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# THE EXAMINATION OF THE EFFECTS OF BAREFOOT TRAINING ON RUNNING BIOMECHANICS, SPRINT PERFORMANCE, AND AGILITY DEVELOPMENT IN CHILDREN AGED 8 TO 11

**Zsanett GERE[1*], Péter SZABÓ[2]**

**ABSTRACT.** *Introduction*: the human foot has been described as a masterpiece of engineering and art, yet modern footwear has often limited its natural function and reduced sensory feedback. this has led to inefficient movement patterns in children and adults. *Objective*: the purpose of this study was to examine the effects of a ten-week barefoot training program on agility, sprint performance, and running biomechanics in children aged eight to eleven years. *Material and methods*: the program included three weekly sessions lasting seventy minutes each. sixteen children began the program, and nine completed it. assessments before and after the intervention included a change-of-direction speed test, a twenty-meter sprint, and biomechanical measurements of stance phase and ground reaction force using a motion analysis device. *Results*: the barefoot training program improved agility and sprint performance in the participants. significant reductions in stance phase duration were observed in the right leg, indicating shorter ground contact time and improved running efficiency. no meaningful changes were observed in the left leg or in the average ground reaction force for either leg. *Discussion*: the improvements in performance may be linked to enhanced foot strength and neuromuscular coordination. however, the small sample size and short intervention period limited the generalization of the findings. *Conclusions*: barefoot training appeared to improve agility, sprint speed, and running mechanics in children. it may strengthen the foot and support the inclusion of barefoot exercises in youth physical development programs.

**Keywords:** Barefoot training; running biomechanics; agility; sprint performance; children

[1] Faculty of Physical Education and Sport, Babeş-Bolyai University, Cluj-Napoca, Romania
[2] Department of Individual Sports, Babeş-Bolyai University, Cluj-Napoca, Romania
* Corresponding author: gere.zsanett49@gmail.com

## INTRODUCTION

In recent years, barefoot running has increased in popularity. Until the 1970s, most individuals, including athletes, ran barefoot or in minimal footwear. The introduction of the modern running shoe—with cushioned heels, arch support, and reinforced soles—marked a significant shift in running practices (Lieberman, 2012).

One reason for the renewed interest in barefoot running is that, despite technological advancements in running shoes, the incidence of running-related injuries has not decreased (Jenkins & Cauthon, 2011). Research indicates that the rate of such injuries is notably lower among barefoot runners (Robbins & Hanna, 1987). According to Lieberman (2012), a professor of biological anthropology at Harvard University, one cause of foot and knee injuries may be that modern running shoes weaken the muscles of the feet, leading to overpronation and related joint problems. The stiff soles and arch supports typical of conventional running shoes may impede the natural adaptation of muscles and bones (Lieberman, 2012). Moreover, individuals who wear expensive running shoes advertised as providing additional protective features (e.g., increased cushioning or "pronation correction") are significantly more likely to experience injuries than those who wear inexpensive shoes -less than 40 US dollar (Marti, Vater, Minder, & Abelin, 1988). Barefoot training is often promoted on the assumption that it strengthens the musculoskeletal system and consequently enhances athletic performance (de Villiers & Venter, 2014). For example, an eight-week study involving netball players found that participants who trained barefoot demonstrated significantly greater foot stability, agility, and sprint performance over 10 and 20 meters compared to those who trained wearing shoes. Lieberman (2012) emphasized that "how someone runs is probably more important than what they wear on their feet, but what they wear on their feet can affect their running" (p. 64). In other words, footwear can be a determining factor in both running success and injury risk. The influence of running shoes on landing patterns will be discussed in the following section.

### *1. Types of Foot Strike Patterns*

The literature typically identifies three types of foot strike patterns in running:

- Rearfoot strike (RFS): the heel contacts the ground before the forefoot, commonly referred to as "heel-toe running."
- Forefoot strike (FFS): the forefoot contacts the ground before the heel ("toe-heel-toe running").
- Midfoot strike (MFS): the heel and forefoot contact the ground simultaneously, typically beginning with the outer edge of the sole. The heel remains on the ground only briefly before lifting again, functioning like a spring.

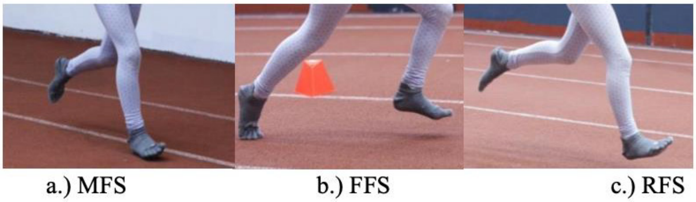


**Fig.1.** 3 types of landing. Snapshot of a Barefoot training participant

### *2. The Ideal Landing Technique*

It is often suggested that there are as many running techniques as there are runners. However, an important question arises: *Is there an ideal landing technique during running?* Brewer et al. (2017) found that when runners land on their heels, the foot typically strikes the ground ahead of the body's center of gravity. This movement disrupts forward momentum and requires greater energy expenditure to maintain speed. In contrast, when landing on the ball of the foot, the foot strikes the ground more vertically, minimizing braking forces and reducing the loss of momentum.

Approximately 75% of shod runners (i.e., runners wearing shoes) use a rearfoot strike (RFS) pattern, whereas barefoot runners more frequently adopt a midfoot strike (MFS) or forefoot strike (FFS) pattern. These strike types are associated with shorter stride lengths and lower stress on the ankle and Achilles tendon (Lieberman, 2012). Moreover, the more experience runners have running barefoot, the more likely they are to employ an FFS pattern (Lieberman et al., 2015).

### *3. Impact Peaks and Ground Reaction Forces*

Lieberman et al. (2010) compared habitual barefoot runners with habitual shod runners and examined their ground contact techniques. The researchers found that the vertical impact peak force was approximately three times lower among habitual barefoot runners using an FFS pattern than among habitual shod runners using an RFS pattern, whether barefoot or wearing shoes. These findings suggest that forefoot striking may attenuate impact forces and potentially reduce injury risk.

### *4. Biomechanics of Galloping*

Galloping is typically performed using a forefoot strike pattern. Sprinters generally possess a stiffer Achilles tendon than distance runners, which contributes to more efficient energy transfer during propulsion. Mizushima et al. (2021)

investigated the long-term effects of a school-based barefoot program involving children aged 10–12 years over a four-year period. Their findings indicated that barefoot participants exhibited shorter ground contact times, longer flight phases, and higher running speeds, regardless of footwear condition. In contrast, the control group, which wore shoes, showed no significant performance improvements associated with footwear use.

## PURPOSE

The purpose of this research is to obtain empirical evidence regarding the performance benefits of barefoot training. Specifically, the study aims to examine the effects of regular barefoot training on agility and 20-meter galloping speed, comparing post-training outcomes to pre-training assessments. In addition, the research seeks to determine whether barefoot training produces measurable changes in running biomechanics during the stance phase.

More precisely, the study investigates how barefoot running influences the average horizontal ground reaction force (Fx Average) in the sagittal plane. The objectives of the 10-week training program are to improve movement speed combined with directional changes, enhance 20-meter galloping performance, and promote a more natural landing pattern during running. Furthermore, the program aims to increase overall performance, strengthen the leg and foot musculature, and reduce the risk of running-related injuries.

## MATERIALS AND METHODS

### *Participants*

*Selection of Subjects*

Between November and December 2023, researchers introduced the program to children in six primary schools, distributing informational leaflets to students in grades two through four. Written parental consent was obtained for all participants, in accordance with ethical research guidelines. The children contributed to the study by completing both pre- and post-training assessments and by participating in the full training intervention.

*Description of Participants*

The study sample was heterogeneous and selected using convenience sampling. Of the 16 initial participants, 9 completed the program, resulting in a dropout rate of approximately 50%. Eight participants were included in the biomechanical analysis of running, while nine completed the 20-meter gallop and 505-agility tests. The average age of participants was 10 years. The final sample included seven boys and two girls.

### *Procedure*

The same assessments were administered during both the pre-test and post-test phases. These included the 505-agility test and the 20-meter gallop. In addition, running biomechanics were analyzed using a G-force measuring platform. The biomechanical variables measured were:

Ground contact time (stance time) – the duration of the foot's contact with the ground, and Horizontal ground reaction force (Fx) – the force exerted by the body against the ground in the front-to-back (sagittal) direction. Measurements were taken on January 9 and January 11, 2024 (pre-test), and again on March 26 and March 28, 2024 (post-test). The first testing session focused on assessing parameters related to running technique, while the second session included the galloping and 505-agility tests.

### *Tools and Methods Used in the Pre- and Post-Tests*

*505-Agility Test*

Unit of Measurement: Seconds (s), recorded to two decimal places

Objective: To assess movement speed in combination with directional change

Description and Procedure: Participants began each trial from a standing start. Timing commenced with the initiation of movement. Each participant performed two trials per leg—one involving a turn to the left and the other to the right. The fastest time recorded across all trials was considered the final result.

*20-Meter Gallop*

Unit of Measurement: Seconds (s), recorded to two decimal places

Objective: To measure the ability to complete a 20-meter distance in the shortest possible time

Description and Procedure: Each participant started from a standing position with their preferred foot placed behind the starting line. Two attempts were performed, and the fastest recorded time was retained for analysis.

*Measurement of Stance Phase Duration During Running Using a G-Force Measuring Platform*

Unit of Measurement: Seconds (s), recorded to two decimal places

Objective: To measure the duration of the stance phase during running

Description and Procedure: Participants began from a standing start position, placed on a box or platform aligned with the G-Force measuring device. In response to an auditory signal, participants initiated running, ensuring that their trailing foot made contact with the force platform during the stance phase. Each participant completed three trials per leg, and the mean value of these three attempts was used for analysis.

*Measurement of Horizontal Ground Reaction Force (Fx Average) Using a G-Force Measuring Platform*

Unit of Measurement: Newtons (N)

Objective: To quantify the average horizontal ground reaction force (Fx Average) exerted by the body on the ground in the sagittal plane

Description and Procedure: This measurement followed the same protocol as the stance phase assessment. Participants performed the trials under identical conditions, and the average horizontal force generated during ground contact was recorded for analysis.

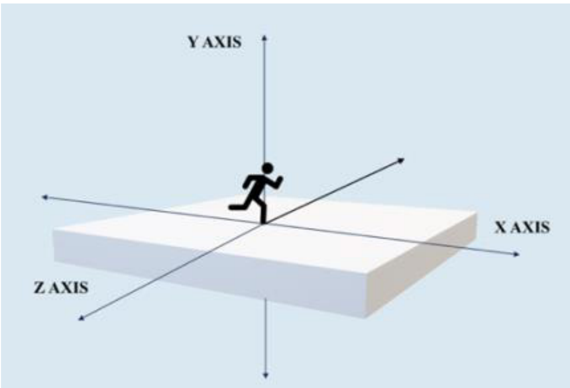


**Fig. 2**. Direction of the axes with respect to the center of gravity of the body.

### ***Methods Used in the Research***

*Research Design*

This study employed an experimental research design. Both primary and secondary data sources were utilized to collect information and statistical data. Primary data consisted of the children's individual measurements, training program details, and resulting performance outcomes. Secondary data were derived from theoretical knowledge and empirical studies in the existing literature, which informed the planning and structure of the training program. Information related to the design of the training program, test protocols, and exercise selection was gathered through a literature review of relevant academic and professional sources.

### *Materials*

*Applied Training Plan*

The training plan was developed in accordance with the participants' age, motivation, and physical fitness, with intensity levels increasing progressively throughout the intervention. During the sessions, participants wore five-toed socks ("foot gloves") designed to closely replicate the mechanics and energetics of barefoot running. Training sessions were conducted three times per week, each lasting 70 minutes, between January 15, 2024, and March 24, 2024.

The first sessions took place on the indoor athletics track at the Iuliu Hațieganu University Sports Park, followed by sessions at the Cluj Arena indoor track. Each session was structured into three distinct components:

1. Warm-up phase: Activities designed to activate the leg and foot muscles.
2. Main phase: Running, jumping, strength, and agility exercises.
3. Cool-down phase: A progressively longer jog, concluding with the final half-lap at a submaximal pace.

The specific warm-up component aimed to prepare the lower limbs for dynamic activity and included the following exercises: running drills, preparatory and activation movements, foot massage using a tennis ball, heel and toe lifts, leg swings, running in place, and various gait patterns (e.g., bear walk).

### *Data Analysis*

A combination of descriptive and inferential statistical methods was used to analyze the collected data. The test results were processed using percentages, statistical indicators, and the software programs SPSS and JASP. Additionally, Microsoft Word and Microsoft Excel were used for data organization and visualization. Results are presented in the form of tables and figures to enhance interpretability. To verify the assumptions for the paired-samples t-test, the Shapiro–Wilk test was performed to assess data normality. The results confirmed that the assumption of normality was met, indicating that the use of the paired-samples t-test was appropriate for the analyses.
Statistical significance was set at $p \leq .05$ for all analyses.

## RESULTS

### *505-agility test*

The processed data are expressed in seconds (s) to two decimal places, representing the time required for participants to complete the designed distance while performing a 180° change of direction from a standing start with each leg.

**Table 1.** Results of the paired-samples t-test comparing pre- and post-training performance for the left and right legs.

*Paired Samples T-Test*

| Measure 1 | | Measure 2 | t | df | p | Mean Difference | SE Difference |
|---|---|---|---|---|---|---|---|
| 505_pretest_Left | - | 505_post_Left | 6.675 | 8 | < .001 | 0.369 | 0.055 |
| 505_pre_Right | - | 505_post_Right | 2.532 | 8 | .035 | 0.302 | 0.119 |

*Note.* Student's t-test. p <= .05

A paired-samples t-test was conducted to compare the pre- and post-training performance of the left leg in the 505-agility test. The analysis revealed a significant improvement from the pre-training measurement (M = 3.33, SD = 0.38) to the post-training measurement (M = 2.96, SD = 0.27), t(8) = 6.67, p < .001. These findings suggest that barefoot training positively influenced agility, specifically enhancing movement speed combined with rapid directional changes.

Table 1. also presents the pre- and post-training results for the right leg. A paired-samples t-test was conducted to compare pre- and post-training 505-agility performance for the right leg. The analysis revealed a significant improvement from the pre-training measurement (M = 3.27, SD = 0.46) to the post-training measurement (M = 2.97, SD = 0.17), t(8) = 2.53, p = .035.

For the left leg, all participants showed a decrease in time for movement speed combined with directional change. For the right leg, all participants except two demonstrated a reduction in time. These findings indicate that barefoot training positively affects agility, specifically by enhancing movement speed in combination with rapid changes in direction.

### *20-Meter Distance Run*

**Table 2.** Results of the paired-samples t-test comparing pre- and post-training performance in the 20 meter gallop.

*Paired Samples T-Test*

| Measure 1 | | Measure 2 | t | df | p |
|---|---|---|---|---|---|
| 20_m_pretest | - | 20_m_post test | 2.583 | 8 | 0.32 |

*Note.* Student's t-test. p <= .05

Table 2 presents the results of the paired-samples t-test comparing pre- and post-training performance in the 20-meter gallop. Performance was measured as the time required to complete the designated distance from a standing start, expressed in seconds. All participants except two (participants 6 and 7) demonstrated a decrease in completion time.

A paired-samples t-test was conducted to compare pre- and post-training performance. The analysis revealed a significant improvement from the pre-training measurement (M = 4.02, SD = 0.42) to the post-training measurement (M = 3.77, SD = 0.24), t(8) = 2.58, p = .032.

These findings indicate that barefoot training positively affects galloping performance, specifically by improving forward speed.

### *Support phase results*

**Table 3**. Results of the paired-samples t-test comparing pre- and post-training performance for the left and right legs in stance phase duration.

*Paired Samples T-Test*

| Measure 1 | | Measure 2 | t | df | p |
|---|---|---|---|---|---|
| Stance_ph_pre_L | - | Stance_ph_post_L | 0.800 | 7 | .450 |
| Stance_ph_pre_R | - | Stance_ph_post_R | 2.255 | 7 | .059 |

*Note.* Student's t-test. p <= .05

Table 3 presents the results of the paired-samples t-test comparing pre- and post-training stance phase duration for the left and right legs. Stance phase duration was measured as the time (s) each participant's foot remained in contact with the force platform during running from a standing start.

A paired-samples t-test was conducted to compare pre- and post-training measurements for the left leg. No significant difference was found between the pre-training (M = 0.29, SD = 0.03) and post-training (M = 0.28, SD = 0.06) measurements, t(7) = 0.80, p = .450. Although the difference was not statistically significant, a partial improvement in stance phase duration was observed among the participants. All participants, except two (participants 4 and 8), demonstrated a decrease in stance time, and one participant's time remained unchanged.

A paired-samples t-test was conducted to compare pre- and post-training stance phase duration for the right leg. The analysis revealed a significant reduction from the pre-training measurement (M = 0.29, SD = 0.038) to the post-training measurement (M = 0.26, SD = 0.036), t(7) = 2.25, p = .05. These results suggest that barefoot training influenced the stance phase, resulting in a shorter ground contact time.

A shorter stance phase generally corresponds to an increased flight phase and higher running speed (Kennedy, 2018). The stance phase can be divided into three major components: the amortization phase, the verticality phase, and the momentum phase (Szabó & Vasile, 2010). During the momentum phase, which serves as the primary propulsive phase of the running stride, rapid and forceful extension of the supporting leg is required. As running speed increases and the stance phase shortens, the momentum phase must occur more rapidly and powerfully, resulting in a stronger, more explosive push-off from the supporting leg.

Previous research suggests that shorter ground contact times are often associated with forefoot strike (FFS) or mid-midfoot strike (MMS) patterns, as heel contact typically requires more time (Hasegawa, Yamauchi, & Kraemer, 2007). It is therefore plausible that the reduced stance phase observed in the current study reflects an adoption of FFS or MMS running patterns. However, further investigation using more advanced biomechanical measurement tools is necessary to confirm this hypothesis.

## Measurement of the force exerted by the body on the ground on the x-axis (front-back direction) (Fx Average)

**Table 4**. Results of the paired-samples t-test comparing pre- and post-training performance for the left and right legs in average ground reaction force along the x-axis (front–back direction; Fx Average).

*Paired Samples T-Test*

| Measure 1 | | Measure 2 | t | df | p |
|---|---|---|---|---|---|
| Fx_av_pre_L | - | Fx_av_post_L | 0.679 | 7 | .519 |
| Fx_av_pre_R | - | Fx_av_post_R | 1.509 | 7 | .175 |

*Note.* Student's t-test. p <= .05

Pre- and post-training anterior–posterior ground reaction force measurements were recorded in Newtons (N), with negative values indicating force applied in the anterior–posterior direction. These values represent the horizontal force exerted by participants on the ground from a standing start in the sagittal plane.

A paired-samples t-test was conducted to compare pre- and post-training measurements. No significant difference was observed between the pre-training (M = –59.44, SD = 20.42) and post-training (M = –64.73, SD = 33.64) measurements, t(7) = 0.68, p = .519. Despite the lack of statistical significance, a partial improvement is evident, as many participants exhibited reduced force exertion. These findings suggest that during ground contact, the reduced horizontal force may indicate decreased impact on the body, resulting in a lower load on the musculoskeletal system. All participants except three (participants 5, 7, and 8) demonstrated a decrease in force magnitude for the left leg.

A paired-samples t-test was conducted to compare pre- and post-training measurements. No significant difference was found between the pre-training (M = –52.92, SD = 13.39) and post-training (M = –62.42, SD = 22.35) measurements, $t(7) = 1.51$, $p = .175$. Despite the absence of statistical significance, a partial improvement was observed, as the horizontal force decreased for many participants. A reduction in force magnitude was observed for all participants except two (participants 3 and 5) for the right leg.

This reduction suggests that during ground contact, participants experienced lower impact forces, resulting in a reduced load on the musculoskeletal system.

## DISCUSSION

In accordance with the research objectives, this study analyzed the changes resulting from a ten-week barefoot training program, as reflected in differences between pre- and post-training measurements. The program led to improvements in foot mechanics and running performance in children aged 8–11 years. It produced significant gains in 505-agility ($p = .035$) and 20-m gallop speed ($p = .032$), together with a shortened right-leg stance phase ($p = .05$). Similar performance benefits have been reported in other youth and adult cohorts. De Villiers & Venter (2014) observed that eight weeks of barefoot training improved ankle stability and agility in netball players, mirroring the present study's agility gains despite a different sport context. Mizushima et al. (2021) examined a four-year school-based barefoot program and documented reduced ground-contact times, longer flight phases, and faster sprint speeds across ages 10-12, aligning with our finding that a shorter stance phase translates to higher running speed. Early injury-prevention work by Robbins & Hanna (1987) reported lower running-related injury incidence among barefoot runners, supporting the notion that the biomechanical adaptations seen here (e.g., reduced horizontal ground-reaction force, though not statistically significant) may confer protective effects.

Finally, Lieberman (2012) highlighted that habitual barefoot runners tend to adopt fore- or mid-foot strike patterns, which lower impact peaks and improve efficiency; our observed right-leg stance reduction likely reflects a shift toward such strike patterns, as suggested in the discussion. Consequently, despite variations in sample size, duration, and sport-specific tasks, the studies consistently demonstrate that barefoot training enhances neuromuscular efficiency, shortens ground-contact time, and yields measurable improvements in speed and agility.

## CONCLUSIONS

The ten-week barefoot training program produced measurable improvements in running performance, stance phase stability, and the strength of the foot and ankle musculature in children aged 8–11 years. A statistically significant reduction in stance phase duration was observed in the right leg, indicating a potential improvement in running efficiency; however, no significant changes were found in the left leg or in the average horizontal ground reaction force.

Due to the small sample size, participant dropout, and the short duration of the intervention, the findings cannot be generalized to the wider population. The results should therefore be interpreted as preliminary and exploratory. Nevertheless, the observed trends are consistent with previous research reporting beneficial adaptations in neuromuscular coordination and foot function following barefoot or minimal-footwear training.

Further studies with larger samples, longer intervention periods, and more comprehensive biomechanical analyses are required to confirm these findings and to better understand the long-term effects of barefoot training on running mechanics and performance in children.

### AUTHOR CONTRIBUTIONS

*Zsanett Gere and Péter Szabó* contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

### CONFLICT OF INTEREST

The authors declare no conflict of interest.

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