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Evaluation of preadolescent athletes' running performance in a middle distance event

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Introduction. **Sport biomechanics focuses on the evaluation of athletes' running stride characteristics with training shoes and barefoot. Few studies have assessed the running performance of shod and unshod preadolescent athletes, and they have been carried out only in laboratory conditions. Aim of Study: The aim of this study was to evaluate the performance of preadolescent athletes in the 1000 m running event by applying two protocols: with training shoes and barefoot.** **Material and Methods.** **Forty three (n = 43) preadolescent athletes were recruited for the study. In the first testing session the participants' anthropometric data and their VO_2max were recorded. The athletes were randomly assigned to compete in two testing protocols in counterbalanced order. The t-test assessed the performance in two protocols while the ROC curves were applied to illustrate the discrimination between performances relative to the athletes' gender. Pearson's correlation coefficient analysis was applied to evaluate the intercorrelations between the athletes' VO_2max, and their anthropometric characteristics during an 1000m running event shod and unshod.** **Results.** **The results showed that boys performed better than girls in the 1000 m event, shod and unshod. Pearson's correlation analysis presented a substantial effect on the VO_2max and body fat in the preadolescents' performance in both protocols. In spite of the fact that boys performed slightly better than girls, the t-test did not confirm the significant differences in the athletes' 1000 m performance barefoot.** **Conclusions.** **The importance of the present study lies in the fact that the running performance of preadolescent athletes barefoot is not worse than their performance in training shoes, and this can provide an incentive for future research concerning the content of training programs of young athletes.**

KEY WORDS: human foot, running shoes, endurance, athletics.

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Introduction

The human foot is a biomechanical masterpiece that comprises 28 bones, 19 ligaments, 32 major muscles and 200.000 nerve endings [1]. Since ancient times footwear such as sandals and shoes have been developed to protect and assist the lower limbs in daily kinetic and kinematic activities, since the majority of human movements, such as walking, running and jumping start and end in the feet. In classical Greece athletes competed barefoot in Olympic running events. From the mid-20th century to the present time scientists have concentrated in their research on the innovative technology of sport shoes. The heel height, cushioning and seaming technology, and shoe weight were the stimulus for further research on modern training shoes used in a variety of individual and team sporting activities [2, 3].

A great part of footwear research refers to preadolescent and adolescent athletes whose future performance as top-level athletes can be defined by the innovative technology of training shoes [4]. More specifically, it has been confirmed that an elevated heel of any height on children's footwear shortens the Achilles tendon, and in result a permanently shortened tendon may appear [5]. In addition, it was reported by a gait analysis study that soles over 6mm thick prevent 80-90% of children's foot flexibility, thus denying the foot its normal step sequence [6]. Furthermore, it was postulated that the slimmer and more flexible children's shoes do not change foot motion as much as conventional shoes, and therefore, should be generally recommended for children [7].

In the last two decades sport sciences have developed innovative technologies in the construction of sport footwear, especially in midsole cushioning as well as in shoe weight [8, 9]. Technologies such as the Torsion, Gel Cushioning System, Wave, Dynamic Fit and ZigZag have been applied in contemporary footwear accounting for the type of movement and surface in view of shock absorption, decreased risk of injuries and enhancement of athletes' competitive performances. On the other hand, there has been an increasing research interest in barefoot jogging and running in recreational as well as in competitive sports. Today most people think that barefoot running is dangerous and hurtful, but everyone can actually run barefoot without the slightest discomfort and pain. For instance, some well-known international athletes have successfully competed barefoot, including Zola Budd from South Africa and the late Abebe Bikila from Ethiopia.

The science of sport biomechanics focuses on the evaluation of athletes' running stride characteristics with training shoes and barefoot [10]. A motion analysis study which evaluated the biomechanics of children's barefoot sprint running showed a decreased plantar flexion of the ankle joint, decreased angular velocity of the knee joint as well as a significant decrease of the angular velocity of the calf [11]. In the majority of endurance athletes who train with shoes, the foot contact with the running surface at the landing phase takes place at the heel, while in barefoot running the foot landing starts with the ball of the foot and ends with the heel [4].

Aim of Study

Few research studies have assessed the running performance of preadolescent athletes with training shoes and barefoot and they have all been carried out in laboratory conditions [12, 13]. The present study evaluated the maximal endurance performance of preadolescent boys and girls in field conditions by using protocols of a 1000 m track and field event with training shoes and barefoot.

Materials and Methods

Testing Procedures

First, the physical and anthropometrical characteristics of participants were assessed. More specifically, the runners' age, training experience, body mass, body stature, body fat, thigh and calf circumferences and foot length were measured and their VO_2max was estimated. The tests were carried out with a standard 72-hour rest between testing sessions. The athletes were required to complete in two 1000 m trials with training shoes and barefoot in counterbalanced order. Both trials were performed during the competitive period of the runners' annual training plan on the same 400 m track with a 16 mm thick synthetic (rubber) surface. The participants during both 1000 m running protocols competed at the same time of the day in identical testing conditions with the ambient temperatures ranging from 22°C to 25°C. All participants performed a standardized warm-up which included 20 min of jogging, stretching and dynamic exercises for the lower limbs and 6 x 50-100 m runs.

Equipment

The participants' running performances were recorded in both 1000 m trials by experienced coaches and athletics judges with the use of Casio HS-30W Professional Sport Waterproof 10 Lap Memory Stopwatches (Casio Group, Japan, 2000). The VO_2max was estimated with the latest testing protocol updates of the $MSRAT_{20m}$ – 20 m Multistage Shuttle-Run Aerobic Test [14, 15]. A portable CD player, a CD with a booklet, a measuring tape and marking cones were used for the $MSRAT_{20m}$ in order to predict athletes' maximal aerobic performance. Subcutaneous fat was measured with a Harpenden Skinfold caliper HSK-BI (Baty International, Œ 0120, West Sussex, UK) on the right side of the athletes' body, and body fat was determined from the sum of two skinfolds thickness to the nearest 1 mm. Body mass was measured to the nearest 100 g on a calibrated floor scale (Seca 770). The subjects were standing in the center with relaxed arms, without shoes and wearing only light sportswear. Stature was measured with a stadiometer (Seca 240) to the nearest 0.1 cm, barefoot with the head in the Frankfort horizontal plane.

Participants

Forty three (n = 43) preadolescent athletes from three athletics clubs were recruited for the study. Their mean age, stature and body mass were 10.6 ± 1.1 years, 145 ± 10 cm and 36.8 ± 8.7 kg, respectively. The group of participants consisted of twenty two (n = 22) boys and twenty one (n = 21) girls with a mean training track and field experience of 1.5 ± 1 years, exercising at least 4 times per-week. The experimental protocol was explained to each subject, but they were not informed about the specific purpose of the study. Furthermore, none of the participant athletes had ever trained barefoot. The parents were informed about the research and they were asked to provide their written informed consent prior to their children's participation. The study was approved by the Ethics Committee of the Democritus University of Thrace.

Statistical analysis

Descriptive statistics were generated for all categorical variables. The scatterplots were used to determine whether a linear model is reasonable for the variables of athletes' running performance in shod and unshod testing protocols. The t-test (paired samples) was applied to compare the participants' finish times in 1000 m with training shoes and barefoot. The Receiver Operating Characteristic (ROC) curves were used to illustrate the discrimination between performances in the 1000 m with shoes and barefoot, relative to athletes' gender. The correlation analysis (Pearson's coefficient) was applied in order to measure linearity in the interaction between the variables: "running performance", "anthropometry" (stature, body mass, body fat, lower limbs circumferences, foot length) and "VO_2max". One way ANOVA was used to evaluate the differences between performances in both testing protocols according to participants' gender. All statistical analyses were carried out with the SPSS-PASW 18.0 for Windows (SPSS Inc., Chicago, Il, USA). The level of statistical significance was set at $p < 0.05$.

Results

The physical and physiological characteristics of the participants are shown in Table 1. Pearson's correlation analysis revealed significant inter-correlations only between the participants' running performance, the VO_2max and body fat in both testing protocols. More specifically, the correlation between athletes' performance in 1000 m with training shoes and VO_2max was as high as 0.73 ($p < 0.001$), while the correlation between the participants' 1000 m performance with training shoes and the percentage of body fat was reported as acceptable (0.45, $p < 0.05$). Similarly, Pearson's r values between

Table 1. Physical and physiological characteristics of participants (95% confidence interval)

Variable	Boys	Girls
Age (years)	10.6 (10.1-11.1)	10.7 (10.2-11.1)
Body mass (kg)	36.7 (32.7-40.7)	41 (36-45.9)
Stature (cm)	144 (139-149)	148 (143-153)
Body fat (%)	15.5 (13.4-17.7)	21.4 (18.3-24)
Thigh circumference (cm)	39.2 (37.7-40.8)	42.8 (40.3-45.4)
Calf circumference (cm)	28.7 (27.7-29.8)	30.8 (29.2-32.3)
Foot length (cm)	21.6 (20.7-22.4)	22 (21.4-22.7)
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	36.8 (34.4-39.3)	34.5 (32.9-3.2)

Table 2. Linearity evaluation (Pearson's *r* correlation coefficients) of the 1000 m running shod and unshod performances in relation to the athletes' physical and physiological parameters

Variable	*r*	p values	significance
Shod performance			
Body mass	0.03	0.87	n.s.
Stature	–0.30	0.06	n.s.
Body fat	0.45	0.03	sig.
Thigh circumference	0.17	0.28	n.s.
Calf circumference	0.06	0.72	n.s.
Foot length	–0.30	0.06	n.s.
VO_2max	0.73	0.001	sig.
Unshod performance			
Body mass	0.17	0.29	n.s.
Stature	–0.18	0.26	n.s.
Body fat	0.46	0.002	sig.
Thigh circumference	–0.23	0.15	n.s.
Calf circumference	0.16	0.32	n.s.
Foot length	0.20	0.21	n.s.
VO_2max	0.63	0.001	sig.

the barefoot performance and VO_2max of adolescent athletes were high (0.73, $p < 0.001$), while the participants' percentage of body fat and barefoot performance interaction was acceptable (0.46, $p < 0.05$). Pearson's correlation coefficient between the testing protocols and athletes' physical and physiological parameters are presented in Table 2.

The t-test revealed no differences in the 1000 m running performance of the athletes with shoes and barefoot ($t_{(1.41)} = 0.31$, $p = 0.76$). Thus, the mean performance of the participants in the 1000 m event with training shoes was 5.20 min, while the performance in 1000 m barefoot was 5.18 min, which was slightly better than the trial with training shoes. The ROC curve classified the parameters of the testing protocols in boys (with shoes and barefoot) and it showed that they did not coincide with the reference line avoiding the selected bias. The area under the curve (AUC) defined more true positive results in the boys' 1000 m running performance with training shoes (0.55, p = 0.09) than barefoot (0.54, p = 0.09). Similarly, the binary classifier ROC analysis showed that the testing protocols in girls did not coincide with the discrimination threshold avoiding the statistics bias. The area under the curve (AUC) indicated stronger evidence for the positive actual state in the girls 1000 m running performance with shoes (0.45, p = 0.09) compared to barefoot (0.46, p = 0.09). The evaluation of the diagnostics testing protocols by applying the ROC analysis in relation to gender are presented in Figures 1 and 2.

The results of one-way ANOVA showed that the athletes' running performance in both testing protocols in relation to gender did not yield any significant differences. In spite of the fact that the boys' mean performance barefoot in the 1000 m event (5.05 min) was slightly better than their mean performance in 1000 m with training shoes (5.15 min), the analysis of variance did not confirm statistically significant differences ($F_{(1.42)} = 0.50$, $p = 0.48$). Similarly, the performance of the preadolescent girls' in the 1000 m event showed no significant differences between the shod (5.29 min) and unshod (5.30 min) finish times ($F_{(1.41)} = 1.25$, $p = 0.27$).

Discussion

It is important to note that the preadolescent athletes' performance in the 1000 m event barefoot was not worse than their running performance in this event with training shoes. In contrast, a marginal performance improvement in the 1000 m was noted in both boys and girls when they ran barefoot in relation to their performance with training shoes in the above event (5.18 min vs. 5.20 min). This last finding remains in accordance with

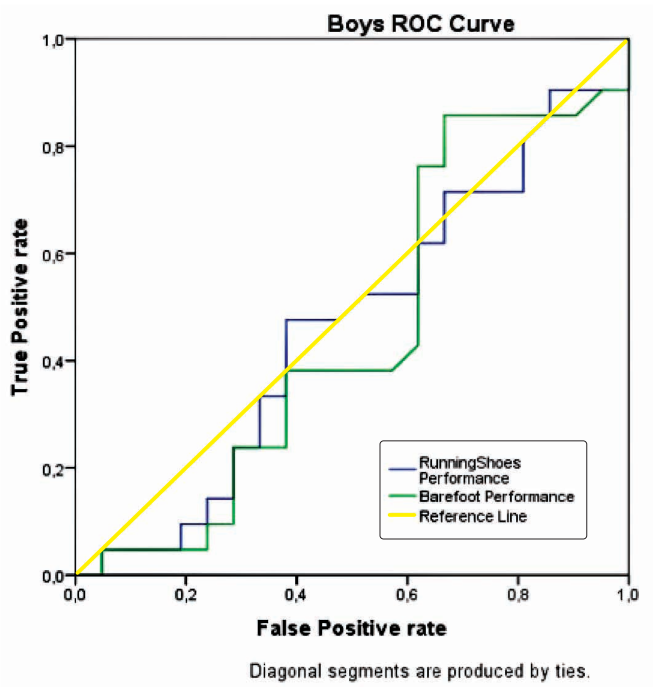

Figure 1. The intercept of the ROC curve in athletes' running performance shod and unshod in preadolescent boys

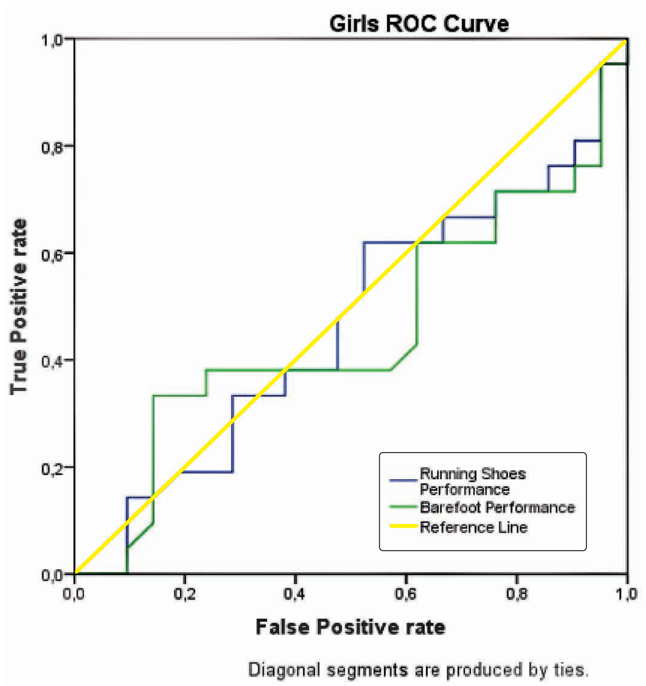

Figure 2. The intercept of the ROC curve in athletes' running performance shod and unshod in preadolescent girls

results of other studies which confirmed that the shod and unshod performances did not differ in preadolescent runners [4, 16]. A possible explanation is that the participants in this study changed the mechanics of foot contact at the landing phase. Instead of landing with the rear foot during the running stride, as it is usually done with training shoes, they improved their running pace by contacting the running surface with the ball of the foot during barefoot running [17, 18]. Thus, the athletes' finish times in the 1000 m barefoot improved marginally without differentiating the running economy.

Moreover, among the participants of similar age (10.6 years), the girls were shown to have a taller stature, body mass, body fat as well as greater thigh and calf girths in relation to boys while the boys' VO_2max was slightly better than that of the girls. According to the above, the VO_2max and the lean body mass of all the participants strongly interacted with the shod and unshod athletes' performance in the 1000 m running event. For this reason, the boys with higher VO_2max and lower body fat performed better than the girls, not only in the 1000 m with training shoes (5.15 min vs. 5.29 min) but also in the 1000 m barefoot (5.05 min vs. 5.30 min). In accordance with a similar design study, these findings confirm that the preadolescents' high aerobic capacity and low percentage of body fat affect the endurance performance in developmental age athletes in middle and long distance running events [19, 20].

As regards the gender and comparing the two testing protocols, the boys seem to have better finish times in the 1000 m barefoot in relation to their running performance with training shoes (5.05 min vs. 5.15 min), while the performance of the girls in the 1000 m unshod and shod did not differ (5.29 min vs. 5.30 min). The above findings are in contrast with results of studies which report that the barefoot performance is worse than running performance with training shoes in preadolescent boys and girls in endurance track and field events [21].

Conclusion

The present study revealed that the barefoot performance of preadolescent athletes is not worse than that their running performance with training shoes. Additionally, this study showed better barefoot mean finish times in the 1000 m event in boys compared to the girls'. If barefoot running was included in the annual training planning of athletes in their developmental age, it could possibly offer a significant advantage to the competitive performance in future world-class endurance runners.

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