, this study is strengthened throughout by the use of previously validated (Costello et al., 2017; Costello et al., 2017b) assessment methods or gold standard assessment techniques (Compher, Frankenfield, Keim, & Roth-Yousey, 2006), reducing measurement error within constructs of energy balance notorious for poor assessment validity and reliability (Dhurandhar et al., 2014). Ultimately, this increases confidence in study findings and inferred practical applications.

To conclude, this study provides novel insights into the energy intake, expenditure and balance of professional young RL players during a pre-season period. Despite consuming large average energy intakes, players reported a daily energy deficit that resulted in an undesirable loss in BM. Accordingly, practitioners operating within professional collision-based sports need to be aware of the distinct TEE of professional young collision sport athletes, ensuring a consistently sufficient energy intake to meet their unique energetic demands. This is of particular importance within youth athlete cohorts across pivotal developmental periods (i.e. pre-season). In practise, collision-sport athletes are encouraged to account for the energetic '*impact*' of collisions, by (re)fuelling appropriately for the "muscle damage caused" alongside the kinematic "work required". Whereas, practitioners and coaches are encouraged to regularly assess the energy balance of professional young RL players via daily fasted BM weigh-ins, supporting desired manipulation of energy intake via comprehensive, systematic, and theoretical behaviour change science.

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