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Article

Bioefficacy analysis of core strength in cheerleading ala c bar movements and pedestal athletes

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Abstract: Objective: The aim of this study was to investigate the kinematic characteristics of the Ara C-bar maneuver in cheerleading and the effect of base athlete's core strength on their bioefficacy, with a view to providing a scientific basis for enhancing athletes' performance. **Methods:** Kinematic analysis was performed on 99 cheerleaders, and a three-dimensional motion capture system was used to measure key parameters during their movements, and a questionnaire survey was combined to assess the athletes' core strength levels. The relationship between core strength and athletic performance was explored through statistical analysis of the data. **Results:** The results of the questionnaire survey showed that athletes generally agreed on the importance of core strength training, with 85% of the participants indicating that core strength training had a significant effect on improving athletic performance. Kinematic analysis showed that changes in base athletes' hip moments during the Ala C bar movement significantly affected the movement's stability and fluidity. Athletes with higher levels of core strength demonstrated better control and stability during the execution of the movement, which significantly increased the success rate of completing the movement ($p < 0.05$). **Conclusion:** Cheerleading base athletes' effectiveness in the Ala C bar maneuver is significantly impacted by their core strength. Enhancing core strength training enhances athletes' technical proficiency and stability while facilitating the execution of other challenging actions. In order to maximize athletes' competitive level, trainers are advised to concentrate on developing core strength in their training regimens. The impact of various training techniques on the development of core strength and their unique mechanisms of action on athletic performance could be further investigated in future studies.

Keywords: cheerleading; ala C bar; core strength; athletic performance; Bioefficacy

1. Introduction

Cheerleading operates as a sport that integrates gymnastics, dance and skills, and its difficult movements require a high level of strength, flexibility, coordination and core strength [1]. In this context, the study in this paper focuses on the Ala C-bar maneuver in skill cheerleading, especially on the effect of the base athlete's core strength on the biomechanical efficiency of the maneuver. The Ala C-bar maneuver, which originates from ballet, has high rotational difficulty and is one of the most important movements that reflect the skill level of cheerleading [2]. The successful completion of this maneuver requires athletes to have sufficient iliopsoas muscle control, ankle strength and leg flexibility, and therefore puts high demands on athletes' core strength [3]. For base athletes, core strength is not only the key to maintain the stability of the movement, but also directly affects the smoothness and quality of the movement [4]. However, there is a lack of research on the bioefficacy analysis of the core strength of this movement, especially the core strength performance and optimization strategies of base athletes when supporting the team members to complete the Ala C bar movement [5].

In the scoring system of cheerleading, movements such as lifts, throws, and pyramids occupy the majority of the total score [6]. As the executors of these movements, base athletes need to have strong core strength to ensure the stability of the movements and the efficiency of power transmission [7]. Insufficient core strength may lead to unstable center of gravity and unsmooth movements, which may affect the team's overall score [8]. Therefore, it is important to study the effect of core strength of base athletes on the completion of Ala C bar movements to improve the overall performance quality of cheerleading [9]. The analysis of core strength bioefficacy of base athletes not only helps to improve athletes' understanding of their own core strength training, but also provides scientific guidance for coaches [10].

The completion of the Ala C-bar movement involves the synergistic movement of multiple joints and precise core strength control, especially in the continuous rotation phase, where the athlete needs to keep the torso upright while completing multiple rotations supported by the anchor leg, which is extremely difficult [11]. In addition, the performance of core strength of base athletes during dynamic support has not been fully investigated [12]. In actual training, the means of training athletes' core strength mainly relies on basic strength training, such as pushing trolley exercises, plate support exercises and push-up exercises [13]. Although these training methods can increase core strength, they are still insufficient in the pertinence and scientificity of training, and are difficult to be directly reflected in the quality of the completion of difficult movements such as the Ala C bar [14]. In addition, base athletes need to cooperate with the power output of the power leg during the execution of the movement, so how to strengthen the coordination between the power leg and core strength in training has become a major challenge in current research [15].

Existing studies have mostly used the vector parameter method to analyze the kinematics of cheerleading movements, mainly focusing on the modeling of the simplified structure of the human body and the calculation of joint driving moments [16]. The 7-segment S-curve motion planning method proposed in the literature can better simulate the motion trajectories of the joints when athletes execute the AlaC bar movement, but it does not provide an in-depth analysis of the performance of the base athlete's core strength in the support movement [17]. In addition, current kinematic analyses only focus on changes in driving moments in localized areas such as the power leg and hip joint, failing to adequately consider the impact of core strength on overall stability and efficiency [18]. Although these analyses can help athletes understand the importance of the power leg and hip joint to a certain extent, they lack a quantitative description of the dynamic performance of core strength during support, and it is also difficult to guide the core strength training of base athletes [19].

In order to remedy the shortcomings in the current study, this paper further explores the bioefficacy performance of core strength of base athletes in supporting the Ala C bar movement on the basis of the existing kinematic analysis. This paper innovatively adopted a variety of research methods, including literature, observation, questionnaire and mathematical statistics, in order to comprehensively analyze the effects of core strength on base athletes' performance of the Ala C-bar movement. By investigating the athletes of the cheerleading teams of our school and Jilin Sports Institute, this paper not only reveals the significant influence of core strength on the presentation of cheerleading sets, but also compares the grouping of athletes with different years of training to provide targeted suggestions for core strength training. In addition, this paper utilizes mathematical statistics to summarize and analyze the data, aiming to quantify the influence of base athletes' core strength on the quality of Ara C-bar movement completion, and based on this, propose targeted training improvement programs to optimize athletes' core strength performance.

2. Kinematic analysis of the ala C-bar

2.1. Movement points

Ala C-bar is originated from ballet and belongs to the category of difficult movements. The completion of Ala C bar movement has certain requirements on the learner's core strength, iliopsoas muscle control ability, ankle strength, and leg flexibility and agility [20]. The Ala C-bar movement can be divided into the following two stages.

Starting phase.

Step 1: Body facing first, left foot five places in front, hands one place at the ready (**Figure 1**).

Figure 1. Illustration of the start-up phase.

Source: The picture is from Cheer program [21].

Step 2: Move both hands from one to two (**Figure 1**).

Step 3: Scrub the floor with your left foot to the side two position, and open your hands to the seventh position while scrubbing the floor on the side.

Step 4: With the left foot inserted backward, do a four-position squat with both legs, and change the seven-position hand to the six-position with the left hand in front. Then, with the legs and arms, rotate the body counterclockwise (overhead view) for one full rotation to complete the start-up phase, followed by step 5 of the continuous rotation phase (**Figure 1**).

Continuous rotation phase.

Step 5: Half squat with the right leg while the left leg extends out to the second 90 degree position, keeping the pelvis upright and hands to the second position.

Step 6: Straighten the right main leg, reaching the toes. At the same time, open the left leg outward and open both hands actively to the flat seven position. The body rotates counterclockwise by inertia (overhead view) for 1 week, followed by Step 5, forming a cycle of movement.

From the point of view of technical training, the uprightness of the body, the height and openness of the power leg control, and the coordination of the arms, the power leg and the head are the keys to the high quality completion of the Ala C bar movement, pay attention to the center of gravity is always in the main leg, the center of gravity downward, and the main leg squatting and standing movement should be stabilized.

A detailed analysis of the various phases of the Ala C-bar movement will help athletes to better understand and master the essentials of the movement, thus improving the quality of its completion. The movement can be divided into three main phases: the beginning phase, the rotation phase and the end phase.

(1) Starting phase

In the beginning phase, the athlete needs to establish the correct posture and the foundation of the movement. First, facing straight ahead, the left foot is placed in front of the fifth position and the hands are in the first preparatory position. By gradually adjusting the arm position (e.g., from first to second position) and sliding the feet (e.g., sliding the left foot to second position on the side), the athlete is prepared for the subsequent rotational movements. During this phase, special attention should be paid to the stability of the body and the distribution of the center of gravity to ensure that balance is maintained before completing a full rotation.

(2) Spinning Phase

The rotation phase is the core of the Ala C-bar movement. In this phase, the athlete needs to rely on inertia to complete successive rotations of the body and keep the body vertical. The starting position of the rotation is formed by the semi-squat support of the right leg and the abduction of the left leg to reach the 90 degree position. At this point, the hips remain neutralized and the hands are placed in second position. Then, the supporting leg (right leg) is gradually straightened, the left leg is opened outward at the same time, and the hands are spread out to the flat seven position, relying on inertia to complete the counterclockwise rotation. The key is to keep the center of gravity on the main leg and control the rotation speed and posture.

(3) Finishing phase

At the end of the rotation, the athlete needs to restore the initial balance and naturally close the posture to ensure the integrity and grace of the movement. At this time, the left leg can be gradually withdrawn, and adjust the posture of the hands and upper body, slowly stop the rotation, so that the whole movement has a smooth ending. Athletes should keep the center of gravity stable in the ending phase to avoid swaying or losing balance due to inertia.

Technical Training Recommendations

A detailed analysis of the different phases will help athletes focus on improving key techniques during training, such as body alignment, control of the lead leg, arm coordination and stability of the center of gravity. Each phase requires the athlete to maintain focus and precise control to ensure that the center of gravity is always on the lead leg, thus improving the quality of completion of the Ala C-bar movement.

2.2. Kinematic analysis

The continuous rotation phase is the main phase of the AlaC bar motion, so this paper mainly analyzes this phase. In order to facilitate the model description, we take the 5th step of the continuous rotation phase of the AlaC bar as the initial state, and take its front direction as the y-axis direction to model the human body. Taking the right leg as the main leg and the left leg as the power leg as an example, the simplified structure of the human body is shown in **Figure 2**, and the body parts represented by each serial number are listed in **Table 1**, and the dimensions of the body parts measured by an athlete are listed in **Table 1**.

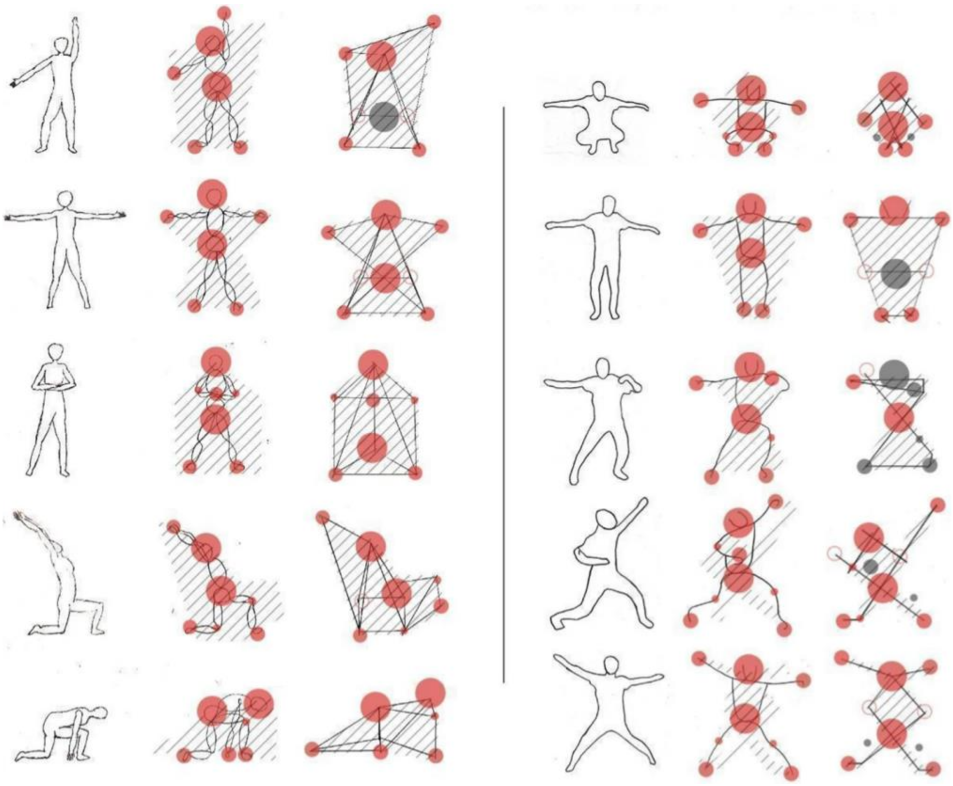

Figure 2. Model of human body structure.

Table 1. Human body structure number and size parameters.

Part Number			**Dimension**		
Serial number	**Joint**	**Component**	**Name**	**Symbol**	**Value/cm**
1	Right heel	Right foot	Right High	l_1	9
2	Right ankle	Right calf	Calf length	l_2	36
3	Right Knee	Right thigh	Thigh length	l_3	45

Table 1. (*Continued*).

Part Number			Dimension		
Serial number	**Joint**	**Component**	**Name**	**Symbol**	**Value/cm**
4	Right Hip	Torso	Hip Spacing	w_1	31
5	Left Hip	Left leg	Shoulder Spacing	w_2	40
6	Right shoulder	Right Upper Arm	Shoulder-hip height difference	h_1	37
7	Left shoulder	Left Upper Arm	Upper arm length	l_4	30
8	Right elbow	Right lower arm	Lower arm length	l_5	21
9	Left Elbow	Left lower arm			

In this paper, the vector parameter method is used for kinematic analysis. In **Figure 2**, $oxyz$ is the global coordinate system, and the joint coordinate system $o_i x_i y_i z_i$ (not shown in **Figure 2**) is fixed to member i. The initial direction $oxyz$ is consistent with that of the joints, and the rotational axis vectors e_i of the joints are shown in **Figure 3**, and their values are listed in **Table 2**. θ_i denotes the angle of rotation of member i around the rotary axis e_i (relative to the coordinate system $o_s x_s y_s z_s$, s is the number of the root member connected to member i, hereinafter), b_i is the linkage vector, denotes the vector o_s pointing to o_i, the expression of which is included in **Table 2**. In **Table 2**, α_2 and α_3 are the angles of the calf/thigh with respect to the positive direction of the z-axis in the initial state (their values are taken as 30). Note that joint 4 (right hip joint) has two degrees of freedom, the first one is rotation around the e_4'-axis with an angle of θ_4', and the second one is rotation around the e_4-axis with an angle of θ_4.

Table 2. Joint and rod vector parameters.

$\boldsymbol{i}$	$\boldsymbol{e_i}$			$\boldsymbol{b_i}$		
	$\boldsymbol{e_{ix}}$	$\boldsymbol{e_{iy}}$	$\boldsymbol{e_{iz}}$	$\boldsymbol{b_{ix}}$	$\boldsymbol{b_{iy}}$	$\boldsymbol{b_{iz}}$
1	1	0	0	0	0	0
2	0	1	0	0	0	l_1
3	1	1	0	0	$l_2 \times \sin\alpha_2$	$l_2 \times \cos\alpha_2$
4 (1)	0	1	0	0	$-l_3 \times \sin\alpha_3$	$l_3 \times \cos\alpha_3$
4 (2)	1	0	0	0	0	0
5	0	1	0	$-w_1$	0	0
6	0	1	0	$-(w_1 - w_2)/2$	0	h_1
7	0	1	0	$-(w_1 + w_2)/2$	0	h_1
8	0	1	0	0	l_4	0
9	0	1	0	0	l_4	0

Define the chi-square transformation matrix.

$$rotx(\theta,b)=\begin{bmatrix}1 & 0 & 0 & b_x\\ 0 & cos\theta & -sin\theta & b_y\\ 0 & sin\theta & cos\theta & b_z\\ 0 & 0 & 0 & 1\end{bmatrix} \quad (1)$$

$$rotz(\theta,b)=\begin{bmatrix}cos\theta & -sin\theta & 0 & b_x\\ sin\theta & cos\theta & 0 & b_y\\ 0 & 0 & 1 & b_z\\ 0 & 0 & 0 & 1\end{bmatrix} \quad (2)$$

Then the chi-square transformation matrix for each component i can be obtained from the vector parameters in **Table 2** as:

$${}^{s}H_i=\begin{cases}rotx(\theta,b_i) & (i=2,3)\\ rotx(\theta',b_i)rotz(\theta_i,0) & (i=4)\\ rotz(\theta_i,b_i) & (i\neq 2,3,4)\end{cases} \quad (3)$$

As a result, the position H_i of each member i in the global coordinate system can be obtained as:

$$H_i=\begin{cases}\prod_{j=1}^{i} {}^{i-1}H_i (i=1,2,3,4)\\ H_4\,{}^{4}H_i (i=5,6,7)\\ H_6\,{}^{6}H_i (i=8)\\ H_7\,{}^{7}H_i (i=9)\end{cases} \quad (4)$$

2.3. Motion planning

Considering an ideal situation, assuming that the athlete's torso and supporting leg keep rotating at the same angular velocity during the movement, and the rotation time of 1 week is T = 1 s, of which the opening leg time is t_k = 0.2 s and the closing leg time is t_h = 0.8 s, then the output angles of the body parts at the three moments of t = 0, t_k, T are planned as listed in **Table 3**.

The Ala C-bar maintains an overall rotation of the body at the t = 0, t_k, T moments, and therefore has the following velocity plan:

$$\dot{\theta}_i(t)=0,(i\neq 1,t\in\{0,t_k,T\}) \quad (5)$$

Table 3. Output angle planning (unit: degrees).

Freedom	Open and close both arms			Single arm opening and closing			Size ***T***		
	0	t_k	***T***	**0**	t_k	***T***	**0**	t_k	***T***
θ_1	0	70	360	0	70	360	0	70	360
θ_2	0	0	30	0	0	30	0	0	30
θ_3	0	−30	0	0	−30	0	0	−30	0

Table 3. (*Continued*).

Freedom	**Open and close both arms**			**Single arm opening and closing**			**Size *T***		
	0	t_k	***T***	**0**	t_k	***T***	**0**	t_k	***T***
θ_4	0	0	0	0	0	0	0	0	0
θ_5	0	90	0	0	90	0	0	90	0
θ_6	0	−90	0	0	0	0	−90	−90	−90
θ_7	0	90	0	0	90	0	90	90	90
θ_8	0	0	0	0	0	0	150	0	150
θ_9	0	0	0	0	0	0	−150	0	−150

The 7-segment S-curve proposed in the literature was used to plan the motion of each joint except the right heel, and the displacement curves of each joint were obtained as shown in **Figure 3**.

The data in the article mainly demonstrates the movement parameters and angle planning of each joint and limb, but it lacks an in-depth exploration of the biological and physiological mechanisms behind these data. For example, the effects of each joint angle and velocity on the athlete's body structure and muscle groups during exercise could be explained, and how athletic performance could be optimized by adjusting these parameters. Further discussion of the role of these joint angles on muscle loading, muscle control and body stability will help the reader to understand the physiological importance of these parameters.

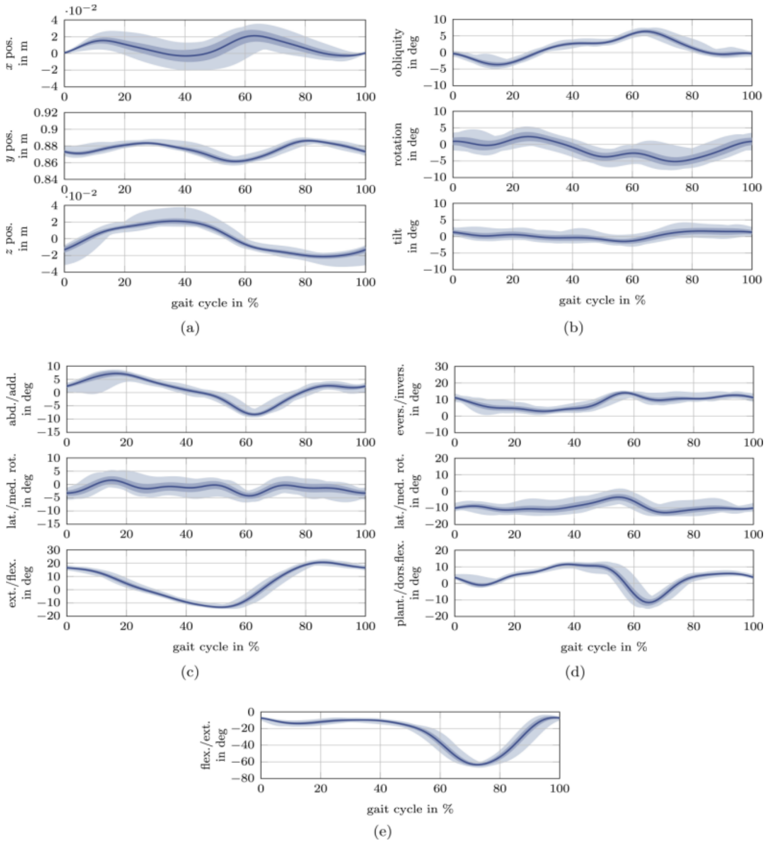

Figure 3. Motion planning for each joint.

It is possible to explain how the parameters listed in the table meet the demands of specific phases of Ala C-bar exercise, such as the body's ability to support, rotate and maintain balance. In particular, the double-degree-of-freedom rotation for the right hip can be further explored in terms of how the movement is achieved and the demands placed on the athlete's muscle control. Combining this data with biomechanical requirements can better demonstrate why specific parameter settings are required at a given stage of the movement.

the values in angle planning indicate the changes in the athlete's stance at each moment in time, but it is possible to analyze in more detail how these angles affect muscle contraction, joint pressure distribution, and the demands placed on the core musculature. In particular, the 7-segment S-curve involved can be explained how it helps to control the smoothness of motion at each joint, reducing joint loading and optimizing movement fluidity.

Maintaining synchronized angular velocities of the trunk and the supporting leg in motion planning actually places high demands on the body's coordination and core strength. The physiological basis behind this control strategy can be further explained, such as the role of core muscles in supporting balance and rotation.

By digging deeper into these biological and physiological dimensions, the background and rationale of the data can be better demonstrated to help readers understand the importance of the data from a mechanistic perspective, thus enhancing the scientific and professional nature of the article.

3. Optimization of ara C-bar hand movements

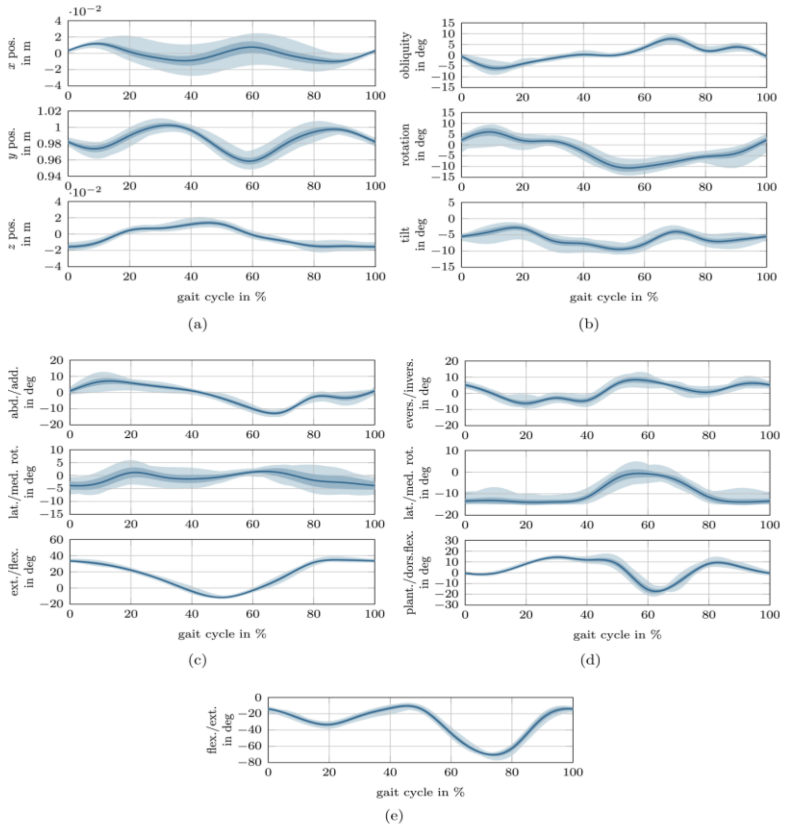

Figure 4. Right heel driving moment.

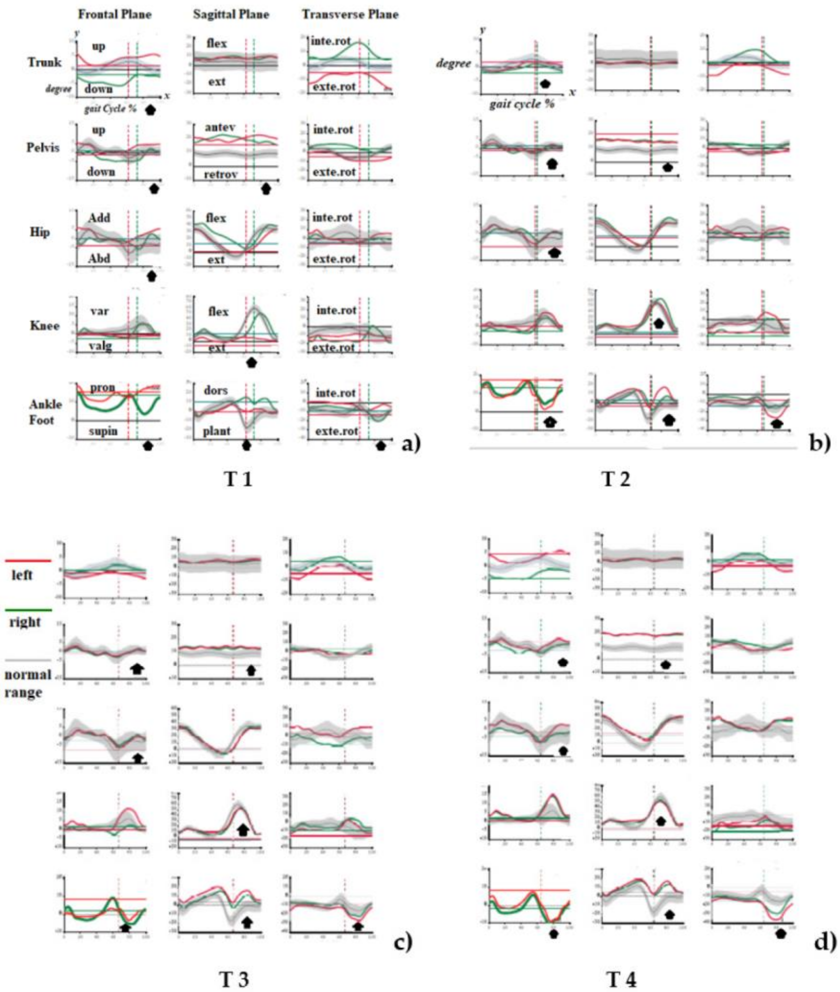

Figure 5. Hip driving moments.

From **Figures 4** and **5**, the following analysis results can be obtained. In section 2.3, motion planning is performed for the leg movements and three common hand movements of the Ara C bar, and the required driving moments of each joint can be obtained by substituting the results of the motion planning into Equation (4), of which the driving moment curves of the right heel, hip, and shoulder joints, which are more important for the dynamic analysis, are shown in **Figures 6–8**, respectively.

(1) From **Figure 5**, it can be seen that the left hip joint driving force corresponding to the three hand movements is basically the same, indicating that the left hip joint driving force is independent of the hand movements.

(2) The maximum driving moment (absolute value) of the left hip joint (power leg) is about 11, which is larger than the driving moments of other joints. Therefore, the power leg is the main source of power for the Ara C-bar maneuver. Since the torso and the right leg are set to rotate at a uniform speed, only a portion of the driving moment of the left hip joint is transmitted to the right heel through the left hip joint.

(3) From **Figure 5**, it can be seen that among the three hand movements, the heel joint and right hip joint driving moments required for the size T are the smallest, and the magnitude of the driving moments is also the smallest, which indicates that this movement is easier to be mastered by the athletes.

4. Research object and method

Objects of study: core strength training and its methods for skill cheerleading base athletes

Subjects: Our school's Joyful Sun Cheerleading Team; Jilin Sports Institute Skill Cheerleading Team

Research Methods

Literature method: searching and reviewing the literature about the employment situation of college students through China Knowledge Network and reading related books to provide theoretical support for this study.

Observation method: By observing the training of our school's Jiao Yang Cheerleading Team, we found problems from it and conducted the research.

Questionnaire survey method: to our school skill cheerleading team athletes, coaches, and Jilin Sports Institute skill cheerleading team athletes, the skill cheerleading base athletes core strength training and its methods to investigate. Jilin Sports Institute and our school skill cheerleading training methods are basically the same, are used to basic strength training means to carry out core strength training, mostly using simple two head up exercises, push trolley exercises, flat support exercises, push-up exercises and other means [22,23].

Questionnaire design: the survey object 99 athletes (61 athletes in our school; 38 athletes in Jilin Institute of Physical Education), athletes issued 100 copies, 99 copies were recovered, the effective number of 99 copies, the effective rate of 99.

Mathematical and statistical method: the use of inductive summary, comparative analysis, logical analysis of the content and results of the interviews to analyze and summarize for a more in-depth study of the skills cheerleading core strength training to do a summary.

5. Results and analysis

5.1. Importance of core strength in skill cheerleading programs

The individual scores for slogan, lifting, pyramid, blue throw, tumbling, set fluency, transition, and overall impression, audience attraction, etc. are added up to determine the final score in the skill cheerleading competition. The highest percentage of the score, which made up 75% of the total, was earned by lifting (25 points), throwing and catching (15 points), pyramid (25 points), and tumbling (10 points). Strong physical fitness is necessary to complete the program's most demanding component flawlessly. For the base athlete to finish the competitive exercises, core attributes are particularly crucial. In order to maintain stability and enhance the different capacities amongst the muscles, a base athlete must have a strong core. This is achieved through the management of brain nerves.

In **Table 4**, the number of people with three months of training is dominant at 59%, followed by those with more than two years of training at 23%, followed by those with one year of training at 15%, and the remaining two years and six months are very small in percentage.

Table 4. Years of training in skill cheerleading.

	Number of respondents	Three months	Six months	One year	Two years	More than two years
Male	55	30.6%	5.5%	18.0%	26.6%	19.7%
Female	45	52.5%	6.6%	9.3%	13.8%	18.3%
Total	100	59%	4%	15%	8%	23%

In **Table 5**, the number of people who think that the core strength has a great influence on the display of sets of movements accounted for 77% of the total number of people, the influence of the general accounted for 21%, and the number of people who think that there is no influence accounted for 2%, of which 71.2% of the male students think that the strength of the core strength of the technique cheerleading has a great influence, 26.9% of the people think that the influence of the general, and only a small part of people think that there is no influence, which only accounted for 1.9% of the male students. 1.9% of the total number of male students; 68.0% of female students think that core strength has a great influence on skill cheerleading, 22.8% think that it has a general influence, and 9.2% think that it has no influence. So the skill cheerleading athletes think that core strength has a very important influence on the skill cheerleading program, and we should pay more attention to the core strength training in the training [24,25].

Table 5. The effect of core strength on the presentation of skill cheerleading routines.

	Number of respondents	Has a significant impact	Average influence	No impact
Male	55	71.2%	26.9%	1.9%
Female	45	68.0%	22.8%	9.2%
Total	100	77%	21%	2%

5.2. Research on core strength training content of skill cheerleading base athletes

Table 6 shows that skill cheerleading athletes in ordinary training often core strength training accounted for 51% of the total number of investigators, of which boys accounted for 62.7%, girls accounted for 45.6%, and in the training of occasional core strength training of boys accounted for 26.8%, girls accounted for 31.8%, which shows that skill cheerleading athletes in the training of the training attaches great importance to the training of the core strength.

Table 6. Frequency of core strength training in skill cheerleading training.

	Number of respondents			
Male	55	62.7%	26.7%	10.6%
Female	45	45.6%	31.9%	22.5%
Total	100	51%	36%	13%

Skill Cheerleading Core Strength Training.

Cheerleading skill action highlights the word “stable”, in skill cheerleading set action or single action, the completion of the whole set of action is required to be “stable”, stable, high quality can better reflect the athlete’s proficiency in the whole set of action. When the top athletes are doing skill movements, the base athletes play the role of foundation, which puts higher requirements on the core strength of the base athletes, and only if the base strength is strong enough, can they make more difficult skill movements. The proportion of core strength training methods chosen through the questionnaire survey is shown in **Table 7**.

Table 7. Skill cheerleading core strength training frequently used movements (multiple choice).

	Number of respondents	Weighted or deadlift exercises	Self-supporting or weighted log lifts and repetitions	Weighted or deadlift planks	Deadlift with own weight or weight	Compound push and pull exercises	Controlled Inversion Exercise	Trolley Push Exercise	Inverted Crawling Exercise
Male	55	46.6%	26.9%	32.0%	28.8%	23.3%	25%	21.5%	21.5%
Female	45	33.9%	19.5%	27.5%	17.7%	15.8%	13.5%	25%	15.8%
Total	100	64%	39.9%	47%	40.8%	29.9%	30.1%	35.1%	29.1%

According to the data in **Table 7**, in daily training, male athletes chose weighted or self-weighted double overhead presses (46.6%) the most, and other training contents accounted for a relatively even proportion in training, among which self-weighted or weighted planks (32.0%) and self-weighted or weighted push-ups (28.8%) were the training methods chosen by male athletes with a larger proportion. Among female athletes, because of their different roles in the team, the movements of female athletes were more inclined to core strength in unstable condition, so they had to train core strength in a more comprehensive way when choosing the training content, in which deadlift or deadlift double overhead (33.9%) was the most chosen content, followed by deadlift or deadlift plate support (27.5%). Of the total number of players, 64% chose the deadlift or deadlift double overhead exercise and 47% chose the deadlift or deadlift plate support exercise.

5.3. Problems of core strength training for skill cheerleading base athletes

5.3.1. Inadequate awareness of core strength training

Core strength training has been discussed more often in the context of sports program training in recent years, and both coaches and players have become more aware of the value of core strength for sports programs. A single muscle cannot sustain a sports program; rather, a combination of muscles is needed to overcome technical challenges. Similar to this, a good core strength training method involves more than just working the main muscles in the core; it also involves deep muscle training and the application of the principle of lateral migration. To maximize the effectiveness of the exercise, the training should be integrated with the sports program to determine its content. There is currently no clear theory to explain core strength training, according to several academics, and the theoretical choice of core strength training differs. The technique used to control the stabilizing state of the pelvic and trunk position muscles during skill cheerleading training is known as "skill cheerleading core strength training." In **Table 8**, the players' knowledge of core strength is not very perfect, in which the proportion of male players who know more about core strength (53.5%) is the largest, and most of the female players have only heard of core strength training (52.2%), and the ones who know a lot about core strength only account for 9.1% of the total number of girls, so it is necessary to popularize the knowledge of core strength among the players in the future training. We should popularize the knowledge of core strength to the players in the future training [26,27].

Table 8. Whether they know about core strength training or not.

	Number of respondents	Realise	Fairly well	I've heard of it	Never heard of it
Male	55	21.5%	53.5%	21.5%	3.5%
Female	45	9.2%	25.1%	52.2%	13.5%
Total	100	17%	41%	30%	12%

5.3.2. The effect of formation choreography

Cheerleading cheerleading players neatly arranged that is, repetition, the composition of the graphic has a sense of rationality, order and rhythmic aesthetics. (**Figure 6**) Repeat composition reflects the harmony and unity of the flower ball cheerleading formation changes, the overall visual effect. Cheerleaders are neatly and orderly arranged, and the height and angle of the kicking leg are high and consistent, including the turning of the head, which fully demonstrates the neatness and rhythmic beauty. Neat and orderly is the product of the rules of flower ball cheerleading, and at the same time, it is in line with the "beauty" that has been symbolized by people through many times.

Figure 6. Visual effect of flower ball cheerleading formation.

Source: The picture is from Cheerleaders arms raised Stock Photos and Images [28].

High and low ups and downs, frequent changes, and staggering are used in flower ball cheerleading formation changes to create a powerful sense of movement and visual impact, providing viewers with a lovely visual experience. (**Figure 7**) The entire image conveys a sense of leaping and space, and the use of ups and downs and interlacing transforms the entire formation into a dynamic change of beauty. The use of flower balls up and down, left and right ups and downs, and interlacing creates tension while also bringing a distinct and clear feeling by neatly lining up.

Figure 7. The visual effect of undulating and staggered formation of flower ball cheerleading.

Source: The picture is from Cheerleaders arms raised Stock Photos and Images [28].

Radiation and agglomeration composition can cause visual illusion, have a center point, have a very strong focus and form the center of vision, human vision will also be led to the center point, the flower ball cheerleading formation changes in the process of using this principle of aesthetic composition, so that the changes in the formation of the formation of a more visual effect. (**Figure 8**) The use of radiation and agglomeration, the rapid gathering and spreading of the formation, in the form of gathering or dispersion, makes the visual impact extremely strong.

Figure 8. Flower ball cheerleading change formation visual effect.

Source: The picture is from Cheerleaders arms raised Stock Photos and Images [28].

6. Conclusion

By methodically examining the kinematic characteristics of the Ala C bar movement and the bioefficacy of core strength in base cheerleaders, the following findings were obtained from this study:

The Ala C-bar movement's kinematic analysis revealed that the athlete's ability to fully utilize their core strength as well as effectively regulate their iliopsoas and leg strength was necessary to complete the movement. The movement's breakdown revealed that the legs played a major driving role throughout the start and continuous rotation phases, while the athlete received steady support from the hip joint's moment change characteristics.

The study's findings demonstrated that base athletes' stability and performance in challenging movements are directly impacted by their core strength. We verified the value of core strength training in raising athletes' overall competitive level by a questionnaire survey and statistical analysis of 99 athletes.

This study suggests a number of focused training techniques meant to boost base athletes' performance by strengthening their cores, based on the kinematic analysis and the significance of core strength. These techniques not only help athletes stay stable throughout the Ala C bar maneuver, but they also offer a theoretical foundation and helpful advice for using it in other challenging maneuvers.

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References

1. Carrillo-Hormaza, L., López-Parra, S., Stahr, P. L., Keck, C. M., & Osorio, E. (2023). Natural dispersion of biflavonoids from Garcinia madruno extracts: A green and sustainable processing to improve the solubility and dissolution rate. Food and Bioproducts Processing, 141, 199-209.
2. Swaminathan, N., Anandham, R., Paranidharan, V., & Balachandar, D. (2023). Evaluation of Suitable Polymers for the Development of High-Concentrated Liquid Biofertilizers. International Journal of Plant & Soil Science, 35(19), 731-740.
3. Geetha, R., & Vijayalakshmi, R. (2023). Study on the performance of natural fiber reinforced concrete of different strength with DIP technique and T-Test Analysis. Journal of Materials and Engineering Structures «JMES», 10(2), 227-240.
4. Schumacher, S., Tahiri, H., Ezan, P., Rouach, N., Witschas, K., & Leybaert, L. (2024). Inhibiting astrocyte connexin-43 hemichannels blocks radiation-induced vesicular VEGF-A release and blood–brain barrier dysfunction. Glia, 72(1), 34-50.
5. Chen, Y. K., Simon, I. A., Maslov, I., Oyarce-Pino, I. E., Kulkarni, K., Hopper, D., ... & Del Borgo, M. P. (2023). A switch in N-terminal capping of β-peptides creates novel self-assembled nanoparticles. RSC advances, 13(42), 29401-29407.
6. El Ghoubary, N. M., Fadel, M., & Abdel Fadeel, D. (2024). Non-pigmented laser hair removal mediated via sepia melanin nanoparticles: in vivo study on albino mice. Drug Development and Industrial Pharmacy, 50(6), 524-536.
7. Konstantinidou, M., Visser, E. J., Vandenboorn, E., Chen, S., Jaishankar, P., Overmans, M., ... & Arkin, M. R. (2023). Structure-Based Optimization of Covalent, Small-Molecule Stabilizers of the 14-3-3σ/ERα Protein–Protein Interaction from Nonselective Fragments. Journal of the American Chemical Society, 145(37), 20328-20343.
8. He, S., Zhang, J., Liu, Z., Wang, Y., Hao, X., Wang, X., ... & Wang, R. (2023). Upregulated cytoskeletal proteins promote pathological angiogenesis in moyamoya disease. Stroke, 54(12), 3153-3164.
9. Wu, Z., Huang, X., Huang, L., & Zhang, X. (2024). 102-Plex Approach for Accurate and Multiplexed Proteome Quantification. Analytical Chemistry, 96(4), 1402-1409.
10. Xiao, J., Tian, W., Abdullah, Wang, H., Chen, M., Huang, Q., ... & Cao, Y. (2024). Updated design strategies for oral delivery systems: Maximized bioefficacy of dietary bioactive compounds achieved by inducing proper digestive fate and sensory attributes. Critical Reviews in Food Science and Nutrition, 64(3), 817-836.
11. Purkait, A., Hazra, D. K., Kole, R., Mandal, S., Bhattacharrya, S., & Karmakar, R. (2024). Harnessing the Carrier Solvent Complexity of Crop Biostimulant Liquid Formulations Using Locally Available Transesterified Waste Cooking Oil: Economic Recycling, Solvent Performance, and Bioefficacy Evaluation. Journal of Agricultural and Food Chemistry, 72(2), 1017-1024.
12. Guo, L., & Sun, Y. (2024). Economic Forecasting Analysis of High-Dimensional Multifractal Action Based on Financial Time Series. International Journal for Housing Science and Its Applications, 45(1), 11-19.

13. Altay, A., & Mirici, İ. H. (2024).Efl Instructors' Implementations of 21st Century Skills in Their Classes. International Journal for Housing Science and Its Applications, 45(2), 37-46.
14. ZHAO, Jingjing. The Semantic Function of Modern Chinese" Negation+ X" Modal Words Based on Communication Technology and Big Data Corpus. Journal of Combinatorial Mathematics and Combinatorial Computing, 122: 275-286.
15. Wu, Y. (2024). Exploration of the Integration and Application of the Modern New Chinese Style Interior Design. International Journal for Housing Science and Its Applications, 45(2), 28-36.
16. Chen, P. (2024). Research on Business English Approaches from the Perspective of Cross-Cultural Communication Competence. International Journal for Housing Science and Its Applications, 45(2), 13-22.
17. Abbasi, A., Hashemi, M., Kafil, H. S., Astamal, M. A., Lahouty, M., Tajani, A. G., ... & Nasirifar, S. Z. (2024). A critical review on the bioavailability promotion of the food bioactive compounds: nano lipid carriers perspective. Pharmaceutical Sciences, 30(3), 282-303.
18. Tiwari, S., Singh, B. K., & Dubey, N. K. (2023). Aflatoxins in food systems: recent advances in toxicology, biosynthesis, regulation and mitigation through green nanoformulations. Journal of the Science of Food and Agriculture, 103(4), 1621-1630.
19. Zhao, C., Liu, D., Feng, L., Cui, J., Du, H., Wang, Y., ... & Zheng, J. (2024). Research advances of in vivo biological fate of food bioactives delivered by colloidal systems. Critical Reviews in Food Science and Nutrition, 64(16), 5414-5432.
20. Mokarrami, A., Capacci, A., Trio, B., Della Morte Canosci, D., & Merra, G. (2024). Relationship between Gut-Microbiota and Sport Activity. Central European Journal of Sport Sciences and Medicine, 45, 25-53.
21. Cheer program. Available online: https://www.tumbleshine.com/cheer (accessed on 1 October 2024).
22. Suttithumsatid, W., Toriumi, T., Sukketsiri, W., Nagasaki, Y., & Panichayupakaranant, P. (2024). Enhanced Stability of α-Mangostin-Rich Extract and Selective Cytotoxicity against Cancer Cells via Encapsulation in Antioxidant Nanoparticles (AME@ NanoAOX). ACS Biomaterials Science & Engineering, 10(8), 5027-5038.
23. XIAO, Ting; LI, Qiong. The Evaluation of Classroom Teaching Quality of College Business English Translation Based on AI and Central Tendency Adaptive Enhancement. Journal of Combinatorial Mathematics and Combinatorial Computing, 119: 53-62.
24. Jadhav, A. C., Annaldewar, B. N., & Jadhav, N. C. (2023). 2 A current perspective on nanocomposite and nanohybrid material: Developments and trends. Nanocomposite and Nanohybrid Materials: Processing and Applications, 17, 29-54.
25. Safaeian Laein, S., Katouzian, I., Mozafari, M. R., Farnudiyan-Habibi, A., Akbarbaglu, Z., Shadan, M. R., & Sarabandi, K. (2024). Biological and thermodynamic stabilization of lipid-based delivery systems through natural biopolymers; controlled release and molecular dynamics simulations. Critical Reviews in Food Science and Nutrition, 64(22), 7728-7747.
26. Lu, H., Wang, J., Huang, M., Ahmad, M., Cong, L., Tian, M., ... & Tan, C. (2023). Bitterness-masking assessment of luteolin encapsulated in whey protein isolate-coated liposomes. Food & Function, 14(7), 3230-3241.
27. Zhang, P., Sun, J., Li, J., Zhang, H., & Liu, K. (2023). Biosynthesis, assembly, and biomedical applications of high-performance engineered proteins. ACS Chemical Biology, 18(7), 1460-1472.
28. Cheerleaders arms raised Stock Photos and Images. Available online: https://www.alamy.com/stock-photo/cheerleaders-arms-raised.html?sortBy=relevant (accessed on 1 October 2024).