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REVIEW

Sports Physiology in Adolescent Track-and-Field Athletes: A Narrative Review

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Abstract: The present study aimed to review the physiological aspects of adolescent track-and-field (TAF) athletes. A search of Scopus on 27/12/2022 using the syntax ABS (track-and-field) AND ABS (children) OR ABS (adolescent) showed 121 documents, and 45 were considered for further analysis. In addition, handsearching was conducted to identify Russian literature missing in Scopus. Differences were shown in performance characteristics among disciplines, especially between throwers and the other athletes. The sex difference in performance (ie, a better performance in boys than in girls) started in early adolescence. A relative age effect was more pronounced in athletes under 13 years old. Despite the wide use of nutritional supplements, an insufficient intake of vitamins has been found. The age of training onset and body weight were identified as risk factors for problems with menarche. The inclusion of track-and-field training programs in physical education was beneficial for health and physical fitness. The need to collaborate closely with parents and coaches was identified, especially, regarding education in topics such as the age of training onset, relative age effect, and doping. In conclusion, the existence of many disciplines with different anthropometric and physiological characteristics highlighted the need for a discipline-specific approach.

Keywords: running, jumping, throwing, speed, strength, endurance, age, maturation

Ontogenetic Foundations of Track and Field Training

The physical qualities underlying the biomechanics and physiology of track and field (TAF) exercises develop unevenly in ontogenesis.[1,2] The well-known sports pediatrician Bar-Or[3] called children-athletes "metabolic non-specialists", emphasizing the versatility of their abilities and the weak focus on one or another specialization of sports movements. This is largely due to the uneven development of skeletal muscle tissue,[4] muscle contraction control systems,[5] as well as mechanisms for providing working muscles with oxygen and substrates.[6] Although studies of physiological mechanisms in children and adolescents are extremely complex and encounter several barriers, including in the field of bioethics, a certain amount of research has taken place. For example, the well-known study by Astrand[7] made it possible to compare the maximum oxygen consumption during treadmill running in children and adults aged 6 to 60 years. In this study, it was shown for the first time that the value of the relative (per kilogram of body weight) maximal oxygen uptake (VO_{2max}) reaches its highest value already at the age of 9–11 years, and in the future, it can only decrease if a person does not train. In recent studies, VO_2max was measured in children 4–5 years old,[8] and it was also quite high. The explanation for this phenomenon may lie in the peculiarities of the fiber structure of the skeletal muscles of children and adolescents. In the works of Kornienko et al[9] showed a non-linear ∩-shaped change in the proportion of type 1 oxidative fibers in the structure of large muscles, such as biceps, triceps, and quadriceps femoris, with a maximum at the age of 8–14 years. Jansson[10] also comes to similar conclusions. Electron microscopy data show an approximately twofold excess in the number of mitochondria and their cross-sectional area in the biceps of an 11-year-old boy compared to a 35-year-old man.[4]

All this evidence indicates a relatively early development of the aerobic capacity of the child. Slower at the initial stages of ontogenesis, anaerobic capabilities develop, which underlie the manifestation of strength and speed. In addition, the data of biomechanical studies have shown that in the process of development of a child's locomotion, the support

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phase in running prevails for up to 4–5 years, and the non-support phase ("flight phase") begins to prevail by 5–6 years – only at this age, the child learns to run and do not go at high speed.[11] At the age of 12–14 years, there is an approximately twofold increase in the activity in the muscles of phosphofructokinase, the nodal enzyme of anaerobic glycolysis.[12] The anaerobic capabilities of the body, which determine the results in jumping and throwing, as well as in sprinting, are formed later, and reach their maximum development after puberty.[13] The influence of sex hormones on performance characteristics of the youthful organism is well known.[14] In this context, the present research aimed to review the physiological aspects of adolescent TAF athletes. A search of Scopus on 27/12/2022 using the syntax ABS (track-and-field) AND ABS (children) OR ABS (adolescent) showed 121 documents, and 45 were considered for further analysis. In addition, handsearching was conducted to identify Russian literature missing in Scopus.

Physiology

By definition, the inclusion of events relying on strength, speed, and endurance performance implies that the athletes participating in different TAF events would vary in their physiological characteristics. For instance, Housh et al[15] examined the knee flexors and extensors' strength (isokinetic, dominant leg, 180°/sec) in elite female TAF athletes (age 16.4 years). They observed that in absolute knee strength, throwers were stronger than middle-distance runners, and sprinters, whereas jumpers had greater relative strength in knee extension than middle-distance runners, and throwers were stronger had greater strength in this movement than middle-distance runners.[15] An interpretation of the different outcomes of the between-events comparisons in absolute and relative to body mass values is the difference in body mass among athletes. Also, de Freitas et al[16] examined female TAF athletes (age 14 years) and showed that throwers were the heaviest, with the most skinfold thickness, the strongest in the shot put and slowest in 60m sprint and 800m run, whereas distance runners had the highest cardiorespiratory fitness. Moreover, Knight et al[17] studied the influence of event specialty (sprinters, distance runners, and throwers), gender, and leg dominance on single-leg static balance (under two conditions: one with eyes open and one with eyes closed) among adolescent TAF athletes. They observed that the displacement of the center of pressure in the lateral-medial direction for both conditions differed between legs, with the non-dominant leg showing larger displacement than the dominant leg; however, no difference was shown among events. In summary, the few studies on the variation of physiological characteristics by event highlighted a distinguished profile for each event, especially between throwers and the rest athletes.

In addition to the existence of physiological differences among disciplines, TAF athletes differed from other sports as well as from non-athletes.[18,19] According to Valimaki et al, children 11–13 years, who participated in TAF training, had superior performance in ergometric tests on cycle ergometer than non-trained children.[18] Ballester et al[20] examined the association of externally paced (TAF) and self-paced sports (soccer) with vigilance performance in children (age 11 years) by evaluating the cardiovascular fitness (measured by Leger Multi-stage fitness test) level of athletes and non-athletes. Both TAF and soccer players had better cardiovascular fitness than non-athletes. Soccer players exhibited higher performance in vigilance than TAF athletes and controls. Huang et al[19] compared the physical fitness of TAF, wushu athletes, basketball players and non-athletes aged 12–15 years. They showed that TAF and the other athletes had better fitness than non-athletes. TAF athletes had better cardiorespiratory fitness than the other groups, worst flexibility and balance than wushu athletes, and less agility than basketball players.

The jumping ability was a popular topic of research in TAF.[21–23] Moresi et al[21] investigated the reliability of two long jump tasks (standing broad jump – SBJ – and reactive jump) and the possibility to predict 10m sprint time in elite TAF girls. They observed that these tests had good reliability and SBJ was a good predictor of 10m sprint time. Furthermore, Çakir-Atabek[22] examined the relationship between anaerobic power (30s Wingate anaerobic test – WanT – on cycle ergometer) and vertical jump performance in adolescent TAF athletes (age 15.8 years). He observed that SJ and CMJ related with power indices of the WAnT, and the magnitude of these relationships was larger when values were in absolute rather than in relative to body mass. With regard to the trainability of jumping ability, Focke et al[23] studied whether contralateral transfer resulting from a bilateral exercise program may be observed in adolescent TAF athletes. The jumping ability of the dominant leg was evaluated throughout a 12-week exercise program in two experimental groups: group performing long jump exercises with both legs, and a group performing exercises of this sport only with the dominant leg. The authors of that study observed a better result of jumping ability of the dominant leg in bilateral compared to unilateral exercise program. Consequently, bilateral exercise programs may be adopted in the early training of TAF athletes to enhance jumping ability of the dominant take-off leg. The abovementioned studies[21–23] highlighted the importance of jumping ability in TAF and considered validity and reliability aspects of exercise testing.

The type of exercise has been shown as a major determinant of bone parameters,[24] and accordingly, several studies[24–26] focused on the skeletal system of TAF athletes. Greene et al[25] reported that TAF athletes displayed 34% and 15% larger bone strength at the distal and proximal tibia, respectively, compared with non-active controls. Moreover, Agostinete et al[26] compared different sports for bone density in adolescents (age 10–17 years) showed that TAF had lower bone density than gymnastics and soccer, but higher than swimming. Kopiczko et al[24] tested boys aged 14–17 years (TAF, swimmers and non-athletes). They found that independent of birth weight, TAF athletes presented better values in bone parameters, whereas swimmers with normal or low birth weight had less favorable values than non-athletes.

The quality and quantity of sleep have been shown to relate with physical and cognitive performance of TAF athletes. Suppiah et al[27] studied the effect of a brief afternoon nap on 20m sprint time in competitive male TAF athletes (age 14.8 years) who were habitually short sleepers. They observed an increase of sprint time from 3.385s to 3.411s suggesting a negative effect of napping due to sleep inertia. Patel et al[28] studied sleep and cognition in TAF athletes (age 15.9 years) and found a total sleep time of 6:18 h:min and total time in bed 8:21 h:min. They noted an association of sleep loss with larger cognitive impairments and decreased academic abilities in the classroom. Steidten et al[29] evaluated overnight immune regulation during three nights in adolescent TAF athletes of both sexes (age 16.4 years). They observed that sleep duration was inversely related to changes in white blood cells and lymphocytes, and concluded that overnight sleep duration was a significant aspect of immunological overnight adjustment for TAF athletes of this age.

Kachenkova et al[30] examined the effect of TAF training on functional system of external respiration in a study where participants (young men) were categorized into three experimental groups (two, four and six training units per week) and a control group consisting of physically inactive men. They observed that the health-improving development of the lung tissue and respiratory muscles such as lung volumes and speed characteristics of breathing was related to training frequency. As the frequency of training sessions increased, the level of respiratory changes increased, so the best scores of all parameters were found in young men exercising six times a week.[30] Nevertheless, regular sport training often affects the functional characteristics of human body not necessarily in a positive way. In the study of Epishev et al[31] on male junior athletes practicing five different sports, including TAF (6–10 years of sports experience), it was shown that during physical activity (performing the physical working capacity at 170 bpm test) and in the recovery period, 50% of participants had alterations in heart rhythm and conduction in the form of incomplete blockade of the right leg of the bundle of His, extrasystole, early repolarization, grade I sinoatrial block, and pacemaker migration. Their analysis of stabilometric data, carried out taking into account the division by sports disciplines, indicated differences between disciplines. Between the data of stabilometry and ECG, correlations of medium strength were revealed.[31]

Gudimov et al[32] assessed the functional state of female students of sports science department involved in TAF training compared to non-athletes and observed a similar anthropometric profile. However, functional tests showed differences between TAF athletes and non-athletes, where the Harvard Step Test Index in TAF athletes was higher, breath hold while inhaling was longer and heart rate recovery time after 20 squats was shorter in TAF athletes than in non-athletes. These findings highlighted a positive impact of TAF on the functional state of female students.[32]

Anthropometry

In agreement with research on physiological characteristics that showed a distinguished profile of throwers, studies on anthropometric characteristics also highlighted a similar trend. Thorland et al[33] examined anthropometry in elite young athletes (TAF, gymnastics, diving and wrestling), and noted that the most striking differences in this sample considered throwers, who had taller height, heavier body mass, were fatter, and of unique somatotype compared to other disciplines. With regards, to the variation between TAF events, Housh et al[34] investigated whether anthropometry discriminated elite adolescent male athletes (age 17.7 years) by event (middle distance runners, sprinters/hurdlers, jumpers and throwers). They found that most of the variance between groups was accounted for by differences in anthropometry and body build (somatotype and frame size) between middle distance running and throwing. The anthropometric characteristics were related to physiological characteristics. For instance, Cumming et al[35] investigated calf radiographs provide measurements of bone, muscle, and fat widths in TAF athletes (age 13–16 years) and found that these measurements were correlated with ergometric tests and with performance in some TAF events.

Based on a study involving young TAF athletes, it is proposed to take into account the results of anthropometry and psychomotor testing when choosing a narrow specialization in athletics.[36] In particular, young athletes of muscular body type, who have a high reaction rate, can be oriented to sprinting. Athletes with an asthenic body type who have shown high performance in testing the sense of time can be oriented in middle-distance running or stayer and marathon running. The ability to accurately assess and differentiate the spatial and power parameters of movement is a significant indicator when choosing jumping types of athletics and throwing, for which thoracic and digestive somatotypes are most characteristic.[36]

The study by Shatunov and Bekmansurov[37] presented an attempt to consider the anthropometric characteristics of young TAF athletes (long jump) when choosing training methods. In terms of the length of body parts, young athletes aged 15–16 were similarly categorized into two groups: one with low indicators of the longitudinal dimensions of the body, jump due to muscle strength (G1), and one with higher indicators of body size, jump due to technical readiness (G2). The control group (G3) trained according to the standard method. G1 adopted mainly training loads of strength and speed-strength character, whereas G2 had loads aiming at improving the jump technique. At the same time, the total amount of training load in all groups was the same. At the end of the 4-month experiment, in G1 and G2, the indices of special physical fitness in the tests "Long jumps from a full run" and "Long jumps from 10 running steps" increased by 5–7%, whereas no change was shown in G3.[37]

The study of the formation of gender differences in young athletes at the age of 7–8 years is the subject of the work of Zotova et al[38] 37 boys and 20 girls from the Olympic reserve school in Kazan were examined. The results obtained were compared with population standards, and also between groups of boys and girls. Indices of physical development and performance of the examined children correspond to age norms. The following differences were revealed by sex: boys are ahead of girls in terms of body length and systolic pressure, as well as dexterity, while girls have higher flexibility. Thus, already at such an early age in young athletes, gender features of their physical and functional development are revealed.[38]

The body composition of students involved in volleyball and TAF athletics was compared based on the results of anthropometric measurements and bioimpedancemetry.[39] The survey involved boys and girls volleyball players, girls TAF athletes, as well as boys and girls not involved in sports. Volleyball players showed higher indicators of total body water, intra- and extracellular fluid, fat-free, fatty and active cell mass in relation to athletes and the control group. Differences in anthropometric measurements were established depending on the sports specialization of female students. Volleyball players have higher mass, length, mass index and body area, pelvic, hip and wrist circumferences in relation to the results obtained in athletes. Significantly lower values of body mass index, chest and pelvis circumference were recorded in female athletes in comparison with female students from the control group. In young men, there were no differences in anthropometric characteristics.[39]

Maturation

With regard to maturation aspects, the scientific interest has been focused on sex differences in patterns of development,[40,41] the relative age effect,[42] differences between TAF athletes and non-athletes,[43] comparison between countries[44] and training content.[45,46] Handelsman[40] highlighted the different patterns of development between sexes, since the performance of boys in TAF disciplines starts to outscore that of age-matched girls in the early adolescence. He noticed that the beginning and rate of sex divergence did not differ for TAF (running and jumping) and swimming, and they were related to the increase in circulating testosterone in boys. Furthermore, he concluded that the sex divergence in sport performance starts at the age of 12–13 years and achieves adult plateau in the late teenage years with the timing and tempo closely parallel to the rise in circulating testosterone in boys during puberty. Elsewhere, Malina et al[41] evaluated sex differences in functional performances of youth TAF athletes. They found that boys in both 11–13- and 14–15-years age groups scored higher than girls in four performance tests (grip strength, standing long jump, 2 kg medicine ball throw and 20 m sprint) but differences between girls and boys were larger in age 14–15 years. They interpreted this finding largely to the male adolescent spurt in body dimensions and composition, muscle strength and power.

The relative age effect – which describes the benefit of children born early in a year – is a topic that has attracted the scientific interest during the last years. In TAF, Kearney et al[42] investigated the relative age effect using a database of competition results in the UK. They showed that the relative age effect was widespread, but more pronounced during under 13 years competitions. This finding was in agreement with research on weightlifting,[47,48] where it was shown that a relative age effect was present in both female and male athletes independently of weight category.

Loko et al[43] studied the age-related growth and performance characteristics in TAF girls in the light of nonactive girls (age 10–17 years). They observed that TAF girls had higher height, lower body mass, BMI as lower and better physical performances than nonactive girls. Ohtsuki et al[44] examined male and female TAF runners of Japan and China (age 13–17 years) and found that the Japanese TAF athletes were more advanced in skeletal age (0.15–0.39 years) than the Chinese, whereas Chinese were taller than the Japanese (2.5–6.9 cm).

Nikitushkin and Akhapkin[45] believed that the age period of 10–13 years was the most favorable stage of ontogeny for the development of speed-strength abilities, which were important for all varieties of TAF. The predominant orientation of the training process, which provided the greatest increase in sports results, especially at the initial stage of sports training in TAF – at the age of 9–10 years, continued to arouse discussion and interest of researchers. In the work of Diakova et al,[46] arguments were presented in favor of predominantly speed-strength training, against the traditional running load. According to the authors, jumping training at this age allowed young athletes to increase the results of the long jump, triple jump, running by 60 m, running 150 m. The effectiveness of jumping training for girls aged 15–16 in terms of physical performance was also demonstrated in the study by Mozgovaya.[49]

Nutrition

Nieper[50] conducted a survey of the nutritional supplementation habits of national-level TAF athletes, and observed an increase rate of use of supplements (~60% of participants). Seventeen unique supplements were reported, with each participant consuming ~2.5 supplements (multivitamins and minerals had the highest popularity). In this study, participants used supplements for several reasons (eg, health, performance). A paradoxical finding was that, although most participants had access to specialized staff (ie, nutritionist), they did not use this possibility. Coaches, doctors and nutritionists were identified as the most popular sources of information about supplementation practices. In another survey, Aerenhouts et al[51] investigated nutritional habits of adolescent TAF athletes, and observed that all participants reported daily intake of breakfast. Girls consumed fruits, whereas boys juices and sport drinks between meals. Protein intake was in accordance with the official recommendations for sport populations. Surprisingly, fat intake accounted for more than 30% of the total energy intake in the majority of participants, whereas fiber and vitamin intake was low despite the use of supplements.

The variation of nutritional habits across countries should be taken into account by professionals working with TAF athletes. For instance, Okano et al[52] compared the nutritional habits and exercise programs between adolescent Japanese and Chinese athletes in TAF and basketball. They found that the energy intake was about two times greater in Chinese than in Japanese athletes. Chinese athletes had larger intake of carbohydrates, protein, calcium, and iron than Japanese athletes.

The Female Adolescent Athlete

Important concerns about the female adolescent TAF athlete included the attitude of girls towards muscularity, body dissatisfaction, menarche as a function of body mass, thinness and bulimia. Mosewich et al[53] noted that female athletes were often concerned with achieving a lean body requested to optimize performance. They interviewed female adolescent and adult TAF athletes and highlighted that muscularity was considered as a complex and context-specific experience.[53] Kopczynski and Vogelsang[54] reported that anthropometric traits of female TAF athletes were dependent on the fitness requirements of different sports and, consequently, did not coincide with the actual stereotype of a female body shape. Body dissatisfaction can induce a detrimental self-perception.[54] Female elite throwers and runners were questioned about self-perception in a study where BMI was related with body dissatisfaction.

Tsukahara et al[55] examined female sprinters and long-distance runners of ninth-grade and observed a direct relationship between BMI and menarche attainment. They proposed a BMI cutoff value for menarche ~17kg/m^2. Furthermore, Kinoshita and Fukuda[56] mentioned that female distance runners were prone to thinness in order to improve sport achievements and were at higher risk for health compared to non-athletes. Also, they reported that the number of thin female runners was continuously augmented.

Bosi[57] evaluated bulimic behavior in adolescent female long-distance runners and non-athletes. They observed a tendency toward bulimia in about one-third of participants and concluded that participants were in risk to develop eating disorder, considering their emphasis on weight control and the use of inadequate means of keeping within the desired range (eg, fasting, intense physical activity).

Importance of TAF for Physical Education

Several studies examined the role of TAF in relationship to aspects related to physical education, such as physical activity levels in adolescence[58] and TAF within a physical education lesson[59] or after-school.[60] Tammelin et al noted that TAF was one of the sports that being practiced at adolescence associated with high or very high physical activity level at adulthood.[58] In another study, Tanaka et al[59] compared physical activity and sedentary time of different types of physical education lessons. They observed that the time spent in moderate-to-vigorous physical activity during TAF and gymnastic lessons was lower than that during ball game lessons, whereas TAF and ball game lessons had less sedentary time than gymnastic lessons.

Considering the relationship of physical activity and obesity, Topp et al[60] examined the effect of a 14-week after-school training and nutritional intervention (three days/week including two days of flexibility, resistance, and TAF training) on risk factors for childhood obesity in children of age 5–10 years. In this sample consisted of 60% overweight or obese children, cardiovascular fitness, body composition and dietary habits improved during the exercise program. Furthermore, Petros et al[61] investigated the effect of IAAF Kids' Athletics – a 12-week TAF teaching program – performance characteristics of children (age 11–12 years). They observed that the participants who followed this exercise program ameliorated perceived effort and increased willingness to maintain TAF training more than participants who followed a program based on skill learning method. In addition, Barth et al[62] examined the relationship of high-level adult TAF athletes' long-term effectiveness of training and change of performance with their training patterns as children and adolescents. They found that coach-led multi-sport training during that early age was a predictor of adult training effectiveness and performance.

Health

Several concerns have been identified about health-related issues such as the early specialization of TAF athletes,[63] psychomotor performance,[64] anxiety, inappropriate eating behaviors,[65] doping,[66] access to medical services[67] and psychological aspects.[68] Capranica et al[63] considered the debate if early specialization (ie, engagement in training focusing on a single event such as long jump instead of jumps) would lead to better performance compared to a late specialization. They reviewed research results and highlighted risk of children that specialized on a young age for somatic and psychological adverse health consequences.

With regard to psychomotor performance, Sanabria et al[64] investigated if aerobic capacity, sport-type participation (externally paced, self-paced or sedentary), could explain the relationship between the training and vigilance capacity. They found that externally paced sport training such as basketball resulted in significantly shorter reaction time compared to self-paced sport such as TAF and sedentary condition. Moreover, Fortes et al[65] analyzed the relationship between anxiety and inappropriate eating behaviors in adolescent female TAF athletes (age 12–17 years). They observed that State – Trait Anxiety Inventory – Trait was associated to oral control and the environmental and social factors that facilitate food consumption in girls.

In TAF, Rossi et al[66] noted that the recent practice of doping has increased in a large degree and concerned both elite and recreational athletes, eg, in secondary education a use of anabolic steroids was recorded in 3–12% of boys and 1% of girls. A variation of doping practice among sports was found with football players presenting the largest and TAF athletes the smallest. A great number of adolescents use doping substances to ameliorate their sports performance either under the guidance of their coach or to reproduce behaviors of elite athletes. With regard to the access to medical services, Timpka et al[67] investigated habits of medical service delivery in competitive adolescent TAF athletes. They noted that even high-level athletes had complications to understand indications of ill health, and suggested that the medical support should be provided independently of the socioeconomic status of parents and local societies. They highlighted also the fact that athletes usually managed their health incidents in their own without support of a sport organization.

Modern sport makes serious demands on the psyche of the athlete. So, for TAF, the problem is not only to reproduce high results, but also to overcome unfavorable pre-start conditions that can affect the results of the performance. In this regard, it is of interest to analyze some personal characteristics of adolescents involved in athletics and compare them with the sports achievements of these athletes.[68] Authors compared the total results of the subjects' runs at a certain distance during the observation period with personality characteristics: the level of stress resistance, anxiety, and the type of character. It is shown that in the group of athletes who were successful in their achievements, the indicators of stress tolerance were higher, and anxiety, on the contrary, were lower compared to athletes who showed the worst result in the competition. Successful athletes were dominated by the choleric type of character. In the group of less successful athletes, the phlegmatic type of character prevailed.[68]

The Role of Coach and Parents

Coach and parents play an important role and are particularly influential on the daily life of a child athlete, and education of both of them on topics such as age of specialization is needed.[69–71] Kearny et al[69] observed that parents are more expected than coaches to have confidence in that successful adult high-level athletes had accomplished success in early adolescence and to link that success to innate capacity rather than training process.[69] A similar percentage of parents and coaches presented understanding of the relative age effect, whereas the most striking differences concerned ideal development practices during adolescence, with parents more expected to support early specialization.[69] Erickson et al[70] investigated the effect of parents on athletes' attitudes, experiences and behaviors about doping TAF athletes. They observed that the parent–athlete relationship influenced athletes' lives in and beyond sport, and suggested that the parent–athlete relationship (in)directly deters athletes from doping.

With regard to social support, Juriana et al[71] studied parents of children aged 0–6 years in a TAF club which has a age-tailored program, which aimed at training fundamental movement skills. They observed that the backing from the parents was important in creating children's positive attitudes to involve in sport. Hegarty et al[72] invited all National Collegiate Athletic Association Division I cross-country and TAF coaches to complete a questionnaire on depression awareness. They found that distance coaches had better score on depression awareness than sprints coaches, and coaches assessed that ~10% of their athletes had a complication related to depression.

Conclusions

In summary, a variation of physiological and anthropometric characteristics by discipline was observed especially between throwers and the other athletes. With regard to the role of maturation, it is important to consider both the different rate of development between girls and boys as well as the relative age effect and the question of the early specialization. Scientists and professionals working with children and adolescent TAF athletes should also be concerned about aspects such as body weight in girls, the use of TAF training within school physical education curriculum and collaboration with coaches and parents.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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