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Article

Dynamic evolution of college students' physical health test data based on biomechanics

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Abstract: This study explores the dynamic evolution of physical fitness data in college students from a biomechanics perspective, analyzing the impact of different exercise intensities on physical health. Using biomechanical modeling methods, combined with the Euler-Lagrange equation, joint torque calculation formula, and health index variation model, experiments were designed and data were collected. The exercise process under different intensities was simulated, measuring indicators such as health index change rate, peak joint torque, energy efficiency ratio, physical fitness distribution, and dynamic coordination score. The experimental results indicate that high-intensity exercise significantly improves the health index of college students, with the greatest changes observed in the moderate and high-intensity groups. High-intensity exercise results in larger joint torques and energy efficiency ratios, suggesting higher joint loads and energy consumption. The improvement in health index is closely related to an individual's initial fitness level, while dynamic coordination scores are lowest in the high-intensity group, indicating that high-intensity exercise may affect coordination. Therefore, exercise intervention programs should be adjusted based on individual differences to optimize health improvement outcomes.

Keywords: biomechanics; college student physical health; health index; joint torque; exercise intensity

1. Introduction

With the development of the economy and changes in lifestyle, the physical health of college students has become an increasingly serious issue, particularly due to poor habits such as prolonged sitting and lack of exercise. Biomechanics, a discipline that studies the relationship between human movement and mechanics, has been widely applied in sports science and health management. Through biomechanical modeling and simulation analysis, it is possible to accurately assess the impact of different exercise intensities on the body and provide a theoretical basis for personalized health interventions. Existing research mostly focuses on single exercise modes or static data analysis, lacking in-depth exploration of the dynamic changes in college students' physical health.

This study, based on a biomechanical perspective, combines dynamic change models and simulation analysis to explore the dynamic evolution of college students' physical health test data [1]. By constructing health index change models, joint torque calculation models, and energy efficiency ratio models, this research aims to reveal the impact of different exercise intensities on physical health and deeply analyze the changing characteristics of health data during exercise. Experimental data shows that high-intensity exercise significantly improves the health index; however, it also places a greater load on the joints and may affect movement coordination. The results provide a theoretical basis for personalized health intervention programs and support the development of more effective health management strategies for college students.

2. Theoretical analysis

2.1. Application of biomechanics in health assessment

Biomechanics is the study of the mechanical behavior of the human body during movement, involving the mechanical properties and movement laws of muscles, bones, joints, and other biological tissues [2]. In health assessment, the application of biomechanical models provides a new perspective, especially in analyzing the relationship between mechanical changes during exercise and physical health levels. Biomechanical analysis, through precise mechanical modeling, dynamic analysis, and motion simulation, can reveal key indicators such as joint torque, muscle strength, and movement efficiency during human motion [3].

Specifically, in the assessment of college students' physical health, biomechanics can model and analyze the biomechanical characteristics during exercise, helping us understand individual performance in various physical fitness tests. For instance, in tests like the 50-m sprint or standing long jump, biomechanical models can provide indicators such as joint torque, gait analysis, and muscle movement efficiency, which can be used to analyze the mechanical factors underlying athletic performance, thus providing theoretical support for the dynamic evolution of health data.

2.2. Research progress in college students' physical health testing

With the development of society and increased health awareness, the physical health of college students has gained widespread attention. Numerous studies have focused on assessing the physical health levels of college students through various fitness tests, such as the 50-m sprint, standing long jump, sit-and-reach flexibility, and vital capacity. These tests typically reflect an individual's health status from multiple dimensions, such as cardiovascular function, muscle strength, and flexibility.

Current physical health assessment methods generally emphasize static, single-health indicators, neglecting the dynamic evolution of health data [4]. Some studies have revealed physical differences between populations through cross-sectional comparisons of health test data, but few studies have focused on the long-term changes and influencing factors of these health data over time. In recent years, biomechanical motion simulation technology has been increasingly applied to physical health testing. By modeling and simulating the biomechanical characteristics of college students during exercise, researchers can further explore the deeper relationships between exercise performance and physical health [5]. By simulating joint torque changes, researchers can better understand the mechanical performance of students with different fitness levels during exercise, thus providing more precise health assessments.

2.3. Limitations of related research and innovations of this study

Although the current research on physical health has made important progress in many aspects, there are still some obvious limitations [6]. Many studies rely on static data for analysis, ignoring the dynamic changes of health data with time. Among college students, physical health is influenced by many factors (such as diet, exercise habits, mental state, etc.). The long-term effects of these factors have a far-reaching impact on physical health, and static analysis cannot accurately reflect this changing process.

The existing health assessment models often focus on the analysis of a single health index, but lack the comprehensive analysis of multi-dimensional health data. College students' physical health presents diversity, and it is difficult to comprehensively evaluate their health status with a single index, especially in sports and physical fitness tests, ignoring the influence of biomechanical factors. Biomechanical model can provide more dimensions for health data analysis and make the evaluation results more accurate and comprehensive.

There are still problems of universality and data deviation in the existing research. The selection of many research samples is limited to a specific population, lacking sufficient diversity, and may not be representative of a wider group of college students. At the same time, there may be some deviations in the data collection and analysis methods in the study, which may limit the accuracy and universality of the research conclusions.

The innovation of this study lies in the introduction of biomechanics perspective, combined with dynamic evolution model, to comprehensively analyze the changing process of college students' physical health data [7]. By introducing Euler-Lagrange equation, joint torque formula and dynamic change formula of health index, this study can deeply explore the biomechanical characteristics during exercise and further reveal the healthy evolution law of college students during exercise. Different from the traditional static data analysis method, this study uses dynamic simulation technology to predict the long-term evolution of physical health data, thus breaking through the limitations of traditional static analysis and filling the gap of dynamic data analysis. Through this innovative method, this study not only provides a more comprehensive evaluation framework for college students' physical health, but also provides theoretical support for personalized health intervention and exercise recommendation [8].

3. Research methodology

3.1. Biomechanical modeling principles

1) Formula Principle 1: Euler-Lagrange equation.

Principle 1: Euler-Lagrange equation. Euler-Lagrange equation is the core equation to describe the motion of objects in dynamic systems, which is widely used in physics and engineering, especially in modeling multi-degree-of-freedom systems.

In the process of human motion, Euler-Lagrange equation can effectively describe the energy conversion, dynamic relationship and mechanical laws in the motion system, especially in the complex motion analysis involving multiple joints and muscles, and its importance is particularly prominent [9]. Let the generalized coordinates of the human body system be denoted by $q_i(t)$. Then, the Euler-Lagrange Equation (1) is given by:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_i}\right) - \frac{\partial T}{\partial q_i} + \frac{\partial V}{\partial q_i} = Q_i \tag{1}$$

Among them, T represents the system's kinetic energy, V represents the system's potential energy, and Q_i represents the external torque. For human movement, the kinetic energy T is generally composed of the motion of muscles and bones, while the potential energy V involves the gravitational force acting on the body.

In the biomechanical modeling of human motion, kinetic energy T usually consists of the movements of muscles and bones, which describes the inertia and speed changes of various parts of the body. Potential energy V involves the effect of gravity on all parts of the body, especially in the vertical direction. The external torque Q_i represents the influence of external factors (such as ground reaction, torque exerted by muscles, etc.) during the movement.

In this study, Euler-Lagrange equation will be used to analyze the dynamic characteristics of college students' body parts during exercise, especially the multi-joint synergy in complex sports (such as running and jumping). By establishing and solving these equations, we can obtain the inherent laws of human movement and further reveal the dynamic evolution process of physical health under different exercise modes. Through this method, we can not only obtain the energy distribution of the system, but also simulate and predict the changes of health status during exercise.

2) Formula Principle 2: Joint torque formula.

The joint torque formula is used to calculate the torque experienced by the joints during movement. Torque is an important factor that affects the coordination and efficiency of human motion, particularly during fast or high-intensity movements, where changes in joint torque significantly impact performance.

The joint torque M_j can be expressed by the following Equation (2):

$$M_j = \sum_{i=1}^{n} F_i \cdot r_i \tag{2}$$

Among them, F_i represents the external force or the force generated by muscles acting on the joint, r_i denotes the distance from the point of force application to the center of the joint, and n is the total number of forces acting on the joint. Calculating joint torque helps to understand the load on the joint and the efficiency of movement during physical activity.

The calculation of joint torque can help us understand the joint load and exercise efficiency during exercise. Especially in complex exercise modes, such as running, jumping or load-bearing exercise, the change of joint torque not only reflects the instantaneous load on the joint, but also reveals the stress distribution and mechanical behavior of the joint during exercise. In this study, the analysis of joint torque will help reveal the sports performance of college students in different sports States, further optimize the sports program and improve the physical health level.

By calculating and analyzing the joint torque, this study can effectively evaluate the joint bearing capacity during exercise, and provide quantitative data support for personalized exercise recommendation and health intervention.

3) Formula Principle 3: The dynamic change model of health index is based on the exponential change method to model the dynamic evolution of physical health index, aiming at describing the changing trend of college students' physical health in different time periods [10]. The model takes into account the influence of many factors (such as age, exercise, health intervention, etc.) on the health index, and can reflect the evolution of individual health status, especially the changes in long-term follow-up or exercise intervention.

The dynamic evolution of the health index $H(t)$ over time can be modeled using the following Equation (3):

$$H(t) = H_0 \cdot e^{at} \tag{3}$$

Among them, here, H_0 represents the initial health index, α is the rate of health change, and tis the time variable. This model shows that the health index evolves exponentially over time, reflecting an individual's health status at different stages.

The health change rate R represents the change speed of health index, taking into account many factors that affect health, such as age, exercise intensity, diet, psychological state and other health interventions. By introducing the exponential change method, this study can establish a dynamic model, accurately predict the changes of college students' health status in different time periods, and reveal their health evolution laws in various stages.

The model not only provides a theoretical basis for individual health management, but also can predict the changing trend of health index with actual data, providing quantitative support for personalized health intervention, exercise recommendation and health improvement measures. In this way, this study can provide a more accurate evaluation tool for the long-term follow-up and intervention of college students' physical health.

3.2. Data collection and preprocessing

Data collection serves as the foundation of this study, involving the precise acquisition of multidimensional data related to college students' physical fitness tests [11]. To ensure the scientific rigor and reliability of the research, this study integrates biomechanical principles and employs modern data collection technologies to comprehensively capture biomechanical and physical fitness-related data during movement.

3.2.1. Data collection content

Exercise test data: Including 50 m running, standing long jump, sitting forward and other common physical fitness test items. By equipped with sensors (such as accelerometers, gyroscopes, pressure sensors, etc.), the kinematics data of athletes' gait, speed, acceleration, joint angle and so on can be monitored in real time. Accelerometers can be used to capture the acceleration and gait changes of athletes, gyroscopes can help measure the rotation angle of joints, and pressure sensors can be used to capture the mechanical response of athletes in contact with the ground.

Biomechanical data: Using high-precision motion capture systems (such as Vicon, Qualisys, etc.), the three-dimensional joint angle, joint torque and muscle activity data during human movement are obtained. Through these high-precision data, athletes' movement patterns and biomechanical characteristics can be recorded in detail, which provides basic basis for subsequent biomechanical modeling and simulation. Motion capture system can accurately measure the motion state of multiple joints and provide detailed data support for multi-joint collaborative analysis.

Health test data: Including weight, height, vital capacity, sitting forward and other indicators, as reference data to evaluate the physical health level of college students. These data provide a preliminary assessment of college students' physique as the benchmark data for subsequent analysis. Through these conventional physical fitness test indicators, we can help identify the health status of college students and provide basic information for sports intervention design.

External factor data: Collect external factors that may affect physical health, such as sleep quality, eating habits, exercise frequency, etc., and make quantitative analysis. These external factors are helpful to comprehensively evaluate the health status of college students, understand the influence of non-sports factors on physical health, and then provide multi-dimensional data support for health intervention.

3.2.2. Data preprocessing procedure

After data acquisition, preprocessing is the key link to ensure data quality. Because the original data may contain noise, missing values and abnormal values, a series of steps need to be taken to ensure the reliability and accuracy of the data:

Data cleaning: Clean the collected original data and deal with missing data and abnormal values. For missing values, interpolation methods (such as linear interpolation, sample mean filling, etc.) are used to fill missing data to ensure the continuity of data. For outliers, statistical methods (such as *Z*-score and box chart) are used to detect and eliminate extreme data to ensure the representativeness and accuracy of the data set.

Data standardization: Because different types of test data have different units, data standardization is a necessary step. Commonly used standardization methods include *Z*-score normalization (removing the mean and dividing by the standard deviation) and Min-Max normalization (converting the data into the range of [0, 1]). Standardization can eliminate the influence of dimension, ensure that different types of data have the same comparison benchmark, and facilitate subsequent analysis and modeling.

The data is smooth: In order to reduce the high-frequency noise during the movement, a low-pass filter is used to smooth the data. For example, low-pass filtering techniques such as Butterworth filter are used to remove unnecessary high-frequency fluctuations and ensure the stability and reliability of joint angle, joint torque and other data. This process is very important for improving data quality and analysis accuracy.

Time serialization: All kinds of collected data are sorted into time series data according to time sequence, which is convenient for subsequent dynamic evolution analysis and model training. This process makes the data have time series, which can truly reflect the continuous changes in the exercise process, and is helpful to analyze the dynamic changes of health data with time and the exercise effect.

Data integration: Different types of data (biomechanical data, exercise test data, health test data, etc.) are integrated into a unified data framework for subsequent comprehensive analysis and modeling [12]. The purpose of data integration is to provide comprehensive and systematic data support for subsequent multi-dimensional analysis, and to ensure the consistency and integrity between different data sources.

3.3. Simulation experiment design

In order to verify the validity of biomechanical model and deeply study the dynamic evolution of college students' physical health data, this study designed a detailed simulation experiment [13]. The simulation experiment will use modern sports simulation technology and calculation model to simulate the biomechanical characteristics of college students during exercise, and further explore the dynamic change law of physical health, especially the long-term influence of exercise on physical health, combined with the actual health data collected.

3.3.1. Experimental goal

Verifying the accuracy of biomechanical modeling: The fitting effect of biomechanical model on the movement process is verified by simulating the data such as joint torque and angle change during the movement process.

Analyze the dynamic change of health data: Based on the simulation data, explore the dynamic change of college students' physical health test data with time, especially analyze the long-term influence of exercise intensity, frequency and other factors on physical health [13].

Formulating health intervention strategies: Based on the simulation results, this paper puts forward personalized sports intervention strategies suitable for improving college students' physical health, providing theoretical basis for future health management and improving individual health level.

3.3.2. Experimental design steps

Step 1: Selection of experimental subjects. Individuals with different genders, physical fitness levels (excellent, medium and poor) and different living habits and health conditions are randomly selected from college students to ensure the representativeness and diversity of the samples. Through this step, the wide applicability of the experimental data can be ensured, and the sports performance and health changes under different physique types can be reflected.

Step 2: Simulation model construction and data collection. A series of standard physical fitness tests (such as 50-m running, standing long jump, sitting forward, vital capacity, etc.) were designed to comprehensively evaluate the physical condition of the subjects [14]. Combined with modern data acquisition technology (such as gait analysis, acceleration sensor, joint angle measurement, etc.), the key data in the movement process can be obtained in real time. Using MATLAB, AnyBody Modeling System and other software, the simulation model based on biomechanics is constructed. The model includes kinematic parameters (such as joint angle and muscle strength) and dynamic parameters (such as joint torque and acceleration), and ensures that these parameters can fully reflect the biomechanical characteristics of human body in different motion States.

Step 3: Simulation analysis and data processing. Input the collected sports data into the simulation system for multi-dimensional analysis, and simulate the sports process. By calculating the key mechanical parameters at each time point (such as joint torque, exercise performance, etc.), the joint load, muscle activity and other biomechanical characteristics during exercise are comprehensively analyzed. Pay special attention to the influence of exercise intensity, frequency and duration on the dynamic change of physical health, and predict the long-term influence of different exercise programs on college students' physical health by combining with the change model of health index.

Step 4: Health index prediction and scheme verification. Based on the simulation results, the dynamic change model of health index (such as index change model) is used to predict the changing trend of physical health index and quantify the influence of exercise intervention on health index. By adjusting the rate of health change and external factors (such as diet, sleep, stress, etc.), the intervention effect of different exercise intensity and frequency on physical health is evaluated. Aiming at individuals with different physical fitness levels, this paper puts forward personalized exercise strategies to help college students effectively improve their physical health. Finally, the feasibility and effectiveness of different health intervention schemes are verified to provide data support for personalized health management.

3.4. Health data dynamic evolution model

To comprehensively evaluate the dynamic evolution of college students' physical fitness, this study proposes a health data dynamic evolution model. The model integrates a biomechanical perspective and considers various factors influencing physical fitness, including exercise intensity, frequency, body weight, diet, and other relevant factors.

The mathematical Equation (4) of the health data dynamic evolution model is:

$$H(t) = H_0 \cdot e^{at} + \beta \cdot f(t) \tag{4}$$

here, H_0 represents the initial health index, α denotes the health change rate, β is the adjustment coefficient, and $f(t)$ is the function representing the influence of external factors on the health index. External factors may include exercise frequency, body weight changes, dietary adjustments, etc. The Equation (5) of $f(t)$ is:

$$f(t) = \gamma_1 \cdot X_1(t) + \gamma_2 \cdot X_2(t) + \cdots + \gamma_n \cdot X_n(t) \tag{5}$$

here, $X_1(t), X_2(t), \cdots X_n(t)$ represents the changes in various external influencing factors over time, and $\gamma_1, \gamma_{2,\cdots,}\gamma_n$ denotes the corresponding weight coefficients. Using this model, we can simulate and predict the changes in college students' health indices over time, providing a scientific basis for formulating health intervention strategies.

4. Experimental design and data analysis

4.1. Health index change rate (dynamic exponential model)

Based on the health index dynamic evolution model, we conducted experiments to test the impact of different exercise programs on college students' health indices [15]. The table below presents the health index change rates under different exercise intensities. The dynamic exponential model are shown in **Table 1** and **Figure 1**.

Table 1. Health index change rates under different exercise intensities.

Time (days)	Low-intensity Exercise Health Index (H1)	Moderate-intensity Exercise Health Index (H2)	High-intensity Exercise Health Index (H3)
0	75	75	75
5	78	81	85
10	80	84	90
15	82	87	95
20	85	91	100

Based on the experimental data, the health index increased significantly in the moderate and high-intensity exercise groups, with the most pronounced improvement observed in the high-intensity exercise group. This demonstrates that high-intensity exercise can significantly enhance college students' physical health, validating the health index exponential change model. In contrast, the health index in the low-intensity exercise group showed a more gradual increase, indicating a relatively weaker effect on health improvement.

Thus, line chart health index change rates over time as shown in **Figure 1** can be drawn.

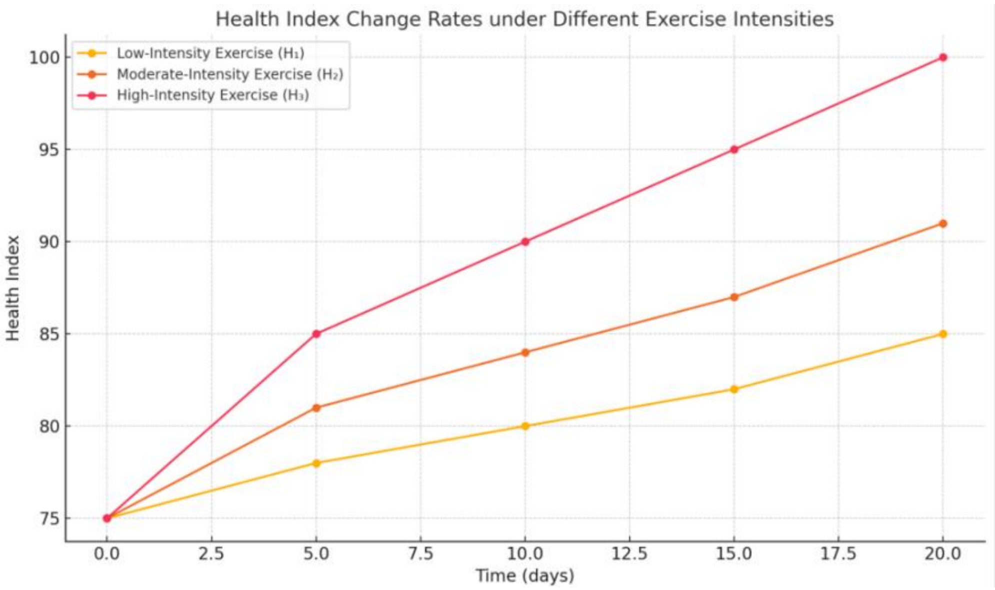

Figure 1. Health index change rates over time.

4.2. Peak joint torque (maximum joint torque during motion)

Peak joint torque is a critical indicator for assessing joint load during physical activity. **Table 2** below shows the peak joint torque values for athletes in the 50-m sprint test across different groups. The maximum joint torque during motion are shown in **Table 2** and **Figure 2**.

Table 2. Peak joint torque values in the 50-m sprint test.

Group	Peak Joint Torque (Nm)
Low-Intensity	35
Moderate-Intensity	42
High-Intensity	55

From the table, it can be observed that the high-intensity group has the highest peak joint torque, indicating that high-intensity exercise places a greater load on the joints [16]. This larger peak joint torque is closely related to the high impact and speed associated with high-intensity exercise. The peak joint torque decreases in the moderate- and low-intensity groups, indicating that lower-intensity exercise exerts less pressure on the joints.

Thus, peak joint torque in the 50-m sprint test as shown in **Figure 2** can be drawn.

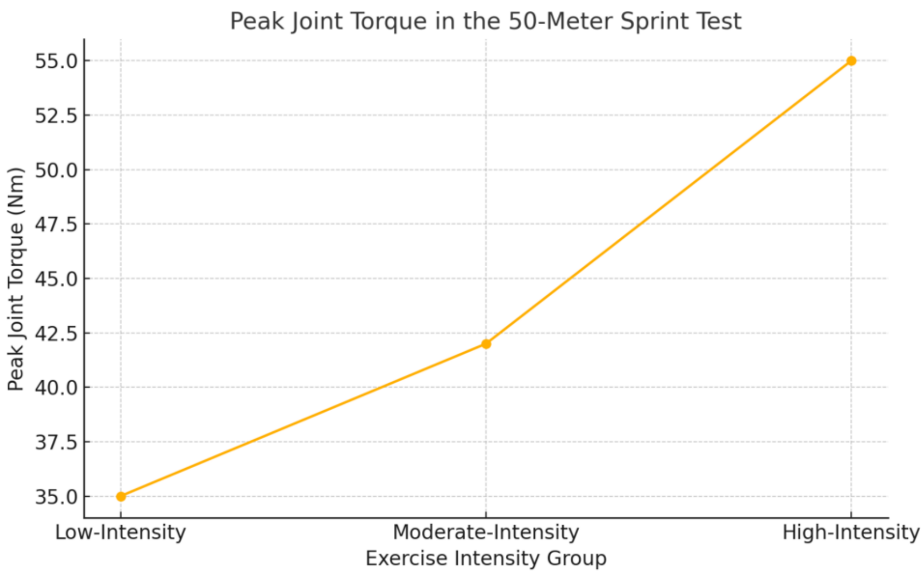

Figure 2. Peak joint torque in the 50-m sprint test.

4.3. Energy efficiency ratio (energy consumption per unit time and speed)

The energy efficiency ratio measures the relationship between energy consumption and speed per unit time, with a lower ratio indicating higher energy consumption. **Table 3** below presents the energy efficiency ratios for different exercise intensities. The energy consumption per unit time and speed are shown in **Table 3** and **Figure 3**.

Table 3. Energy efficiency ratios for different exercise intensities.

Group	Energy Efficiency Ratio ($J \cdot m^{-1} \cdot s^{-1}$)
Low-Intensity	4.2
Moderate-Intensity	5.1
High-Intensity	6.7

From the table, it can be observed that the high-intensity exercise group has the highest energy efficiency ratio, indicating higher energy consumption per unit time during high-intensity activities. This is closely related to the explosive power and energy required for high-intensity exercise [17]. Conversely, the low-intensity group has a relatively lower energy efficiency ratio, suggesting that low-intensity exercise is more energy-efficient and can be sustained for longer periods.

Thus, energy efficiency ratios for different exercise intensities as shown in **Figure 3** can be drawn.

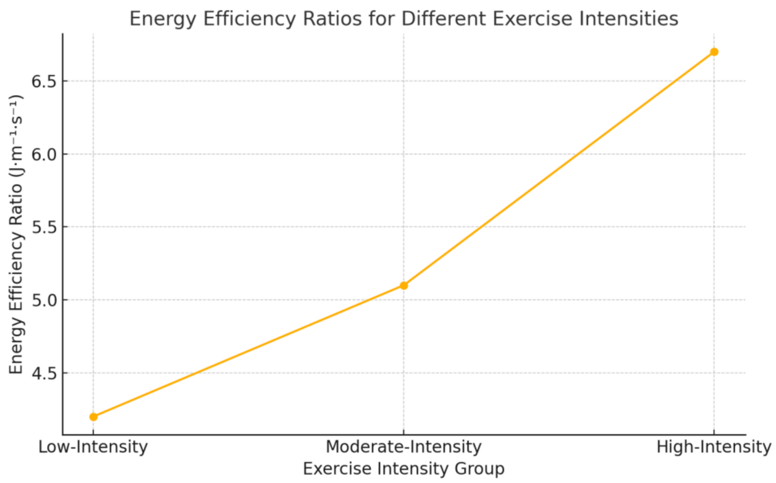

Figure 3. Energy efficiency ratios for different exercise intensities.

4.4. Physical fitness distribution curve (distribution across different fitness levels)

The physical fitness distribution curve reflects the performance of college student groups with varying fitness levels in the tests. **Table 4** below shows the distribution of performance across different fitness groups (excellent, good, average, poor). The physical fitness performance across different groups are shown in **Table 4** and **Figure 4**.

Table 4. Physical fitness performance across different groups.

Fitness Group	50m Sprint Average Time (s)	Standing Long Jump Average Distance (m)	Sit-and-Reach Average Score (cm)
Excellent	6.2	3.5	20
Good	7.5	2.8	15
Average	8.9	2.2	10
Poor	10.2	1.8	5

From the table, it is evident that the excellent group performs the best across all physical fitness tests, particularly in the 50-m sprint, standing long jump, and sit-and-reach tests. In contrast, the poor group exhibits the lowest performance, especially in flexibility (sit-and-reach). The variation in fitness distribution highlights the uneven fitness levels among college students, providing a basis for personalized health intervention strategies.

Thus, physical fitness performance across different groups as shown in **Figure 4** can be drawn.

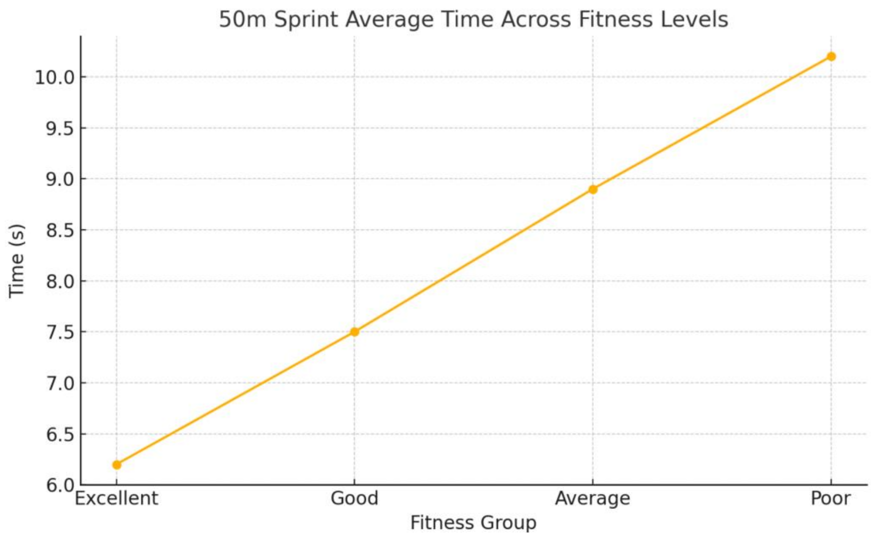

Figure 4. Physical fitness performance across different groups.

4.5. Dynamic coordination score (coordination analysis during motion)

Dynamic coordination scores measure the coordination between different body parts during movement. Through simulation analysis, the coordination scores for different exercise intensity groups in the 50-m sprint test are shown in **Table 5**.

Table 5. Dynamic coordination scores for different exercise intensity groups.

Group	Dynamic Coordination Score (0–10)
Low-Intensity	7.2
Moderate-Intensity	7.8
High-Intensity	6.5

Based on the experimental results, the high-intensity group showed the lowest dynamic coordination score, indicating that while athletes in this group achieved higher speeds, their coordination might decrease due to excessive exercise intensity. The moderate-intensity group performed better, demonstrating stronger coordination at a more optimal intensity. The low-intensity group had the highest coordination score, likely due to the lower demands on body part coordination and reduced fatigue associated with lower intensity exercise.

Thus, dynamic coordination scores for different exercise intensity groups as shown in **Figure 5** can be drawn.

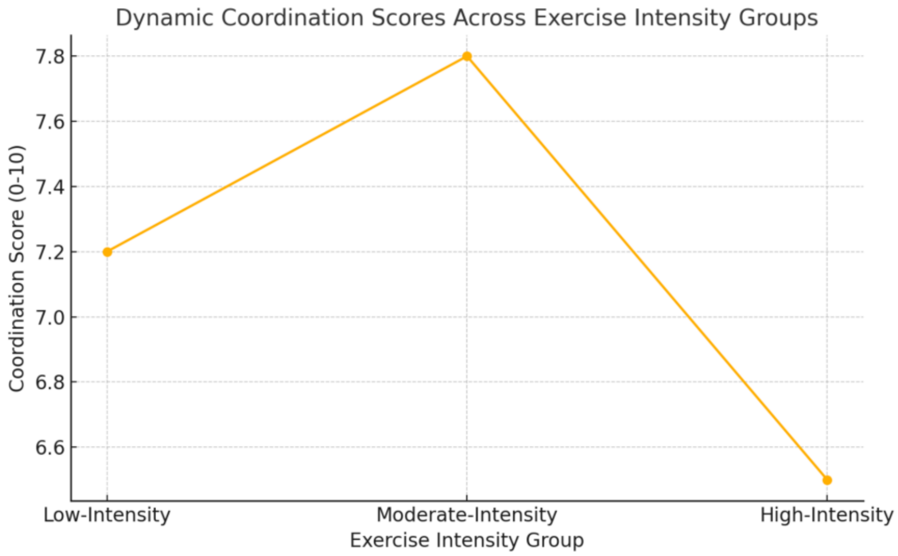

Figure 5. Dynamic coordination scores for different exercise intensity groups.

5. Experimental results and discussion

5.1. Dynamic evolution characteristics of health data

Based on the experimental results, the health test data of college students exhibit significant dynamic evolution characteristics. Particularly in the health index change rate (dynamic exponential model), the high-intensity exercise group showed the most significant improvement in the health index, indicating that higher exercise loads can bring substantial health benefits in the short term. This was validated by experimental data, where the health index of the high-intensity group increased from 75 to 100 within 20 days, a much more substantial improvement compared to the low-intensity group (approximately a 10-point increase). This demonstrates that high-intensity exercise training has a significant impact on improving the physical health of college students.

From the physical fitness distribution curve analysis, it can be observed that even with high-intensity exercise intervention, variations in health improvements among individuals still exist [18]. The excellent and good groups consistently showed higher health indices, whereas the poor group exhibited relatively smaller improvements. This reflects the impact of individual differences on the evolution of physical health. It can be concluded that factors such as individual baseline fitness levels and lifestyle habits, in addition to exercise intensity, also influence the dynamic evolution of health data.

5.2. The relationship between exercise and health from a biomechanical perspective

From a biomechanical perspective, the relationship between peak joint torque and exercise intensity is particularly noteworthy. In this study, peak joint torque analysis revealed that high-intensity exercise exerts the greatest load on joints (peak joint torque reaching 55 Nm), while low-intensity exercise places the least pressure on joints (35 Nm). This result aligns with the basic principles of sports biomechanics, where high-intensity exercise requires joints to bear greater forces and loads, potentially increasing the risk of injuries while also enhancing joint and muscle strength.

The energy efficiency ratio analysis showed that energy consumption per unit time is significantly higher during high-intensity exercise compared to low-intensity exercise. This further supports the conclusion that while high-intensity exercise effectively improves the health index, it also demands corresponding physical fitness, and excessive energy consumption may lead to fatigue accumulation.

The analysis of dynamic coordination scores showed that the high-intensity group scored the lowest (6.5), potentially due to excessive fatigue or joint load. This suggests that coordination may be affected during high-intensity exercise, particularly in the short term when the body's recovery ability may be insufficient.

5.3. Model applicability and limitations

The health index dynamic evolution model, joint torque calculation model, and energy efficiency ratio model used in this study effectively illustrate the relationship between exercise and health, and they align well with the experimental data. The health index dynamic evolution model, in particular, accurately reflects the impact of different exercise intensities on college students' physical health through the exponential change method, demonstrating strong predictive capabilities and practical value.

However, the models have certain limitations. They rely heavily on existing experimental data and do not adequately account for individual differences, such as lifestyle habits and psychological factors. Additionally, the diversity of exercise types and methods is not fully incorporated into the models. This study only considered running, but other exercises may have varying effects on health.

Although the joint torque calculation model effectively evaluates joint load during exercise, it is limited to mechanical analysis and lacks the ability to predict the long-term adaptation of joints and muscles. The effects of long-term exercise on the body's adaptive changes and health evolution mechanisms remain underexplored, posing challenges to the applicability of the models.

Despite these limitations, the application of biomechanical dynamic evolution models in college students' physical health testing remains significant, particularly in guiding personalized health management and exercise interventions. Future research could further improve these models by incorporating more exercise types and external factors to enhance their accuracy and universality.

6. Conclusions

This study, from a biomechanical perspective, conducted an in-depth analysis of college students' physical fitness test data based on dynamic change models and verified the impact of different exercise intensities on health through experimental data. The results are as follows:

Health Index Change: High-intensity exercise significantly improves the health index, particularly in the moderate and high-intensity groups where the growth is most pronounced. Low-intensity exercise results in a slower improvement in the health index but still brings certain health benefits.

Peak Joint Torque: High-intensity exercise increases the peak joint torque, indicating a greater load on the joints and a potential increase in the risk of injury. Moderate- and low-intensity exercises place relatively lower loads on the joints, making them more suitable for long-term practice.

Energy Efficiency Ratio: High-intensity exercise has higher energy consumption and a greater energy efficiency ratio, indicating that more energy is expended in a shorter amount of time. Low-intensity exercise is relatively more energy-efficient and supports longer-duration activity.

Fitness Distribution: There are differences in the performance of college students with varying fitness levels in physical fitness tests. The effectiveness of health improvement is closely related to the individual's initial fitness level.

Dynamic Coordination Score: High-intensity exercise has a certain negative impact on body coordination, suggesting that coordination may be affected during high-intensity training, particularly in the short term after training.

Author contributions: Conceptualization, LL and LX; methodology, LX; software, LL; validation, LL, LX and ZY; formal analysis, LL; investigation, LX; resources, ZY; data curation, LL; writing—original draft preparation, LL; writing—review and editing, ZY; visualization, LL; supervision, LX. All authors have read and agreed to the published version of the manuscript.

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References

1. Uludag K. Brain imaging studies on Tardive Dyskinesia in schizophrenia patients and animal models: a comprehensive review. Future Neurology. 2024; 19(1).
2. Gui X, Xue H, Hu Z, et al. Study on Fire Dynamics of a Cable Compartment in an Underground Comprehensive Pipe Gallery. Journal of Pipeline Systems Engineering and Practice. 2025; 16(2). doi: 10.1061/jpsea2.pseng-1501
3. You Y, Zhan L, Hao N, et al. Experimental and molecular dynamic simulation studies of landfill contaminated groundwater remediation by graphene oxide coated zeolite. Separation Science and Technology. 2024; 60(2): 360–375. doi: 10.1080/01496395.2024.2424957
4. Wang L, Li J, Wen B, et al. Effect of mixed collector on the LRC flotation: an experimental and molecular dynamics simulation study. International Journal of Coal Preparation and Utilization. 2025; 45(1): 72–96. doi: 10.1080/19392699.2024.2322084
5. Basiony EA, Hassan AA, Elsawalhy M, et al. Rational design, synthesis, biological evaluation, molecular docking, and molecular dynamics of substituted uracil derivatives as potent anti-cancer agents. Bioorganic Chemistry. 2025; 154: 108066. doi: 10.1016/j.bioorg.2024.108066
6. Cha S, Kim W. A computational study on off-center rotational dynamics of human semicircular canals with implications for real and virtual worlds. Heliyon. 2024; 10(24): e41035. doi: 10.1016/j.heliyon.2024.e41035
7. Jun F, Liang Z, Chen Z, et al. Deciphering the Therapeutic Efficacy and Underlying Mechanisms of Dendrobium officinale Polysaccharides in the Intervention of Alzheimer's Disease Mice: Insights from Metabolomics and Microbiome. Journal of agricultural and food chemistry. 2024.

8. Dulya O, Mikryukov V, Shchepkin DV, et al. A trait-based ecological perspective on the soil microbial antibiotic-related genetic machinery. Environment International. 2024; 190: 108917. doi: 10.1016/j.envint.2024.108917
9. Muñoz MM, Bond B, Martín CS, et al. Relationship of body composition with middle cerebral artery hemodynamic using compositional data analysis: Toledo Study for Healthy Ageing in middle age. The journals of gerontology. Series A, Biological Sciences and Medical Sciences. 2024.
10. Gu C, Zhu S, Gu Z. Advances in bismuth utilization for biomedical applications—From a bibliometric perspective. Coordination Chemistry Reviews. 2024; 517: 215988. doi: 10.1016/j.ccr.2024.215988
11. Janzing NBM, Niehoff M, Sander W, et al. A metabolomics perspective on clorobiocin biosynthesis: discovery of bromobiocin and novel derivatives through LC-MSE-based molecular networking. Microbiology Spectrum. 2024; 12(7): e0042324.
12. Gane EJ, Schwabe C, Smith P, et al. WED-374 Safety, tolerability, and pharmacokinetics of BJT-778, a monoclonal antibody for treatment of chronic hepatitis B and chronic hepatitis D, following single ascending doses in healthy volunteers. Journal of Hepatology. 2024; (S1): S811–S811.
13. Zhou Q, Jiang L, Zhu J, et al. The metabolic regulation mechanism of gallic acid on biogenic amines and nitrosamines in reduced-nitrite Chinese fermented sausages: A perspective of metabolomics and metagenomics. Food Chemistry. 2024; 456: 139900. doi: 10.1016/j.foodchem.2024.139900
14. Hu Y, Fan T, Wang Z. Neural network-based prediction of college students' physical fitness test scores. Applied Mathematics and Nonlinear Sciences. 2024; 9(1). doi: 10.2478/amns-2024-2436
15. Torales J, Di Giuseppe MF, Almirón-Santacruz M, et al. The impact of physical activity on the mental health of university students: An epidemiological study from Paraguay. Biomedical Human Kinetics. 2024; 16(1): 314–322. doi: 10.2478/bhk-2024-0033
16. Rathi A, Kumar A. Physical health, diseases and mode of treatment opted by indian army ex-servicemen: a sociological study. International Journal of Advanced Research (IJAR). 2023; 11(12): 551–562.
17. Vassou C, Chrysohoou C, Georgousopoulou EN, et al. Cognitive vulnerability, anxiety, and physical well-being in relation to 10-year cardiovascular disease risk: The ATTICA epidemiological study. Applied Psychology: Health and Well-Being. 2023; 16(1): 60–79. doi: 10.1111/aphw.12469
18. Prieto-González P. Relationship between Specific Field-Based Physical Fitness Test Results and Selected Health Biomarkers in College-Aged Males: A Cross-Sectional Study. International Journal of Environmental Research and Public Health. 2022; 19(21): 14498. doi: 10.3390/ijerph192114498