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GENDER DIFFERENCES IN RUNNING GAIT UTILISING PROSENSE SENSORS WITH THE SMART4FIT APP

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(Original scientific paper)

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Abstract
Introduction: Step length and step rate are among the most important biomechanical running variables, and they can vary according to gender or running speed. So far, very few studies have examined gender differences in running gait using wearables. Therefore, this study aimed to assess gender differences in step length and step rate while running at different treadmill speeds using two accelerometers. Method: The study included 20 recreational runners (10 women and 10 men) who ran on the treadmill according to a predetermined protocol while wearing two Prosense accelerometer sensors on each leg. The protocol included treadmill activities lasting 10 minutes: a 3-minute warm-up (at 8km/h), followed by one minute of running at speeds of 8, 10, 12, and 14 km/h (used for analysis), and 3 minutes of cool down (8 km/h). The analysis included the average length of individual steps (step length) and the number of steps per minute (step rate) for each speed. Data was extracted using the previously established MotionXrays methodology. Results and discussion: Two-way between-within ANOVA with Bonferroni posthoc showed a significant increase in both step length and step rate with increased running speed ($p<0.001$), while only gender differences were presented in the 14km/h running speed. In particular, men had greater step length ($p=0.046$), while women had greater step rate ($p=0.038$). This can be explained by the difference in average height between the tested females and males (12.5cm), which represents a significant factor in running biomechanics. Conclusion: The results obtained in this research highlight the importance of different approaches when teaching and practising running techniques in male and female recreational runners, especially when running faster.

***Keywords**: wearables, treadmill, accelerometer, step length, step rate*

Introduction

Recreational running is among the most popular activities, offering numerous health and psychological benefits (Marković, 2020). We are witnessing a dramatic increase in the number of recreational runners worldwide, leading to the organisation of numerous races and events (Germini, 2022). Modern technology, which has rapidly emerged in recent decades, has also impacted the world of running in many ways. In particular, it encompasses a wide range of innovations and advancements that help recreational runners improve and evaluate their performance. The portable devices provide a wealth of information that helps us analyse the performance or technique of running itself (Manson, 2022). They are much more accessible to recreational runners than expensive laboratory testing, which is why the use of portable running devices is constantly growing. With the rise of the market and the development of inexpensive technology used for creating portable sensors, they have become a widely accepted tool in daily physical activity, and additionally, they also provide reference and valuable data (Germini, 2022; Xiang, 2022)

Among the most important biomechanical variables used in running assessments are stride length and step rate. These variables can vary depending on gender or running speed (Rajkumar, 2020). Previous research has demonstrated differences in kinematic, physiological, and biomechanical parameters between genders during running (Bruening, 2020; Senefeld, 2021). The majority of differences are associated with anthropometric variations between men and women. Different centres of mass movement, as well as the movement of individual extremities resulting from significant differences in average height between the two groups examined, lead to somewhat different outcomes.

So far, only a few studies have investigated gender differences in running performance using portable devices. Due to differences in performance and patterns, the same gender differences could also affect the training processes.

Therefore, this study aimed to assess gender differences in step length and step rate while running at different treadmill speeds using two accelerometers. We hypothesise that both step length and step rate will increase with increasing speed, but men will increase their stride length more while women will increase step rate.

Material & methods

Participants

The study included 20 recreational runners (ten women and ten men), students of the Faculty of Sport and Physical Education in Belgrade. Their anthropometric data is presented in Table 1. Before the experiments, students were informed about the research's protocol and purpose. Students volunteered to participate in the study and signed consent forms. The research was conducted following the principles of the Helsinki Declaration.

	Men	Women
Age (years)	23 ± 2.01	22 ± 1.69
Body mass (kg)	80.44 ± 13.68**	62.65 ± 7.87
Body height (cm)	183 ± 4.97**	170 ± 5.54
Body mass index (kg/m^2)	24.41 ± 3.13*	21.64 ± 1.91

Table 1: Data was presented as mean ± standard deviation; * significantly different from women at $p < 0.05$; ** significantly different from women at $p < 0.01$.

Procedures

Two variables were analysed in the research:

The average length of individual steps (step length)

The number of steps per minute (step rate) for each speed

To obtain data on the participants' body composition, the Total InBody 720 bioimpedance was used. The Total InBody 720 is a device used to measure a person's overall body composition. At the beginning of the testing, participants were instructed to be barefoot and wear sportswear. Their participant number, body height, and age were entered to identify the participants. Following the manufacturer's instructions for the bioimpedance, participants were instructed to stand upright, place their feet on the analysers, and hold the handles of the analyser. Maintaining this proper position ensures contact with the body with eight electrodes (2 for each arm and leg). When properly positioned on the bioimpedance, they must remain still and look straight ahead (Gibson et al., 2008).

The next step in the testing protocol is running on the treadmill. The protocol included a 10-minute treadmill activity, consisting of a 3-minute warm-up (at 8 km/h), followed by a 4-minute run, starting at 8 km/h and gradually increasing by 2 km/h every minute to 10 km/h, then 12 km/h, and finally 14 km/h. After running, a 3-minute cool-down followed (at 8 km/h). ProSense sensors were used to measure the physiological parameters of the participants while running. ProSense sensors are lightweight, portable devices; two of them (one for each leg) are placed above the ankle, as shown in Figure 1. The sensors are connected via Bluetooth to the Smart4Fit Android application on a smartphone, which displays the indicators on its screen. Data on the participant's body weight and height are entered into the application, as well as the name of the exercise the participant performed. The sensor is equipped with an accelerometer, gyroscope, and magnetometer, which provide data on acceleration, angular velocity, and the speed of the magnetic field (Earth) at a sampling rate of 50 Hz. They also provide data on kinematic parameters such as speed, force, energy, and power, and importantly for this research, data on instabilities (even small ones) and variations between individual body segments of the participants.

Figure 1: Display of the 'Proses' sensor during treadmill running

Statistical analysis

Before all statistical tests, descriptive statistics were calculated as a mean and standard deviation. The Kolmogorov-Smirnov (KS) test and visual inspection of histograms and QQ plots confirmed data distribution normality.

Two-way between-within ANOVAs were performed on Step length and Step rate to assess differences between running speed (i.e., 8, 10, 12, and 14km/h; within factor), gender (i.e., men and women; between factor), and their interaction (running speed x gender).

For all ANOVAs, the post hoc Bonferroni test was performed. Effects size was presented via eta squared (ŋ2), where the values of 0.01, 0.06, and above 0.14 were considered small, medium, and large, respectively (Cohen, 1988). The alpha level was set at $p < 0.05$.

All statistical tests were performed using Microsoft Office Excel 2007 (Microsoft Corporation, Redmond, WA, USA) and SPSS 26 (IBM, Armonk, NY, USA).

Results

Two-way between-within ANOVA applied on step length (SL) showed significant main effects of running speed [$F_{(3,18)} = 652.3$, $ŋ^2 = 0.97$, $p < 0.001$] and running speed x gender interaction [$F_{(3,18)} = 5.80$, $ŋ^2 = 0.24$, $p = 0.003$]. In contrast, no significant main effects were found on gender [$F_{(3,18)} = 1.33$, $ŋ^2 = 0.07$, $p = 0.26$]. Post hoc analysis (in both men and women) showed that SL was significantly different in each running speed ($p < 0.01$). Furthermore, men only had longer SL than women when running at 14 km/h ($p<0.05$; Figure 2).

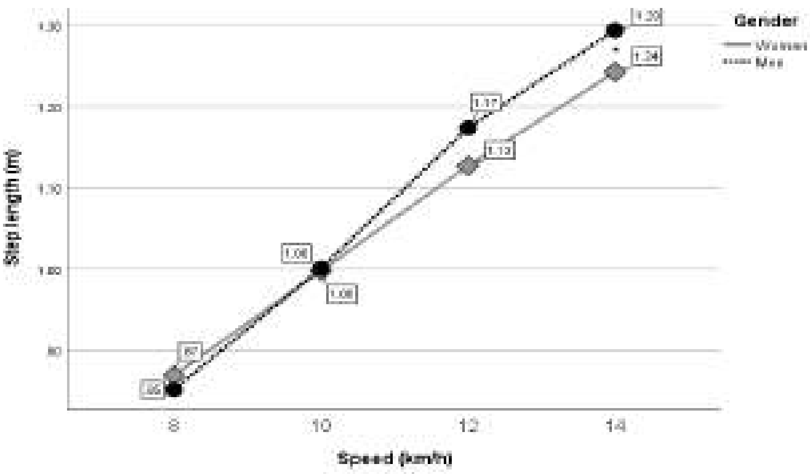

Figure 2: Step length in different running speeds

The same two-way between-within ANOVA applied on step rate (SR) showed significant main effects of running speed [$F_{(3,18)} = 120.4$, $ŋ^2 = 0.87$, $p < 0.001$] and running speed x gender interaction [$F_{(3,18)} = 3.65$, $ŋ^2 = 0.17$, $p = 0.029$]. In contrast, no significant main effects were found on gender [$F_{(3,18)} = 2.08$, $ŋ^2 = 0.10$, $p = 0.17$]. Similarly to SL, post hoc analysis (in both men and women) showed that SR was significantly different in each running speed ($p < 0.01$). Furthermore, women only had higher SR than men when running at 14 km/h ($p<0.05$; Figure 3).

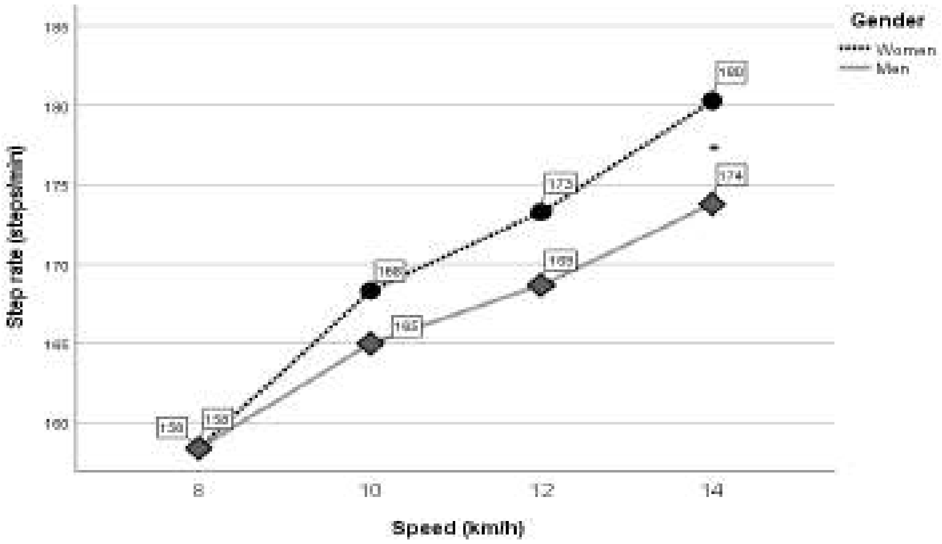

Figure 3: Step rate in different running speed

Discussion

This study assessed gender differences in step length and step rate while running at different treadmill speeds using two accelerometers. We hypothesised that both step length and step rate would increase with increasing speed, which was confirmed. Our second hypothesis, which posits that women will increase their step length more while women will increase their step rate, was only partially confirmed. The data obtained aligns with previous studies that compared these two parameters (Hunter et al., 2003; Barnes et al., 2013; Rajkumar, 2020). Previously identified differences in running kinematics between genders are noteworthy, not only associated with body height but also with joint mechanics and the overall locomotor system (Bruening et al., 2020; Ortega et al., 2021). As emphasised earlier, there is a significant difference in anthropometric parameters between men and women groups of participants, contributing to the divergence in the obtained results. The difference in average height between groups is substantial (12.5cm), consequently leading to a difference in the length of the lower extremities, which has been found to influence running gait greatly (Šentija et al., 2011; Taylor-Haas et al., 2022).

Two-way between-within ANOVA with Bonferroni post hoc analysis revealed a significant increase in both step length and rate with the increase in running speed ($p<0.001$), consistent with previous research where differences in running kinematics escalated with increasing running speed (Bruening et al., 2020). In our study, this is reflected in the fact that men increased their step length as running speed increased, significantly differing from women at a speed of 14km/h ($p=0.046$), while women exhibited higher step rate values ($p=0.038$). The negative correlation between step length and step rate has been previously established, with some authors attributing it primarily to the length of the lower extremities (Hunter et al., 2003; Barnes et al., 2013), aligning with our results, which are most dependent on participant height.

Figures 2 and 3 show that differences in the tested parameters consistently increase. As previously mentioned, this stems from the significant difference in average height between the groups. With increasing speed, women had to increase their step frequency due to their shorter limbs. At the same time, men employed a more energy-efficient strategy by simply lengthening their strides, which is considerably more economical. The differences in initial speeds are small but still noticeable, indicating the precision of the apparatus used in the testing. The difference is greatest at that speed because the protocol concludes there; however, if we continued increasing the speed, the difference would also increase. The human body is trained to conserve energy in every possible way, as quickly demonstrated by the example of our subjects. Men would achieve the desired running speed by increasing the length of their steps until it becomes insufficient, at which point they would also progressively increase their step rate.

Limitations

The limitation of this research is undoubtedly the small number of participants, and we aim to include a larger number of participants in future studies, dividing them based on different criteria. Additionally, we must mention that new equipment was used, requiring further testing and verification to refine it and expand its comprehensive application.

Conclusion

The results indicated significant differences between genders when running faster, primarily due to variations in participant anthropometry. This research leads us to the conclusion that a distinct approach is necessary for teaching and training the techniques of male and female recreational runners. The modern technology employed in this study is an excellent tool for runners and their coaches seeking additional analysis during physical activities such as running. It is necessary to form male and female groups with similar anthropometric characteristics to determine specific differences between genders, which presents an excellent avenue for future research.

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