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Energy Expenditure Pattern of Adolescent Athletes: A Narrative Overview

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Abstract

Adolescent athletes are at a crucial time of growth and development, and require additional energy for growth demands, over and above training energy expenditure. This study aims to understand the energy expenditure pattern of adolescent athletes, particularly in athletics, football and weightlifting events. This narrative review adopted a scoping design and search keywords related to energy or energy expenditure, athletes (adolescent, junior, young) specific to sporting category (athletics, runner, middle distance runner, soccer, football, weightlifting) were used in PubMed and Google Scholar using appropriate Boolean operators. A total of 1385 articles were screened for title, followed by abstract for content related to energy expenditure and/or energy intake of adolescent aged 10-17 years. Post screening, 8 articles related to track athletes, 24 articles related to football/soccer and 4 articles related to weightlifting were selected and data extraction of key physical variables and energy were carried out. The mean energy expenditure ranged from 29 to 57 kcal/kg body mass among track athletes and 42 to 61 kcal/kg body mass among football players, with lower end of the range expended by girls and higher end by boys, irrespective of the training season. There was limited research carried out on energy expenditure pattern of weightlifters being an anaerobic sport. Among Indian weightlifters, the energy expenditure was reported to be higher due to competition season, with 51 to 60 kcal/kg body mass among boys and 45 to 58 kcal/kg body mass. The calorie expenditure pattern collated will be useful in setting fuel requirements and planning a diet specific to a sport

Introduction

During adolescence, energy should be inclusive of the growth demands as well as the substrate demands for the physical training and competition (Aerenhouts, Deriemaeker, Hebbelinck, & Clarys, 2011). The energy expenditure pattern (kcal/day) of adolescent athletes has been reported to be 3640 ± 830 among males and 3100 ± 720 among females (Carlsohn et al., 2011). However, due to metabolic variation between individuals, it is important to estimate individual energy

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requirements for improved accuracy (Petrie, Stover, & Horswill, 2004). Even other factors like training load, seasonal variation and participation in more than one sport also influence the energy expenditure pattern of adolescent athletes (Desbrow, Burd, Tarnopolsky, Moore, & Elliott-Sale, 2019). The energy needs for growth may be estimated by understanding the energy deposited in growing tissues and energy for synthesis of new tissues (Torun, 2005). The energy deposited in growing tissues is estimated to be 8.6 kJ/gram (approximately 2.1 kcal/gram) of daily weight gain as suggested by WHO (1982). If the weight gain is approximately 7kg per year, then the energy utilised towards growth would only be approximately 40 kcal per day and this seems to be negligible in comparison with the energy expenditure for physical training and competition undergone by the adolescent athlete. Further, the energy required of synthesis is incorporated in the total energy expenditure measurement (Desbrow et al., 2019).

Materials and Methods

Study Design

The narrative exploration followed a scoping review design with inclusion criteria including all original observational studies or baseline data of intervention studies of athletes aged 10-17 years (adolescent) using search databases like PubMed and Google Scholar.

Literature Search and Screening

An attempt was made to understand energy expenditure pattern of adolescent athletes. This was done by conducting a search on PubMed and Google Scholar. Keywords and Boolean operators such as “Athletics OR Runner OR Sprinter OR Middle-distance runner”, “Soccer OR Football”, “Weightlifting OR Weightlifter” AND “Adolescent OR Junior OR Young” AND “Energy OR Energy expenditure” were used to carry out the search. For athletics, a combination of Runner OR Sprinter OR Middle-Distance Runner AND Adolescent OR Young yielded 287 articles, which were all screened for energy expenditure related articles. For football or soccer, a total of 387 articles and weightlifting alone 711 articles were available, the titles of each of the article was screened to find its suitability.

Study Selection and Data Extraction

After removing repeated articles, about 8 articles for athletics, 24 articles for football (in UK) or soccer (In USA and Australia) and 4 articles for weightlifting that met the inclusion criteria of 10-17-year-old athletes and containing measured values for energy expenditure were selected. If an intervention or case-control study was selected, only the baseline physical characteristics were included and if a longitudinal study was selected, only the age range of 10-17 years were included. Research focussing on older adolescent and adults aged 17 years and above were excluded from the review. Studies conducted before 2000, have also been excluded considering the changes in body mass and fat-free mass over the years. The data pertaining to author, year, athlete basic characteristics, country, level of competition, energy expenditure and energy intake, methods of measurement were selected for this review.

Results and Discussion

Event-Specific Fuelling of Adolescent Athletes

Considering the importance of energy and its role in maintaining the normal physiological functioning of the body, especially among adolescent athletes, there is a need to explore event specific guidelines of energy expenditure pattern. This study was initiated to determine event and phase specific energy requirements by considering three events (Athletics-Track event, Football, Weightlifting) utilising different energy systems for fuelling. The existing literature on energy intake and energy expenditure pattern of athletics (track events), football and weightlifting are presented in Table 1 to Table 3.

Athletics

Athletics is inclusive of track and field events with varied fuel utilisation and energy expenditure pattern. Among track athletes, the sprinters rely more on the Adenosine Tri Phosphate /Creatine Phosphate (ATP/CP) system for fuelling, while the middle-distance runners rely more on anaerobic glycolysis and the long-distance or endurance runners on the aerobic energy production (Table 4). Each of these events have unique physique with sprinters being more muscular and middle-to-endurance runner being leaner. At the international level, the Kenyan runners with their leaner physique and higher aerobic capacity have been excelling in the middle to long distance track events. The mean energy intake pattern of junior male and female

Kenyan runners was found to be 3157 and 2028 kcal per day, respectively (presented in Table 1). From the existing literature (Table 1), the mean energy expenditure pattern of junior track athletes ranged from 3151 to 3609 kcal per day among boys and for girls it ranged from 1427 to 2467 kcal per day. Energy deficits were observed among the Flemish athletic league sprinters (Aerenhouts, Zinzen, & Clarys, 2011). The energy expenditure pattern was determined using the fully factorial approach in most of the above studies. Thus, pointing to the need for research to provide measured values of energy cost and energy expenditure pattern of track athletes.

Football/Soccer

Team sports mostly involve high-intensity intermittent activities that are repeated over a period of 30 to 90 minutes, depending on the type of sport. They involve the anaerobic energy system for high intensity movements and aerobic energy system for the repeating nature of the event with continuous movement. This is particularly true in case of soccer or football. The term "soccer" is used in America (USA) and Australia, while the more popular terminology "football" is used by United Kingdom (UK), Europe and rest of the world, including India. Both these refer to the same sport, involving a spherical ball with a total match time of 90 minutes with 11 players on the field, as opposed to oval or ellipsoid shaped ball with 15 players on the field in the rugby league football game lasting 80 minutes. Both these are distinct events requiring varied fuel sources. The present study deals with the fuel demands of soccer (US and Australia) or football (UK and Europe) event only. In soccer, 70% of the activities performed are of low intensity, however, the average oxygen uptake of the elite soccer player reaches up to maximal intensity of 70% of VO_{2max} (Bangsbo, Mohr, & Krustrup, 2006). This is due to the high intense bouts of ball kicking and tackling involved in the sport. Nevertheless, more than 90% of the energy production was observed to be aerobic (Bangsbo, 1994).

From the existing literature (presented in Table 2), the absolute mean energy intake pattern of soccer players ranged from 1903 to 3952 kcal per day among boys and among girls it ranged from 2079 to 3122 kcal per day. In relative terms, the mean energy intake of football players ranged from 40 to 65 kcal per kg body mass, and few studies reporting lower intake were either estimated in the transition phase with lower training load (Hickson et al., 1987) or projected an under-reporting (Caccialanza, Cameletti, & Cavallaro, 2007) among boys. While in girls, it ranged from 35 to 40 kcal per kg body mass, except a higher intake of 58.6 kcal per kg body mass projected among Iranian players (Hosseinzadeh et al., 2017). The mean energy expenditure pattern of football players ranged from 2552 to 3833 kcal per day among boys and 2403 to 3311 kcal per day among girls. In relative terms, the mean energy expenditure of boys and girls were within the range of 40 to 55 kcal per kg body mass, except one study that showed above 60 kcal per kg body mass among boys (Rico-Sanz et al., 1998).

Majority of the studies showed mean energy deficits among football players, except one study (Rico-Sanz et al., 1998). These studies used factorial approach based on predictive models and activity recalls to arrive at the energy expenditure pattern, while one study (Briggs et al., 2015) used physical activity recorders (accelerometers). Thus, it is evident that studies on junior soccer players have not employed the actual measured values using portable indirect calorimetry method for energy cost of sporting activities and the energy expenditure pattern of soccer players.

Weightlifting

Strength and weight-class sport has a training structure of repeated bouts of high intensity activity lasting from few second to around 3 minutes. The energy for these activities are predominantly from the ATP/CP system, followed by anaerobic glycolysis (Åstrand, Rodahl, Dahl, & Strømme, 2003; Petrie et al., 2004). Weightlifting involves two multi-joint whole-body lifts, which is the snatch and the clean and jerk. During competitions, they produce the highest absolute and relative peak power outputs and the isometric peak force is about 15-20% higher than other strength and power sport (Storey & Smith, 2012). Weightlifters tend to have higher metabolic cost and the adult weightlifters were reported to be consuming adequate energy, however, the macronutrients like protein and fat were consumed more than carbohydrates (Slater & Phillips, 2011; Storey & Smith, 2012). From the limited literature on energy intake of junior weightlifters (Presented in Table 3), the national-level German weightlifters (Heinemann &

Zerbes, 1989) found to consume higher mean energy compared to other young weightlifters from Germany (Bauer, Jakob, Berg, & Keul, 1994) and China (Chen et al., 1989). Till date scanty research exists on the energy expenditure pattern of Weight-class sports, particularly weightlifters ≤17 years of age (Storey & Smith, 2012) and there is a need for research on nutrition of young weightlifters, especially energy expenditure pattern.

Table 1
Energy Intake and Energy Expenditure Pattern of Adolescent Track Athletes

Sl. No.	Study	Participants	Method	Body Mass (BM) kg	Energy Intake (EI) kcal/day	Energy Expenditure (EE) kcal/day
1	Muia, Wright, Onywera, and Kuria (2016)	Elite Kenyan female middle to long distance athlete (16-17y, G=56)	EI by 5-day food record EE by factorial approach using activity records	G: 48.5 ± 6.1	G: 2028 Range: 2090 - 2155	G: 1427 ± 238
2	Aerenhouts, Zinzen, et al. (2011)	Flemish Athletics League Sprinters (16.5±1.6y, n=16 10 boys & 6 girls)	EI by 7-day food diary EE by Two-axial accelerometer (A) and activity diary (AD)	63.7 ± 5.2	2569 ± 508	A: 3012 ± 518 AD: 3196 ± 590
3	Barrack, Van Loan, Rauh, and Nichols (2010)	High school endurance athletes, USA (16.3±0.2y, G=26)	EI by 7-day food records plus daily 24-hr dietary recall	G: 56.9 ± 1.4	G: 2346 ± 83 (SE)	-
4	Eisenmann and Wickel (2007)	High school distance runners from Michigan (10-19y, B=20; G=8)	EE by factorial approach using 3-day activity records	B: 62.5 ± 7.6 G: 49.8 ± 11.6	-	B: 3609.1 ± 927.5 G: 2467.4 ± 425.6
5	Christensen, Van Hall, and Hambraeus (2002)	Elite Kenyan Kalenjin middle to long distance runners (15-20y, B=12)	EI by 24-hr dietary weighed record plus recall EE by factorial approach using 24-hr hour activity recall	B: 55 ± 1.8	B: 3157.5 ± 67.6 (SE)	B: 3151.5 ± 65.5 (SE)

Table 2
Energy Intake and Energy Expenditure Pattern of Junior/Adolescent Soccer (in US)/Football (in Europe) players

Sl. No.	Study	Participants	Method	Body Mass (BM) kg	Energy Intake (EI) kcal/day	Energy Expenditure (EE) kcal/day
1	Hosseinzadeh et al. (2017)	National Iranian Olympiad athletes (12-18y, Football B=40, G=8)	EI by 3-day recall method	B:61.1± 6.7 G: 53.3± 11.3	B: 3223 ± 467 G: 3122 ± 746	-
2	Braun, von Andrian-Werburg, Schänzer, and Thevis (2017)	Elite German football players (14.8±0.7 y, G=56)	EI by 7-day food records EE by factorial approach using 7-day self-reported activity records	G: 56.8 ± 6.1	G: 2226 ± 368 40 ± 7 kcal/kg BM	G: 2403 ± 195 43.1 ± 4.8 kcal/kg BM
3	Naughton et al. (2016)	English Premier League (EPL) players (U13/14, B=21) In-Season	EI by 7-day food diary	B: 44.7 ± 7.2	B: 1903 ± 432.4	-
4	Amorós, Padilla, and de la Rosa (2015)	Mexican Male National Soccer players (15y, Team A=24)	EI by 4-day self-reported food records EE by factorial approach using predictive models	B: 61.8 ± 1.31	B: 3067 ± 151 50.3 ± 8 kcal/kg BM	B: 3118 ± 41
5	Briggs et al. (2015)	English Premier League players (15.4±0.3, B=10) CP	EI by 24-hr weighed food records plus 24-hr recall EE by tri-axial accelerometery method	B: 57.8 ± 7.8	B: 2245.5 ± 321.2	B: 2552.3 ± 245.2
6	Baker, Heaton, Nuccio, and Stein (2014)	Team sports athletes (14-19y, B=22, G=7)	EI by 24-hr direct observation by dieticians EE by factorial approach using predictive models	B: 74.0 ± 11.9 G: 62.3 ± 6.8	B: 3522 ± 1137 G: 2299 ± 495	B: 3791 ± 870 G: 3311 ± 1092

Note: *B = Boys; G = Girls; y = age in years; CP = Competition phase; Training Season/Phase was not reported by most studies; Values are presented as Standard deviation, unless otherwise specified.*

Table 2 Contd.

Sl. No.	Study	Participants	Method	Body Mass (BM) kg	Energy Intake (EI) kcal/day	Energy Expenditure (EE) kcal/day
1	Gibson, Stuart-Hill, Martin, and Gaul (2011)	Canadian female soccer athletes (15.7± 0.7y, G=33)	EI by 4-day food record EE by factorial approach using predictive equations	G: 60.9 ± 8.2	G: 2079 ± 460 35 ± 10 kcal/kg BM	G: 2546 ± 190 42 ± 3 kcal/kg BM
2	Caccialanza et al. (2007)	Italian First Division Soccer League players (15-17y, B=75)	EI by 4-day food record EE by factorial approach using predictive equations	B: 69.8 ± 7.4	B: 2640 ± 614[#]	B: 3450 ± 260
3	Iglesias-Gutiérrez et al. (2005)	Spanish adolescents (14-16y, B=33)	EI by 7-day self-weighed food records EE by factorial approach using predictive equations	B: 65.1 (Range: 54.3-87.8)	B: 3003 Range: 2261 - 4007	B: 2983 Range: 2705 - 3545
4	Ruiz et al. (2005)	Arenas Football Club Players (14y, B=18)	EI by 3-day food diary	B: 62.8 ± 2.2	B: 3456 ± 309 54.6±15.5 kcal/kg BM	-
5	Clark, Reed, Crouse, and Armstrong (2003)	NCAA Division I Soccer players (19.7±0.7y, G=14) Pre-season	EI by 3-day food diary	G: 62.0 ± 4.8	G: 2290 ± 310	-
6	Rico-Sanz et al. (1998)	Puerto Rican Olympic Team (15-19y, B= 8)	EI by 12-day food record EE by factorial approach using 12-day activity records	B: 63.4 ± 3.1	B: 3952 ± 1071 62±12 kcal/kg BM	B: 3833 ± 571
7	Hickson et al. (1987)	High school football athletes (US) (12-18y, B=134) TP	EI by 24-hr food record	B: 67.7 ± 13.9	B: 2680	-

Note: *[#]Suggested Under-reporting; B = Boys; G = Girls, y = age in years; TP = Transition phase; Training Season/Phase was not reported by most studies*.

Table 3
Energy Intake Pattern of Junior Weightlifters

Sl. No.	Study	Participants	Method	Body Mass (BM) kg	Energy Intake (EI) kcal/day	Energy Expenditure (EE) kcal/day
1.	Bauer et al. (1994)	Young German weightlifters (14-17y, B=11)	EI by 7-day food diary	B: 69.5 (mean)	B: 2676.9 (mean) 38.5 kcal/kg BM	-
2.	Chen et al. (1989)	Amateur weightlifters from china (16±1y, B=5)	EI by 3-5-day weighed food records	B: 71 ± 2	B:4113 ± 555 58 ± 8 kcal/kg BM	-
3.	Heinemann and Zerbes (1989)	National level German Weightlifters (15-19y, B=15)	EI by 3-day semi-weighed diary	B: 95 (Range: 82 - 118)	B: 7504.8 (mean) 79.0 kcal/kg BM	-

Note: *B = Boys; G = Girls, y = age in years*

Table 4
Fuel Systems involved across events.

Event time range	Event example	Approx. % VO_{2max}	% Energy Contribution		
			Creatine Phosphate	Glycolysis	Oxidative
0.5 to 1 min	400-m running Individual cycling time-trial (500m to 1 km) 100-m swimming disciplines	~ 150	~ 10	~ 47-60	~ 30-43
1.5 to 2 min	800-m running 200-m swimming disciplines 500-m canoe/kayak disciplines	113-130	~ 5	~ 29-45	~50-66
3 to 5 min	1500-m running 400-m swimming disciplines 1000-m canoe/kayak disciplines	103-115	~ 2	~ 14-28	~ 70-84
5 to 8 min	3000-m running 2000-m rowing	98-102	< 1	~ 10-12	~ 88-90

Energy Expenditure Studies in India

Studies on energy expenditure pattern and energy balance of Indian adult athletes across various events and phases of training have been carried out by the National Institute of Nutrition and specific guidelines based on the intensity of each event was suggested (NIN-ILSI, 2007). These studies reported the energy expenditure pattern for Indian adult footballers in their preparatory phase to be 3150 kcal per day (55 kcal per kg body mass), for middle-distance runners in the competition phase, it was 3486 kcal per day (66 kcal per kg body mass) while for strength event like boxing in competition phase, the mean energy expenditure was 4424 kcal per day (65 kcal per kg body mass). Ramana (2010) also observed that there was 30 to 48 % variation in total energy expenditure from transition to competition phase among sprinters, middle-and-long distance runners. Ismail, Wan Nudri, and Zawiah (1997) also reported the variation in energy expenditure pattern of Malaysian National-level adult athletes across events. The total energy expenditure of adolescent Indian track athletes (Boys: 59 to 84; Girls: 53 to 68 kcal/kg body mass) were highest in their Competition phase (CP), followed by weightlifters (Boys: 51 to 60; Girls: 45 to 58 kcal/kg body mass) in CP and football players in Preparatory phase (Boys: 53 to 68; Girls: 39 to 62 kcal/kg body mass) (Cherian, 2019; Cherian, Sainoji, Nagalla, & Yagnambhatt, 2018; Cherian, Shahkar, Sainoji, Balakrishna, & Yagnambhatt, 2018).

Conclusion

Energy Expenditure pattern of adolescent athletes can provide a useful direction for framing menu plans and macronutrient fuelling in sports academies. Though there is a considerable variation in energy expenditure across age, sporting groups, and phase of training, limited data is available at present to determine the level of differences. Future studies should be directed to map these differences and to understand the high-risk zones/phases of energy deficiency among adolescent athletes, especially in the Indian setting.

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