SIN-CHN SCIENTIFIC PRESS PTE.LTD.

Molecular & Cellular Biomechanics 2025, 22(1), 872.
https://doi.org/10.62617/mcb872

Article

Cloud-based adolescent physical health research incorporating cell molecular biomechanics insights into predictive modeling and biometric algorithms

Huanpin Li

Institute of Physical Education, Hunan University of Science and Engineering, Yongzhou 425199, Hunan; lihuanpin0908@163.com

CITATION

Li H. Cloud-based adolescent physical health research incorporating cell molecular biomechanics insights into predictive modeling and biometric algorithms. Molecular & Cellular Biomechanics. 2025; 22(1): 872. https://doi.org/10.62617/mcb872

ARTICLE INFO

Received: 22 November 2024
Accepted: 12 December 2024
Available online: 3 January 2025

Abstract: The physical health of adolescents is critical to their future development and quality of life. However, there is still much room for improvement in monitoring and intervention of adolescent physical health in colleges and universities. Based on the National Standard for Student Physical Fitness and Health, this study proposes a physical health management framework for adolescents that combines a cloud platform and real-time data analysis. Through an innovative health monitoring and early warning system and feedback mechanism, the effectiveness of health intervention was significantly improved. Body mass index is related to the balance between energy intake and expenditure at the cellular level. Excessive calorie intake can lead to an increase in adipose cells, which secrete molecules that can affect overall metabolism and biomechanical stress on tissues. Lung capacity is linked to the elasticity and strength of the alveolar cells and the connective tissue in the lungs. he proper functioning of these cells, regulated by intracellular signaling pathways and molecular interactions, determines the efficiency of gas exchange. The 50-meter run, seated forward bending, standing long jump, pull-ups/sit-ups, and 800-meter/1000-meter run all involve muscle contractions. Muscle cells contain actin and myosin filaments, and the sliding of these filaments, regulated by calcium ions and other molecular signals, generates the force required for movement. The graded early warning parameters established by the system can thus be seen as indicators of potential disruptions in these cell molecular biomechanical processes. The innovative health monitoring and early warning system and feedback mechanism not only help students recognize the weaknesses in their physical functions from a macroscopic level but also potentially identify areas where cell molecular biomechanical imbalances may exist. This enables physical education teachers to formulate personalized training plans that can target and correct these imbalances, as experimentally validated by the system's ability to accurately identify health risks and enhance the overall health of students.

Keywords: adolescent physical health; warning system; exercise prescription; gait recognition; energy expenditure rate; health assessment model; cell molecular biomechanical processes

1. Introduction

Because of its long-term effects on public health, economic productivity, and societal well-being, adolescent physical health has emerged as a crucial global concern [1]. Adolescent physical fitness has a significant impact on cardiovascular health, musculoskeletal strength, and general quality of life, making it a reliable indicator of future health outcomes. However, sedentary lifestyles and poor eating habits have caused juvenile fitness levels to decline globally, which has prompted governments, educational institutions, and researchers to create novel, evidence-based strategies for tracking and enhancing the physical health of adolescents [2,3].

Traditional monitoring methods, such as the National Student Physical Health Standards, evaluate parameters like body composition, cardiovascular fitness, and muscular strength, providing benchmarks for assessing fitness levels [4]. However, these systems often lack feedback mechanisms and personalized interventions, limiting their effectiveness. Adolescents frequently struggle to interpret test results or take corrective action, and physical education instructors face challenges in tailoring interventions due to insufficient actionable insights [5,6].

This study addresses these limitations by integrating advanced predictive models, structured feedback systems, and personalized exercise plans into adolescent health monitoring. By leveraging multidimensional indicators, it provides precise, actionable recommendations for proactive fitness management [7,8].

Current challenges include the binary nature of traditional evaluation systems, which overlook nuanced changes in fitness levels, and the absence of structured feedback for guiding adolescents and educators [9]. Additionally, these systems often fail to account for the dynamic nature of physical health or fully utilize wearable devices for real-time monitoring.

To overcome these issues, this study proposes an integrated framework with the following innovations:

- Clearly defined health thresholds based on gender and age-specific variations to evaluate fitness across dimensions such as body composition, physical function, and quality.
- A two-tiered warning system to classify fitness indicators as "average" or "poor," offering actionable insights and promoting timely interventions.
- A stochastic model for predicting exercise limits and energy expenditure, enabling accurate assessment of endurance and recommendations for optimal exercise intensity and duration.

2. Physical health promotion management

2.1. Cloud-based framework

A cloud-enabled platform for managing student physical health utilizes the mobile Internet as an efficient service hub, emphasizing accessibility, functionality, and user engagement for adolescents [10]. This innovative approach to promoting youth health operates across two primary dimensions: the organizational structure and the system's functional components.

At its core, the platform employs a "four-in-one" collaborative framework that connects students, physical education instructors, schools, and regulatory authorities [11]. This integrated model enables seamless management and sharing of student health data (see **Figure 1**). Grounded in the National Student Physical Fitness Standards, the system incorporates a comprehensive framework comprising five interdependent components: monitoring, evaluation, early warning, feedback, and intervention. Together, these elements create a robust mechanism for enhancing physical fitness.

The platform's key functionalities are organized into three critical domains:

- Systematic collection, organization, and storage of health metrics.

- Identification of physical fitness levels and timely generation of alerts for areas of concern.
- Creation of personalized health profiles to guide tailored interventions and strategic planning.

By adopting this cloud-based, data-driven, and user-focused approach, the platform delivers an interactive and effective system for managing and improving adolescent physical health.

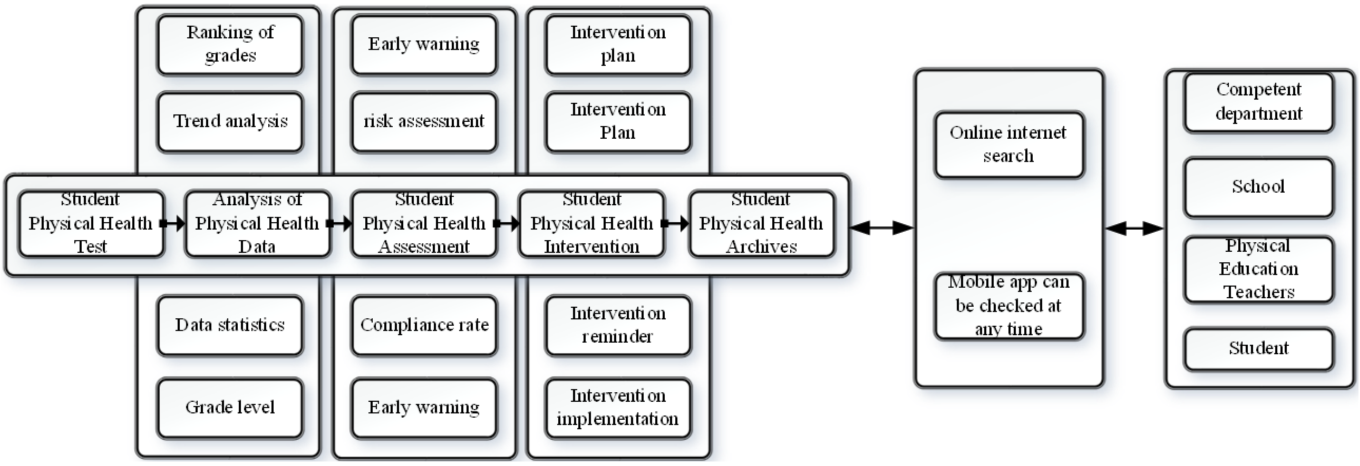


Figure 1. Cloud-based management platform.

In the "Cloud Management Platform + Student Health" framework, the cloud platform's data processing and information management capabilities are leveraged to their fullest potential. This approach not only significantly improves the timeliness, precision, and accessibility of physical health assessments and student health services but also introduces an innovative paradigm for handling student health data. By enabling a more holistic and integrated management of health records, the platform facilitates early detection of deficiencies and the delivery of targeted interventions to address specific areas of concern.

2.2. Enhancing adolescent physical health

The early warning mechanism for student physical health is anchored in evaluations aligned with the National Student Physical Fitness Standards. These assessments utilize comprehensive fitness test data to systematically analyze adolescents' overall physical fitness levels and identify discrepancies across various fitness parameters. This dual-level evaluation process not only determines total fitness scores but also highlights imbalances in individual health metrics, enabling the generation of precise and actionable early warnings.

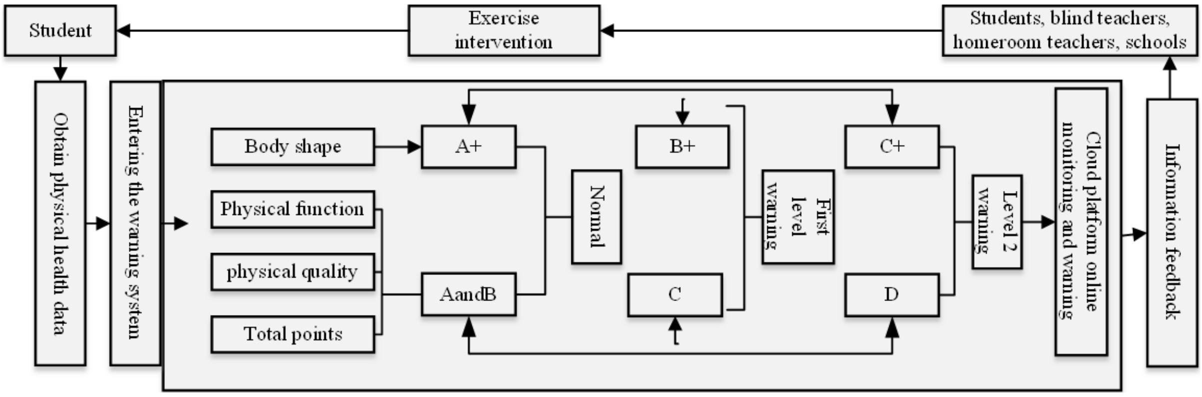


Figure 2. Youth physical health warning model.

Note: denotes "normal" "low weight and overweight" and "obesity" in the BMI index; in the standard, it denotes "excellent" "good" "pass" and "fail" levels.

Two main components make up the implementation of an early warning system for student physical fitness (see **Figure 2**). First, students' total fitness scores are evaluated in accordance with the Standards' criteria, where "good or above" is necessary to be eligible for merit-based rewards. Scores that fall between the "pass" and "fail" standards are given early warnings, indicating areas that need attention. The second element focuses on the "weaknesses" of each student's physical characteristics and includes an unbalanced warning for particular individual signs. This includes the assessment of key factors such as physical form, functionality, and fitness levels, which are categorized into "Level 1" and "Level 2" warnings based on performance.

Given the geographical variations in students' physical conditions, the parameters outlined in the Standards are adjusted accordingly (refer to **Table 1**) [12,13]. When students' fitness test results fall below the prescribed thresholds, notifications are issued to students, physical education teachers, class instructors, and school authorities. These alerts aim to increase students' awareness of their health status, prompting targeted interventions and exercise regimens to enhance their overall fitness.

Table 1. Adolescents' threshold of physical health prediction parameters.

Type	**Index**	**Male threshold**		**Female threshold**		**Grade**
		Freshman and sophomore	**Junior and senior**	**Both freshmen and sophomores**	**Younger and older**	
Body shape	BMI index (kg/m^2)	≤17.9	≤17.2	≤17.2	≤17.2	Low body weight
		23.5–28.5	23.5–28.5	23.5–28.5	23.5–28.5	Overweight
		≥29	≥29	≥29	≥29	Obesity
Physical function	Vital capacity (ml)	3101–4300	3201–4400	2001–3000	2051–3050	pass
		≤3100	≤3200	≤2000	≤2050	Fail
	50meter run (seconds)	7.3–9.2	7.2–9.1	8.5–10.4	8.4–10.3	pass
		≥9.3	≥9.2	≥10.5	≥10.4	Fail
	Sitting forward flexion (cm)	3.8–17.7	4.3–18.2	6.1–19.0	6.6–19.5	pass
		≤3.7	≤4.2	≤6.0	≤6.5	Fail

Table 1. (*Continued*).

Type	Index	Male threshold		Female threshold		Grade
		Freshman and sophomore	**Junior and senior**	**Both freshmen and sophomores**	**Younger and older**	
Physical quality	Standing long jump (cm)	209–248	211–250	152–181	153–182	pass
		≤208	≤210	≤151	≤152	Fail
	Pull-ups/sit-ups (reps)	11–15	12–16	27–45	28–47	pass
		≤10	≤11	≤26	≤27	Fail
	800 meters/1000 m (min s)	3.44–4.33	3.42–4.31	3.46–4.35	3.44–4.33	pass
		≥4.34	≥4.32	≥4.36	≥4.34	Fail
Total points	Indicator and (score)	61–80	61–80	61–80	61–80	pass
		≤60	≤60	≤60	≤60	Fail

At its core, a single-tiered warning system falls short of truly addressing the purpose of student physical health alerts. It is only when students fully comprehend the current state of their physical functions and the potential risks, they face that their awareness of their fitness levels can be meaningfully heightened [14,15]. This underscores the significance of creating a comprehensive feedback mechanism for physical health alerts. The feedback form should elucidate the specifics of the student's warning status and deliver the information in a personalized "profile" format to both the student and the physical education instructor [16,17].

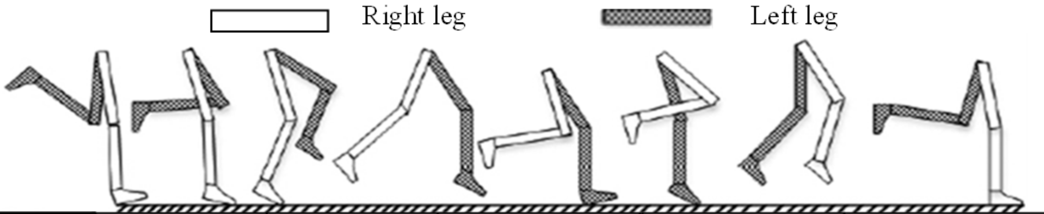
Students can use the early warning signs as a basis for targeted exercise aimed at strengthening their weaker areas because such a feedback system gives them a clear picture of where they stand in terms of physical health indicators. This procedure raises students' awareness of their own health by providing them with thorough feedback on their physical health statistics. It also creates a sense of urgency that prompts them to reflect on their fitness evaluations and to participate in suitable physical activities. Additionally, teachers of physical education can use these early warning indicators to provide students with individualized instruction and assistance, which will increase the effectiveness of physical education classes and help kids become more fit overall.

3. Gait recognition

3.1. Running dynamics

To accurately determine the displacement of the body during running, it is essential to first analyze the gait cycle. The running movement can be broken down into two primary phases: the support phase and the flight phase [18,19]. **Figure 3** illustrates the movement sequence of both the left and right legs over a given time frame.

The support phase can be further subdivided based on the stance of the legs: (i) the left leg is in support while the right leg swings, and (ii) the right leg is in support while the left leg swings. These alternating leg motions occur continuously during running. To estimate the body's displacement, it is crucial to detect the gait pattern and then apply suitable methods for displacement calculation based on the identified gait phase.



Process label	Process 1	Process 2	Process 3	Process 2	Process 1
Human state	Support period	Leap period	Support period	Leap period	Support period
Right leg state	Support period	Swinging leg			
Left leg state	Swinging leg		Support period	Swinging leg	

Figure 3. Movement sequence.

3.2. Centroid displacement

Displacement during the support phase is computed using the lower body joints' flexion and extension angles. The movement of the body in the XOY plan view is depicted in **Figure 4**.

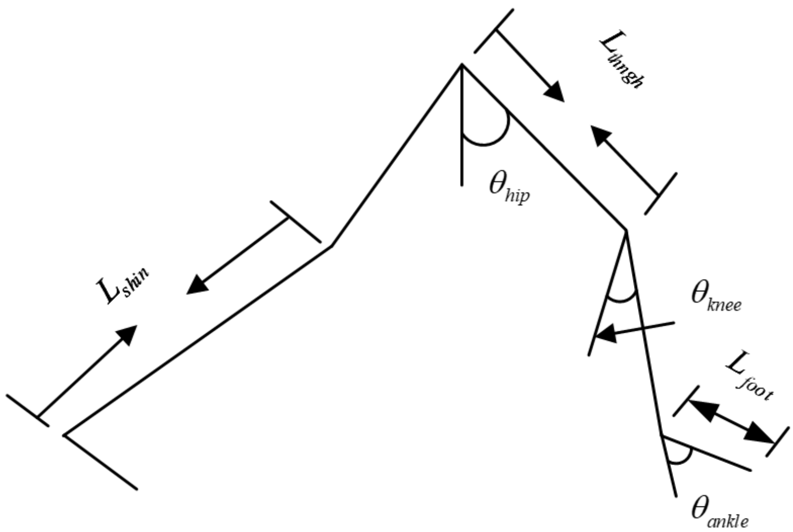


Figure 4. The XOY plane view of the human mobility mechanism.

We estimate displacement during a running phase using stratification information. As previously stated, the vector sum of the foot, thigh, and knee lengths is referred to as the root. According to Equations (1) and (2):

$$S_{\text{root}}^{x} = S_{\text{thight}}^{x} + S_{shiin}^{x} + S_{\text{foot}}^{x} \tag{1}$$

$$S_{\text{root}}^{y} = S_{\text{thigh}}^{y} + S_{\text{shin}}^{y} + S_{\text{foot}}^{y} \tag{2}$$

$S_{\text{foot}}^{x}\, S_{\text{thight}}^{x}\, S_{\text{root}}^{x}\, S_{shiin}^{x}$ represents the vectors on the X-axis for the root, thigh, calf and foot, respectively, $S_{\text{root}}^{y}\, S_{\text{thight}}^{y}\, , S_{\text{shin}}^{y}\, , S_{\text{joot}}^{y}$ represents the vectors up the Y-axis for the root, thigh, calf and foot, respectively.

$$S_i^x = L_k\, sin(\theta_{i,t+\Delta t}) - L_k\, sin(\theta_{i,t})$$
$$S_i^y = L_k\, cos(\theta_{i,t+\Delta t}) - L_k\, sin(\theta_{i,t}) \tag{3}$$

$$S_{\text{root},t+\Delta t}^x = S_{\text{root},t}^x + S_{\text{root},t}^x\, cos(\theta_{\text{root}})$$
$$S_{\text{root},t+\Delta t}^y = S_{\text{root},t}^y + S_{\text{root},t}^y\, sin(\theta_{\text{root}}) \tag{4}$$

$S_{\text{root},t+\Delta t}^{x}\, , S_{\text{root},t+\Delta t}^{y}$ is represented as the root vector on the X and Y axes at the time node of $t+\Delta t$ and θ_{root} is the angle of the root vector.

5. Experiment

5.1. Health evaluation

The exercise energy expenditure rate serves as the foundation for the health evaluation model for young athletes, which aims to ascertain the athlete's activity limit energy expenditure rate and evaluate their general health.

Based on data on energy expenditure during a continuous, real-time workout, the following is used to evaluate the health of an exerciser [20]. The exercise data real-time monitoring system can collect energy expenditure data in real time from all exercisers. Every 30 seconds, the energy expenditure rate is changed to match the workout energy expenditure in order to facilitate the analysis and computation that follows. The energy expenditure rate of an exerciser throughout a 10-minute period is shown in **Table 2**.

Table 2. An athlete's rate of energy expenditure.

Time (min)	Energy consumption rate (kcal 30s)	Time (min)	Energy consumption rate (kcal 30s)
1	3.63	3	6.96
6	4.08	3	7.29
9	3.47	7	6.64
12	4.30	4	5.22
15	4.17	5	4.99
18	5.69	8	4.03
9	5.74	10	3.84
4	4.88	10	4.26
7	5.79	7	3.12
10	6.82	9	2.69

The energy consumption rate transfer data for two neighboring 30 s can be obtained using the state space division mentioned above, as indicated in **Table 3**.

Table 3. Transfer of energy consumption rate.

Number of transfers		After transfer				Amount to
		A	**B**	**C**	**D**	
Before transfer	A	1	0	0	1	2
	B	2	4	1	0	5
	C	1	2	2	0	4
	D	0	0	2	2	5

As seen in **Figure 5**, we can plot the exerciser's energy consumption rate for each time period against this workout limit energy consumption rate to determine the exerciser's constant energy in the current exercise state. A consumption rate of 5.602 kcal/s is observed.

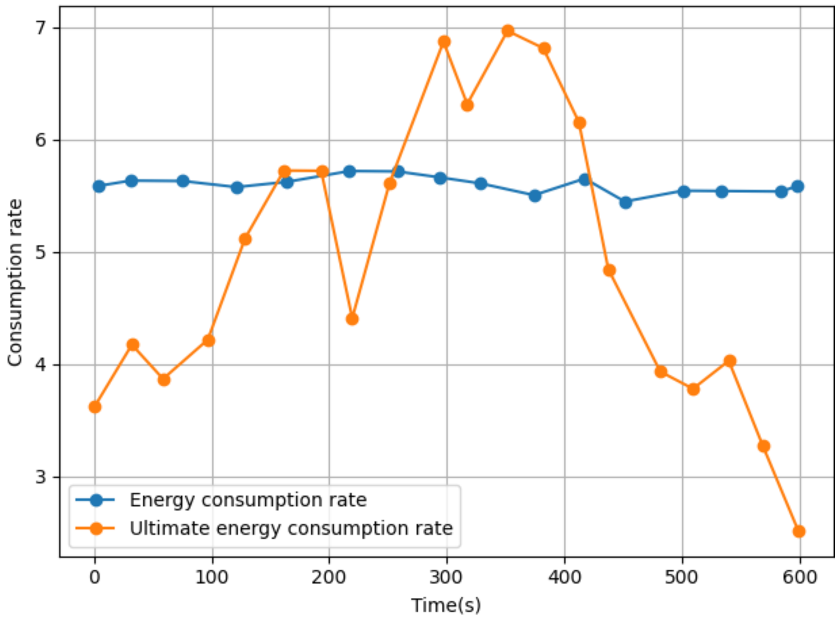


Figure 5. Rate of energy expenditure.

Figure 5 shows a decline in physical strength when the exerciser's energy expenditure rate starts to go below the maximum rate of 5.602 kcal/30s at approximately 450 seconds and keeps going down throughout the exercise.

5.2. Comparative validation

A real-time exercise data monitoring system recorded the exercise data of 20 exercisers who were chosen to run a 2-kilometer course in order to confirm the correctness of the health assessment model's findings for exercising people [21,22]. Each athlete's prediction error in the health assessment model may be computed, and the results are displayed in **Figure 6**. All 20 participants' exercise stopping times fell within 20% of the actual exercise stopping time that the model predicted, as seen in **Figure 6**.

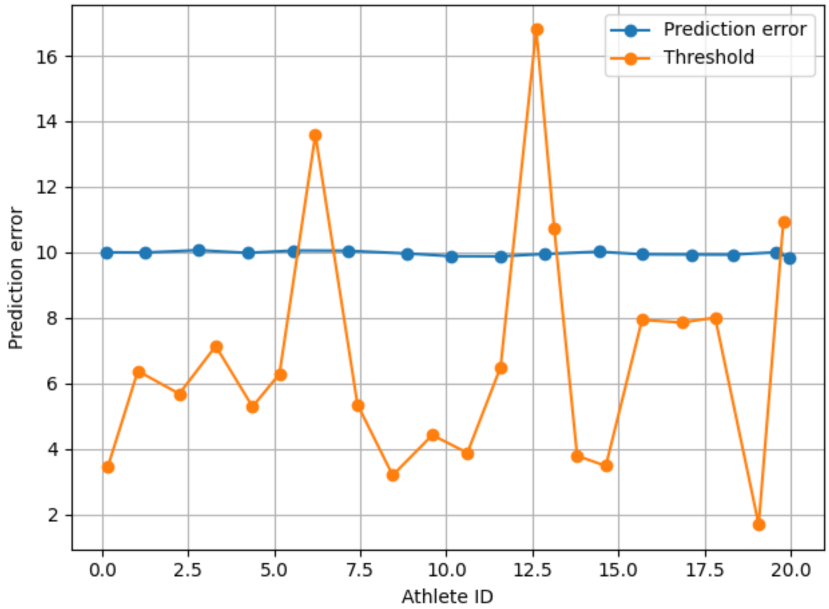


Figure 6. Error chart comparing the suggested and actual times.

6. Conclusion

This study addresses the pressing issue of adolescent physical health by presenting a comprehensive framework for assessment, prediction, and intervention. By leveraging multidimensional indicators—such as body composition, physical function, and quality metrics—alongside advanced algorithms for real-time data analysis, the research bridges critical gaps in current fitness evaluation systems. The integration of a threshold-based health evaluation model, early-warning feedback mechanisms, and personalized exercise prescriptions underscores a robust and innovative approach to adolescent health management.

The structured, two-tiered warning system empowers adolescents and educators to pinpoint specific areas requiring intervention, fostering a proactive approach to health management. Through the application of predictive algorithms, the study offers forward-looking insights into health trends, enabling timely actions to mitigate potential risks. Moreover, the deployment of advanced sensors for real-time monitoring and gait analysis ensures precise evaluations of physical performance, providing a modernized perspective on fitness assessment.

In addition to identifying deficiencies in existing systems, this research delivers a scalable, scientifically validated solution that is practical for real-world implementation. The framework's multidimensional design facilitates a holistic understanding of adolescent health, while its emphasis on actionable and predictive insights represents a significant advancement in the fields of physical education and health science.

Funding: College teachers' health management and exercise under the background of physical and medical integration: Intervention Research, Xiangjiao Tong [2019]90, Project number: 18A475.

Ethical approval: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Hunan University of

Science and Engineering (protocol code: HUSEKYP20240603302J and date of approval 2024, 06, 03).

Conflict of interest: The author declares no conflict of interest.

References

1. Zhang, S. , & Mao, H. . (2021). Optimization analysis of tennis players' physical fitness index based on data mining and mobile computing. Wireless Communications and Mobile Computing, 2021(11), 1-11.
2. Bardid, F. , Utesch, T. , Stodden, D. F. , & Lenoir, M. . (2021). Developmental perspectives on motor competence and physical fitness in youth. Scandinavian Journal of Medicine and Science in Sports, 31(S1), 5-7.
3. Martin, K. . (2022). Investigating the reciprocal temporal relationships between tobacco consumption and psychological disorders for youth: an international review. BMJ open, 12(6), e055499.
4. Jansson, A. K. , Chan, L. X. , Lubans, D. R. , & Duncan, M. J. . (2022). Effect of resistance training on hba1c in adults with type 2 diabetes mellitus and the moderating effect of changes in muscular strength: a systematic review and meta-analysis. BMJ open diabetes research & care, 10(2).
5. Tl, M. , Jn, B. , Carlton, T. , Mckenzie, T. L. , & Suau, L. . (2021). Objective assessment of physical activity and associated contexts during high school sport practices. Frontiers in Sports and Active Living, 3, 548516.
6. Rollo, S. , Fraser, B. J. , Seguin, N. , Sampson, M. , Lang, J. J. , & Tomkinson, G. R. , et al. (2022). Health-related criterion-referenced cut-points for cardiorespiratory fitness among youth: a systematic review. Sports medicine(1), 52.
7. Furr, H. N. , Nessler, J. A. , & Newcomer, S. C. . (2021). Characterization of heart rate responses, duration, and distances traveled in youth participating in recreational skateboarding at community skateparks. Journal of strength and conditioning research, 35(2), 542-548.
8. Haile, S. R. , T Fühner, Granacher, U. , Stocker, J. , & Kriemler, S. . (2021). Reference values and validation of the 1-min sit-to-stand test in healthy 5- to 16-year-old youth. BMJ Open, 11(5), 956-63.
9. Romero-Caballero, L. . (2021). Fitness evaluation in young and amateur soccer players: reference values for vertical jump and aerobic fitness in men and women. Science & sports, 36(2).
10. Daniel.López-Plaza, Borges, P. J. , Alacid, F. , & Argudo, F. M. . (2021). Influence of maturity status on morphology, grip and throwing speed in young elite water polo players. The Journal of sports medicine and physical fitness, 61(11), 1441-1447.
11. Contreras-Osorio, F. , IP Guzmán-Guzmán, Cerda-Vega, E. , L Chirosa-Ríos, R Ramírez-Campillo, & Campos-Jara, C. . (2022). Effects of the type of sports practice on the executive functions of schoolchildren. International journal of environmental research and public health, 19(7).
12. Tanaka, C. , Abe, T. , Tanaka, S. , Hatamoto, Y. , Miyachi, M. , & Inoue, S. , et al. (2022). Results from the japan 2022 report card on physical activity for children and youth. Journal of exercise science and fitness, 20(4), 349-354.
13. Kiers, K. , Ellenberger, L. , Jermann, J. , Oberle, F. , Frey, W. O. , & Sprri, J. . (2022). Prospective study on dynamic postural stability in youth competitive alpine skiers: test-retest reliability and reference values as a function of sex, age and biological maturation. Frontiers in physiology, 13, 804165.
14. D Henriques - Neto, M Hetherington - Rauth, Magalhes, J. P. , Sardinha, L. B. , Correia, I. , & PB Júdice. (2022). Physical fitness tests as an indicator of potential athletes in a large sample of youth. Clinical Physiology and Functional Imaging, 42(2), 88-95.
15. Huerta-Uribe, N. , R Ramírez-Vélez, Izquierdo, M. , & A García-Hermoso. (2023). Association between physical activity, sedentary behavior and physical fitness and glycated hemoglobin in youth with type 1 diabetes: a systematic review and meta-analysis. Sports Medicine, 53(1), 111-123.
16. Sardar, M. S., Rasheed, K., Cancan, M., Farahani, M. R., Alaeiyan, M., & Patil, S. V. Fault Tolerant Metric Dimension of Arithmetic Graphs. Journal of Combinatorial Mathematics and Combinatorial Computing, 122, 13-32.
17. Kyan, A. , Tanaka, S. , Takakura, M. , Olds, T. , & Tanaka, C. . (2021). Validity of japanese version of a two-item 60-minute moderate-to-vigorous physical activity screening tool for compliance with who physical activity recommendations. The Journal of Physical Fitness and Sports Medicine, 10(2), 99-107.
18. Thomis, M. , Starkes, J. L. , Vrijens, S. , Ooms, G. , & Helsen, W. F. . (2021). Leveling the playing field: a new proposed method to address relative age- and maturity-related bias in soccer. Frontiers in Sports and Active Living, 3(24).

19. Masumoto, K., & Mercer, J. A. (2023). Influence of speed on running strategies during forward and backward running with body weight support. The Journal of sports medicine and physical fitness, 63(2), 241-249.
20. Li, D. The Comprehensive Training Effect of Translation Ability of College English Majors Based on Machine Learning. Journal of Combinatorial Mathematics and Combinatorial Computing, 120, 399-410.
21. Lee, J. B., Sung, B. J., & Seo, T. B. (2023). The relationship between driving distance and different types of contraction in core muscles in korea elite female golfers. The Journal of sports medicine and physical fitness, 63(1), 1-7.
22. Bulca, Y., Bilgin, E., Altay, F, & Demirhan, G. . (2022). Effects of a short video physical activity program on physical fitness among physical education students. Perceptual and motor skills, 129(3), 932-945.