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Study on the Influence of Elastic Compression Pants Elasticity and Movement Speed on Human Joint Protection

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Abstract
The aim of this study was to clarify how human movement speed and pants elasticity affect the athletic performance of knee joint protection by testing pants with different elastic properties: CP1 (tight pants) and CP2&CP3 (elastic compression pants), which reinforce the knee joint. In addition, CS (cotton sport pants) was developed as a control garment. Three subjects wore CP1, CP2, CP3 and CS while running on the treadmill at three kinds of human movement speed. A three-dimensional motion capture instrument was used to capture the three-dimensional trajectory of the marked points of lower limbs. As a result, the influence of the movement speed on the kinematic parameters (AKJ & gait cycle) was more obvious than the fabric elasticity. If elastic pants are worn during running, the change of AKJ will be stable with the increase of speed. When non-elastic pants are worn, the effect is opposite. Not only that, elastic compression pants are efficient in reducing the motion amplitude of the knee joint during the suspension period as far as 41°, making it highly practical in terms of stability. That is, the elastic fabric can protect the joints when the lower limbs are in motion. Moreover, with the increase of speed and elasticity, the elastic pants can reduce the gait cycle by up to 22% compared with non-elastic pants alone. Through the kinematics mechanism of human joints, these findings may translate into an effect on protective performance and a reduction in sport injuries. Therefore, it is necessary to wear elastic pants, especially compression pants, when running at higher speed, as the average gait cycle gradually decreases. This research shows that the knee joint protection functions of elastic compression garments differ according to the level of elasticity and differential movement speed, providing theoretical support for designing and producing elastic compression pants. It also acts as a guide for the research of lower limb joint protection.

Keywords
fabric materials, movement speed, protective performance, angle of knee joint, 3D motion capture.

1. Introduction

Elastic compression pants are formed by upgrading on the basis of tight-fitting sweatpants, which basically inherits the structure and characteristics of tight-fitting sweatpants. They can reduce the vibration of the wearer's leg muscles during exercise, and alleviate the impact of strenuous exercise on the knee joint, displaying a significant effect on athletic performance and reducing injuries[1, 2, 3].

Knee joints are the most delicate and complex joints of the human body and are prone to injury. When an external load is over the critical value of muscle, the external impact will cause damage to the knee joints, easily resulting in secondary damage[4, 5]. Taking longitudinal movement as an example, a change in the flexion angle of the hip and knee joints in longitudinal movement will cause lower limb injuries[6, 7]. Not only that, a reduction in the knee flexion angle may increase the moment of knee extensor muscle, leading to ligament overload[8, 9]. Therefore, an increase in the knee flexion angle in the longitudinal movement of lower limbs, such as jumping movement, may effectively reduce the probability of knee joint injury.

However, clothing's protective performance is mainly through pressure generated by dressing to share the ligament load and enhance the stability of joints, in order to help joints scatter too much improper force[10]. Therefore, it is very important and essential to study the protective effect of sportswear on the knee joint. In previous research of knee protection, Yan et al. [11] explored the effect of wearing knee pads on the knee flexion angle and found that a sudden stop and turn around would make a strong twist of the knee joint and cause damage. Greene et al. [12] evaluated the effects of prophylactic knee braces on an athlete's speed and agility and concluded that braces showed a variable tendency in migration and could affect the protective function as well as the athlete performance. Steffen et al. [13] studied the impact force of different directions & different heights on the knee joint, and found that the effect of the knee protection device depends on the direction and height of the impact. The above-mentioned researches basically focus on how to use knee pads to protect the knee joint, but in daily life people seldom wear knee pads when running as it is one of the most common sports activities. In fact, nowadays more and more enthusiasts choose compression pants as their daily sports trousers because these trousers can not only improve the subjective comfort of sports but also play a role in relieving fatigue [14, 15] and speed up sports recovery [16, 17].

The whole running process is a chain movement; skeletal joints such as the hip, knee and ankle joints are linked with each other by absorbing, generating and transmitting energy to the next link to complete the energy transmission of the whole process of movement [18]. However,

Subjects	HT/(cm)	WT/(kg)	WC/(cm)	HC/(cm)	TC/(cm)	KC/e(cm)	AC/(cm)	BMI
S1	163.1	47.8	64.0	88.0	53.0	35.4	24.3	17.99
S2	164.0	49.2	68.0	89.0	56.0	36.0	25.1	18.29
S3	162.6	47.5	64.5	87.6	53.5	35.0	24.5	17.96
Mean	163.0	48.2	65.5	88.2	54.2	35.5	24.6	18.08
SD	(0.6)	(0.8)	(4.75)	(0.5)	(1.7)	(0.3)	(0.2)	(0.35)

Note(s): HT-Height; WT-Weight; WC-Waist circumference; HC-Hip circumference; TC-Thigh circumference; KC-Knee circumference; AC-Ankle circumference

Table 1. Body shape parameters of subjects (n=3)

	CP1	CP2	CP3	CS
Fabric	85% nylon 15% spandex	80% nylon 20% spandex	76% nylon 24% spandex	100%cotton
Knee circumference /cm	30	28	26	40
Applied percentage of fabric stretch/%	Wale: 63.5 Course: 76.3	Wale: 78.1 Course: 81.6	Wale: 84.2 Course: 86.8	Wale: 46.3 Course: 50.5

Table 2. Experimental compression pants

the joints of lower limbs, as the bearing parts of ground impact, will be subjected to greater load, especially in order to obtain a greater speed of movement. The lower limbs are often twisted to a great extent, and it is easy to generate greater force, thus causing joint damage. In the past, the effect of joint protection was usually evaluated by using ROM as an index, but the operation of measuring the range of motion by a goniometer is cumbersome and the accuracy insufficient [19, 20]. On the other hand, until now most researches have focused on studying the effects of knee pad and related products. The development of technology, especially three-dimensional motion capture equipment, makes the accurate measurement and evaluation of human knee movement possible. At the same time, as more and more people like to wear compression pants which are comfortable and make it easy to move when running or jogging, it is necessary and of great importance to clarify the protection mechanism of compression garments on the human knee by using three-dimensional motion capture technology.

Therefore, in this paper, the protective effect of elastic compression pants during running were investigated and the influence of running speed and the elasticity of compression pants is discussed. Besides this, the angle of the knee joint was chosen and measured to evaluate the evaluation index of the protective effect. The paper aimed to interpret how movement speed and the fabric elasticity of compression pants affect the athletic performance of knee joint protection. The result of this paper can help instruct on the design and manufacture of comfortable sports-wear to prevent or decrease the unnecessary injuries caused by improper clothes.

2. Experimental methods

2.1. Subjects of experiment

A review of the relevant literature[21,22,23] shows that more research has been done on the changes in exercise parameters in males caused by compression pants, while less has been done on females. Besides that, there are individual differences between males and females. Hence, this paper took females as the research subject. Three females aged 22 with an average body size were chosen as the subjects, whose details are shown in Table 1. All subjects reported no history of orthopedic injury of the lower extremity joints. Before testing, informed written consent was obtained from each subject in accordance with the University's Ethics Committee. The data obtained by each experimenter are multiple cycles, so that the trend of the human joint protective effect can be obtained.

2.2. Experimental clothing

According to the market research results, one pair of tight pants (CP1) and two pairs of elastic compression pants (CP2 & CP3) with a higher spandex content and gradient compression effect (MZP-X, China) were selected for the experimental clothing. All of these garments were ergonomic and met the needs of women in sports condition. In addition, one pair of cotton sport pants (CS) was added to compare the influence of fabric parameters on the protection effect of the human knee joint. The basic parameters are shown in Table 2.

2.3. Test device

A treadmill (U20, provided by Zhejiang U-may technology Co. Ltd.) and a Qualisys-Oqus500+ dynamic capture instrument (provided by Sweden Qualisys Co. Ltd.) were adopted in the experiments. The dynamic capture instrument, surrounded by 9 cameras, was able to capture the whole laboratory and motion capture software as well as data export software were used to process the three-dimensional coordinates of the point after optically capturing the marker ball on the experimental object. The instrument is shown in Fig. 1.

Fig. 1. Dynamic capture instrument

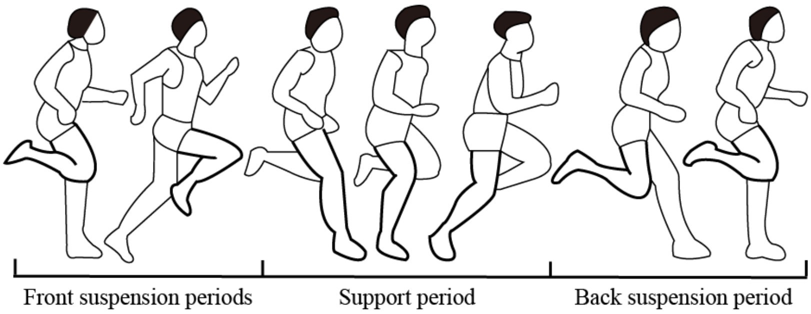


Fig. 2. Running cycle

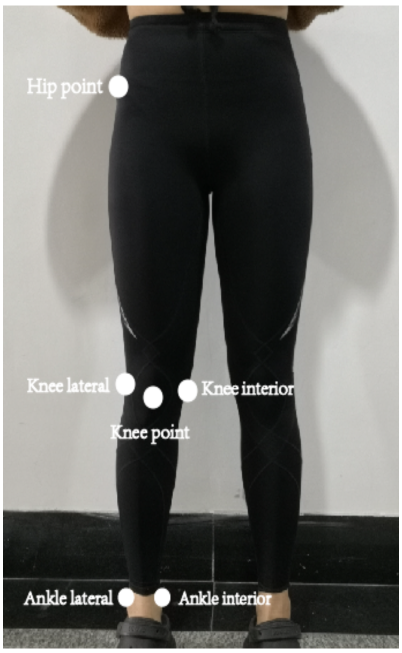


Fig.3. Distribution of lower limb marker points

Corresponding part	Marker point name
Hip joint	HP (hip point)
Knee joint (lateral and interior)	KP (knee point), KL (knee lateral), KI (knee interior),
Ankle (lateral and interior)	AL (ankle lateral), AI (ankle interior),

Table 3. Rigid body and corresponding names of the marker point

2.4. Establishment of marker points

The movement cycle of the lower limb during our running process is shown in Fig. 2. From Fig 2 we can see that the running cycle consists of front suspension, support & back suspension periods and both legs have nearly the same movement characteristics. When the left leg is in the position of the support period, the right leg is in the position of the suspension period. Furthermore, the included angle between the thigh & calf, i.e. the angle of the knee joint, is changing constantly and the angle of the knee joint for the leg in the support period is larger than that of the leg in the suspension period.

Since both legs have the same movements, one was necessary for further investigation and the left leg was taken as an example to be the dynamic capture object of the test. With the movement characteristics and the marking point definition rules recommended by the instrument taken into consideration, three, two and one marker points were selected and stuck on the thigh, calf and hip parts of the pants, respectively, shown in Fig. 3 & Table 3.

2.5. Data acquisition

As shown in Fig. 4, in the process of periodic gait movement, the knee angle is the included angle between the thigh and calf, hence the angle of the knee joint (AKJ) is selected for evaluation. In order to verify the influence of compression pants on human joint protection performance, three experimental subjects were required to wear pants with different elasticity, shown in Table 2, and run on the treadmill at a speed of 5km/h, 8km/h and 11km/h. The three speeds can represent low, medium and high speed during daily running.

After the space vector coordinates of each marker point were obtained, the knee joint midpoint (KMP) and ankle joint midpoint (JMP) were calculated using the intermediate coordinates of KL & KI, AL & AI. Then the knee angle β was acquired according to the formula of the space vector included angle and the anti-formulas of trigonometric functions calculated, shown in Eq. (1) and Eq. (2).

$$\alpha = \frac{(x_{KMP}-x_{HP})(x_{KMP}-x_{JMP})+(y_{KMP}-y_{HP})(y_{KMP}-y_{JMP})+(z_{KMP}-z_{HP})(z_{KMP}-z_{JMP})}{\sqrt{(x_{KMP}-x_{HP})^2+(y_{KMP}-y_{HP})^2+(z_{KMP}-z_{HP})^2}\sqrt{(x_{KMP}-x_{KMP})^2+(y_{KMP}-y_{KMP})^2+(z_{KMP}-z_{JMP})^2}} \quad (1)$$

$$\beta = arcos(\alpha) \quad (2)$$

Where α is the cosine of the joint angle, and β is the angle of the knee joint (AKJ).

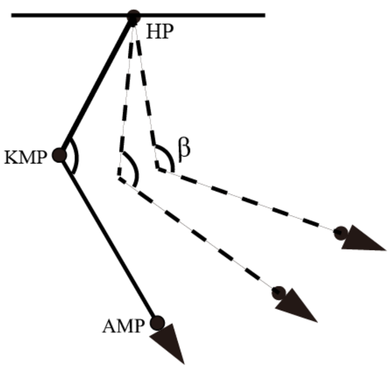


Fig. 4. Diagram of left side of lower limb during running

3. Results and discussion

3.1. The influence of individual differences on AKJ

Since there are differences among the body shape parameters of experimental subjects, in order to verify whether there is any difference in the protective performance when different subjects wear the same pants at the same running speed, the AKJ values of different experimental subjects were plotted. As we found that there are similar trends for CP1 to CP3, they could be grouped as the elasticity category, in comparison with CS, the non-elasticity group. Fig. 5 and Fig. 6 show the results of three subjects wearing CP2 and CS at three different speeds, representing the elasticity and non-elasticity groups, respectively. From Fig. 5 and Fig. 6, it can be seen that except 5km/h, the overall AKJ change trends of the different subjects in different states are basically similar and the curve changes show a wave shape, with concaves and peaks in different degrees.

From Fig. 5 and Fig. 6, we can also see that when wearing elastic pants, the lower the movement speed, the more obvious the difference of AKJ among the individual subjects, whereas with the increase of speed, the difference among individuals gradually decreases and tends to be stable. However, when wearing non-elasticity pants, the effect is opposite. That is, the faster the speed, the greater the influence on the gap of AKJ among individuals and the greater the curve fluctuation of AKJ with the

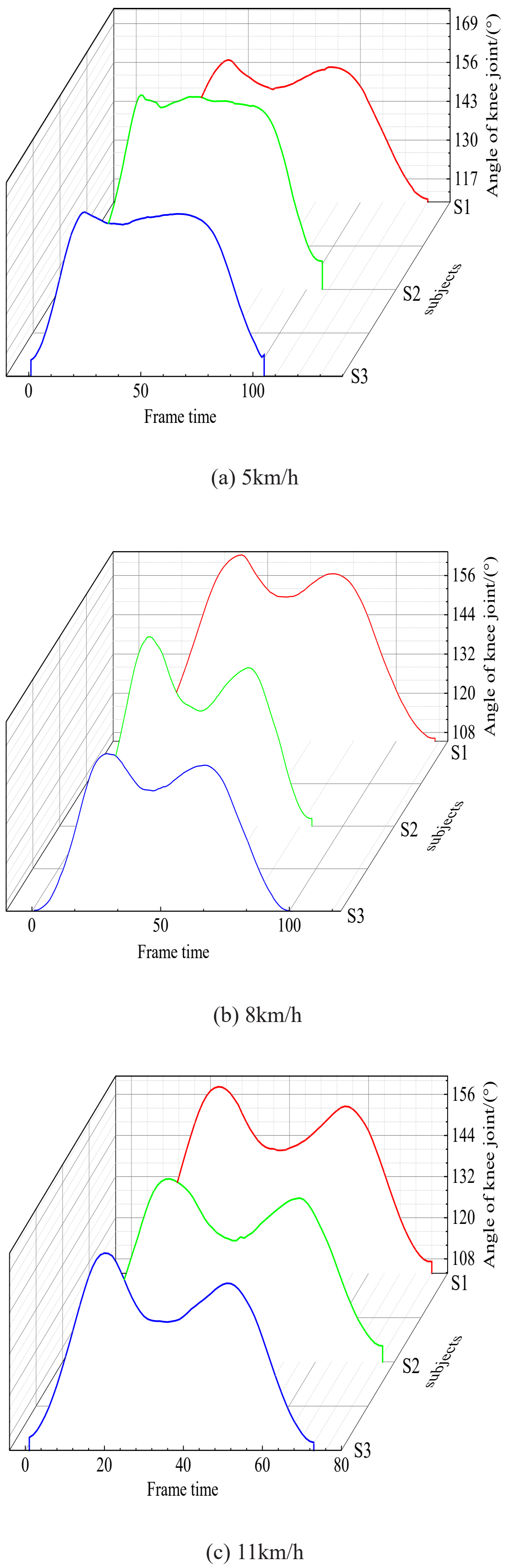


Fig.5. AKJ of different subjects with elastic pants at different speeds

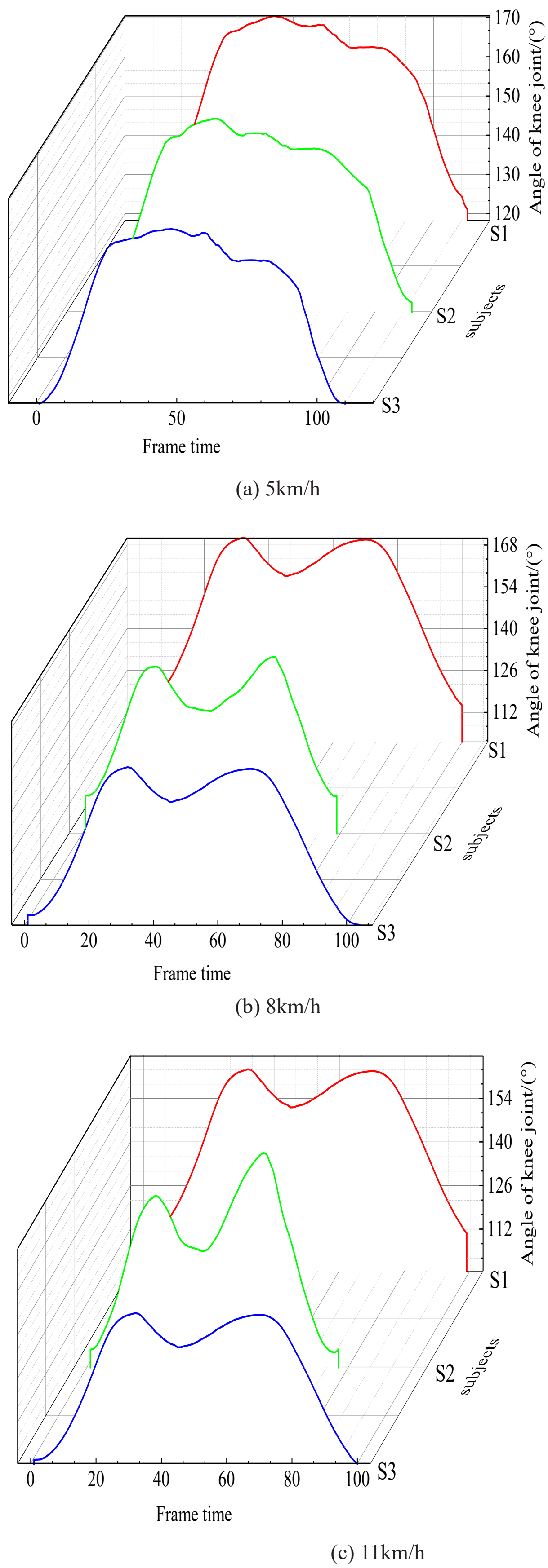


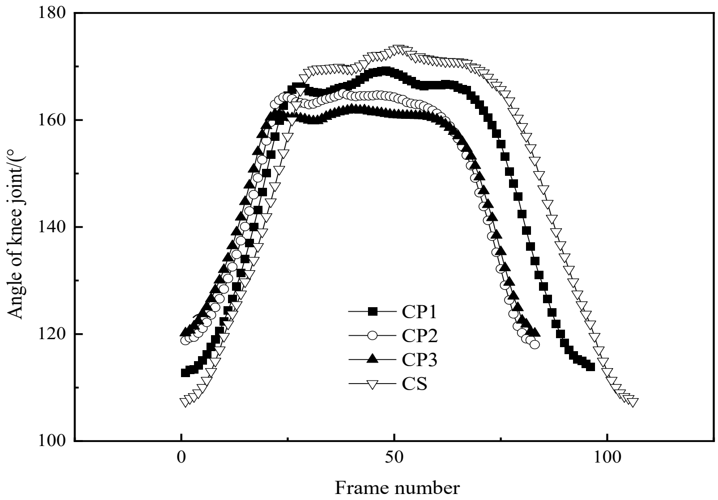
Fig.6. AKJ of different subjects with non-elastic pants at different speeds.

increase of speed. Generally speaking, different people will have different changes in AKJ when wearing the same elastic or non-elastic pants and running at the same running speed.

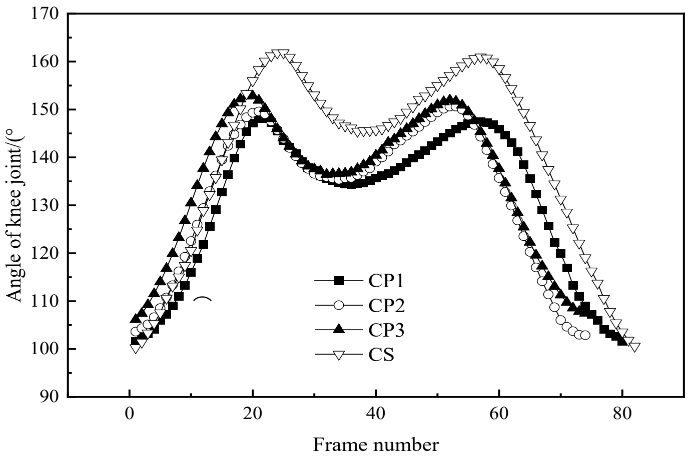
3.2. The influence of fabric elasticity on AKJ

In order to further analyse the influence of pants elasticity on the human AKJ on the whole, the AKJ of the three subjects and ten gait periods were averaged. The results of different pants at different speed are shown Fig. 7. As mentioned above, when running. the two legs of the human change constantly to complete gait periods. Although the AKJ of over ten gait periods were obtained, it is unnecessary and there is not sufficient space to list all the results in the paper, therefore they are averaged to present the overall trend. In the following analysis, detailed data of the AKJ were acquired from ten gait periods.

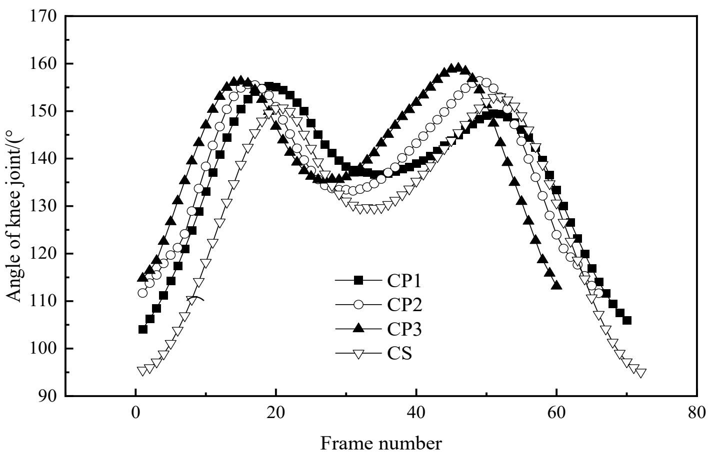
As shown in Fig. 7(a), at q speed of 5 km/h, the AKJ of CP1, CP2 and CP3 shows little difference (≤8°) in the front suspension period of 0~25 frames, and the AKJ of CP1, CP2, CP3 and CS are 168.15°±0.61°, 164.03°±0.63°, 160.90°±1.79° and 172.82°±0.36°, respectively, in the support period. Moreover, the AKJ of CP2 and CP3 (belonging to the compression pants) during the whole process, whether for the front support, the suspension or the back support period, are almost the same. By analysing the whole trend in Fig. 7(a), we can see that the frame numbers as well as the AKJ of CP1, CP2 and CP3 (grouped into the elastic pants) are smaller than CS, which means the elastic force may not only reduce a single gait cycle but also change the mobility of human lower limbs. The average gait cycle of CS is about 110 frames, while that of CP1 (96 frames), CP2 (83 frames) and CP3 (83 frames) are less. In short, compared with non-elastic pants (CS), elastic pants can not only shorten the gait cycle but also decrease the change amplitude of AKJ significantly, playing an obvious role in protecting the human knee. Especially, the two compression pants nearly have the same trend.



(a) 5 km/h



(b) 8 km/h



(c) 11 km/h

Fig.7. AKJ under different fabric elasticity

It can be seen from Fig. 7(b) that at a speed of 8 km/h, the AKJ of CP1, CP2 and CP3 show a small difference (≤3.12°) during the front suspension period. Not only that, the peaks of elastic pants first appear in the supporting period (about 21 frames), and the overall gait cycle decreases to within 80 frames along with the speed. However, the peak of CS appears later (about 27 frames), and the overall gait cycle is shortened from 110 frames to about 83. The overall trend of the AKJ of non-elastic pants is larger than that of elastic pants, and the change amplitudes of AKJ from big to small are CS (60.15°±0.21°), CP1 (48.84°±0.16°), CP2 (45.73°±0.98°) and CP3 (44.25°±0.47°) after the support period, because CP2 and CP3 have higher spandex content than CP1, which proves that fabric elasticity can effectively reduce the range of knee joint movement and flexion movement [24].

Fig. 7(c) shows that the AKJ gap between different pants is larger, and the AKJ of elastic pants is more than that of non-elastic pants in the suspension period, which is consistent with the change rule in Fig. 7(a). In addition, at a speed of 11km/h, the gait cycles of CS is reduced to fewer than 80 frames, and that of elastic pants is also smaller than at 8km/h. During the support period, the depressions of four curves appear alternately. And the change in elastic pants in the suspension period is still significantly smaller than that of CS.

To sum up, elasticity has a great influence on the AKJ. The change in the AKJ is more obvious in the suspension period than in the support period. The reason may be that the legs are supported by the ground during the support period, which weakens the covering force of pants elasticity on joints to some extent. However, the legs hang in the air during the suspension period, and the elasticity of pants has an obvious binding force on the joints, which reduces the movement range of the knee joint. That is, elastic pants can play a more positive protective role on the joints than non-elastic pants. Compared with non-elastic pants (CS), elastic pants can not only shorten the gait cycle, but also decrease the amplitude of the AKJ significantly,

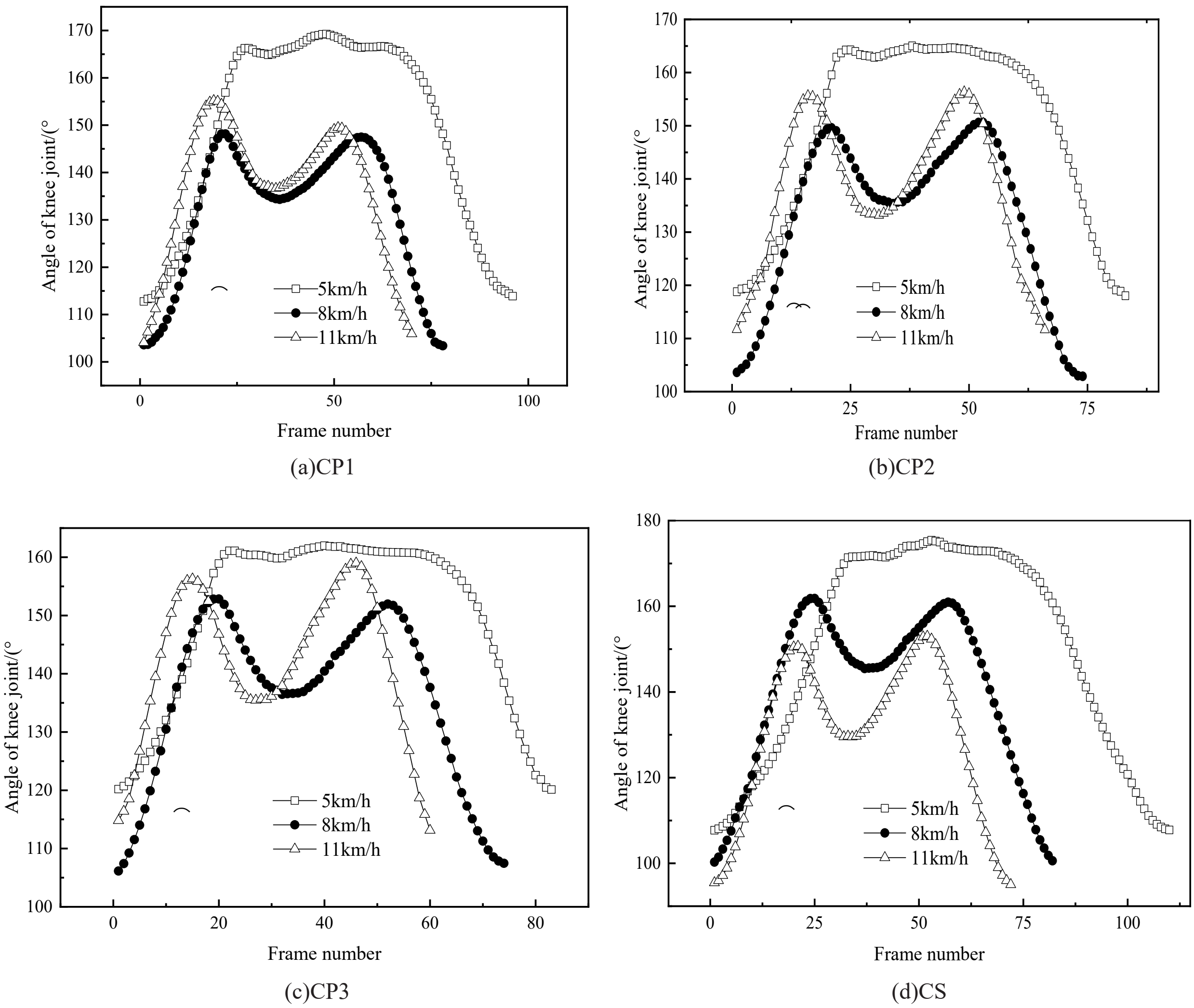


Fig.8. AKJ under different speeds

3.3. The influence of speeds on the AKJ

The AKJ of the same pants at different speeds is shown in Fig. 8, from which a common rule can be seen that the influence of the movement speed on the back suspension period is greater than that of the front suspension period, as three curves of the back suspension period fall apart from each other. On top of that, the movement speed also has an influence on the gait cycle, that is, with the increase of the movement speed, the gait cycle gradually shortens.

As shown in Fig. 8(a)-(c), at the initial stage, the AKJ at 11km/h is larger than at 5 km/h and 8 km/h. However, during the support period, the maximum AKJ, from large to small, are at 5, 11 and 8km/h in turn. In addition, the angle curve of AKJ appears concave with the increase of speed, such as at 8 km/h and 11 km/h. And the maximum value shows a trend of first decreasing and then increasing. Moreover, for CP2 and CP3, the greater the speed, the more obvious the fluctuation and the deeper the concave the curve has. With the change of speed, the number of frames gradually decreases, with CP1 dropping from 96 to 73 frames, CP2 s from 83 to 66 frames, and CP3 from 83 to 62 frames, respectively.

Fig. 8(d) shows that there is little difference in the front suspension period at 8 km/h and 11 km/h, and the minimum value of the AKJ in the front and back suspension periods from large to small are at 5, 8 and 11km/h. Moreover, the minimum value decreases by 4.82±0.60° ~ 7.43±0.76° every 3 km/h with an increase in the process from 5 km/h to 11 km/h. And the maximum value also decreases with 8.81±0.15° ~ 13.42±0.81°. The trends of non-elastic pants are completely different from those of elastic pants, while wearing elastic pants can change the rule of non-elastic pants. Especially, the compression pants (CP2 and CP3) have the most obvious change compared with CP1, whose cycle is about 110 frames at 5 km/h, 80 frames at 8 km/h and 75 frames at 11 km/h.

Generally speaking, different speeds have different effects on the human knee joint angle. For CS, with the increase of the speed, the overall trend shows a gradual decline. However, when the lower limb is wrapped by elastic fabric, the trend of AKJ changes, and that during 8km/h and

11km/h tends to be similar. Not only that, whether the pants are elastic or not, the single gait cycle will gradually decrease with the increase of speed.

3.4. Quantification of the AKJ difference

In order to further quantify the AKJ difference between elastic pants and non-elastic pants, the maximum and minimum values of the three speeds were extracted and averaged. Finally, the maximum AKJ and minimum AKJ were obtained, as shown in Fig. 9.

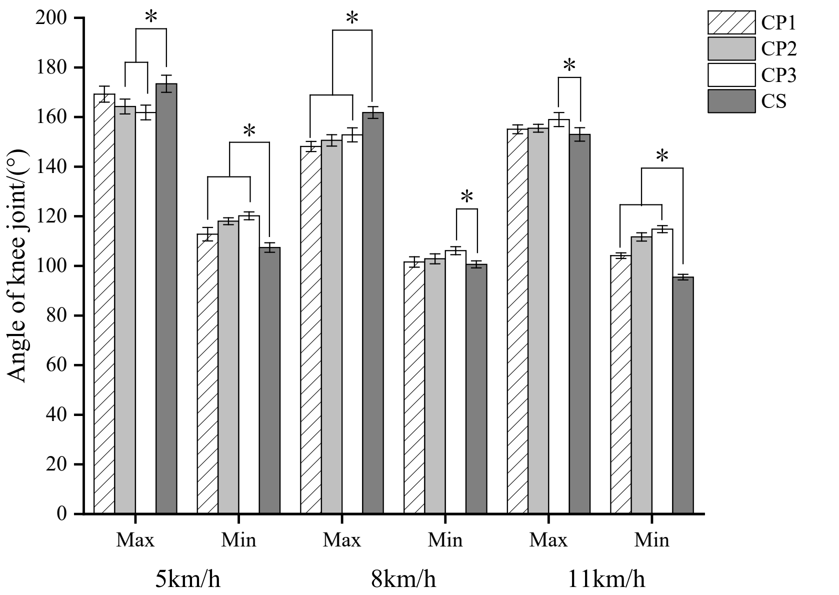


Fig.9. Min and max AKJ of different pants at different movement speeds
*Note: * shows significant difference (p < 0.05), the value of CP is significantly different from that of CS*

It can be seen that for CP1, CP2 and CP3, their maximum AKJ is less by about 4°~13° than that of CS at the speed of 5 km/h and 8km/h. And at the speed of 11 km/h, it is about 2°~5° larger than the value of CS. However, when people wear non-elastic pants, the maximum and minimum AKJ gradually decrease with the increase of speed, which is consistent with the result of change in Fig.8(c). In addition, the minimum AKJ of compression pants appears at 8 km/h, and the maximum AKJs at the three speeds are relatively close. According to the difference in AKJ, for the speed of 5km/h, the motion amplitudes of the knee joint (subtract the max-value from the min-value) from CP1 to CS are 56.46°, 46.22°, 41.65° and 66.02° respectively. For 8km/h, they are 46.54°, 47.73°, 46.67°and 61.22°, respectively, and for 11km/h, they are 50.96°, 43.79°, 44.20° and 57.55°, respectively. In other words, the pants with elasticity at high speeds can effectively reduce the range of motion of the knee joint and play a more positive role in protective performance than non-elastic pants. Generally speaking, in order to avoid knee joint injury, it is necessary to wear compression pants.

4. Comprehensive Evaluation

This paper used the Kruskal-Wallis nonparametric test in SPSS software to analyse the significance of the AKJ and gait cycle corresponding to three subjects wearing different pants at different speeds, respectively. The results of which are shown in Table 4-5. Value P is the significance.

From Table 4, it can be seen that when wearing non-elastic pants, the significant influence of individual differences on the gait cycle becomes more obvious with the speed increase (value P changes from 0.141 to 0.000), though there are some non-significant intra-groups. Moreover, when the elasticity and speed reach a certain extent, the influence of individual differences on the gait cycle is no longer significant. For example, the significance of CP2 is 0.718, and for CP3 it is 0.403 when the speed reaches 11km/h. That is to say, if the speed reaches some level, different individual subjects would not have a significant effect on the gait cycle when they wear elastic pants. However, when non-elastic pants are worn, the trend is opposite.

From Table 5, it can be seen that for all the four pants, at a lower speed (5 km/h or 8km/h), the individual subjects have a significant influence on AKJ ($p< 0.05$), though some intra-groups are not significant. For elastic pants (CP1, CP2 and CP3), the higher the speed, the larger the value of P , i.e. the significance P is lower. at speeds of 5, 8, 11 km/h: 0.000, 0.020 and 0.949 respectively, representing significant, not significant & not significant. When the speed is 11km/h, except for the non-elastic pants CS, the influence of the subjects on the AKJ are all not significant. It may be explained by the fact that all the three factors: individual subjects, moving speed and fabric elasticity do influence human AKJ significantly at lower speed. However, with the increase of speed, the total effect of the speed and elasticity outweigh that of the individual, resulting in the non-significant influence of individual subjects.

The data obtained by the subjects were subjected to averaging calculations and one-way ANOVA (confidence interval 95%) to obtain the significant effects of different fabric elasticity and movement speeds on the evaluation parameters, the results of which are shown in Table 6.

From Table 6 it is seen that the movement speed also has a significant influence on the gait cycle and the AKJ of all pants (with all the value of $p<0.05$), which corresponds well with what is shown in Fig. 8. The average gait cycle of CP1 at the three speeds from high to low is about 100, 80 and 73 frames, respectively, with CP2 83, 74 and 66 frames, respectively, CP3 83, 74 and 62 frames, respectively, and CS 110, 82 and

Movement Speed	Influence significance	Elastic pants	Non- elastic pants
5km/h	H(K)	11.231	4.231
	Value P	0.005*	0.141
8km/h	H(K)	14.665	14.416
	Value P	0.000*	0.000*
11km/h	H(K)	2.897	13.786
	Value P	0.403	0.000*

*Note: * shows significant difference (p < 0.05)*

Table 4. Influence significance of individual differences on the gait cycle

Movement speed	Influence significance	Elastic pants	Non- elastic pants
5km/h	H(K)	25.525	16.423
	Value P	0.000*	0.007*
8km/h	H(K)	12.798	20.121
	Value P	0.020*	0.000*
11km/h	H(K)	0.163	26.085.
	Value P	0.949	0.000*

*Note: * shows significant difference (p < 0.05)*

Table 5. Influence significance of individual differences on AKJ

Evaluation parameter	Average gait cycle	Max-AKJ	Min-AKJ
Elastic pants	0.000*	0.000*	0.000*
Non- elastic pants	0.000*	0.000*	0.000*
Speed (5km/h)	0.000*	0.009*	0.000*
Speed (8km/h)	0.008*	0.000*	0.026*
Speed (11km/h)	0.000*	0.018*	0.000*

*Note: * shows significantly difference (p < 0.05)*

Table 6. Significance test of movement speed and fabric elasticity

78 frames respectively. Not only that, the elasticity also has a significant influence on the evaluation parameters ($p<0.05$) at the three speeds; however, there are some non-significant intra-groups combining the above analysed.

Generally speaking, the elasticity also has a significant influence on the evaluation parameters ($p<0.05$). That is, the gait cycle of elastic pants is shorter than that of non-elastic pants. This is because elasticity has a binding effect on the legs, which will limit the running speed to some extent. Therefore, to achieve the same speed as non-elastic pants, we need to increase the pace frequency, the result of which is the gait cycle reduction of elastic pants. In addition, there are significant differences between the maximum and minimum AKJ of pants with different elasticity. However, when the elasticity is high, there is no significant difference in AKJ at different speeds ($p>0.05$). For example, there is no significant difference in the maximum AKJ between CP2 and CP3 at speeds of 5 and 8 km/h. It shows that the maximum AKJ of these two curves is similar, and the larger the P value, the closer the AKJ value is.

5. Conclusion and way forward

In this study, to evaluate the influence of movement speeds and pants elasticity on human joint protection when running, a 3D motion capture instrument was used to capture the marker point trajectory of lower limbs when the subjects were wearing pants with different elasticity while moving on a treadmill. The angle of the knee joint (AKJ in short) and gait cycle were used for the evaluation. After analysis, the following conclusions were drawn.

Pants elasticity and movement speed have a significant influence on the AKJ as well as the gait cycle. When pants elasticities are different, the AKJ and gait cycle are also different, even when the individual subject and the running speed are the same. Similarly, when running speeds are different, the AKJ and gait cycle are also different, even when the individual subject and pants elasticity are the same. And the significant effect of individual differences on the gait cycle become more pronounced with increasing speed (value P decreases to 0.000*).

However, the individual effect on the parameters evaluated gradually becomes less significant as the elasticity of the pants and the speed of movement increase. When wearing elastic pants during running, the gait cycle obviously decreases, and the change in AKJ tends to be stable with the increase of speed. In addition, when wearing elastic pants, especially compression pants, the motion amplitude of the knee joint is smaller than for non-elastic pants. That is, wearing elastic pants can protect human joints and reduce the probability of knee joint injury.

In short, compared with non-elastic pants, elastic pants can not only shorten the gait cycle but also decrease the amplitude of the AKJ significantly, especially at higher speed. Therefore, it is necessary to wear elastic pants, especially compression pants, when running at higher speed. In the following research, emphasis should be laid on the quantitative relationship between clothing materials and the protective parameters of the human body, to find out the conditions to achieve the optimum protective performance.

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