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STUDY ON RUNNING PARAMETERS MONITORED WITH A SMARTWATCH AS PART OF A SHORT-DISTANCE EXPERIMENTAL TEST

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Abstract This study aims to evaluate physiological parameters and physical performance during a short, high-intensity running event, using a smartwatch to monitor heart rate, power, and cadence. The study hypothesis assumes that these devices can provide accurate and relevant data and that the measured values are influenced by the running speed and effort level of the participants. The testing was carried out during the Researchers' Night event at the "Ștefan cel Mare" University of Suceava, with the participation of 21 people who gave their informed consent for the experiment. Participants performed five repetitions of a 20 m run, while physiological parameters were recorded in real time. The objectives of the study included measuring heart rate, monitoring power output, determining cadence, analyzing the relationship between running speed and physiological response, and verifying the reliability of the data obtained from the smartwatch. The results suggest that the smartwatch is an effective tool for assessing physical performance and identifying individual differences between participants. The study also provides useful information for designing personalized training programs aimed at optimizing heart rate, power, and cadence during high-intensity exercise.

Introduction

In the era of rapid digitalization, information technology has penetrated almost all areas of life, including education and sports activities [15,16]. The use of computational techniques in the evaluation and planning of sports performance has been documented for several decades and is considered an essential tool for objective analysis of performance [8,10,12,13]. Currently, the rapid development of wearable devices and IoT technologies has led to the emergence of new methods for monitoring physical activity. Activity monitoring (AM) is a well-established technique for assessing the level of physical activity of an individual and is used in both sports and medical contexts. The acceptance and use of wearable devices plays a key role in optimizing physical performance, especially in educational settings, where a positive impact on student outcomes has been demonstrated [17].

Smartwatches have become some of the most widely used wearable devices, offering the opportunity to combine activity monitoring with real-time interaction with other medical or research systems. Smartphone and smartwatch technology allows for bidirectional transmission of real-time data, facilitating the development of interactive and adaptive medical applications [5]. However, continuous Bluetooth connectivity and limited battery life remain important factors that can affect user satisfaction and overall usability of these devices [18].

Accelerometry has become an increasingly popular method for assessing human movement in outdoor conditions and is frequently integrated into smartwatches used by runners [11]. However, questions remain about the suitability and accuracy of smartwatches as platforms for monitoring physical activity, highlighting the need for further validation studies [1]. Recent advances in smartwatch technology offer noninvasive alternatives for estimating important physiological parameters, such as lactate threshold, although the measurement protocols and results obtained are less validated compared to standardized laboratory tests [7]. At the same time, performance prediction features can support amateur runners in setting realistic goals and preparing for competition [2]. Although smartwatches are great for general training monitoring, special data interpretation is needed in the case of highly trained athletes, where the validity of estimates of indicators such as VO_2max can vary significantly [4]. Given the high popularity of smartwatches for running among amateur athletes, assessing their reliability and validity remains fair for predicting performance over different running distances [3]. Furthermore, although these devices are equipped with high-resolution screens, most applications provide limited visual feedback in the form of real-time textual information, which may restrict their educational and motivational potential during sports activities [14].

Material-method

Study Hypothesis: It is assumed that the use of a smartwatch can provide accurate data on heart rate, power, and cadence during stair running repetitions and that these data will be influenced by the participants' running speed and effort. The purpose of this study is to evaluate the physiological parameters and physical performance of participants during stair running at university, using a smartwatch to monitor heart rate, power, and cadence. Study objectives: Measurement of participants' heart rate during physical exercices. Monitoring of power generated during stair running. Determining participants' cadence during each repetition. Analyzing the relationship between running speed and physiological response (heart rate and power). Verifying the reliability of data obtained from the smartwatch in the context of a short, high-intensity exercise. Testing procedure: The testing was conducted during the Researchers' Night event at the "Ștefan cel Mare" University of Suceava, with the participation of 21 people who gave their informed consent to participate in the experiment. The testing was conducted using a smartwatch, and the participants performed five repetitions of stair running at the university, covering a total distance of 20 meters. Inclusion criteria: Healthy individuals without cardiovascular, respiratory or musculoskeletal conditions. Age between 18 and 20 years. No recent injuries that would affect running ability. Not taking medications that could influence heart rate or physical performance. Availability and informed consent to participate in the experiment.

Research methods: The literature review method was used to document theoretical aspects regarding physical performance monitoring, the use of smartwatches in exercise testing, and relevant physiological parameters during running. The observation method allowed the evaluation of participants' behavior and exercise performance, as well as the identification of potential errors or difficulties during testing. Testing Method: Practical testing was conducted by performing five repetitions of stair running at the university, measuring participants’ heart rate, power, cadence, and speed using a smartwatch.

Mathematical-Statistical Method:The collected data were processed using statistical methods, calculating the following indicators: Arithmetic mean: to determine the average value of the measured parameters. Standard deviation: to assess the dispersion of the data. Coefficient of variation: to evaluate the uniformity of the data. Quartiles: to analyze the distribution and variation of values. Graphical Method: Data were represented graphically to visually highlight the relationships between measured parameters, such as heart rate in relation to cadence and running speed.**Table 1 Theoretical program for improving physiological parameters (12 weeks)**

Week	Warm-up (min)	Stair Running / Treadmill	Strength / Plyometric Training	Easy Running (min)	Cool-down / Stretching	Intensity (%)
1–2	10	4 × 20 m, 1 min rest	2 sets × 10 reps: squats, lunges, push-ups	10	5–10	50–60
3–4	10	5 × 20 m, 1 min rest	3 sets × 10–12 reps: squats, lunges, plank	12	5–10	60–65
5–6	10	5 × 25 m, 1 min rest	3 sets × 12 reps: squats, lunges, plank, jumps	15	5–10	65–70
7–8	10	6 × 25 m, 1 min rest	3–4 sets × 12–15 reps: squats, lunges, plank, jumps, superman	15–18	5–10	70–75
9–10	10	6 × 30 m, 1 min rest	4 sets × 12–15 reps: strength + intensive plyometrics	18	5–10	75–80
11–12	10	7 × 30 m, 1 min rest	4 sets × 15 reps: strength + plyometrics + core	20	5–10	80–85

Results

Analysis and Interpretation of Running Speed

The data obtained for participants’ running speed indicate a mean value (X̄) of 21.66 km/h, suggesting that, on average, participants maintained a relatively high pace while running on the university stairs. The data dispersion, represented by the standard deviation (STDEV = 5.35 km/h), shows considerable variation among participants. This means that some participants ran significantly faster or slower than the group average. The coefficient of variation (Cv% = 24.70%) confirms this relatively high variability, indicating that running speed is not uniformly distributed within the group and that there are notable differences between individuals.

Quartile Analysis:

Q1 = 18.20 km/h indicates the value below which 25% of the participants fall; these individuals ran at lower speeds, likely due to a lower fitness level or less running experience.

Q2 = 21.54 km/h represents the median, suggesting that half of the participants ran faster than this speed and half ran slower. The closeness of the mean and median values indicates an approximately symmetrical distribution.

Q3 = 24.30 km/h shows the value above which 25% of the participants fall, highlighting the group of “fast performers” who ran significantly faster than the group average.

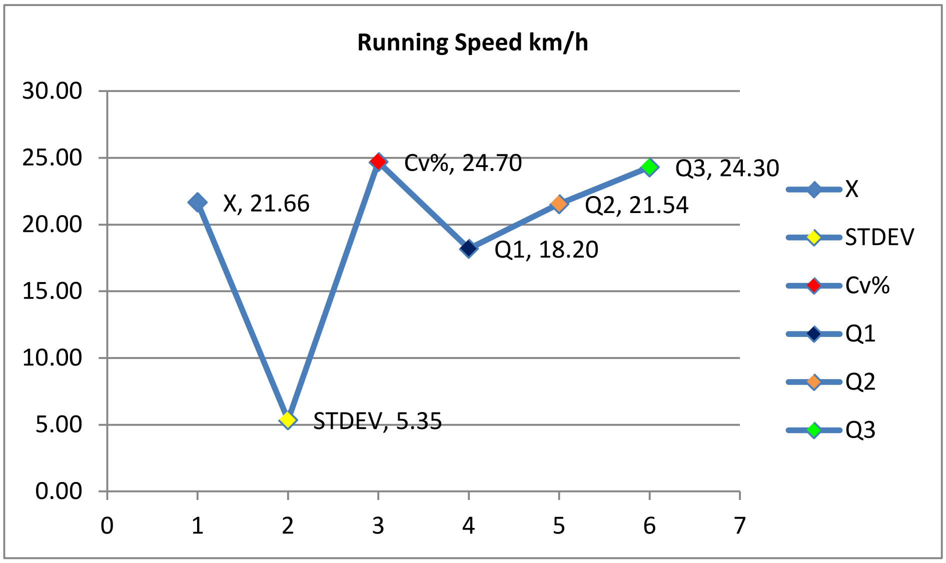

Fig. 1. Distribution of participants’ running speed

Analysis and Interpretation of Running Time

The data obtained for running time show a mean value (X̄) of 30.40 seconds, representing the average duration needed by participants to cover the 20 m distance on the university stairs. The standard deviation (STDEV = 3.12 s) indicates moderate variability among participants, suggesting that most performed close to the average, with some differences between the fastest and slowest individuals. The coefficient of variation (Cv% = 10.27%) confirms that the dispersion is relatively low compared to the mean, indicating that the group is fairly homogeneous in terms of running time.

Quartile Analysis:

Q1 = 28.36 s indicates that 25% of participants completed the distance in less time than this value, representing the fastest individuals in the group.

Q2 = 29.77 s is the median, showing that half of the participants ran in less than 29.77 s and half in more; the closeness of the median to the group mean suggests a symmetrical distribution of running times.

Q3 = 31.20 s shows the value below which 75% of participants fall, highlighting the slower participants who required more time to cover the distance.

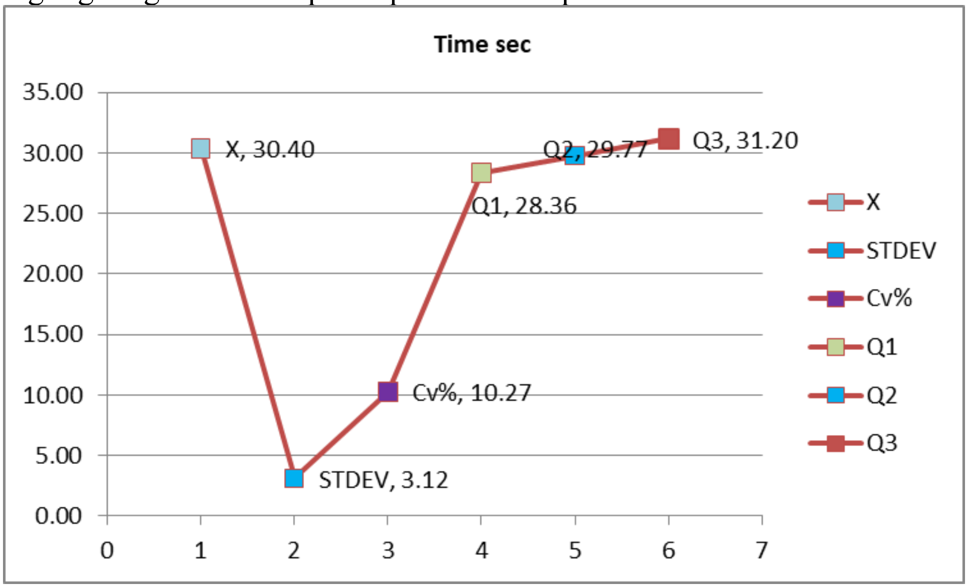

Fig. 2. Distribution of participants’ running time

Analysis and interpretation of heart rate during exercise

The data obtained for participants’ heart rate during exercise show a mean value ($\bar{X}$) of 119.67 bpm, indicating a moderate intensity level during stair running. The standard deviation (STDEV = 7.01 bpm) reflects relatively low variability among participants, suggesting that most had values close to the group mean. The coefficient of variation (Cv% = 5.86%) confirms the homogeneity of the group in terms of cardiovascular response, indicating that heart rate did not vary significantly between individuals.

Quartile analysis:

Q1 = 116 bpm indicates the value below which 25% of participants fall, representing those with a lower cardiovascular response during exercise.

Q2 = 118 bpm is the median, suggesting that half of the participants had a heart rate below 118 bpm and half above. The proximity of the median to the group mean indicates a symmetrical distribution of heart rates.

Q3 = 126 bpm shows the value below which 75% of participants fall, highlighting those with a higher cardiac response during exercise.

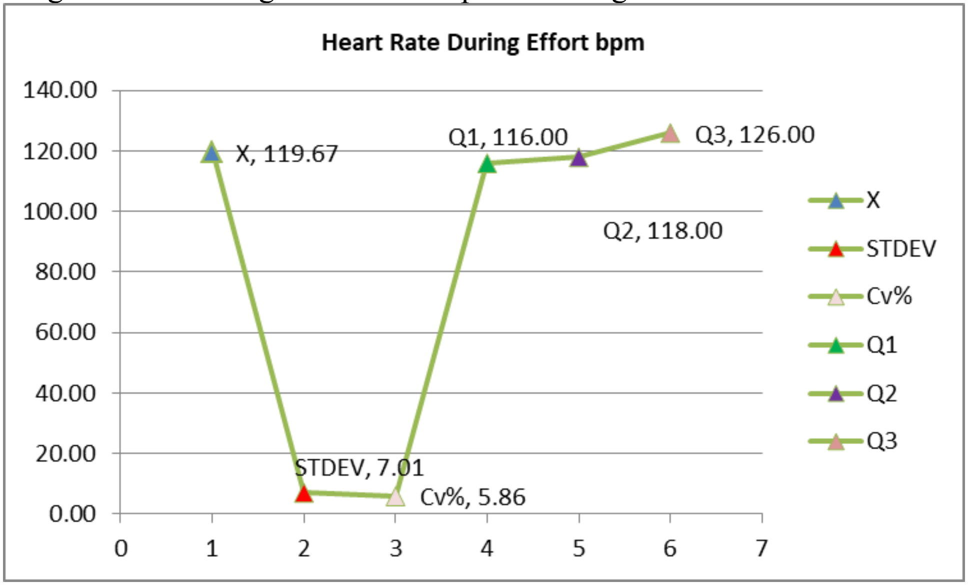

Fig.3 Heart rate distribution during exercise

Analysis and interpretation of power generated during exercise

The data obtained for the power generated by the participants during running show a mean value ($\bar{X}$) of 68.19 W, indicating a moderate level of strength and muscular efficiency during the stair running repetitions. The standard deviation (STDEV = 18.95 W) reflects a high variability among the participants, suggesting that some individuals generated significantly more power than others during the exercise. The coefficient of variation (Cv% = 27.80%) confirms this considerable variability, indicating that the power generated is not uniform within the group and that there are notable differences in strength and running technique between the participants.

Quartile analysis:

Q1 = 60 W indicates the value below which 25% of the participants fall, representing those who generated the least power.

Q2 = 67 W is the median, suggesting that half of the participants generated less than 67 W and half generated more; the proximity of the median to the mean indicates a relatively balanced distribution, but with some extreme values.

Q3 = 81 W shows the value above which 25% of the participants fall, representing the strongest individuals in the group who generated the most power.

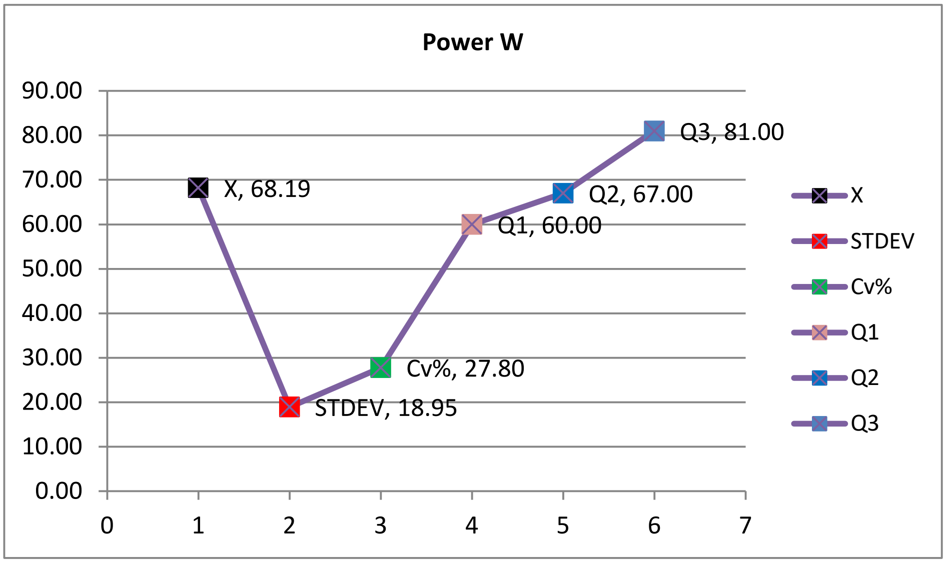

Fig. 4. Distribution of power during exercise

Analysis and Interpretation of Running Cadence

The data obtained for the participants' cadence show a mean value ($\bar{X}$) of 69.86 steps/min, indicating the average step rate maintained during running on the university stairs. The standard deviation (STDEV = 23.68 spm) highlights a very high variability among the participants, suggesting that the running pace differed significantly between individuals, with some running faster and others slower. The coefficient of variation (Cv% = 33.90%) confirms that the group is highly heterogeneous in terms of cadence, indicating the need for individual adjustments to optimize the running pace.

Quartile analysis:

Q1 = 57 spm indicates the value below which 25% of participants fall, representing those with the slowest cadence.

Q2 = 65 spm is the median, suggesting that half of the participants had a cadence below 65 spm and half above; the proximity of the mean to the median indicates a roughly balanced distribution, but with some extreme values.

Q3 = 80 spm shows the value above which 25% of participants fall, highlighting those with the fastest running pace.

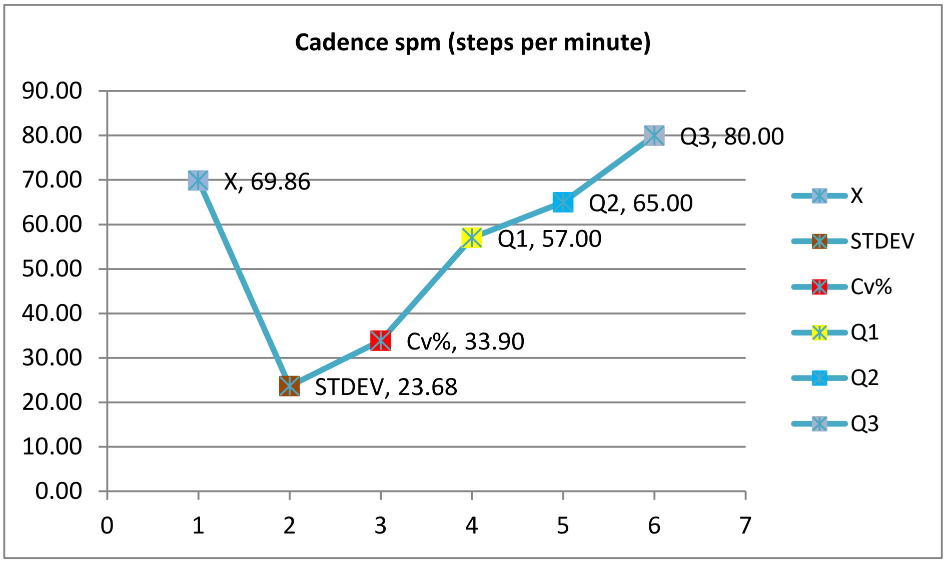

Fig. 5. Distribution of running cadence

Discussions

The results of the study by [6] show that AW, GF and HW smartwatches generally have moderate validity in estimating energy expenditure during outdoor walking and running. However, the small sample size and high variability of the data limit the generalizability of the results, so users should be cautious when interpreting these estimates. Similarly, [9] demonstrated that Apple Watch Series 6 and 7 can be reliably used for heart rate monitoring in the context of strength and conditioning training, although accuracy decreases at moderate and high running speeds. At the same time, the Polar H-10 monitor has been shown to be a viable alternative to clinical electrocardiography for practical applications.

Conclusions

Participants demonstrated a good level of performance during the university stair run, demonstrating adequate cardiovascular efficiency and physical endurance for a short, high-intensity exercise. Significant differences were observed between participants in muscle strength and running pace, indicating that performance was not uniform within the group. Heart rate monitoring revealed homogeneous responses, suggesting that the exercise intensity was appropriate and safe for most participants. The objectives of the study were achieved: physiological and performance parameters were measured, the relationship between running pace and physiological response was analyzed, and the reliability of the data obtained from the smartwatch was demonstrated. The results suggest the need for an individualized training program to increase the strength and running pace of participants with poorer performances, while maintaining the progress of those already well trained. Overall, the study confirms that digital monitoring of exercise parameters is an effective tool for assessing physical performance and optimizing training.

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