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Section: Original Investigation

Article Title: Estimates of Energy Intake and Expenditure in Elite Female Touch Players During an International Tournament

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Running Head: Energy intake and expenditure in touch players

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Abstract

This study assessed energy intake and expenditure of international female Touch players during an international tournament. Energy intake (food diary) and expenditure (accelerometer, global positioning system) were recorded for 16 female Touch players during a four-day tournament, competing in 8.0 ± 1.0 matches; two on days one, two and four, and three on day three. Total daily energy expenditure (43.6 ± 3.1 $Kcal \cdot kg^{-1}$ body mass (BM)) was not different ($P > 0.05$) from energy intake (39.9 ± 9.4 $Kcal \cdot kg^{-1}$ BM). Carbohydrate intakes were below current recommendations (6-10 $g \cdot kg^{-1}$ BM) on days one (4.4 ± 0.6 $g \cdot kg^{-1}$ BM) and three (4.7 ± 1.0 $g \cdot kg^{-1}$ BM) and significantly below ($P < 0.05$) on day two (4.1 ± 1.0 $g \cdot kg^{-1}$ BM). Protein and fat intakes were consistent with recommendations (protein; 1.2 - 2.0 $g \cdot kg^{-1}$ BM, fat; 20 - 35 % total Kcal) across days one to three (protein; 1.9 ± 0.8, 2.2 ± 0.8 & 2.0 ± 0.7 $g \cdot kg^{-1}$ BM, fat; 35.6 ± 6.8, 38.5 ± 6.4 & 35.9 ± 5.4 % total Kcal). Saturated fat intakes were greater ($P < 0.05$) than recommendations (10 % total Kcal) on days one to three (12.4 ± 2.9, 14.2 ± 5.1 & 12.7 ± 3.5 % total Kcal). On average, female Touch players maintained energy balance. Carbohydrate intakes appeared insufficient and might have contributed to the reduction ($P < 0.05$) in high-intensity running on day three. Further research might investigate the applicability of current nutrition recommendations and the role of carbohydrate in multi-match, multi-day tournaments.

Key words: Intermittent, macronutrients, GPS, accelerometer, nutrition

Introduction

Touch rugby, or 'Touch', is a team sport characterised by frequent periods of high-intensity running interspersed with periods of low-intensity activity (Beaven et al., 2014). In the only study on movement characteristics of Touch match-play to date, international male players cover greater relative distance (137.1 ± 13.6 cf. 126.2 ± 17.2 m·min^{-1}), greater high-speed running (619.9 ± 155.2 cf. 564.9 ± 232.7 m) and very high-speed running (118.7 ± 59.9 cf. 68.4 ± 44.5 m), have a higher mean running speed (8.21 ± 0.76 cf. 7.51 ± 1.02 km·h^{-1}) and perform more high-intensity efforts compared to regional players (Beaven et al., 2014). During an international match, these movements are performed during 16 and 24 minutes of activity distributed across approximately 9 bouts, each lasting between 2-4 minutes (Beaven et al., 2014). No similar data exists for female Touch players. Match-day squads comprise six active players and eight interchange players with an unlimited substitution rule. Players compete over two 20-minute halves with a 3-minute half-time, with the sole objective of scoring more 'touchdowns' than the opposition (Federation of International Touch, 2008-2016). Touch is played in single- or mixed-sex squads and consists of three playing positions (wings, links and middles); all of which are exposed to high-intensity intermittent running for the duration of a match. Unlike other rugby codes, Touch does not involve kicking the ball, scrums or high-impact collisions but instead contact is limited to placing a hand on the ball-carrier, making the 'touch' (Beaven et al., 2014).

Given the activity profile described above, glycogen is undoubtedly an important substrate for energy production (Bangsbo et al., 2007) during Touch. Muscle glycogen concentrations decrease by ~40% after an 80-90 minute rugby and soccer match (Bradley et al., 2016; Bangsbo et al., 2007). Whilst time in play is lower compared to soccer and rugby, multiple fixtures over a four-day period means that muscle glycogen is important and potentially performance limiting (Holway & Spriet, 2011). Despite no published data on effects of repeated high-intensity matches over consecutive days, this physical load is likely to result in disturbances to metabolic homeostasis and other central and peripheral factors of fatigue (Dziedzic and Higham, 2014).

Due to challenges associated with calorimetry to assess energy expenditure (EE) in an applied sport setting (Bluck, 2008), a combination of methods is often required. Accelerometer devices can be combined with body-mass derived estimates (ten Haaf & Weijs, 2014) of resting energy expenditure (REE) to estimate total daily energy expenditure (TDEE) (Drenowatz & Eisenmann, 2011). Accelerometers provide valid and reliable measures of physical activity (Hills et al., 2014) and have been used in team sports to estimate EE (Briggs et al., 2015). However, the use of such devices is prohibited during Touch matches and is likely to underestimate EE during high-intensity intermittent exercise (Drenowatz & Eisenmann, 2011). Wearable micro-technology incorporating Global Position Systems (GPS), a 100 Hz tri-axial accelerometer, gyroscope and magnetometer have been proposed as practical and non-invasive methods to quantify exercise EE using a metabolic power model (di Prampero et al. 2005). This approach provides an instantaneous estimate of the amount of energy required, per unit of time, to reconstitute ATP used for work (di Prampero et al., 2005). Metabolic power is estimated using measures of velocity and acceleration captured by a micro-technology device. Although metabolic power parameters underestimate overall EE (Buchheit et al., 2015) when compared to open-circuit spirometry (i.e. 7.2 ± 1.0 cf. 13.2 ± 3.2 $\text{Kcal}\cdot\text{min}^{-1}$; Highton et al., 2016), it possesses a stronger association with EE (r = 0.63) than other measures such as high-speed distance (*r* = 0.50) or Player Load™ (*r* = 0.37; Highton et al., 2016). Given this method has been employed with other non-contact team sports (Polglaze et al., 2017), the metabolic power model offers a useful approach to understand the energy demands of Touch.

Understanding the nutritional intake of an athlete enables sports nutritionists to advise on appropriate interventions that can improve health and performance (Rosenbloom et al., 2006). While data are available regarding the nutritional practices of female soccer (Noack et al., 2016; Martin et al., 2006; Clark et al., 2003), volleyball (Zourdos et al., 2015), hockey (Macleod & Sunderland, 2009) and netball (Heaney et al., 2010), information on nutritional practices of elite female Touch players remains absent. Previous studies demonstrate that female team-sport athletes do not meet their energy needs (Noack et al., 2016; Zourdos et al., 2015; Clark et al., 2003) with lower carbohydrate (CHO) intakes reported compared to sports nutrition recommendations (Thomas et al., 2016; Burke et al., 2011). Sub-optimal energy and CHO intakes have been attributed to players wishing to maintain low body mass or due to under-reporting in self-reported food diaries (Rosenbloom et al., 2006). A limited availability of snacks or appropriate food choices whilst touring might contribute to this (Dziedzic & Higham, 2014). An acute sub-optimal energy and CHO intake has potential implications for players' performances including; reductions in high-intensity running (Bradley et al., 2016), impaired decision-making (Winnick et al., 2005) and delayed recovery (Burke et al., 2006). In an attempt to understand the nutritional practices of elite female Touch players during competition involving multiple matches on consecutive days, the aims of this study were to 1) quantify TDEE and energy intake (EI) of elite female Touch players during an international competition and 2) to determine whether players were meeting the current sports nutrition recommendations.

Methods

Overall Study Design

Using an observational approach, total daily energy expenditure (TDEE) and energy intake (EI) was collected for elite female Touch players during an international Touch tournament in 2016 where players were involved in 6 to 9 (mean ± SD: 8.0 ± 1.0) matches over a four-day period, including a final on day four. Micro-technology was used to estimate energy expenditure (EE) during competition and non-competition periods. Participants completed a four-day food diary to assess their energy and macronutrient intakes.

Participants

With institutional ethics approval and informed consent obtained, 16 elite female Touch players (age 27.4 ± 6.2 years, stature 163 ± 6.0 cm, body mass 60.0 ± 6.5 kg) from an international squad volunteered for this study. Data were collected during a 2016 international tournament (temperature 18 ± 2°C, humidity 86 ± 8%). Players were familiarised with the testing procedures during a previous training camp. All participants were free of injury as confirmed by the organisation's Head of Medical Services.

Procedures

Tournament Structure and Facilities

Table 1 outlines the structure of the tournament. Players had a minimum of 1 h 40 min and a maximum of 4 h 20 min between matches to rest once pre-match preparation, a post-match debrief and cool down was accounted for. There was limited onsite catering and no in-house self-catering facilities in players' accommodation, meaning players were required to be self-sufficient in planning, preparing and bringing their own nutrition and hydration supplies for the duration of the tournament.

Measurement of Energy Expenditure

Accelerometers (10 of GT9X-link and 6 of GT3X-BT; ActiGraph, Pensacola, USA) were initialised with participant characteristics before the data collection period and the sampling frequency was set at 30 Hz (Brønd & Arvidsson, 2016). Two models were used due to equipment availability. Both devices use the same micro-technology. They differ in battery life, mass and the GT3X-BT model lacks a display screen. Each participant wore the same accelerometer device on their dominant wrist at all times outside of match-play which was only removed once the GPS device was fitted pre-match or during exposure to water.

A body mass-based predictive equation validated in athletes of a similar standard (aged 18-35 years) (ten Haaf & Weijs, 2014) was used to estimate REE:

$$REE(Kcal \cdot d - 1) = 11.936 X bodymass(kg) + 587.728 * stature(m) - 8.129 X age(y) + 191.027 * 0 + 29.279$$

Energy expenditure was estimated during match-play using the 100 Hz tri-axial accelerometer within the GPS device (Optimeye S5, Catapult Innovations, Australia) that derives EE from a metabolic power model proposed by di Prampero et al. (2005). Devices were securely positioned between the scapulae in a custom-made vest worn under the playing shirt during each warm-up, match and cool-down. Participants wore the same device throughout the study removing inter-unit variability. Upon completion, GPS data were downloaded (Sprint, Version 5.1, Catapult Sports, VIC, Australia) and exported to a spreadsheet providing daily means for metabolic power and EE variables (mean metabolic power ($W \cdot kg^{-1}$), time (min) above high-power (>20 $W \cdot kg^{-1}$) and EE ($Kcal \cdot kg^{-1}$). Energy expenditure derived from the micro-technology was combined with EE estimated by the ActiGraph devices and estimates of REE to calculate TDEE ($Kcal \cdot kg^{-1}$). Total and relative distance along with measures of relative high-intensity distance (> 14 km·h-1; Beaven et al., 2014) were recorded to provide an understanding of the match demands. Accuracy of micro-technology for measuring distance and metabolic power in team sport activity has been reported (Rampinini et al., 2015), and is reliable for measures of instantaneous speed and acceleration (Varley et al., 2012).

Measurement of Energy Intake

Participants recorded all foods and drinks consumed during the data collection period using a four-day food diary. One diary was not returned at the end of the tournament; thus, analysis is based on 15 players. The researcher (a Registered Dietitian) gave verbal and written instructions asking participants to accurately record volumes, quantities and brand names where possible. The researcher was on site throughout the tournament to assist players in recording food and drink intakes accurately. Nutrient intakes were calculated using Nutritics software (Nutritics Education Edition, v4.097, Ireland).

Statistical Analysis

All data are expressed as means ± standard deviation (SD) and were checked for normality and homogeneity using the Shapiro-Wilk test and Levene's test, respectively. An alpha level of ≤ 0.05 was used to detect significant differences in all tests. Differences in match demands across the tournament were analysed via one-way analysis of variance (ANOVA). Differences in and between TDEE and EI (days one to three) were analysed via two-way ANOVA. If Mauchley's test of sphericity was violated, data was corrected using the Greenhouse Geisser (ε). Day four was shorter so required a separate analysis for EI and EE with a proportion (63.5%) of REE added to reflect the data collection period (0000 h to 1515 h), and as such, were assessed using a paired samples *t*-test. Differences in mean macronutrient intakes (day one to three) and current sports nutrition recommendations were assessed using one-sample *t*-tests. Data were analysed using the Statistical Package for Social Sciences (Version 22, 2015).

Results

There were no differences in match demands between matches (all $P > 0.05$). However, overall high-intensity distance was lower ($P < 0.05$) on day three (20.2 ± 6.8 $m \cdot min^{-1}$) compared to day one (29.0 ± 14.3 $m \cdot min^{-1}$). All data are shown in Table 2.

Daily EI and TDEE assessed over days one to three and EI and EE for day four are shown in Figure 1. Mean daily EI and TDEE was 39.9 ± 9.4 $Kcal \cdot kg^{-1}$ BM and 43.6 ± 3.1 $Kcal \cdot kg^{-1}$ BM, respectively. There was no significant time x condition effect for daily EI and TDEE (F = 0.488, $P > 0.05$) and no difference between daily EI and TDEE over days one to three (F = 0.293, $P > 0.05$). EI (20.7 ± 9.9 $Kcal \cdot kg^{-1}$ BM) was lower than EE (29.4 ± 2.4 $Kcal \cdot kg^{-1}$ BM) on day four ($t = -3.712$ and $P < 0.05$).

Mean daily macronutrient intakes assessed from food diaries compared to current sports nutrition recommendations are shown in Table 3. Mean daily CHO intakes were below the lower threshold of recommended intakes (6 $g \cdot kg^{-1}$ BM) on day one ($t = -1.931$, $P > 0.05$), two ($t = -3.771$, $P < 0.05$) and three ($t = -1.244$, $P > 0.05$) for intermittent team sport athletes. Protein intake was higher than the lower recommendation for protein consumption (1.2 - 2 $g \cdot kg^{-1}$ BM) on day one ($t = 3.056$, *P*

< 0.05), two (t = 4.626, P < 0.05) and three (t = 4.360, P < 0.05) but not upper range on day one (t = -0.686, P > 0.05), two (t = 0.744, P = > 0.05), and three (t = 0.240, P > 0.05). Total fat intake was greater than the lower threshold (20% total Kcal) on day one (t = 8.878, P < 0.05), two (t = 11.220, P < 0.05) and three (t = 11.307, P < 0.05), but not different from the upper threshold of recommended fat intakes (35% total Kcal) on day one (t = 0.360, P > 0.05), two (t = 2.113, P > 0.05), and three (t = 0.613, P > 0.05). However, saturated fat intake was greater than recommended saturated fat intakes for health (10% total Kcal) on day one (t = -7.883, P < 0.05), two (t = 7.809, P < 0.05) and three (t = 8.048, P < 0.05).

Discussion

The aims of this study were to 1) quantify TDEE and EI of elite female Touch players during an international competition and 2) to determine whether players were meeting the current sports nutrition recommendations. Our results indicate players' mean daily EI was not different from their TDEE during an international competition. CHO intake was below and saturated fat intake above current sports nutrition recommendations. This information has immediate practical application to inform nutritional intervention or educational targets for female international Touch players.

Daily EI (39.9 ± 9.4 $Kcal \cdot kg^{-1}$ BM) of elite female Touch players was comparable with that observed in multi-match tournaments for elite netball (39.6 $Kcal \cdot kg^{-1}$ BM; Heaney et al., 2010) and volleyball players (40.7 $Kcal \cdot kg^{-1}$; Zourdos et al., 2015). However, EI is greater than values reported in elite soccer players (30.9 $Kcal \cdot kg^{-1}$ BM; Martin et al., 2006) during single match events where less emphasis may be on EI due to longer times between training and competition. Furthermore, despite a 7-day food diary being a valid method for capturing participants' habitual intakes, it is possible that the 7-day food and activity diary employed by Martin and colleagues (2006) resulted in participant burden and consequently under-reporting (Shim et al., 2014). It is possible that the higher mean EI reported compared to previous studies (Noack et al., 2016; Clark et al., 2003), was a consequence of thorough familiarisation before the tournament and support from the researcher during the data collection period. It is, however, important to note that the use of different nutrient databases to assess nutrient intakes might explain some of the differences between studies (Slimani et al., 2007).

No difference was observed between mean TDEE and EI (days one to three), contrasting with studies reporting a shortfall in energy intake compared to expenditure in female athletes (Noack et al., 2016; Zourdos et al., 2015; Mullinix et al., 2003). However, large individual variation in energy balance (-19.1 to 16.9 Kcal$\cdot$kg^{-1} BM) was observed in this study. Differences in number of matches played, as well as nutrition knowledge, tournament preparation and food availability might have contributed to large individual variation. Consideration of individual nutritional practices is important (Figure 2) to identify those athletes who require nutrition support. An acute energy deficit might lead to poorer performance in tournaments (Bradley et al., 2015), while long-term energy deficits could result in a loss of body and lean mass (Martin et al., 2006) as well as consequences for health (Mountjoy et al., 2014).

Energy intake was lower than EE on day four. This could be because of an early match on day four (0830) resulting in players eating less before the final, potentially impacting on performances at a crucial time. The data collection period on day four does not represent a 24-h period due to equipment availability and access to participants. Meals and snacks consumed outside of this time were therefore not accounted for and may have made up the deficit incurred in the first half of the day.

Whist current CHO recommendations (6-10 g·kg^{-1} BM) are not specific to Touch; the observed CHO intakes might be inadequate to replete and maintain players' glycogen reserves, possibly compromising performance and recovery (Burke et al., 2011). In other multiple sprint sports muscle glycogen decreases by ~40% during an 80-90 minute match (Bradley et al., 2016; Bangsbo et al., 2007), resulting in a reduction in high-intensity running and sprinting (Krustrup et al., 2006; Bradley et al., 2016). It is likely Touch places a lower demand on glycogen stores given a match is shorter in duration (40 minutes cf. 90 minutes) and total distance covered is less compared to soccer (~2300 m cf. ~9500 to 11000 m). No studies have investigated changes in muscle glycogen during multi-match, multi-day tournaments. However, Touch match-play, comprising multiple repeated-sprint matches over four days with as little as <2 h recovery between matches is likely to result in some degradation of muscle glycogen (Williams & Rollo, 2015).

Lower CHO intakes reported by participants might partly explain the lowest high-intensity distance observed in matches 6 (19.3 ± 6.6 m·min^{-1}) and 7 (18.2 ± 6.9 m·min^{-1}), with a reduction in mean high-intensity distance observed between days one and three. Notwithstanding the contribution of an additional match on day three, food diary analysis revealed players had lowest CHO intakes on day two (4.1 g·kg^{-1} BM), which was below (*P* < 0.05) current sports nutrition recommendations (6-10 g·kg^{-1} BM) and may have been inadequate preparation for the congested fixtures on day three. These findings raise interesting questions regarding optimal CHO requirements for athletes participating in multiple matches over consecutive days. Unlike other team sports where nutrition support for competition occurs around a single match, Touch players must consider eating and drinking around a three to four day multi-match tournament (Dziedzic & Higham, 2014). Further research is therefore required to optimise CHO intake for multi-match, multi-day tournaments and how best to periodise this for Touch players.

Protein intakes were above minimum recommendations necessary for maintaining nitrogen balance and stimulating muscle protein synthesis (Phillips & van Loon, 2011). Timing and types of protein ingested by players was not reported, but is an important consideration given its role in reducing muscle damage and enhancing performance during subsequent exercise bouts (Phillips & van Loon, 2011). Future studies could provide a more thorough analysis of Touch players' protein consumption during a multi-day tournament.

Total fat intakes were consistent with current recommendations (20-35% total Kcal) (Thomas et al., 2016) and are comparable with that previously reported (36.1 ± 4.6% total Kcal) in elite volleyball players (Zourdos et al., 2015). However, players' daily saturated fat intakes significantly exceeded maximal recommended intakes (COMA, 1991). Competitive Touch players might compromise high-intensity efforts during competition if fat is consumed in place of adequate CHO (Thomas et al., 2016). Future education could be directed at reducing saturated fat intake during competition allowing for greater CHO consumption whilst maintaining energy balance.

Given the nature of the environment in which data were collected, this study is not without limitations. While a metabolic power approach has been used previously in other sports (Polglaze et al., 2017; Coutts et al., 2015), we acknowledge the possible underestimation of EE during match play by employing this method (Highton et al., 2016; Buchheit et al., 2015). Furthermore, data were gathered from a small sample size from one female International Touch squad during a single tournament. Further research is required using data from multiple teams of both sexes to better understand the nutritional requirements of elite Touch players.

In conclusion, elite female Touch players can balance energy requirements and energy intake during a tournament as no significant difference was observed. Although the unique structure of Touch tournaments (multiple-matches over consecutive days) questions the applicability of sports nutrition recommendations to inform nutritional practices of other team sports (Bradley et al., 2016), players studied here were not meeting recommendations for daily CHO intakes. This, along with large individual variability suggests that individual nutrition support is warranted. Elite female Touch players are meeting recommended intakes for protein and total fat but exceeded recommendations for saturated fat. These findings have immediate practical application as players might benefit from education of adequate CHO as an important substrate for energy production.

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Authorships

This study was designed by NM and CC, data were collected and analysed by NM and ND, data interpretation and manuscript preparation were undertaken by NM, ND, CT and CC. All authors approved the final version of the paper.

Disclosure statement

The authors reported no potential conflict of interest.

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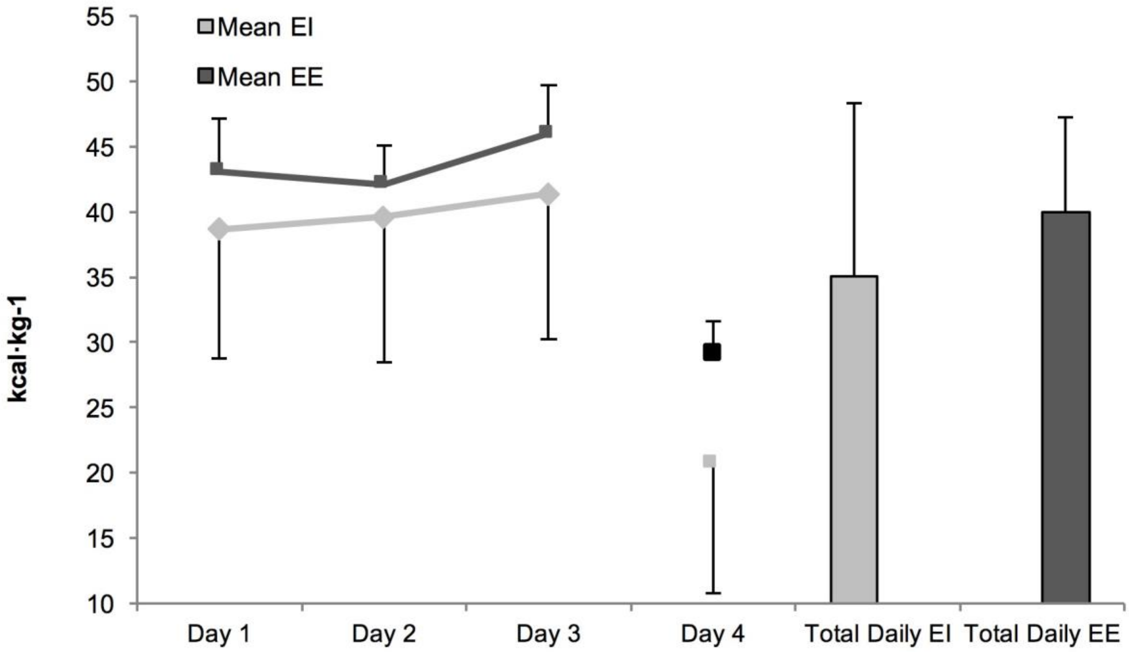

Figure 1. Daily EI (n = 15) and TDEE (n = 16) (kcal·kg^{-1} BM) assessed over days one to three of the tournament and EI (n =15) and EE (n =16) for the data collection period on day four. Data are presented as means ± SD.

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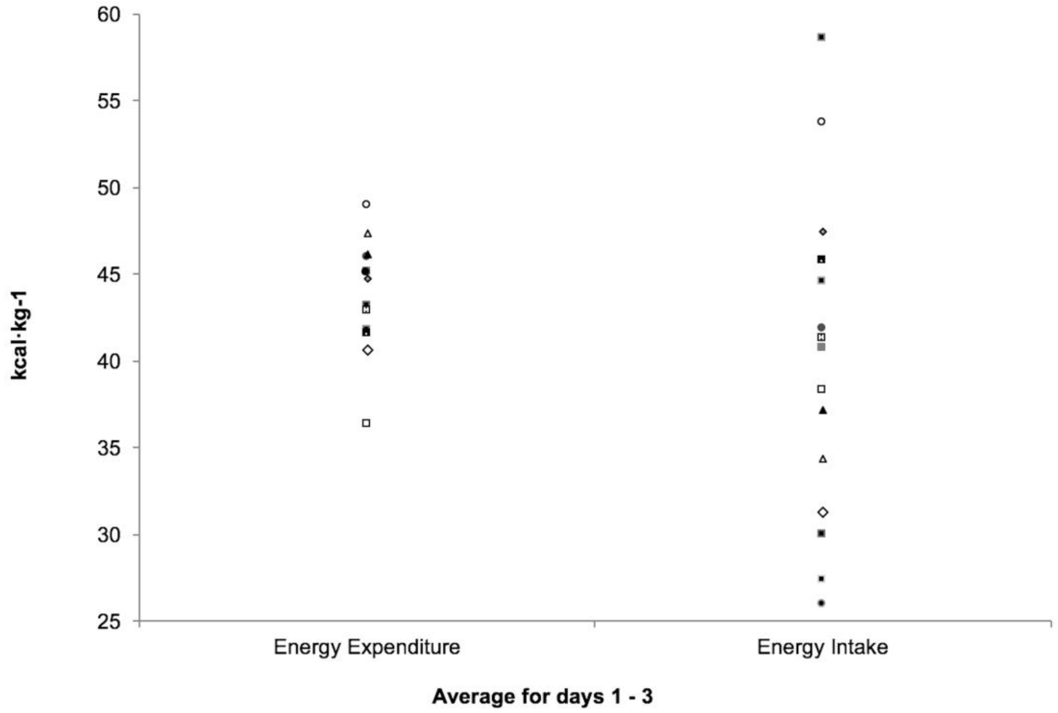

Figure 2. Individual average EE and EI (kcal·kg^{-1} BM) for each participant assessed over days one to three of the tournament.

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Table 1. Daily structure of international Touch tournament for study participants

	Day 1	**Day 2**	**Day 3**	**Day 4**
No. of matches	2	2	3	2
Tap-off times (h: min)	10:40; 14:50	09:50; 13:10	09:00; 12:20; 15:40	08:30; 14:30
Time between matches (min)	140	100	100; 100	260

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Table 2. Mean ± SD movement characteristics per match on days 1 - 4.

	Day 1		**Day 2**		**Day 3**			**Day 4**	
	Match 1	Match 2	Match 3	Match 4	Match 5	Match 6	Match 7	Match 8	Match 9
Playing time (min:s)	20:6 ± 9:9	18:5 ± 9:2	18:0 ± 4.2	18:5 ± 8:6	19:7 ± 7:4	21:5 ± 6:6	21:9 ± 7:0	20:6 ± 7:7	20:6 ± 7:3
Total distance (m)	2493 ± 775	2299 ± 815	2104 ± 566	2160 ± 510	2497 ± 733	2361 ± 762	2308 ± 670	2531 ± 814	2450 ± 729
Relative distance ($m·min^{-1}$)	129.1 ± 24.0	130 .3 ± 18.0	118.6 ± 25.5	124.1 ± 19.4	126.2 ± 14.6	110.6 ± 12.5	106.5 ± 9.8	125.4 ± 12.7	123.3 ± 16.9
Relative high intensity distance ($m·min^{-1}$)	29.3 ± 14.8	29.5 ± 18.8	23.1 ± 7.8	20.6 ± 10.2	23.0 ± 9.6	19.3 ± 6.6	18.2 ± 6.9	23.3 ± 10.4	23.0 ± 12.6
Peak Metabolic power ($W·kg^{-1}$)	12.83 ± 5.2	11.96 ± 2.83	14.48 ± 2.52	11.15 ± 4.51	12.37 ± 3.43	11.67 ± 5.24	11.79 ± 4.17	12.30 ± 4.01	12.62 ± 3.77
Time spent above high metabolic power (>20 $W·kg^{-1}$) (min·s)	2:05 ± 0:27	1:56 ± 0:24	1:49 ± 0:30	1:33 ± 0:20	2:00 ± 0:34	1:48 ± 0:26	1:45 ± 0:21	2.03 ± 0.27	2.01 ± 0.32

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Table 3. Mean daily macronutrient intakes (± SD) (*n* = 15) compared to current sports nutrition recommendations (Thomas et al., 2016 and Phillips & Van Loon, 2011).

	Day 1	Day 2	Day 3	Recommendation
CHO (g·kg^{-1} BM)	4.5 ± 1.0	4.1 ± 1.0*	4.7 ± 1.0	6-10
Protein (g·kg^{-1} BM)	1.9 ± 0.8	2.2 ± 0.8	2.0 ± 0.7	1.2-2.0
Fat (% total Kcal)	35.6 ± 6.8	38.5 ± 6.4	35.9 ± 5.4	20-35
Saturated fat (% total Kcal)	12.4 ± 2.9*	14.2 ± 5.1*	12.7 ± 3.5*	10

*Indicates a significant difference from the recommendation.