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Article

A biomechanical and biological investigation of the impact of cheerleading training on enhancing the physical fitness and musculoskeletal health of girls

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Abstract: Background: Girls' physical health significantly influences their growth, development, and learning capabilities. The biomechanical effects of physical training, such as cheerleading, are increasingly recognized for their role in optimizing musculoskeletal health and functional performance. This study investigates how cheerleading training impacts junior high school girls' physical fitness, with a specific focus on its biomechanical effects on body composition, bone density, and muscle explosiveness. Biomechanical factors such as force generation, joint stability, and bone strength are integral to understanding how physical activities like cheerleading influence the body. **Methods:** Eighty normal junior high school girls with no prior training experience, sixty cheerleaders, and sixty aerobics athletes constituted the study's control and experimental groups. Participants were randomly assigned to either the training group or the control group after three to six months of structured, intense training. Key parameters such as height, body mass, BMI, bone density, muscular explosiveness, and percentages of protein, muscle, fat, and inorganic salts were assessed using exercise biology measurements. Biomechanical evaluations were conducted to assess lower and upper limb force production, lumbar and spinal stability, and joint impact resistance using standardized tests. **Results:** The study revealed significant improvements in body composition among the cheerleading and aerobics groups, including lower fat percentages ($P < 0.05$) and higher protein, muscle, and inorganic salt percentages. Biomechanically, cheerleading training enhanced the muscular explosiveness of the lower limbs ($P < 0.05$), demonstrating increased peak power output and improved reaction forces during jumping and landing activities. Conversely, aerobics training led to significant improvements in the muscular explosiveness of the upper and lower limbs, lumbar, abdominal, and low back muscles ($P < 0.01$), indicating greater overall functional strength and dynamic stability. Bone mineral density (BMD) tests showed that the hip and spine BMD of the cheerleading and aerobics groups were significantly higher than those of the control group ($P < 0.05$), suggesting enhanced bone remodeling and mechanical loading benefits. The aerobics group exhibited superior BMD gains compared to the cheerleading group, particularly in load-bearing areas, indicating higher adaptive responses to varied mechanical stresses. **Conclusion:** This study provides strong evidence that cheerleading training positively impacts junior high school girls' physical fitness, particularly in biomechanical aspects such as body composition, bone density, and muscle explosiveness. The findings highlight the specific biomechanical adaptations induced by cheerleading, such as increased force generation in lower limbs, improved joint loading mechanics, and enhanced bone strength.

Keywords: cheerleading training; physical fitness; biomechanics; musculoskeletal health; Bone Mineral Density (BMD); dynamic postural control; biomechanical modeling

1. Introduction

The sport of cheerleading, which blends artistic ability with competitiveness, has been extensively developed and promoted globally. Cheerleading has become increasingly popular in schools and social groups in recent years, especially for youth groups, as an addition to extracurricular activities or sporting events [1]. Yet, the majority of the research that has been done on cheerleading has focused on the program's promotion, the event's regulations, the athletes' performances, and other broad topics. Research on how cheerleading affects teenagers' physical fitness and the physiological markers of sports biology is still in its infancy. The scientific and systematic development of athletic training has been hampered by this research gap, particularly when it comes to student populations. There is a dearth of exercise biology-based research to back up the scientific recommendations for enhancing students' general physical fitness and health [2]. By investigating the exercise biology underpinnings of cheering training to enhance female students' physical fitness, we want to close the theoretical and practical gaps in this area and offer a more methodical and scientific theoretical foundation for cheerleading instruction [3].

The physical health of teenagers has garnered a lot of attention as global health issues gain significance. The World Health Organization's pertinent statistics indicate that adolescents' physical health status has been declining recently, particularly as sedentary lifestyles have become more popular. The obesity rate, decline in cardiorespiratory endurance, and other issues facing adolescents are especially concerning [4]. Cheerleading is a type of team-based, competitive, and performance-based sports program that offers a variety of physical activities, including aerobic and strength and flexibility training, and offers the ability to fully support the growth of physical fitness [5].

Cheerleading is not just a well-liked campus athletic program in affluent nations like the US, but it is also a hotbed of associated exercise biology research. From the standpoint of exercise biology, numerous international researchers have examined the benefits of cheerleading for physical health, sports injury prevention, and physical quality enhancement, particularly in the areas of strength, explosive force, endurance, and other areas of more in-depth research [6]. According to research, for instance, gymnastics training's core strength, maximal strength, and explosive strength training are quite similar to cheering training's skill motions like lifting and tumbling. Additionally, research from other countries has shown that cheering training improves physical strength, body composition, bone density, and other biological aspects. Cheerleading has a major impact on preventing sports injuries and improving the general health of young people by improving students' physical health, which in turn can increase athletes' athletic performance [7,8].

The mechanism of cheerleading training's impact on youths' physical health and athletic ability from an exercise biology perspective, on the other hand, was not thoroughly explored in domestic research on the exercise biology of cheerleading, which began late and concentrated on curriculum, macro program promotion, and other areas [9]. The promotion of cheerleading and the development of training systems in China lack scientific theoretical guidance due to the dearth of research in this area. This is particularly problematic for the youth group, as there is still a problem with how to improve physical health through the scientific training system of cheerleading [10].

Therefore, investigating the exercise biology underpinning cheerleading training's impact on teenagers' physical fitness, particularly that of girls, is both theoretically and practically significant. In order to theoretically support the scientific and systematic training of cheerleading, as well as to give physical educators a foundation for creating a scientific training program and enhancing students' physical health, this paper systematically examines the effects of cheerleading training on junior high school girls' body composition, bone density, muscle strength, and other sports biology indicators.

Despite cheerleading's widespread use both domestically and internationally and its high regard, there are still several obstacles to overcome in order to conduct pertinent exercise biology research [11]. First of all, cheerleading training is varied and technically challenging; competitive cheering, in particular, demands players to possess high levels of strength, stamina, and flexibility, raising the bar for training theories. There is currently a dearth of research on quantitative study of the micro markers of physical health during the training process, as most studies concentrate on examining cheerleading's social impact and promotion strategy from a macro perspective. Second, there is a dearth of scientific evidence to support the evaluation of the true impact of modifications in students' physical fitness, and the majority of research on the biological underpinnings of cheerleading concentrates on enhancing event regulations and marketing tactics [12].

Furthermore, the effect of individual differences on the efficacy of cheerleading training is frequently overlooked in the research that is currently available. Since teenagers are going through a crucial stage of growth and development, their physiological traits vary widely, and their physical health is impacted differently by cheerleading training and diverse talents. One of the main challenges in the current research is how to create customized training plans based on the physical characteristics of various groups to guarantee that cheerleading training may successfully and scientifically enhance physical health.

To get over the aforementioned problems and ensure that the study's results were comparable and scientific, this work employed a strict control and grouping technique in the study design. The fact that the study participants were junior high school girls divided into three groups—cheering, aerobics, and control—allows for a more objective assessment of the actual benefits of cheerleading instruction on physical fitness and health. This made guaranteed that the baseline traits of the research participants, including height, body mass, etc., were the same for each group. Second, in order to fully assess how cheering training improves students' physical fitness and health, the study used a variety of exercise biology indicators, including body composition analysis, bone densitometry, and muscular explosiveness testing.

Through careful experimental design, scientific training methods, and a methodical analysis of exercise biology indices, the research program for this paper aims to fully unveil the ways cheering training improves the physical health of junior high school girls. The study is novel because it combines the real training effect with the theory of exercise biology. Through the quantitative examination of significant indicators such as muscular explosive force, body composition, and bone mineral density, it also explores the scientific mechanism of cheering training's improvement of physical fitness and its biological foundations.

2. Related work

There is a dearth of research from the perspective of exercise biology on the changes in students' physical fitness and exercise physiological indexes brought by cheerleading into the campus and society, according to the review of the literature. In recent years, relevant researchers have primarily conducted research from the perspective of program development, campus curriculum promotion, and event rules [13]. Additionally, other researchers from other countries have examined cheerleading from the standpoints of sports biology, physical health, sports injury prevention, and epidemiology, particularly in some of the nations that have made significant strides in the growth of this athletic program. Numerous international academics have proposed that there are many parallels between the sport biology theories of gymnastics and cheerleading at the highest levels. They have noted that the study of maximal strength, explosive power, muscle power, and other related research is crucial to the final performance in gymnastics' core stability training, and that the movement of the lifting, tumbling, and other skills in cheerleading depends equally on the basic study of sport biology of endurance and strength and other related sport biology.

Formulating training goals and tasks, choosing training methods and means, controlling the training process, and analyzing training effects all depend on an understanding of sport biology, which is a crucial basis for training theories of various sports and supports training theories from a natural science perspective. The theoretical underpinnings of sports biology are an essential and significant component of training theory, which is a theory that directs and studies the process of sports training, including mass fitness training and competitive sports training [14].

3. Research objectives and methods

3.1. Research population

In May 2024, our school hosted the Thirteenth Student Games and cheering Aerobics Competition in Henan Province, where 60 junior high school girls cheered (a cheering group) and 60 aerobics athletes cheered (an aerobics group). They conducted centralized training using the voluntary enrollment approach, and those who benefited from the training took part in the competitions on the school's behalf. At the beginning of the training, the cheerleading squad and the aerobics squad were entirely randomized. According to the survey, all of the junior high school girls who participated in the cheerleading or aerobics squad in this study were from conventional junior high schools located in various Zhengzhou City districts. At the same time, 80 middle school girls from Henan Province's Experimental Middle School were chosen as the control group. Since the control group was likewise created by voluntary enrollment, both the sampling and the grouping were somewhat random. In this study, the randomized grouping was pursued while rigorously controlling the other factors affecting the research subjects' observational indicators in order to minimize the impact of the various characteristics of the research subjects on the experimental results. 85% of the teams concentrated on the 3–6 month period, and 65% of the teams trained every day for 30 to 60 min during this training cycle, according to the poll, which also showed that training periods varied from 2 to 8 months.

Criteria for the study participants' inclusion:

1) Every study participant was Han Chinese, healthy, and free of bone-related diseases;

2) The cheerleading and aerobics groups trained daily for 30 to 60 minutes from April to June;

3) The control group had no prior cheerleading or aerobics training experience, and neither the cheerleading nor the aerobics groups had any pertinent special training bases at the start of the current training;

4) All study participants had to be born between 2005.06.30 and 2007.06.30, and their height and body mass indexes had to be comparable to those of the other two groups in order to remove the impact of age, height, body mass, and body mass index (BMI) on the observation indexes;

5) All study participants had to actively cooperate with one another and provide their informed consent. Using SPSS20.0 statistical software, a one-way ANOVA was performed on the research subjects' baseline data to balance the characteristics of the three groups. The results showed that there was no difference between the groups except for the training time, and an Independent-Sample Test revealed no difference between the cheerleading and aerobics groups' training times ($t = 0.97$; $P > 0.05$). This means that all three groups' baseline data were balanced, with the exception of the training time, and that all two sports groups' baseline data were also balanced. The baseline data of the three groups were balanced, with the exception of the training time, and all of the baseline data of the two sports groups were balanced. This makes it possible to compare the effects of cheerleading or aerobics training on the body composition, bone mineral density, and muscle explosive power of junior high school girls (**Table 1**). An independent-sample test was performed on the training time of the cheerleading group and aerobics group, and the results showed no difference between the groups ($t = 0.97$; $P > 0.05$).

Table 1. Comparison of research participants' baseline data between groups.

Variable	Cheerleading	Aerobics	Control
Number	60	60	80
Age (years)	13.25 ± 0.55	12.98 ± 0.52	13.22 ± 0.45
Height (cm)	163.25 ± 2.02	163.54 ± 2.85	162.74 ± 3.66
Mass (kg)	52.35 ± 1.44	51.28 ± 1.66	52.68 ± 3.05
Body Mass Index (kg/m^2)	19.98 ± 1.25	19.25 ± 1.02	20.45 ± 1.88
Training time	4.42 ± 0.32	4.35 ± 1.25	-

3.2. Research methods

In May 2024, with informed consent, measurements of height, body mass, BMI, body composition, and muscle strength were taken at the Physical Fitness Test Center of Henan Experimental Middle School and the Physical Education and Health

Laboratory of Zhengzhou Normal College, respectively. The study participants were required to wear uniform shorts and tank tops, step on the scales' footprint mark with bare feet, hold out their chests with their heads up, and look directly in front of them while the ultrasonic height and body mass measuring device SG-700, made by Shanghai Henggang Instrumentation Co., Ltd., measured their height, body mass, and BMI. The measurements were taken consistently between 7:00 and 8:00 a.m. (before breakfast). The BMI was 1.2 mm, the height was measured in centimeters, and the body mass was measured in kilograms. Body mass is measured in kilograms, height is measured in centimeters, and BMI is measured in kilograms per square meter. The subjects' body composition was measured using the IOI353 Body Composition Analyzer, which was produced by the Korean company Jevon. Protein, inorganic salts, fat mass, muscle mass, and body mass data were collected, and the proportion of body mass that each component accounted for was computed. The measurement was performed strictly in compliance with the instrument's instructions. Subjects' muscular explosive strength was measured: 1) The respondents' upper limb explosive power was assessed by having them push a solid ball weighing two kilograms. 2) A solid ball weighing two kilograms was pushed to gauge the upper limbs' explosive strength. The participant was instructed to sit with their back against the chair's back. To keep the subject's back from leaving the back of the chair when pressing the ball, the measuring staff tied a belt around the chest and pulled it back. The respondent used both hands to hold the ball and forcefully pushed it out. They then measured the distance three times between the ball's landing point and the baseline, obtaining the best result in meters. Using a standing long leap to gauge the lower limbs' explosive power. The subject stood barefoot behind the leaping line, bent his knees, and swung his arms to jump as hard as he could. He then measured the distance between the jumping line and the landing place three times, taking the best score in centimeters each time. 3) Bending the knees and holding the head in sit-ups to measure the explosive strength of the lumbar and abdominal flexor muscles. The subject was instructed to lie on the mat, bend his or her legs to a 90-degree angle, and then sit up by tightening his or her abdomen until the front elbows touched the knees. The number of times the subject finished this task in one minute was recorded in times/min.4) The lumbar and back extensor muscles' explosive force was measured using the goat jerk. The subjects were instructed to cross their arms in front of their chests, lie prone on the back extension machine, bend forward to a 90-degree angle, and then return to the starting position. Their backs had to remain straight throughout the exercise, and the number of times they finished it in one minute was recorded in times/min. Using a GE LunarProdigy dual-energy X-ray bone densitometer, the study participants' upper, lower, rib, spine, and hip bones were all subjected to bone densitometry in g/cm^2 in July 2018 at Henan Provincial Staff Hospital. All technical procedures were carried out under the supervision of experts. The subject's guardian was called prior to the measurement to request approval, and the guardian then gave the subject permission to sign the informed consent form.

3.3. Statistical processing

SPSS 20.0 statistical software was used to statistically examine the experiment's data. The fundamental statistics of the pertinent indexes of the study subjects, which were expressed as $\bar{x} \pm s$, were obtained using descriptive statistics. Multiple comparisons across groups were performed using the Bonferroni method of one-way ANOVA. A difference was deemed statistically significant if it was less than 0.05.

Factors such as age, body mass index (BMI), and training base can be analyzed as important variables when exploring the effects of different individual characteristics on research results. These characteristics may significantly affect the physiological or psychological responses of the human body under different conditions, thus creating some bias in the experimental results. Example:

Age: Age plays an important role in metabolic rate, rate of muscle recovery and exercise capacity. Younger individuals generally have higher metabolisms and faster physical recovery, whereas older individuals may be more susceptible to injury or have slower recovery. Therefore, studies need to control for age ranges or group comparisons of different age groups in order to more accurately reflect training effects.

Body mass index (BMI): BMI directly reflects an individual's body fat percentage and overall body shape, and those with a higher BMI may perform differently during aerobic or strength training. In addition, high BMI may affect the loading of the cardiovascular system, making high BMI individuals more susceptible to fatigue during high-intensity exercise. Therefore, stratifying and analyzing participants with different BMIs can better understand the potential impact of body size on study outcomes.

Training basis: Training experience has a significant effect on an individual's ability to adapt to exercise. Individuals with a stronger training base are usually more adaptable to high-intensity or prolonged training, whereas individuals lacking a training base may be less likely to achieve the same results. Therefore, grouping based on training base can help researchers to observe training effects more clearly and ensure that analyses are more relevant.

By taking these individual characteristics into account, differences in the response of different populations to training interventions or health measures can be analyzed more comprehensively, helping to optimize study design and improve the reliability of results.

4. Results

The findings indicated (**Table 2**) that both the cheerleading and aerobics groups had significantly higher ($P < 0.05$) percentages of protein, muscle, and inorganic salts than the control group; in particular, the percentages of protein and muscle were significantly higher ($P < 0.01$), while the percentage of fat was significantly lower ($P < 0.01$). In contrast, the aerobics group had significantly lower ($P < 0.05$) percentages of fat and significantly higher ($P < 0.05$) percentages of protein and muscle than the cheerleading group. were much greater ($P < 0.05$) and the aerobics group's fat percentage was significantly lower ($P < 0.05$) than the cheering group's. The results also revealed (**Table 3**) that the hip bone density was significantly higher in the aerobics and cheerleading groups ($P < 0.05$) compared to the control group, particularly in the aerobics group ($P < 0.01$), and the spinal bone density was significantly higher in the aerobics group ($P < 0.05$). The hip bone density of the aerobics group was also significantly higher than that of the cheerleading group. The cheerleading group's lower limb muscles had a significantly higher explosive power ($P < 0.05$) than the control group, and the aerobics group's upper limb muscles, lower limb muscles, lumbar flexors, and lumbar dorsal extensors all had significantly higher explosive powers ($P < 0.05$), with the lower limb muscles having the highest explosive power ($P < 0.01$). Additionally, as shown in **Table 4**, the aerobics group's upper limb muscles, lower limb muscles, lumbar flexors, and lumbar dorsal extensors also had a significantly higher explosive power ($P < 0.01$) than the cheerleading group. When comparing the aerobics group to the cheering group, the aerobics group's lumbar and abdominal flexors, lumbar and dorsal extensors, and upper and lower limb muscles were all significantly higher ($P < 0.05$).

Table 2. F-test results and basic information for research participants' percentage body composition.

Groups	Fat	Protein	Muscle	Inorganic salt
Cheerleading group	18.88 ± 3.25	16.14 ± 1.82	31.98 ± 1.87	5.28 ± 0.65
Aerobics group	17.85 ± 2.22	17.85 ± 1.56	35.26 ± 1.36	5.26 ± 0.45
Control group	24.56 ± 3.58	14.25 ± 1.98	28.98 ± 1.92	1.58 ± 0.52

Table 3. F-test results and basic statistics for bone mineral density in various study population segments.

Variable	Cheerleading group	Aerobics group	Control group
Upper limb bone	0.75 ± 0.05	0.69 ± 0.02	0.72 ± 0.04
Lower limb bone	0.90 ± 0.04	0.92 ± 0.06	0.90 ± 0.05
Ribs	0.61 ± 0.05	0.59 ± 0.05	0.58 ± 0.04
Spine	0.91 ± 0.15	0.94 ± 0.16	0.91 ± 0.12
Hipbone	1.02 ± 0.11	1.03 ± 0.15	0.98 ± 0.12

Table 4. F-test findings and basic data for muscle explosive power in various research population segments.

Variable	Cheerleading group	Aerobics group	Control group
Upper limb bone	3.58 ± 1.36	4.23 ± 1.01	3.89 ± 1.77
Lower limb bone	170.23 ± 12.48	178.95 ± 10.74	165.75 ± 15.65
Waist abdomen muscle	35.68 ± 6.25	38.98 ± 5.45	32.45 ± 7.26
Lower back muscle	28.56 ± 4.65	30.25 ± 3.65	28.65 ± 4.26

Both the cheering and aerobics groups had notable drops in body weight and BMI following 12 weeks of training. The cheerleading group experienced a more substantial weight loss ($p < 0.001$), indicating that this type of activity is more beneficial for controlling weight. Both the cheering and aerobics groups had a notable improvement in grip strength, indicating that both types of exercise were successful in enhancing participants' muscle strength. According to this study, cheerleading is more successful at helping people control their weight than aerobics, yet both can significantly enhance the participants' physical health markers. The BMI scores were calculated for each participant in the experiment using the SPSS software package to assess the impact of cheerleading exercises on body mass index (BMI). The violin plot showed that the BMI scores were significantly reduced in the High-Exercise Frequency group compared to the Low-Exercise Frequency group (**Figure 1A**). Additionally, body weight was seen to decrease significantly in the High-Exercise Frequency group compared to the Low-Exercise Frequency group, and exercise frequency was found to be positively and significantly related to BMI reduction (**Figure 1B,C**). Based on the statistical analysis of pre- and post-exercise data, the variations in BMI across different participants were calculated, and the relationship between the duration of exercise and BMI changes are shown in **Figure 2A,B**. The differences in BMI reduction between the High- and Low-Exercise Frequency groups suggested that participants who exercised more frequently experienced more significant BMI reduction, while those with lower frequency showed smaller changes (**Figure 2C,D**). The high-frequency exercise group exhibited significant improvements in all monitored health metrics, including BMI and body fat percentage (**Figure 1E**). The correlation of other health parameters such as muscle strength and fat mass with exercise frequency was further investigated. The frequency of cheerleading exercises was significantly linked to improvements in these health parameters (**Figure 1D**). In the comprehensive dataset (source link), participants in the high-exercise frequency group exhibited significantly better overall fitness improvements, including cardiovascular health and muscle endurance, compared to the low-exercise frequency group after the 12-week intervention (**Figure 2E**).

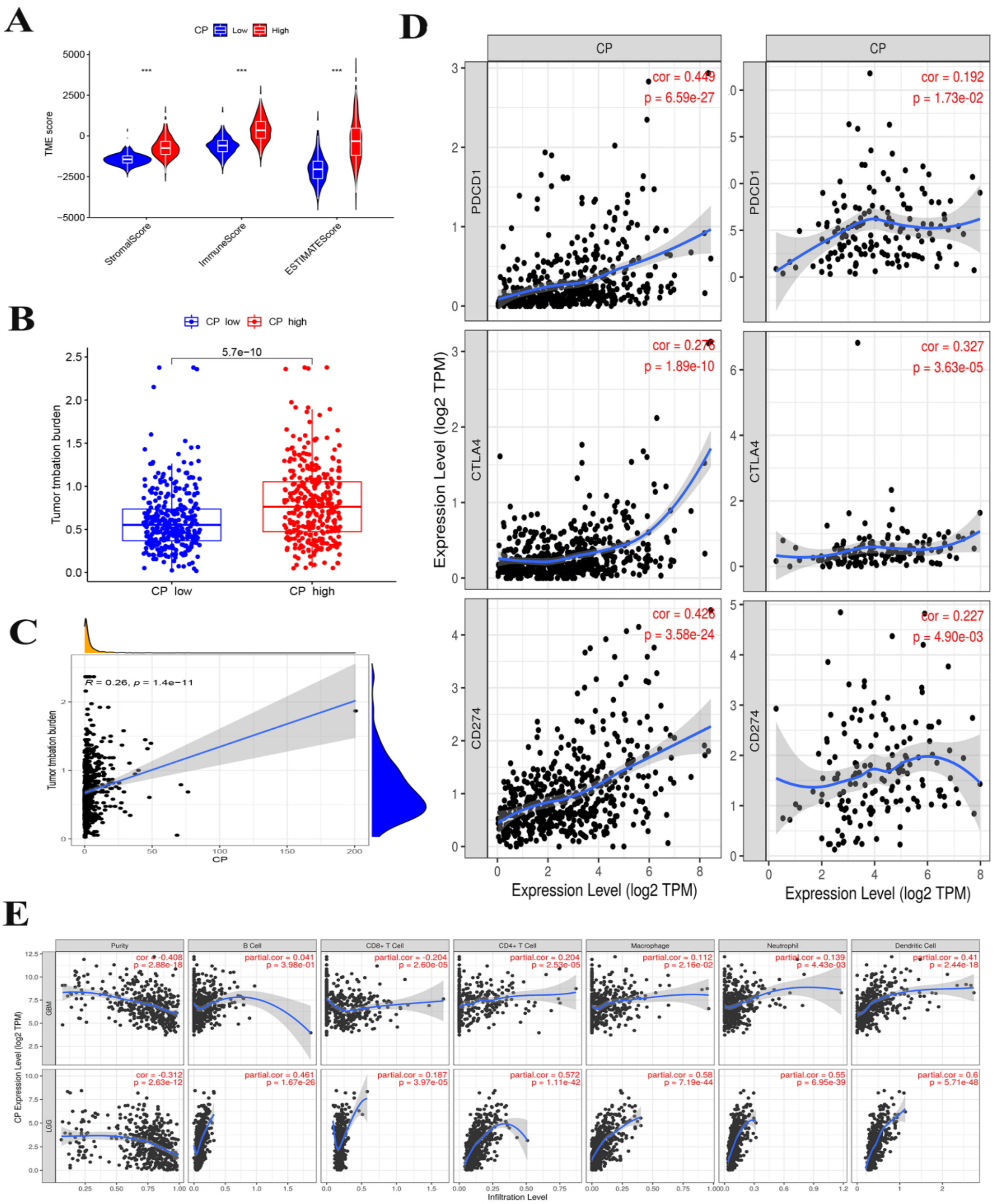

Figure 1. BMI scores between the high-frequency and low-frequency cheerleading exercise groups: **(A)** The BMI scores of cheerleading exercise; **(B)** The body weight comparison; **(C)** The correlation between exercise frequency and BMI reduction; **(D)** Scatterplots of the correlations; **(E)** Exercise frequency in BMI.

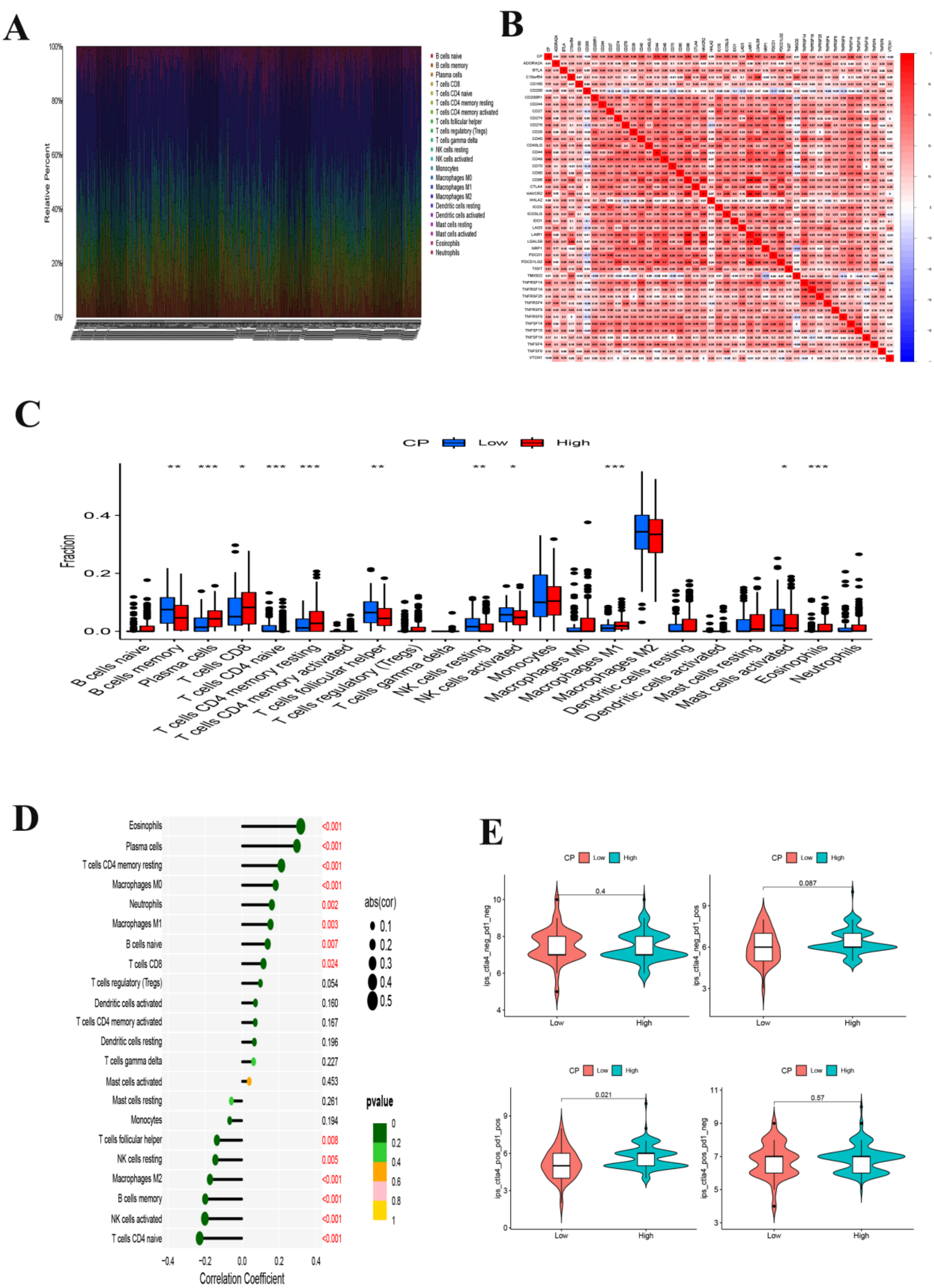

Figure 2. BMI distribution across different cheerleading practice frequencies: **(A)** The BMI distribution; **(B)** The correlation of each BMI-related health factor; **(C)** The variation in BMI across different subgroups; **(D)** The correlation between health-related fitness metrics; **(E)** The impact of high and low exercise frequencies.

5. Discussions

The impact of cheerleading on body composition has received limited attention, although numerous studies highlight the effectiveness of aerobic exercise in improving body composition. Research has shown that obese female college students who engaged in cheerleading exercises experienced significant increases in skeletal muscle content, along with notable reductions in body fat content and percentage. According to this study, middle school girls' body composition could also benefit from cheerleading or aerobic exercise, potentially through increases in protein, muscle, and inorganic salt content, alongside reductions in body fat percentage. However, there is a lack of in-depth microscopic empirical research on the intervention mechanisms by which cheerleading or aerobic exercise affects body composition; current understanding is limited to the exercise effect perspective.

Both cheerleading and aerobic training are aerobic exercises, meaning they rely on an adequate supply of oxygen to fully oxidize and break down body fat. Research has also indicated that aerobic exercise can increase insulin and serum leptin levels in the body. Insulin accelerates the breakdown of glucose and supports gluconeogenesis from fat, while leptin promotes the breakdown of adipose tissue, such as triglycerides, and inhibits fatty acid synthetase, both of which contribute to body fat reduction. Additionally, studies such as [8] have shown that exercise can stimulate muscle growth, evidenced by increased muscle fiber thickness, a rise in myofiber count, and elevated muscle protein content.

The effect of different forms of aerobic exercise on body composition has been further examined in studies such as [9], which found that while both aerobics and jogging can reduce body mass and body fat percentage, aerobics appears to be more effective. This might be attributed to the differences in exercise load characteristics, as aerobic training generally involves higher intensity than cheerleading training, even when the duration of exercise is the same. Furthermore, the frequency, intensity, and duration of exercise could play critical roles in influencing the outcomes of cheerleading and aerobic exercise on body composition. A more in-depth exploration in the Discussion section would help clarify how these factors—particularly the higher exercise load in aerobics—may contribute to the observed differences in effectiveness, as this study suggests that aerobic training may be more beneficial than cheerleading training for improving the body composition of junior high school girls.

Because sport and physical activity are macroscopic manifestations of muscle contraction, numerous studies have demonstrated that they can enhance bone density in people. The mechanical pushing stimulus produced by muscle contraction alters the mechanical environment of the bones, promoting osteoblast activity and increasing bone density. Numerous experimental studies have been conducted in this area, but most of them focus on college students. For instance, [15] found that 20 weeks of aerobics increased the bone density of female college students, and [16] found that aerobics increased the density of female college students' Achilles bones. There are also few studies on the effects of aerobics on human bone density, and even fewer on cheerleading. Additionally, it has been discovered that the impact of sports interventions on BMD is correlated with the sport program, exercise frequency and intensity, the length of a single exercise session, and the duration of the intervention phase within the program [17]. According to the study's findings, cheerleading and aerobics training can both increase the hip bone mineral density of junior high school girls, but the effects on other observation indexes are less clear. Additionally, the intervention effect of aerobics training is superior to cheerleading training, suggesting that while the load structure of the two trainings (program type, exercise intensity, frequency, and single exercise time) has some effect on the improvement of junior high school girls' bone mineral density, aerobics training has a greater impact on movement and exercise intensity than cheerleading training [18], and some studies have found that the duration of the exercise intervention period also affects bone mineral density. This indicates that while the load structure (program type, exercise intensity, frequency, and time) of these two training modalities has a certain effect on raising the BMD of junior high school girls, aerobics training is more intense and has a greater impact than cheerleading training. Additionally, some studies have confirmed that the duration of the intervention period also affects the BMD, such as Shen's study, which found that it takes at least a year to achieve a significant increase in the BMD caused by exercise training, while the training period for either cheerleading or aerobics in this study was only three to six months [19–21].

The study's findings revealed distinct impacts of cheerleading and aerobics training on muscle explosive power in middle school girls. While cheerleading training mainly improved the explosive power of lower limb muscles, aerobics training enhanced the explosive force of both upper and lower limb muscles, including the lumbar abdominal flexors and lumbar back extensors. This difference can be attributed to the technical movement characteristics of each activity. Aerobics demands high levels of explosive force from various body parts, particularly the lower limb muscles, as participants are required to perform rapid movements such as flexion and extension, jumping, rising, turning, and swinging to rhythmic music. This focus on individual strength and aesthetic performance contrasts with cheerleading, which emphasizes positive, energetic teamwork and mainly enhances the explosive power of the lower limbs. In cheerleading, the hands and upper limbs are engaged in supporting movements that require strength but with a balance of flexibility and control, enhancing team spirit and synchronized movement [22–24].

The study also highlights that muscle explosive force, defined as the product of muscle contraction force and contraction speed, can be influenced by the type of muscle fibers involved. Fast muscle fibers, characterized by high force and speed of contraction, may increase in proportion with specific training. Studies have shown that certain training types, such as short-duration cycling, can promote a shift from slow to fast muscle fibers, potentially increasing explosive power. This suggests that aerobics training might increase the proportion of fast muscle fibers in targeted muscle groups, although further research is needed to verify this. Long-term exercise training can also cause adaptive changes in muscle fiber morphology and function, such as fiber thickening, an increase in fiber count, and a rise in mitochondrial density within fibers, all of which can boost explosive power [25].

In summary, cheerleading and aerobics training can improve body composition in middle school girls by enhancing muscle strength and bone density. The technical demands and intensity of aerobics likely contribute to its greater overall effectiveness in comparison to cheerleading.

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References

1. Ridge, Sarah T., et al. Sticking the landing: A comparison of shod vs barefoot landing kinetics and foot muscle characteristics in gymnasts, cheerleaders, and non-athletes. PloS one, 2024, 19.10: e0309157.
2. Renfree, Gillian. Redressing the Balance: Women in Sport and Exercise Academic Network Conference, University of Worcester, United Kingdom, April 19–22, 2021. Women in Sport and Physical Activity Journal, 2023, 31.2: 147–168.
3. Voelker, Dana K., et al. Conforming to reforming: a systems understanding of aesthetic sport coaches' behaviors and practices toward female athletes' bodies. Body Image, 2024, 51: 101784.
4. Balram, Rohini; PANG, Bonnie; KNIJNIK, Jorge. Understanding Indo-Fijian girls' experiences in sport, physical activity and physical education: an intersectional study. Sport, Education and Society, 2024, 29.4: 397–411.
5. Ackerman, Kathryn E., et al. Methodology for studying Relative Energy Deficiency in Sport (REDs): a narrative review by a subgroup of the International Olympic Committee (IOC) consensus on REDs. British Journal of Sports Medicine, 2023, 57.17: 1136–1147.
6. Zou, Ruyun, et al. Study on the relationship and related factors between physical fitness and health behavior of preschool children in southwest China. BMC Public Health, 2024, 24.1: 1759.
7. Sims, Stacy T., et al. International society of sports nutrition position stand: Nutritional concerns of the female athlete. Journal of the International Society of Sports Nutrition, 2023, 20.1: 2204066.
8. Chen, Zhihua. Physical Activities in Pe and Mental Hental: Basis for Enhanced Countermeasures to Physical Activities and Mental Health. International Journal of Biology and Life Sciences, 2023, 4.2: 21–24.
9. Skinner, Annie M., et al. Cross-sectional and longitudinal associations between the 24-hour movement behaviours, including muscle and bone strengthening activity, with bone and lean mass from childhood to adolescence. BMC Public Health, 2024, 24.1: 227.
10. Liu, Chunmei. The Effect of Discussion Method in Environmental Toxicology Teaching. International Journal of Management Science Research, 2023, 6.4: 9–13.
11. Psarianos, Alexandros, et al. The role of physical exercise in opioid substitution therapy: mechanisms of sequential effects. International Journal of Molecular Sciences, 2023, 24.5: 4763.
12. Kasiak, Przemysław, et al. Recalibrated FRIEND equation for peak oxygen pulse is accurate in endurance athletes: the NOODLE study. Scientific Reports, 2024, 14.1: 23133.
13. Boden, Barry P.; ANDERSON, Scott A.; SHEEHAN, Frances T. Catastrophic sports injuries: Causation and prevention. JBJS, 2024, 106.1: 62–73.
14. Mustafa, Ghulam, et al. Effects of Resistance and Strength Training on the Serum Calcium Level of Male Elite Football Athletes. Qualitative Research, 2024, 205–233.
15. Onks, Cayce. 2024 AMSSM Oral Research Poster Presentations. Clin J Sport Med, 2024, 34: 177–245.
16. Bittner, Melissa, et al. Physical Fitness Testing Concerns: Bullying and Inclusion. Physical Educator, 2024, 81.4: 404–428.
17. Miralles-Amorós, Laura, et al. Study the effect of relative energy deficiency on physiological and physical variables in professional women athletes: a randomized controlled trial. Metabolites, 2023, 13.2: 168.
18. Chayun, Danil V. Qualimetry of Psychophysiological Parameters in Aerobic Gymnastics. Журнал Сибирского федерального университета. Гуманитарные науки, 2024, 17.2: 361–373.

19. Hextrum, Kirsten; KNOESTER, Chris; TOMPSETT, James. Inequalities in girls' high school sports participation: How social class, race/ethnicity, and gender route opportunities to play and persist in athletics. Sociological Focus, 2024, 57.2: 63–93.
20. Spears T M, Parikh B, Chalmers P N, et al. Elbow ulnar collateral ligament repair with suture augmentation is biomechanically equivalent to reconstruction and clinically demonstrates excellent outcomes: a systematic review. Arthroscopy, 2023: 00808-3.
21. Xiao Y, Li Z, Xu B. Flexible Triboelectric Nanogenerators based on Hydrogel/g-C3N4 Composites for Biomechanical Energy Harvesting and Self-Powered Sensing. ACS Applied Materials & Interfaces, 2024, 16(11): 13674–13684.
22. Ross L K, Lalka A, Keeter C, et al. Playing surface and sport contact status modulate time to lower extremity musculoskeletal injury at a greater level than concussion history among collegiate student-athletes. Journal of ISAKOS, 2024, 9(4): 628–634.
23. Demiray E B, Kurt T, Duman Z Y, et al. Clinical tissue engineering approach and biotechnological advances to improve athlete healthcare. Spor Hekimliği Dergisi, 2023, 58(4): 185–192.
24. Shing E Z, Wade Z W, Ihn H, et al. Open and arthroscopic management of chondral and chondrolabral defects of the hip. Operative Techniques in Sports Medicine, 2024: 151062.
25. Ferraro S L, Batty M, Heyworth B E, et al. Acute pelvic and hip apophyseal avulsion fractures in adolescents: a summary of 719 cases. Journal of Pediatric Orthopaedics, 2023, 43(4): 204–210.