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Quantifying the relationship between two key components of exhausting running at Heart Rate Deflection Point in girls

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Abstract

Purpose: For most trainers, the relationship between training volume and intensity as key components is a very important and effective issue. Therefore, the aim of the present study was to investigate the relationship between two key components of exhausting running at Heart Rate Deflection Point (HRDP) in girls. **Methods:** A number of 40 girls of physical education of Mohaghegh Ardabili University were selected as subjects with an age range of 19 to 23 years. Then, they ran individually in four separate sessions with an intensity of 70, 80, 90 and 100% of heart rate breaking point with a minimum interval of 72 hours. Using non-linear regression, the relationship between exercise volume and intensity was analyzed. **Results:** The findings showed that the inverse relationship between the volume (as a dependent variable) and the intensity (as an independent variable) of exhausting running at the HRDP of young girls' follows the non-linear 2nd degree function. **Conclusion:** According to the results of this study, it can be said that the inverse relationship between the volume and the intensity of running is non-linear. The noteworthy point is that in this estimation, the training volume was fitted based on the intensity, the relevant equation, which has a practical aspect for sports science trainers and researchers. Heart rate, as an important physiological index available to all coaches, can easily estimate the running time of young girls using the fitted equation.

Keywords: Running, Exhausting, Heart Rate Deflection Point, Quantification.

Introduction

The most important training components are the volume and intensity of training, which are usually changed in different training programs depending on the main goals; it can be said that the effectiveness of any training program depends on these components (Bompa & Buzzichelli, 2019). Intensity means the amount of effort used in each training session, and the more the athlete does per unit of time, the higher the intensity. Training intensity is a qualitative component of activity in a training session, on the other hand, the amount of training performed by an athlete in a period of time or a training session is called training volume and is a quantitative component of training (Baechle & Earle, 2008). In other words, the more work is done in a certain time unit, the higher the training intensity will be (Bompa & Buzzichelli, 2019). In some sports, it is difficult to distinguish between training volume and intensity when planning training; For example, when a swimmer swims fast, the distance and duration of the activity indicate the volume of the exercise and the speed of the execution indicates the intensity of the exercise (Laursen, 2010). Different emphasis on training volume and intensity has different effects on training adaptation (Wakayoshi et al., 1993).

Sports training can be done with different degrees: low intensity training, moderate intensity training and high intensity training (Borrega-Mouquinho, Sánchez-Gómez, Fuentes-García, Collado-Mateo, & Villafaina, 2021). The correct evaluation of the volume is done using one of the units of time, distance and repetition. Often, the duration of a training session or the number of repetitions, the main tool used in calculating the volume of training and the speed of doing work, or the amount of work done per unit of time, usually refers to the intensity of training (Tartibian, Fasihi, Eslami, & Fasihi, 2025). Determining the optimal combination of volume and intensity in simple disciplines where there are objective evaluation methods is easily done, but in other sports disciplines, such as team disciplines, gymnastics and fencing, the total amount of activities, technical elements, repetitions, distance and speed of doing them and the relationship between the components (L. Fasihi, Shahrbanian, & Jahangiri, 2025). The composition of the exercise makes it difficult to determine the optimal combination between volume and intensity. However, determining the optimal combination of volume and intensity of work is very difficult and usually depends on the characteristics of the sports field (Cummins et al., 2019).

In an increasing physical activity, blood lactate increases from low to high intensity with increasing workload, when its level increases from 2mmol/l, also the amount of pulmonary ventilation increases disproportionately compared to the amount of carbon dioxide VE/VO2, under the name of the first threshold of lactate which is equivalent to 40-60% of maximum oxygen consumption vo2max. With increasing exercise intensity, blood lactate level increases from approximately 4mmol/l and VE/VO2 increases further, which is defined as the second lactate threshold, which is equivalent to 60-90% of vo2max. The volume and intensity of training and their relevance are specific to different training periods and are determined for each period separately according to the athletes' abilities and training goals. Naturally, the relationship between training volume and intensity is inverse, the higher the training intensity, the lower the training volume (Lloyd et al., 2012). However, despite the inverse relationship between training volume and intensity, the manner and nature of this inverse relationship is still unclear. Although in the review of the research literature, Bompa has shown that if the training intensity of a sprinter is reduced to 40%, his workload can be increased by 400-500% (1), but apart from the above-mentioned case, in the review of the research literature There is no study on how there is an inverse relationship between training volume and intensity, especially during endurance activities such as running! In other words, it has not yet been shown in the research literature that if the training intensity increases to a certain extent, how much the training volume will decrease. Now, the basic point that can be raised is that during endurance physical activity such as running, if the training intensity increases from 70% to 80% of the maximum oxygen consumption or from 80% to 90% of the maximum heart rate, the training volume will decrease for a few minutes. Does is the inverse relationship between training volume and intensity linear? In other words, is the contribution of changes in training volume equal in different intensities? Therefore, the present study was carried out with the aim of quantifying the relationship between the volume and intensity of exercise during sprint running with intensities of 70, 80, 90, and 100% of heart rate breaking point by female students, in order to first find out that increasing the intensity of exercise, What reduction in volume (duration of running) it produces, and secondly, quantify the mathematical equation related to changes in volume versus running intensity.

Methods

Forty female students of Physical Education Department of Mohaghegh Ardabili University were selected and studied as subjects. All subjects were non-smokers and did not have any problems or restrictions in terms of orthopedics or pathological complications and were not under any type of medical treatment. The average age of the subjects was 21.44 ± 2.24 years, height 162.68 ± 5.41 cm, weight 55.60 ± 5.34 kg, and maximum oxygen consumption 45.62 ± 3.13 ml/kg/min. Subjects did not perform any exercise program for at least 5 days before the study. Standard environmental conditions (ambient temperature 20-23 degrees Celsius and relative humidity 55-65%) were observed during training sessions and various tests. All exercises were done before (8 to 12) and in the afternoon (14 to 18). Subjects were instructed to maintain their usual diet and were asked to refrain from physical activity during the study (Basu et al., 2010). All the tests and working principles were explained to the subjects before their participation in the research program.

To estimate the percentage of body fat as a control variable, the thickness of subcutaneous fat was measured from three points of the chest, abdomen and thigh. The measurements were taken in the natural state of the body (dry and not warm skin). To eliminate the measurement error, only one expert person performed the measurement of subcutaneous fat. A Lafayette model lipometer made in England was used to measure skin fat thickness in millimeters. Body density was determined using the Jackson and Pollock equation (Barnas & Ball, 2020). Relative body fat was calculated using the satiety equation (Rudnev, 2020). To prevent the effect of interstitial water accumulation on subcutaneous fat thickness, all anthropometric variables and body composition were measured after 14 hours of the last training session. Body mass index was obtained by dividing weight (kg) by the square of height (meters) (Jokar, Behpoor, Fasihi, Fasihi, & Ebrahimi Torkamani, 2021).

Mean and standard deviation were used to describe the data. Analysis of variance with repeated measurements was used to check the difference in the distance traveled in each of the restorative protocols and to calculate the energy cost. The error rate was taken into account at the level of five hundredths ($P \leq 0.05$). In the data analysis, only steady state data were used in each of the restorative protocols, and recorded as mean ± standard deviation. Pearson's correlation coefficient was used to check the relationship between variables. The inverse relationship between training volume and intensity was calculated using non-linear regression.

Protocols for determination of HRDP and restorative running

In general, the current research had two protocols. The first protocol was to determine HRDP for each subject, and the second protocol was to run at 70, 80, 90 and 100% HRDP until reaching the limit of exhaustion. Both protocols were performed on a treadmill. In the implementation of the first protocol to determine HRDP, the subjects warmed up for about 10-15 minutes at 50% of the maximum heart rate and did stretching exercises. Then they started the short-term incremental exercise test on the treadmill (GXT), which consisted of consecutive 30-second steps at a constant speed and 1.5% incline. Running speed increased by 1 K/h when moving to the next stage (Amann & Dempsey, 2008), these stages continued until the subject reported a score higher than 17 on the Borg scale

(Gharakhanlou & Fasihi, 2023). The heart rate changes of the subjects' activity during the implementation of the protocol were recorded moment by moment by the polar device, finally the information was entered into the computer program designed by Dmax method in the personal computer. HRDP was calculated for each subject using the parallel straight line mathematical model (PSLS). Two days after determining the HRDP, the subjects were called to implement the restorative protocol.

In the second step, first, the 70, 80, 90 and 100% of HRDP were calculated for each subject and the heart rate and speed corresponding to these points were determined. Finally, four separate training protocols were performed on the treadmill in four separate stages with at least 72 hours of rest intervals, with an intensity of 70, 80, 90 and 100% of HRDP. Verbal encouragement for maximum effort was done by the subjects during the execution of the tests.

Calculate the cost of energy consumption

Pulmonary ventilation (VE), oxygen consumption (VO2) and exhaled carbon dioxide (VCO2) were measured at intervals of 5 seconds using a respiratory gas analyzer (Power Cube-Ergo, Ganshorn Medizin Electronic GmbH, and Germany). The device was calibrated according to the manufacturer's instructions before performing the test and recalibrated after use for 10 subjects.

The highest VO2 value during the incremental Bruce test was considered as the VO2peak value when one of the following four criteria was observed in subjects: (a) plateau in VO2 despite increasing treadmill speed; (b) respiratory exchange ratio higher than 1.2; (c) observing the maximum heart rate equal to 100% of the equation of 220 - age; and (d) waiting until the subject reported a score higher than 17 on the Borg scale (Midgley, McNaughton, Polman, & Marchant, 2007). The first and second ventilator thresholds were determined automatically using computer software. In fact, in this model, lung ventilation is accompanied by an increase in the amount of oxygen consumed (VE/VO2) and no increase in the amount of carbon dioxide produced (VE/VCO2) (Binder et al., 2008). The second ventilator threshold was determined as the point at which a rapid increase in VE/VCO2 and a drop in CO2 partial pressure occur (Albesa-Albiol et al., 2019). Both the first and second conditioning thresholds were determined and recorded by experienced researchers. The energy cost of the subjects was estimated by converting VO2 to kilocalories. It was assumed that one milliliter of consumed oxygen produces approximately five kilocalories of energy (Stoedefalke & Hawkins, 2022). The body's oxygen consumption was measured using VO2 and VCO2 breathing, and the respiratory exchange ratio was calculated from these values (Braga, Pinto, Pinto, & de Carvalho, 2018).

RESULTS

The mean and standard deviation of the subjects' anthropometric and physiological measurements are presented in Table 1.

Table 1: Anthropometric and physiological measurements of subjects

Variable	mean and standard deviation
Age (years)	21.44 ± 2.4
Height (cm)	162.68 ± 5.41
Weight (kg)	55.60±5.34
Body fat (percent)	15.12±4.25
Fat-free mass (kg/m2)	50.55±4.52
Maximum oxygen consumption (ml/kg/minute)	45.62±3.13

The mean and standard deviation of total distance traveled, speed, and other physiological values during running with 70, 80, 90, and 100% HRDP are presented in Table 2.

Table 2: The mean and standard deviation of subjects' running and physiological variables

Percentage of HRDP **Variable**	**70%**	**80%**	**90%**	**100%**
Distance traveled (km)	16.08±3.14	7.98±2.39	3.69±2.05	1.18±1.25
Running speed (km/h)	7.51±0.98	8.72±0.28	10.32±0.81	12.21±0.83
Heart rate (bpm)	131.13±6.86	148.53±7.21	171.19±6.27	198.44±7.20
Oxygen consumption volume (ml/kg/minute)	27.63±1.61	30.44 ± 3.31	32.25±2.05	43.22±3.11
Total energy expenditure (kcal)	1179.60 ± 227.33	657.37±155.19	285.63±74.42	71.26±46.22

Our results showed that the total energy expenditure of the subjects decreases as the running speed increases. The inverse relationship between running speed and energy expenditure was due to decreased distance traveled (Figure 1)

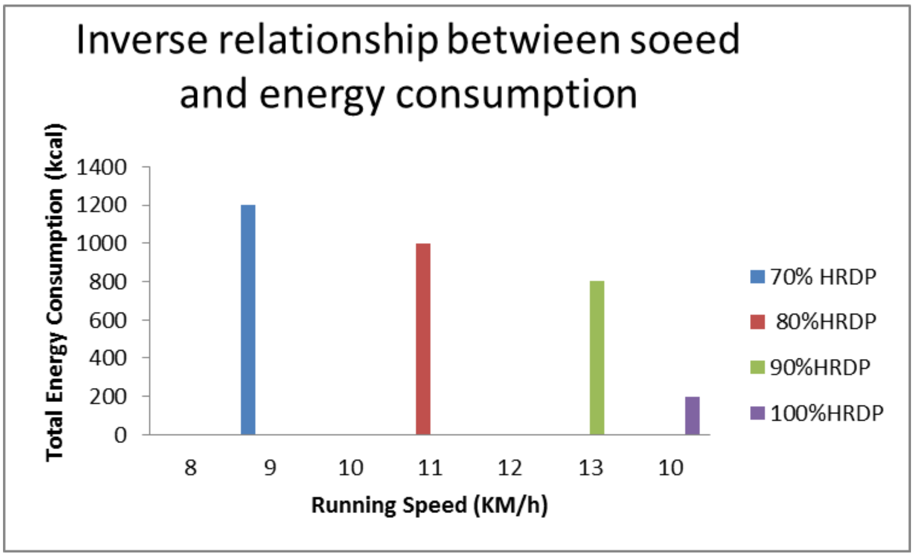

Figure 1: Inverse relationship between running speed and energy expenditure

The results of this research showed that when the training intensity is increased by 10% from 80% to 90% HRDP, the duration of running is reduced from 57 minutes to 23 minutes. Likewise, when the training intensity (running) is increased by 10% as the percentage increases (from 70% to 80% of HRDP); the running time is reduced to less than half, from 122 minutes to 57 minutes. Although not clearly visible in Figure 2, however, when exercise intensity was increased from 90% to 100% HRDP, run duration decreased from 23 minutes to 5 minutes. Overall, increasing exercise intensity by 30% from 70% to 100% HRDP decreased running time from 122 minutes to 5 minutes. In this research, it was shown that the decrease in running time with increasing training intensity follows the 2nd degree nonlinear regression function, and this inverse relationship is not linear, and exercise volume (VE) is a function of training intensity. The relationship between exercise volume and intensity based on the amount of oxygen consumed is shown in the following equation:

$$VE\ min = 0.3866\ (Vo_2)^2 - 37.089\ (Vo_2) + 895.19 \qquad (R^2 = 0.6994)$$

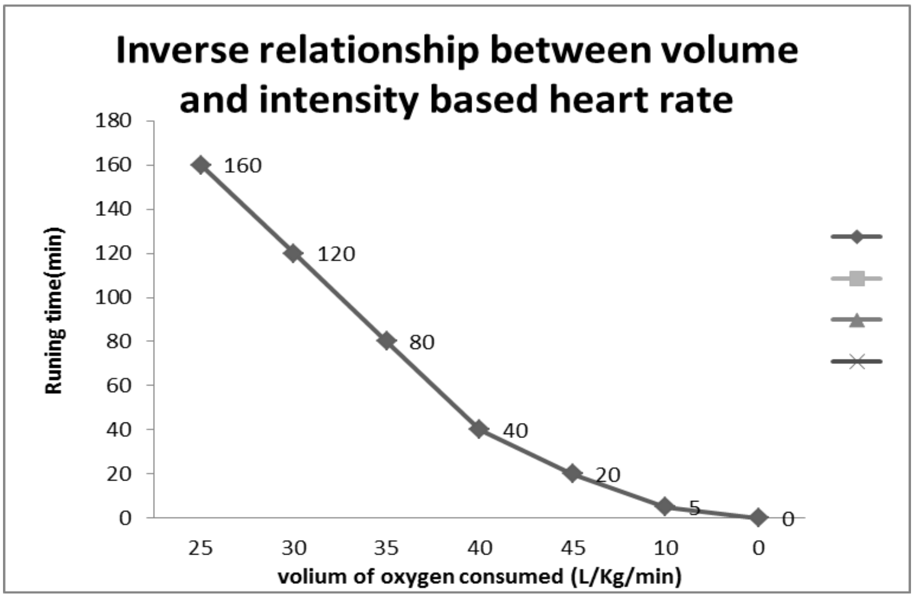

Figure 2: The inverse relationship between the volume and intensity of exercise based on the volume of oxygen consumed

The pattern of changes between exercise volume and intensity when considered based on heart rate is similar to changes in percentage of oxygen consumption (Figure 3). The inverse relationship between heart rate-based exercise volume and intensity also follows a quadratic regression function:

$$VE\ min = 0.0225(HR)^2 - 9.4672\ (HR) + 997.91 \qquad (R^2 = 0.7926)$$

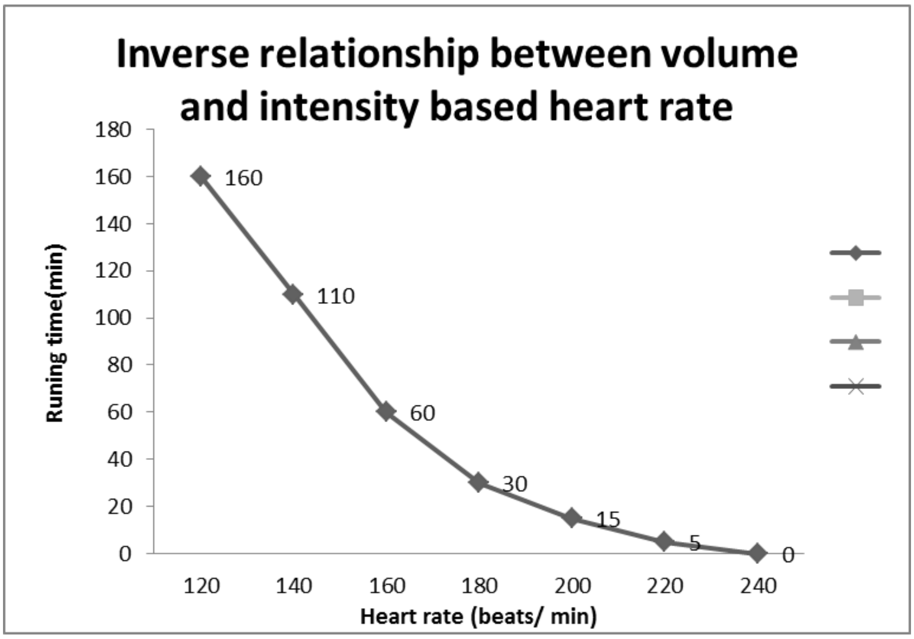

Figure 3: Inverse relationship between volume and intensity of exercise based on heart rate

Discussion

The aim of the present research is to quantify the inverse relationship between the volume and intensity of exercise during stress tests. It seems to be one of the rarest researches that can be seen in the literature, because in the present research, in order to quantify these two important components of exercise, 128 laboratory test sessions were conducted. It was done on consecutive days over the course of three months. However, considering that this research was carried out in a laboratory environment and on a treadmill, in this research we studied the effect of increasing the intensity of exercise as an independent variable on decreasing the amount of exercise as a dependent variable.

The results of the research showed that when the training intensity (treadmill running speed) increases from 70% to 100% HRDP, a great decrease in training volume (running time) occurs. This reduction in running time leads to a reduction in energy consumption. In other words, when the intensity of exercise reaches from 70% to 100% of

HRDP, not only the volume of exercise decreases, but also the total cost of energy consumption is greatly reduced (A. Fasihi, Siahkouhian, Jaafarnejad, Bolboli, & Fasihi, 2021). This inverse relationship between training volume and intensity in conditioning protocols follows a quadratic polynomial or quadratic regression function. In this function, exercise intensity is considered as a variable and exercise volume as a function.

Stavelno and his colleagues showed that the maximum and average heart rate during a sports event gradually decreases with the increase in the duration of the activity. In the same way, metabolic activities undergo fundamental changes as the activity duration increases. In particular, the heart rate in the 5 km event is high compared to the above marathon event in athletics and is performed with high intensity (Esteve-Lanao, Lucia, deKoning, & Foster, 2008). In another research work, these researchers showed that the average maximum heart rate percentage and therefore the average training intensity during long-term competitions systematically and regularly decreases and the longer the competition and sports event, the lower the work intensity. will be It seems that different physiological systems work hand in hand to establish homeostasis and balance of the athlete's body in order to maintain the rhythm of the athlete's activity so that they can continue the athlete's activity (Noorbergen, Konings, Micklewright, Elferink-Gemser, & Hettinga, 2016).

During the activity with intensity equal to 100% of HRDP, subjects work with their highest endurance capacities (Noorbergen et al., 2016). In this case, the required oxygen cannot be supplied for a long time (Fryer et al., 2015). According to Gandelsman and Smirnov, during high-intensity running, the body needs more than 66 to 80 liters of oxygen per minute. Due to the fact that the oxygen stored in the body tissues cannot meet the needs of the athlete, the boxer athlete may face 80-90% oxygen to maintain his rhythm. If such an activity continues, the body cannot supply the oxygen needed by the athlete, and in the same way, the phosphagen stored in the muscle cells cannot supply the required energy, and finally the athlete faces a very high oxygen deficit and is unable to It will not continue the activity and this is the time when the athlete reaches a state of stagnation (Kodejška, Michailov, & Baláš, 2016).

When the activity is performed at 80% of HRDP, the organism of the athlete's body is challenged for prolonged activities. The activity of the cardio-respiratory system accelerates significantly and the heart muscle is stressed for a long period of time. During running, blood oxygen saturation decreases and aerobic energy is dominant and can provide up to 90% of the required energy. It is very important to maintain the rhythm of the step and the uniform distribution of energy throughout the long run (Zatsiorsky, Kraemer, & Fry, 2020). When running at a low intensity, i.e. with 70% HRDP, due to the long duration of the activity, the total energy expenditure is very high (Welcker, Speakman, Elliott, Hatch, & Kitaysky, 2015). In this type of activity, blood sugar levels decrease because glycogen stores are depleted (Kohn et al., 2015). During this activity and long runs, the energy required for muscle contraction is mainly provided by fat metabolism (Esteve-Lanao et al., 2008).

When running at 90% HRDP, the training intensity is still at the maximum level and puts a lot of pressure on the central nervous system, hampering the body's ability to maintain high intensity and speed for a long time. Therefore, even though the energy exchange in muscle cells reaches very high levels, the cardiorespiratory system does not have enough time to respond to the training stimulus, and therefore, the response of the cardiovascular system to the training stimulus is at a low level. In this case, the athlete experiences an oxygen deficit equivalent to 60 to 70% of the energy required for running (Hasanli, Nikooie, Aveseh, & Mohammad, 2015).

Modulation and regulation of muscle power output during endurance activity, i.e. running for a long time, mainly depends on the sensory feedback that is gradually sent from tired muscles (Amann, Romer, Subudhi, Pegelow, & Dempsey, 2007). The central nervous system receives this sensory feedback and sends inhibitory commands, which are basically based on the information sent to the central nervous system from tired muscles. The inhibitory mechanism of the central nervous system is dependent on the accumulation of metabolic side products produced in active muscles (Amann & Dempsey, 2008). Therefore, the increase in peripheral fatigue is set at a high level and the sensory feedback sent from the active muscles to the central nervous system causes the peripheral fatigue of the muscles to decrease (Calbet, 2006). This can potentially cause muscle damage. These findings are consistent with scientific evidence that fatigue increases during running with different distances and shows that the amount of physiological pressure that is applied to the organism of the athlete's body is controlled through active mechanisms (Billat, Demarle, Slawinski, Paiva, & Koralsztein, 2001). Considering the phenomenon of cardiac impulse, perhaps the use of heart rate to evaluate and measure physiological pressures can be mentioned as a limitation in the present research. In the cardiac drive phenomenon, with the increase in the duration of running at low intensities and the prolongation of the activity time, the heart rate increases gradually. In addition, the longer the duration of the exercise, the higher the heart rate as a result of the cardiovascular drive. Cardiovascular drive is lower in high-intensity activities compared to long-term training (Eston, Faulkner, St Clair Gibson, Noakes, & Parfitt, 2007).

Although different mechanisms and physiological factors are involved in heart rate responses to different exercise intensities, however, in terms of application, the results of the present research can be useful; because basically controlling the volume and intensity as the main training variables is very important for all coaches and athletes. Although in the current research, the number of studied samples included 40 young girls; however, the results of this research were able to provide a basis for fitting mathematical equations with the aim of determining the amount of exercise based on the intensity of exercise. In other words, the results of the present research provided two useful equations to coaches and athletes, which can be very useful and efficient in terms of application in different fields, especially athletes in different fields of athletics, and by using these two equations, it is possible to use these two equations in a laboratory environment. And in the field environment, he estimated the amount of exercise based on the intensity of the exercise. In particular, heart rate, as an important physiological index available to all coaches, can easily estimate the running time of young girls using the fitted equation.

Conclusion

According to the results of the present study, it can be concluded that the inverse relationship between exercise volume and intensity is not linear and follows the 2nd degree regression function, and in light of such findings, two functional equations based on the amount of oxygen consumed and heart rate to predict the exercise volume based on The intensity of training among young girls was proposed and presented, which seems to be useful for athletes and coaches of various sports, especially athletics.

Conflict of Interests

The authors declare that there is no conflict of interest.

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Reference

Albesa-Albiol, L., Serra-Payá, N., Garnacho-Castaño, M. A., Guirao Cano, L., Pleguezuelos Cobo, E., Maté-Muñoz, J. L., & Garnacho-Castaño, M. V. (2019). Ventilatory efficiency during constant-load test at lactate threshold intensity: Endurance versus resistance exercises. PloS one, 14(5), e0216824.

Amann, M., & Dempsey, J. A. (2008). Locomotor muscle fatigue modifies central motor drive in healthy humans and imposes a limitation to exercise performance. The Journal of Physiology, 586(1), 161-173.

Amann, M., Romer, L. M., Subudhi, A. W., Pegelow, D. F., & Dempsey, J. A. (2007). Severity of arterial hypoxaemia affects the relative contributions of peripheral muscle fatigue to exercise performance in healthy humans. The Journal of Physiology, 581(1), 389-403.

Baechle, T. R., & Earle, R. W. (2008). Essentials of strength training and conditioning: Human kinetics.

Barnas, J., & Ball, S. D. (2020). Validation of a Skinfold Prediction Equation Based on Dual-Energy X-Ray Absorptiometry to Estimate Body Fat Percentage in Women. Measurement in Physical Education and Exercise Science, 24(2), 115-122.

Basu, A., Sanchez, K., Leyva, M. J., Wu, M., Betts, N. M., Aston, C. E., & Lyons, T. J. (2010). Green tea supplementation affects body weight, lipids, and lipid peroxidation in obese subjects with metabolic syndrome. Journal of the American College of Nutrition, 29(1), 31-40.

Billat, V. L., Demarle, A., Slawinski, J., Paiva, M., & Koralsztein, J.-P. (2001). Physical and training characteristics of top-class marathon runners. Medicine and science in sports and exercise, 33(12), 2089-2097.

Binder, R. K., Wonisch, M., Corra, U., Cohen-Solal, A., Vanhees, L., Saner, H., & Schmid, J.-P. (2008). Methodological approach to the first and second lactate threshold in incremental cardiopulmonary exercise testing. European journal of preventive cardiology, 15(6), 726-734.

Bompa, T. O., & Buzzichelli, C. (2019). Periodization-: theory and methodology of training: Human kinetics.

Borrega-Mouquinho, Y., Sánchez-Gómez, J., Fuentes-García, J. P., Collado-Mateo, D., & Villafaina, S. (2021). Effects of high-intensity interval training and moderate-intensity training on stress, depression, anxiety, and resilience in healthy adults during coronavirus disease 2019 confinement: a randomized controlled trial. Frontiers in psychology, 12, 643069.

Braga, A. C. M., Pinto, A., Pinto, S., & de Carvalho, M. (2018). The role of moderate aerobic exercise as determined by cardiopulmonary exercise testing in ALS. Neurology research international, 2018(1), 8218697.

Calbet, J. A. (2006). The rate of fatigue accumulation as a sensed variable. The Journal of Physiology, 575(Pt 3), 688.

Cummins, C., Welch, M., Inkster, B., Cupples, B., Weaving, D., Jones, B., . . . Murphy, A. (2019). Modelling the relationships between volume, intensity and injury-risk in professional rugby league players. Journal of science and medicine in sport, 22(6), 653-660.

Esteve-Lanao, J., Lucia, A., deKoning, J. J., & Foster, C. (2008). How do humans control physiological strain during strenuous endurance exercise? PloS one, 3(8), e2943.

Eston, R., Faulkner, J., St Clair Gibson, A., Noakes, T., & Parfitt, G. (2007). The effect of antecedent fatiguing activity on the relationship between perceived exertion and physiological activity during a constant load exercise task. Psychophysiology, 44(5), 779-786.

Fasihi, A., Siahkouhian, M., Jaafarnejad, A., Bolboli, L., & Fasihi, L. (2021). Effect of Fatigue at Heart Rate Deflection Point on Ankle Muscle Co-Contraction during Running in Healthy Individuals and Those with a Pronated Foot. The Scientific Journal of Rehabilitation Medicine, 10(1), 58-68.

Fasihi, L., Shahrbanian, S., & Jahangiri, M. (2025). Effects of Combined Training on Fatigue in People with Multiple Sclerosis: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. فیزیک درمانی-نشریه تخصصی فیزیوتراپی, ۱۵(۱), ۰-۰.

Fryer, S. M., Stoner, L., Dickson, T. G., Draper, S. B., McCluskey, M. J., Hughes, J. D., . . . Draper, N. (2015). Oxygen recovery kinetics in the forearm flexors of multiple ability groups of rock climbers. The Journal of Strength & Conditioning Research, 29(6), 1633-1639.

Gharakhanlou, R., & Fasihi, L. (2023). The role of neurotransmitters (serotonin and dopamine) in central nervous system fatigue during prolonged exercise. New Approaches in Exercise Physiology, 5(9), 138-160.

Hasanli, M., Nikooie, R., Aveseh, M., & Mohammad, F. (2015). Prediction of aerobic and anaerobic capacities of elite cyclists from changes in lactate during isocapnic buffering phase. The Journal of Strength & Conditioning Research, 29(2), 321-329.

Jokar, P., Behpoor, N., Fasihi, L., Fasihi, A., & Ebrahimi Torkamani, B. (2021). The Effect of a Twelve-week Endurance Swimming Training on Structural and Functional Features of Heart in Inactive Male Adolescents. Scientific Journal of Rehabilitation Medicine, 10(4), 756-767.

Kodejška, J., Michailov, M. L., & Baláš, J. (2016). Forearm muscle oxygenation during sustained isometric contractions in rock climbers. Auc Kinanthropologica, 51(2), 48-55.

Kohn, N., Toygar, T., Weidenfeld, C., Berthold-Losleben, M., Chechko, N., Orfanos, S., . . . Karges, W. (2015). In a sweet mood? Effects of experimental modulation of blood glucose levels on mood-induction during fMRI. Neuroimage, 113, 246-256.

Laursen, P. B. (2010). Training for intense exercise performance: high-intensity or high-volume training? Scandinavian journal of medicine & science in sports, 20, 1-10.

Lloyd, R. S., Faigenbaum, A. D., Myer, G. D., Stone, M., Oliver, J., Jeffreys, I., & Pierce, K. (2012). UKSCA position statement: Youth resistance training. Prof Strength Cond, 26, 26-39.

Midgley, A. W., McNaughton, L. R., Polman, R., & Marchant, D. (2007). Criteria for determination of maximal oxygen uptake: a brief critique and recommendations for future research. Sports Medicine, 37, 1019-1028.

Noorbergen, O. S., Konings, M. J., Micklewright, D., Elferink-Gemser, M. T., & Hettinga, F. J. (2016). Pacing behavior and tactical positioning in 500-and 1000-m short-track speed skating. International Journal of Sports Physiology and Performance, 11(6), 742-748.

Rudnev, S. G. (2020). Body composition in athletes: history, methodology and computational prospects. Paper presented at the Proceedings of the 12th International Symposium on Computer Science in Sport (IACSS 2019).

Stoedefalke, K., & Hawkins, M. A. (2022). The accuracy of the ACSM prediction equations, for determining walking caloric expenditure, in college-aged males and females. Journal of American College Health, 70(1), 130-133.

Tartibian, B., Fasihi, L., Eslami, R., & Fasihi, A. (2025). Comparison and Prediction of Hepatic Encephalopathy Complications in Liver Transplant Patients Using Random Forest Algorithm in Active and Inactive Men. Physical treatments-specific physical therapy journal, 15(1), 0-0.

Wakayoshi, K., Yoshida, T., Udo, M., Harada, T., Moritani, T., Mutoh, Y., & Miyashita, M. (1993). Does critical swimming velocity represent exercise intensity at maximal lactate steady state? European journal of applied physiology and occupational physiology, 66, 90-95.

Welcker, J., Speakman, J. R., Elliott, K. H., Hatch, S. A., & Kitaysky, A. S. (2015). Resting and daily energy expenditures during reproduction are adjusted in opposite directions in free-living birds. Functional Ecology, 29(2), 250-258.

Zatsiorsky, V. M., Kraemer, W. J., & Fry, A. C. (2020). Science and practice of strength training: Human Kinetics.

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