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Effect of Ballet Dance on Ankle Joint Muscle Strength Based on Isokinetic Research

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Abstract: *Several studies have demonstrated that dance training can enhance muscle strength. This study aims to compare the muscle strength of ankle joints between college students with and without ballet dance training, analyzing the differences between the two groups and explaining the influence of dance on muscle strength. A total of 48 healthy college students volunteered to participate, with the experimental group consisting of 24 ballet students (12 males, aged 21.5±0.9 years; 12 females, aged 20.9±1.8 years) and the control group consisting of 24 non-dance students (12 males, aged 20.7±0.9 years; 12 females, aged 20.6±0.8 years). The German ISOMED2000 Isokinetic test device was used to measure ankle joint strength, with angular velocities set at 60° and 180° and the testing mode set to concentric-concentric. The testing included ankle joint flexion and extension movements, and the measured indicators included peak torque (PT), relative peak torque (PT/BW), relative work (TW/BW), relative peak power (PP/BW), and peak torque ratio of flexion and extension(H/Q). By comparing these five indicators of ankle joint isokinetic motion between ballet students and non-dance students, as well as comparing the results with athlete data, the following findings were observed: 1) Ballet students exhibited higher peak torque, relative peak torque, and relative peak power of ankle joint flexor muscles compared to non-dance students, indicating that ballet training significantly improves the maximum strength of ankle joint flexor muscles. 2) The comparison of relative work indicates that ballet training significantly enhances the work capacity of ankle joint flexor muscles. 3) Through the comparison of relative work, relative peak torque, and peak torque ratio of flexion and extension, it was observed that sports such as short-track speed skating and fencing, similar to ballet, can significantly improve ankle joint flexor muscle strength. However, short-track speed skaters and fencers showed higher relative strength in ankle joint extensor muscles compared to non-dance students, whereas ballet students exhibited relatively lower relative strength in ankle joint extensor muscles compared to non-dance students.*

Keywords: *Isokinetic; Ankle Joints; Muscle Strength; Ballet*

1. Isokinetic Technique in Dance Science Research

The isokinetic technique, also known as isokinetic muscle testing and training, is an advanced practical technology for assessing and training muscle function. It has been widely used in muscle function evaluation, exercise training, and injury rehabilitation. [1] In recent years, numerous research studies and practical demonstrations have provided theoretical and practical support for the application of the isokinetic technique in dance training.

Compared to the research in the fields of sports science and rehabilitation medicine, the use of the isokinetic technique in dance science research is relatively limited. Existing studies include the research conducted by D. T. Kirkendall et al., who used the Cyber II isokinetic testing system to investigate the isokinetic strength characteristics of the hamstring muscles and quadriceps femoris in ballet dancers before and during performances.[2] Robin D. Chmelar et al. compared the isokinetic strength characteristics of the knee joints in ballet dancers and modern dancers using the Cybex II isokinetic system to evaluate potential differences between different dance disciplines.[3] Shira C. Hedgepeth conducted knee joint training and testing research on ballet dance learners using the Cybex 11+ isokinetic testing system.[4] Maya Cale'-Benzoor studied the trunk muscle performance characteristics and lumbar spine range of motion in classical ballet dancers using The Lido Back isokinetic trunk dynamometer.[5] However, there is limited research on the isokinetic muscle strength characteristics of the ankle joints in dancers, with only the study conducted by Thomas Kathleen et al. In their research, they tested and studied the isokinetic strength characteristics of ankle plantar flexors in folk dancers, ballet dancers, and non-dancers using the Biodex isokinetic system. Six angular velocity modes were

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set, including 60°/s, 90°/s, 120°/s, 180°/s, 240°/s, and 300°/s, to evaluate the isokinetic muscle strength characteristics among different professional groups. The experimental results showed that the peak torque of the ankle plantar flexors in folk dancers and ballet dancers was significantly greater than that of non-dancers. Additionally, although the peak torque of folk dancers and ballet dancers was similar, due to the strict control of body weight for aesthetic purposes in ballet dancers, the ankle plantar flexor strength advantage in ballet dancers was more pronounced objectively. [6]

2. Role of Ankle Joint Muscle Strength in Dance

The ankle joint supports the entire body weight of dancers, and the majority of dance movements are performed while bearing weight on the ankles. Strong and balanced foot strength is essential to support the body's weight, withstand the transmission of changes in body speed, power, and movement direction, and cope with the resulting high loads. It plays a crucial role in propelling dancers to jump, absorb shock, and maintain stable dance postures. Therefore, ankle joint strength is vital for the execution of dance techniques.

The muscles around the ankle joint extend from the front and back of the inner and outer ankles to the dorsum, heel, and sole of the foot. Their contractions cause dorsiflexion, plantar flexion, inversion, eversion, and internal and external rotation of the ankle and foot. In dance training, all movements involving pointed or flexed feet and squatting actions are performed by the contraction and exertion of the anterior muscles of the ankle joint. The most fundamental exercise in dance class is the "point and flex" exercise, which aims to train ankle strength and lay the foundation for future lower limb movements, dance steps, and various technical skills. In ballet, the *plié*, particularly during a first and fifth position *Grand plié*, requires significant ankle joint strength to withstand the body's weight and control the center of gravity throughout the movement. Strengthening ankle joint strength greatly contributes to shaping dance postures, improving the flexibility of squatting movements, and enhancing the quality of various technical skills such as jumps and turns in dance.

Ankle joint strength is a focal point of dance training and a prerequisite for performing various dance movements. Only with strong ankle joint strength can dancers possess resilient and stable support and execute a variety of footwork. Most dance movements are performed with support from the feet, making the feet the only body part in contact with the floor. The reaction forces from the floor need to be transmitted through the feet. Whether it is ballet, Chinese folk dance, Chinese classical dance, or contemporary dance, foot movements are indispensable. In ballet, in particular, the training of ankle joint strength is of utmost importance. From the first training exercise in ballet class, *Battement tendu*, to the graceful movements on pointe shoes, the support and utilization of ankle joint strength are essential. A beautiful arch of the foot and powerful lower limbs are the aspirations of every dancer.

In dance, ankle movement serves as the solid foundation for full-body motion. Only with flexible and strong ankles can the body's dance movements have a sturdy base. Skills such as jumping, turning, and control in dance all rely on the capabilities of the ankles. Ballet, in particular, places extremely high demands on the feet and requires significant ankle mobility to perform movements on pointe. The feet must be both powerful and flexible, and their use extends beyond their natural range of motion. Therefore, dancers need to enhance foot strength and flexibility. In various other dance styles, techniques involving rapid footwork, *relevés*, squats, running, jumping, or spinning are essential and each dance style has its specific foot placement requirements. Thus, ankle ability is the most important fundamental aspect of dance training. Training exercises that improve ankle ability in dance include pointing and flexing, demi-pointe, *tendu*, small jumps, and other exercises performed on the floor, barre, or with the feet off the ground. These exercises aim to develop dancers' ankle ability to meet the demands of dance movements and enhance their performance in dance. A notable characteristic of dance instruction is training foot strength, flexibility, and the specific range of motion required when dancing on demi-pointe or pointe. The significant forces generated during this process are absorbed by the ankle joint, making ankle injuries relatively common in dance. Therefore, ankle joint strength is crucial for dancers, directly impacting the quality and level of dance technique. Research on ankle joint strength can contribute to the development of training methods and means to enhance ankle ability.

To investigate the characteristics of ankle isokinetic strength in ballet students, this study employed isokinetic technology to test ankle flexion-extension and internal-external rotation isokinetic torques in ballet students. The same set of tests was conducted on ordinary university students (no dance training) using the same testing methods. By comparing the results of the two groups and comparing them with existing relevant research findings, the characteristics of ankle isokinetic strength in ballet students

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were analyzed.

3. Research Objectives

This study selected a total of 48 college students as participants, with 12 male and 12 female ballet majors from Beijing Dance Academy (2013 and 2014 cohorts) and 12 male and 12 female students from the School of Information Engineering at Minzu University of China (2014 cohort). The ballet majors were assigned to the experimental group, while the regular university students (without ballet training experience) served as the control group. All participants were in good physical health with no recent significant injuries, and no adverse reactions were observed during the testing process.

Table 1: Overview of Experimental Subjects

Subject	Gender	Number	Age (years)	Height (cm)	Weight (kg)	Training Duration (years)
Ballet	Female	12	20.9±1.8	166.6±6.1	51.2±4.5	10±1.7
	Male	12	22.2±2.6	181.4±4.0	71.6±7.4	10±2.0
Non-dance	Female	12	0.6±0.8	162.3±6.1	52.2±6.3	0
	Male	12	20.7±0.9	170.9±4.4	61.7±6.3	0

4. Research Design and Methods

The isokinetic muscle strength test in this study was conducted using the Isomed2000 isokinetic testing system, a product from Germany, to measure isokinetic parameters.

The test included angular velocities of 60°/s and 180°/s. The testing mode was concentric-concentric, and the number of test repetitions was based on completing one flexion or extension per cycle. Four cycles of testing were performed at each angular velocity, and four cycles constituted one set. There were two sets of tests for each movement mode, encompassing both 60°/s and 180°/s. A 15-second rest period was given between sets, and the joint range of motion was kept consistent throughout the repeated testing process. The test began with a slow-speed phase (60°/s), consisting of four cycles per set. It emphasized sustained exertion and reaching the designated range of motion with each repetition. Subsequently, the same actions were performed at a fast speed (180°/s). After completing the test on one side, the same procedure was repeated on the other side. The joint movement mode tested was flexion-extension. The ankle joint test indicators included peak torque (PT), relative peak torque (PT/BW), relative work (TW/BW), relative peak power (PP/BW), and peak torque ratio (H/Q), totaling five parameters.

The isokinetic muscle strength test data results were subjected to statistical analysis using SPSS software. The specific procedure involved inputting the collected data into a computer and storing it in Excel format. The SPSS 11.0 statistical software was used to process the data, and the data for each group were presented as means and standard deviations (±S). Independent samples t-tests were conducted to assess significant differences between groups. A significance level of $P<0.05$ indicated statistical significance, while $P<0.01$ indicated highly significant differences.

5. Results and Analysis

The collected data were subjected to statistical analysis using SPSS software. The analysis revealed no significant differences in the test results between ballet major students and regular university students in terms of left and right ankle joint measurements. Therefore, this study focused only on the analysis and discussion of the data from the right side.

5.1 Peak Torque (PT) of Ankle Joint Flexion and Extension

Based on Table 2, it can be observed that the peak torque of the ankle flexor muscles in male ballet major students is significantly higher than that in regular university students, with an extremely significant difference ($P<0.001$). The peak torque of the ankle flexor muscles at an angular velocity of 60°/s in female ballet major students is higher than that in regular university students, showing a highly significant difference ($0.001\leq P<0.01$). The peak torque of the ankle flexor muscles at an angular velocity of 180°/s in female ballet major students is also higher than that in regular university students, but the difference is not significant ($P>0.05$). The peak torque of the ankle extensor muscles in male

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ballet major students is significantly higher than that in regular university students, but the difference is not significant (P>0.05). The peak torque of the ankle extensor muscles in female ballet major students is significantly lower than that in regular university students, but the difference is not significant (P>0.05).

Table 2: Peak Torque of Ankle Joint Flexion and Extension (unit: N•m)

		Flexion		Extension	
Angular Velocity (°/s)		60	180	60	180
Male	Ballet	117.91±23.05***	74.42±11.3***	28.62±4.04	23.91±3.84
	Non-dance	71.03±13.04***	49.67±9.32***	27.15±5.42	21.54±4.18
Female	Ballet	66.34±14.59**	43.02±9.54	16.26±3.11	14.19±2.09
	Non-dance	49.94±12.95**	34.51±6.99	17.23±2.92	14.58±1.82

Note: Data from ballet majors and non-dance majors were subjected to independent samples t-tests. *Significant difference (0.01≤P<0.05); **Highly significant difference (0.001≤P<0.01); ***Extremely significant difference (P<0.001).

The above data indicate that ballet training can significantly improve the maximum absolute strength of the ankle flexor muscles. This is related to the emphasis on foot pointing and dancing en pointe in ballet training. The strength of the ankle flexor muscles is one of the most fundamental aspects of ballet training. From the first movement, *Battement tendu*, to movements such as *Releve*, the training focuses on strengthening the ankle flexor muscles. Later techniques like *sauté*and *Pirouette* are also built upon a strong foundation of ankle flexor muscles. The peak torque of the ankle extensor muscles in female ballet major students is lower than that in regular university students, indicating that their maximum absolute strength in movements like "pointing the foot" is weaker than that of regular university students. This may be attributed to the less frequent training of ankle extensor muscles involved in "pointing the foot" in ballet training. It mainly aims to stretch the muscles at the back of the lower leg and the Achilles tendon, with minimal involvement of the ankle extensor muscles. Therefore, it is recommended to moderately strengthen the ankle extensor muscles (including the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and third fibularis muscles) in female ballet classes, while ensuring the specific training requirements of ballet training.

According to the literature in the field of sports research [7], it is known that for peak torque of the ankle flexor muscles, short-track speed skaters > ballet major university students > regular university students. For peak torque of the ankle extensor muscles, female short-track speed skaters > regular female university students > ballet major female university students. At an angular velocity of 60°/s, the peak torque of the ankle extensor muscles is higher in male short-track speed skaters > ballet major male university students > regular male university students. At an angular velocity of 180°/s, the peak torque of the ankle extensor muscles is similar between male short-track speed skaters and ballet major male university students. It can be concluded that short-track speed skating training places higher demands on ankle joint flexion and extension muscle strength compared to ballet training.

5.2 Relative Peak Torque (BW) of Ankle Joint Flexion and Extension

Table 3: Relative Peak Torque of Ankle Joint Flexion and Extension (unit: Nm/Kg)

		Flexion		Extension	
Angular Velocity (°/s)		60	180	60	180
Male	Ballet	1.61±0.33**	1.03±0.15**	0.39±0.06	0.33±0.06
	Non-dance	1.15±0.18**	0.8±0.12**	0.44±0.07	0.35±0.04
Female	Ballet	1.03±0.16**	0.72±0.09**	0.3±0.04	0.25±0.03
	Non-dance	0.96±0.2**	0.66±0.1**	0.33±0.04	0.28±0.03

Note: Data from ballet majors and non-dance majors were subjected to independent samples t-tests. *Significant difference (0.01≤P<0.05); **Highly significant difference (0.001≤P<0.01); ***Extremely significant difference (P<0.001).

Based on Table 3, it can be observed that the ballet students exhibit significantly higher relative peak torque in the flexor muscles compared to regular university students, with a highly significant difference (0.001≤P<0.01). However, there is no significant difference in the relative peak torque of the extensor muscles between the ballet students and regular university students (P>0.05).

In comparison to the peak torque data mentioned earlier, the differences in relative peak torque between the experimental and control groups are more significant, indicating the effectiveness of measuring the relative strength differences between ballet students and regular university students. The

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data on relative peak torque demonstrates that ballet training significantly improves the maximum relative strength of ankle joint flexor muscles. This can be attributed to the emphasis on pointing the foot and standing on tiptoes in ballet training. The relative peak torque of the ankle joint extensor muscles in ballet students is lower than that of regular university students, indicating weaker relative strength in performing actions such as pointing the foot. Therefore, it is recommended that ballet students, while ensuring the requirements of professional training, should moderately strengthen the ankle joint extensor muscle group, including the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius.

According to data from literature in the field of sports [8], in ankle joint flexion and extension at 60°/s angular velocity, the relative peak torque of the flexor muscles is higher in fencing athletes than in ballet students and regular university students. Similarly, the relative peak torque of the extensor muscles is higher in fencing athletes than in regular university students and ballet students. This indicates that fencing training places a greater emphasis on ankle joint flexion and extension muscle strength compared to ballet training.

5.3 Relative Work (TW/BW) of Ankle Joint Flexion and Extension

Table 4: Relative Work of Ankle Joint Flexion and Extension

		Flexion		Extension	
Angular Velocity (°/s)		60	180	60	180
Male	Ballet	1.09±0.21***	0.79±0.11***	0.27±0.04	0.19±0.04
	Non-dance	0.74±0.15***	0.6±0.1***	0.31±0.06	0.21±0.04
Female	Ballet	0.91±0.18**	0.66±0.14**	0.23±0.03	0.17±0.03
	Non-dance	0.67±0.14**	0.47±0.09**	0.24±0.03	0.16±0.02

Note: Data from ballet majors and non-dance majors were subjected to independent samples t-tests. *Significant difference (0.01≤P<0.05); **Highly significant difference (0.001≤P<0.01); ***Extremely significant difference (P<0.001).

Based on Table 4, it can be observed that the relative work of ankle joint flexion in male ballet major students is significantly higher than that of regular university students, with an extremely significant difference (P<0.001). The relative work of ankle joint flexion in female ballet major students is significantly higher than that of regular university students, with a highly significant difference (0.001≤P<0.01). However, the relative work of ankle joint extension in male ballet major students is not significantly different from that of regular university students (P>0.05). Similarly, there is no significant difference in the relative work of ankle joint extension at an angular velocity of 60°/s between female ballet major students and regular university students (P>0.05).

These data indicate that ballet training can improve the ability of ankle joint flexor muscles to sustain force, thereby enhancing their work capacity. This is attributed to the emphasis on pointing the toes and standing on tiptoe in ballet training. In ballet training, whether it is pointing the toes or performing demi-pointe and en pointe movements, they occur alternately and repeatedly throughout the entire training session, leading to continuous exertion of force by the ankle joint flexor muscles (including the gastrocnemius, soleus, flexor hallucis longus, and flexor digitorum longus), resulting in an improvement in their work capacity. However, the relative work of ankle joint extensor muscles in some ballet major students is lower than that of regular university students, indicating a weaker work capacity during movements like hooking the foot. Therefore, it is recommended that ballet major students should moderately strengthen the training of the ankle joint extensor muscle group (including the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and fibularis tertius) while ensuring the requirements of their professional training.

5.4 Relative Peak Power (PP/BW) of Ankle Joint Flexion and Extension

Based on the data presented in Table 5, it can be observed that male ballet major students exhibit significantly higher peak relative power in ankle joint flexion compared to regular university students at an angular velocity of 60°/s, with a highly significant difference (0.001≤P<0.01). Similarly, at an angular velocity of 180°/s, male ballet major students also demonstrate significantly higher peak relative power in ankle joint flexion compared to regular university students, with a highly significant difference (0.01≤P<0.05). On the other hand, female ballet major students show noticeably higher peak relative power in ankle joint flexion compared to regular university students, but the difference is not statistically significant (P>0.05). Additionally, the peak relative power of extension muscles in female

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ballet major students and male university students during ankle joint flexion at an angular velocity of 60°/s is significantly lower than that of regular university students, although the difference is not statistically significant (P>0.05).

Table 5: Relative Peak Power of Ankle Joint Flexion and Extension (Unit: W/Kg)

		Flexion		Extension	
Angular Velocity (°/s)		60	180	60	180
Male	Ballet	1.05±0.21***	1.36±0.3*	0.26±0.03	0.37±0.09
	Non-dance	0.7±0.16***	1.06±0.27*	0.27±0.05	0.34±0.06
Female	Ballet	0.76±0.18	0.93±0.29	0.2±0.04	0.24±0.06
	Non-dance	0.62±0.15	0.79±0.17	0.21±0.03	0.26±0.04

Note: Data from ballet majors and non-dance majors were subjected to independent samples t-tests. *Significant difference (0.01≤P<0.05); **Highly significant difference (0.001≤P<0.01); ***Extremely significant difference (P<0.001).

These findings suggest that ballet training significantly enhances the maximum relative strength of ankle joint flexor muscles. This can be attributed to the emphasis on pointing the foot and dancing en pointe in ballet training. However, it should be noted that some ballet major students exhibit lower peak relative power in ankle joint extensor muscles compared to regular university students, indicating weaker maximum relative strength when performing movements such as leg extension. Therefore, it is recommended that ballet major students appropriately strengthen the ankle joint extensor muscle group (including the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius) in addition to meeting the specific training requirements of their ballet program.

5.5 Peak Torque Ratio (H/Q) of Ankle Joint Flexion and Extension

Table 6: Peak Torque Ratio of Ankle Joint Flexion and Extension

Angular Velocity (°/s)		60	180
Male	Ballet	4.16±0.82***	3.19±0.75**
	Non-dance	2.67±0.5***	2.34±0.37**
Female	Ballet	4.07±0.34***	3.02±0.42**
	Non-dance	2.91±0.59***	2.38±0.4**

Note: Data from ballet majors and non-dance majors were subjected to independent samples t-tests. *Significant difference (0.01≤P<0.05); **Highly significant difference (0.001≤P<0.01); ***Extremely significant difference (P<0.001).

Based on Table 6, it can be observed that ballet major university students exhibit a significantly higher ratio of peak torque between ankle joint flexor and extensor muscles during ankle flexion and extension exercises at an angular velocity of 60°/s when compared to regular university students. The differences are extremely significant (P<0.001). At an angular velocity of 180°/s, ballet major students also have a higher peak torque ratio compared to regular university students, with the differences being highly significant (0.001≤P<0.01).

The above data indicate that ballet training emphasizes pointing and standing on tiptoe, leading to enhanced strength in the ankle joint flexor muscles. As a result, the ratio of flexor to extensor muscle strength in ballet major university students is significantly higher than that of regular university students. The ratio of peak torque in ankle joint among ballet major students demonstrates a distinct professional characteristic, which is closely related to long-term specialized training. While maintaining the professional requirements, ballet major students may appropriately strengthen the strength training of ankle joint extensor muscles to ensure relative balance and joint stability.

Studies in the field of sports science have shown that the ratio of peak torque between ankle joint flexor and extensor muscles during ankle flexion and extension exercises at an angular velocity of 60°/s follows the order of fencing athletes (front leg) > ballet major university students > short-track speed skaters > regular university students. At an angular velocity of 180°/s, the order is short-track speed skaters > ballet major university students > regular university students. This indicates that fencing, short-track speed skating, and ballet training all emphasize training of ankle joint flexor muscles to a greater extent than extensor muscles. In fencing, the front leg serves as the braking and supporting leg during lunge movements, requiring constant eccentric and concentric contractions of the muscles surrounding the ankle joint. In short-track speed skating, the ankle joint acts as the finishing point of the entire push-off action, and the muscles surrounding the ankle joint control the main joint muscles for controlling the skating path. The intensity differences in these three training methods result in

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variations in the ratio of peak torque between flexor and extensor muscles. Due to the emphasis on power during rapid movements in short-track speed skating and the emphasis on ankle flexion during ballet training, the ratio of peak torque is higher in short-track speed skaters at a fast speed (180°/s), whereas ballet major university students exhibit a higher ratio at a slow speed (60°/s).

6. Conclusion and Suggestion

Based on the measurements and analysis of five indicators of ankle joint isokinetic exercises in ballet major and regular university students, as well as comparisons with athlete data, the following conclusions can be drawn: 1) Ballet major university students exhibit higher peak torque, relative peak torque, and relative peak power of ankle joint flexor muscles compared to regular university students. This indicates that ballet training significantly improves the maximum strength of ankle joint flexor muscles. 2) By comparing the relative work, it is evident that ballet training significantly enhances the functional capacity of ankle joint flexor muscles. 3) Comparing the relative work, relative peak torque, and peak torque ratio between flexion and extension, it is observed that sports such as short-track speed skating and fencing, similar to ballet, can significantly improve the strength of ankle joint flexor muscles. However, short-track speed skaters and fencing athletes demonstrate higher relative strength in extensor muscles compared to regular university students, while ballet major university students exhibit lower relative strength in ankle joint extensor muscles. In light of these findings, it is recommended that ballet major university students focus on targeted exercises to strengthen ankle joint extensor muscles while ensuring the requirements of their professional training.

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