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Original Article

Evaluation of sprinting performance in adolescent athletes with running shoes, spikes and barefoot

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Abstract:
The aim of this study was to evaluate the sprinting performance in a 30m run in adolescent athletes' by applying three testing conditions: wearing running shoes, spikes and barefoot. 33 runners aged 11.9±1.1 years (19 boys & 14 girls) were recruited for the study and competed at the testing conditions in a random order with a standard of 48-hour rest. The participants' anthropometrical data (age, body mass, stature, foot length) were measured besides with their footwear parameters (running shoes & spikes masses). The t-test was applied in order to compare the runners' sprinting performance and the ANOVA was used in order to evaluate the 30m finish times in all testing trials in relation to the gender. Pearson analysis measured the inter-correlations among the "testing protocols", "anthropometry" and "footwear parameters". The results showed that the participants' performance with spikes (5.28±0.4s) was not significantly better than that with running shoes (5.30±0.5s) or barefoot (5.31±0.5s). The correlation analysis did not present any significant interaction between the foot length and running shoes-spikes mass with the athletes' performance in all testing protocols. In summary, the findings of this study recorded that the adolescent athletes' barefoot sprinting performance was not significantly worse than that of wearing running shoes and spikes.
Key words: speed, footwear, strike pattern, training.

Introduction

Humans have been engaged in running activities for millions of years. In classical Greece, during the Olympic Games the athletes competed barefoot but from the late 20th century to present time a great number of scientists have based their research on the innovative technology of the sport shoes (Nigg, 1986; Bramble, & Lieberman, 2004). Barefoot running may induce an adaptation that transfers the impact to the yielding musculature, thus sparing the fascia and accounting for the low incidence of plantar fasciitis in barefoot runners (Henning, Valiant, & Liu, 1996). When running barefoot on hard surfaces, the athlete compensates for the lack of cushioning underfoot by plantar-flexing the foot at contact, thus giving a softer landing (Frederick, 1986; Yessis, 2000). In addition, the contemporary shoes generally reduce sensory feedback without diminishing injury-inducing impact–a process–described as the "perceptual illusion" of training shoe (Robbins & Gouw, 1991).

A great part of research in running mechanics refers to the adolescents whose future performance as top-level athletes can be defined by the innovative technology in the training or racing shoes (Rao, & Joseph, 1992; Rossi, 2002). The contemporary running shoes appear to attenuate loading since long-axis tibial acceleration is reduced during shod running in children (Thomson, et al., 1999; Waneger et al., 2011). In addition, during the training or competition of the developmental age athletes, the shod running presented an increase in the prevalence of the rearfoot strike pattern from 62% barefoot to 97% with running shoes (Clarke, Frederick, & Cooper, 1983). Furthermore, it was recently proved that the minimalist and more flexible shoes do not change the foot motion as much as the conventional shoes and therefore they should generally be recommended for young runners (Wolf et al., 2008).Moreover, the barefoot running is not only rare in competition but also there are no published controlled trials concerning the effects of running barefoot on simulated or real competitive performance. In addition, there is a lack of data concerning the shod and unshod running performance in developmental age athletes and the relative studies were mainly implemented in laboratory conditions. Because of the fact that the training with running shoes and spikes is widely used in young runners by their trainers we hypothesized that barefoot running could alter the finish times in a short maximal

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sprint. Thus, the purpose of this study was to compare the adolescent boys' and girls' sprinting performance in the 30m by wearing running shoes, racing shoes (spikes) and barefoot.

Method

Participants

A total of thirty three (n=33) athletes aged 11.9±1.1 years volunteered to participate in this study. The athletes consisted of nineteen (n=19) boys (11.6±0.8 years) and fourteen (n=14) girls (12.3±0.4 years) with a training experience of 2.3±1 years in Athletics, completing at least 4 sessions per-week. Only the athletes who were injury free for at least 5-weeks and have participated in sprint races were included. The nature of the experimental protocol was fully explained to each participant but they were not informed about the specific purpose of the study. Furthermore, none of the adolescent athletes had ever been trained barefoot since the beginning of this study. The participants' parents were informed about the research and they signed a written consent prior to their children's participation. The study was approved by the Ethics Committee of the Democritus University of Thrace.

Testing Procedures

The initial screening of this study included the evaluation of the anthropometrical characteristics (age, body mass, stature, foot length) of the participants as well as the measurement of their running shoes and spikes mass. The testing trials run in the afternoon in identical conditions with the ambient temperatures ranging from 22°C to 25°C and they were carried out with a standard 48-hour rest. Each participant was required to complete three (3) testing conditions with running shoes, spikes and barefoot in random order. Moreover, the athletes individually run the 30m sprints from a crouch start as fast as they could, simulating a race. All trials were applied during the competitive period of the athletes' annual training periodization, in a synthetic indoor running track. Prior to the testing trials, the athletes performed a typical warm-up which included a 20min jogging, dynamic stretching for the low limbs and acceleration running exercises as well as 6x30-60m runs at the intensity of 91-96% wearing only their running shoes or a combination of their running shoes and spikes according to the testing conditions. Barefoot running familiarization of the participants of this study was conducted by applied the above warm-up barefoot.

Equipment

The athletes' sprinting performances were measured electronically *(Performance Pack-Model 63520, Lafayette Inc)* with the use of 2 pairs of transmitter-photocells in starting line as well as in the 30m finish line *(Infrared Photocell Control Model 63501 R)*. Body mass was measured at the nearest 100g on a calibrated floor scale (Seca 770). Each participant was standing in the center with relaxed arms, without shoes and wearing only light sportswear. Stature was measured with a stadiometer (Seca 240) at the nearest 0.1cm in bare feet with the head in Frankfort horizontal plane. Finally, the foot length of the participants was measured on the floor from the heel to the tip of the longest toe at the nearest 0.5cm, while the pairs of their running shoes and spikes mass were weighted at the nearest 1g by using a digital scale (Seca 354).

Statistical analysis

Descriptive statistics with exploration was firstly generated for all categorical variables. The scatterplots were used in order to determine whether a linear model is reasonable for the variables of the subjects' sprinting performance with running shoes, spikes and barefoot testing protocols. The one-sample t-test was applied in order to compare the mean finish times in the 30m runs of the studied participants with running shoes, spikes and barefoot. The GLM-Univariate Analysis of Variance (2x3) with the *Bonferroni post hoc* comparisons were used in order to evaluate the differences among the participants' sprinting performance in the 30m in the three testing protocols (fixed factors) according to the subjects' gender (dependent variable). In addition, the Receiver Operating Characteristic (ROC) curves were applied in order to illustrate in graphical plots the discrimination between the finish times in 30m with running shoes, spikes and barefoot relative to the participants' gender. The correlation analysis (Pearson's coefficient) was implemented in order to measure the linearity in the interaction among the variables "sprinting performance", "anthropometry" (stature, body mass, foot length) and "running parameters" (running shoes & spikes mass). All statistical analyses were carried out by employing the IBM SPSS 20.0 for Windows, (*SPSS Inc., Chicago, IL, USA*). The statistical significance was defined at 5% ($p<0.05$).

Results

The physical characteristics as well as the footwear parameters of the study participants which were derived from exploration statistics according to gender, are illustrated in Table 1.

Table 1. The mean physical and footwear parameters of the participants, (95% CI).

Variables	Boys	Girls
Age (yrs)	11.6 (11-12.2)	12.3 (11.7-12.9)
Body mass (kg)	42.2 (38.3-46)	50.7 (44.9-56.4)
Stature (cm)	150 (145-154)	156 (153-160)
Foot length (cm)	25.7 (24.2-27.2)	25.3 (24.5-26.2)
Running shoes mass (cm)	508 (448-568)	505 (453-556)
Spikes mass (cm)	422 (386-460)	466 (418-514)

The t-test reported that the adolescent athletes performed marginally better only in the testing trial with spikes (5.28±0.4s) in comparison to the 30m sprinting protocols with running shoes (5.30±0.5s) and barefoot (5.31±0.5s). However, the above analysis showed that no significant differences existed in the athletes' sprinting performance wearing spikes ($t_{(1.32)}$=63.5, *P*=0.74), running shoes ($t_{(1.32)}$=54.8, *P*=0.81) and barefoot ($t_{(1.32)}$=58.8, *P*=0.94). The obtained ANOVA results showed that the running performance of the runners in all testing trials did not record any significant differences relative to the gender. The overall better performance in the 30m regarding the gender was recorded in the girls wearing spikes (5.27±0.3s), while the boys' mean sprinting performance was recorded slightly worse (5.28±0.3s). In addition, the mean finish times in the 30m of the boys and girls with running shoes were the same (5.30±0.5s), while the athletes' barefoot running performances appeared to be similar both in boys (5.29±0.6s) and girls (5.35±0.3s). The analysis of variance did not confirm any statistically significant differences in the sprinting performance among the protocols of this study with running shoes ($F_{(1.31)}$=0.1, *P*=0.98), spikes ($F_{(1.31)}$=0.1, *P*=0.97) and barefoot ($F_{(1.31)}$=0.2, *P*=0.71). The participants' performances in the testing trials relative to gender are presented in Table 2.

Table 2. The mean finish times (s) in the 30m runs in all testing protocols relative to gender, (95% CI).

Testing protocols	Boys	95% CI	Girls	95% CI
Running shoes	5.30	5.04-5.56	5.30s	5.08-5.54
Spikes	5.28	4.95-5.60	5.27s	5.06-5.48
Barefoot	5.29	4.98-5.58	5.35s	5.14-5.56

The ROC curves classified the parameters of the three testing trials in boys and they 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' sprinting performance wearing running shoes (0.44, *P*=0.55) than that of spikes (0.43, *P*=0.53) or barefoot (0.39, *P*=0.30). Similarly to the above, the binary classifier ROC analysis illustrated that the testing protocols in girls did not coincide with the discrimination threshold, avoiding the statistics bias. The area under the curve (AUC) indicated a stronger evidence for positive actual state in the girls' performance in the 30m barefoot (0.60, *P*=0.30) compared to the trails with running shoes (0.56, *P*=0.54) and spikes (0.56, *P*=0.55). The evaluation of the diagnostics testing protocols by applying the ROC analysis, in relation to the gender are illustrated in Figures 1, 2.

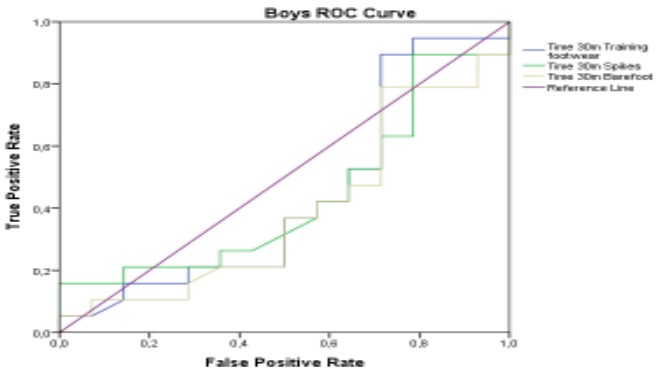

Fig 1. The intercept of the ROC curve in boys sprinting performance with running shoes, spikes and barefoot

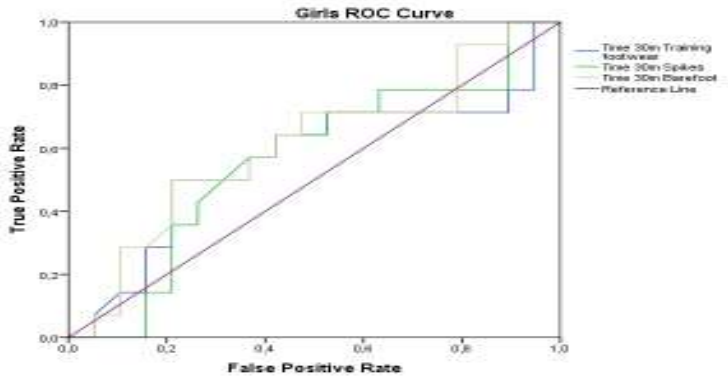

Fig. 2. The intercept of the ROC curve in girls sprinting performance with running shoes, spikes and barefoot

The Pearson's analysis did not present any significant inter-correlations among the participants' body mass, stature and foot length as well as with their running shoes and spikes mass and their sprinting performances in all testing protocols. More specifically, the correlation in their 30m finish times wearing running shoes and foot length was very low (0.02, *P*=0.89), while the correlation between the participants' sprinting performance with spikes and the foot length was reported as low as 0.05 (*P*=0.81). Furthermore, the *r* values between the barefoot performance and the running shoes and spikes mass were 0.20 (*P*=0.26) and -0.27 (*P*=0.13) respectively. The Pearson's correlation of coefficients among the testing trials in the 30m run and the participants' physical and running parameters are presented in Table 3.

Table 3. Linearity evaluation (Pearson's *r* correlation coefficients) of the 30m sprinting performances with running shoes, spikes and barefoot in relation to the participants' physical and running parameters.

Parameters	*r*	*P* values	Significance
Running shoes performance			
Body mass	-0.05	0.81	n.s.
Stature	-0.22	0.21	n.s.
Foot length	0.02	0.89	n.s.
Running shoes mass	0.18	0.32	n.s.
Spikes performance			
Body mass	-0.02	0.91	n.s.
Stature	-0.25	0.15	n.s.
Foot length	0.05	0.81	n.s.
Spikes mass	-0.25	0.17	n.s.
Barefoot performance			
Body mass	0.07	0.70	n.s.
Stature	-0.19	0.31	n.s.
Foot length	-0.05	0.98	n.s.
Running shoes mass	0.20	0.26	n.s.
Spikes mass	-0.27	0.13	n.s.

Discussion

For modern people who have grown up wearing shoes, barefoot locomotion is something difficult to get used to. However, it is of great importance to note that none of this study's participants had any ankle pain or injury when they warmed-up or competed barefoot and they felt very comfortable. In spite of the fact that in all testing trials the athletes' foot strike was forefoot, the results of this performance-related study presented that the barefoot sprint times of the runners in the 30m were not worse than those with running shoes and spikes. This finding did not confirm our hypothesis that the barefoot running could make the runners slower in relation to their performance when they wear cushioned running or racing shoes on track which are widely used in the training programs of the developmental age athletes. Therefore the above is in accordance with recent studies which presented that the shod and unshod performance did not significantly differ in novice runners (Lieberman et al., 2010; Pilianidis et al., 2013).

Regarding the finish times in the 30m, the adolescents who participated in the current study performed slightly better when they wore spikes in relation to barefoot. From the mechanical point of view, the above is interpreted by the fact that the barefoot running would have been slower than the shod running because the foot contact time is systematically shorter when athletes run barefoot (Squadrone & Gallozzi, 2009; Lorenz & Pontillo, 2010). Furthermore, an alternative explanation for the marginally better sprinting performance of the studied participants when they wore racing shoes in the 30m (5.28s) in relation to barefoot (5.31s) performance is that the young athletes habitually wear spikes in their training which causes a change on the mechanics of the foot contact at the landing phase. Thus, instead of landing with the forefoot during the sprinting stride as it is usually done with spikes, they improved their running pace by contacting the track with the ball of the foot, using primarily the calf and foot muscles (Kristen et al., 1998; Tazuke 2004). Furthermore, the barefoot running strengthens the intrinsic and extrinsic muscles of the foot, offering the coaches the chance to apply not only training with spikes but also barefoot running in order to maximize their athletes' lower limbs spring-mass system for their optimal sprinting performance (Squadrone & Gallozzi, 2009).

In contrast with a recent study which assessed the running economy in over ground shod and unshod running and it reported that the participants' oxygen consumption for shod running was 5.7% greater than unshod running (Hanson et al., 2011), the findings of this study presented that the athletes' performance wearing running shoes (5.30s) was similar than that of barefoot (5.31s). Specifically, the cushioned running shoes in the sprints probably compromise the lower limb ability of the runners to act like a spring, affecting the running technique in short (30-60m) or longer runs (80-200m). With bare feet, the limb returns ~70% of the energy stored in it, but with running shoes the return is considerably less (Logan *et al*., 2010). Another possibility is the external work done in compressing and flexing the sole and in rotating the sole against the ground-up to 13% of the work done in running (Webb et al., 1988; Stefanyshyn & Nigg, 2000). Regarding the gender and comparing the testing protocols, the boys and the girls had same finish times in the 30m wearing running shoes (5.30s vs. 5.30s) and spikes (5.28s vs. 5.27s). In addition, their barefoot sprinting performance was marginally better in girls than in boys (5.29s vs. 5.35s). Surprisingly, it is of interest to note that the participants' extremely heavy running shoes (507gr) and spikes (441gr) did not interact with their sprinting performance in any of the testing conditions. Although no studies have shown whether the shoes mass affect the sprinting performance of young athletes, only one gait-analysis study presented that the barefoot running is associated with an improvement in performance as a result of a decrease in mass with the absent of shoes (Divert et al., 2008). A possible explanation for the above results is that the participants of this study run with low running speed as well as that the distance of 30m was too short in order to increase the inter-correlations among the athletes' sprinting performance and the mechanical parameters of the shoes mass.

Conclusion

In summary, the importance of this performance-related study is based on the fact that no differences were found in the finish times of the 30m sprint in the adolescent athletes wearing spikes, running shoes and barefoot. Coaches and athletes should consider the potential and the dynamics of the natural running by using a number of barefoot skills in their training preparation. Future research is needed in order to evaluate if the adaptations of the barefoot training in the developmental age athletes could facilitate the highly competitive performance in world-class sprinters.

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