Professional skateboarding trousers design: according to the three-dimensional kinematic analysis for varied skateboarding manoeuvres

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ABSTRACT – REZUMAT

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The popularity of skateboarding has caused an expansion of enthusiasts worldwide. Moreover, skateboarding is becoming increasingly professional at an international level. Professional skateboarding trousers are regarded as critical equipment and their design research should not be overlooked. This research aims to use motion capture to measure the angular changes characteristics of critical lower limb joints in skaters during sports activities, measure the length of the knee joint during actions, and establish a formula that describes the change characteristics between the angle and the length. The formula would allow for a data reference when designing the elasticity at the knee joints of skateboarding trousers. Thus, the initial step in this research methodology was to use a Vicon motion capture system to test and analyse the kinematic characteristics of seven skaters in the squat, jump, ollie, pop shove it, heel flip, kickflip, and 180° ollie. Based on the kinematic characteristics, the dynamic movements were broken down into static postures at 0°, 45°, 90°, 112.5°, and 135°. The body surface drawing method was then employed to measure changes in the knee joint body surface dimensions of the subjects. Next, the experimental data were analysed to explore the relationship between angle and length changes. Finally, the design was developed based on the data. Analysis and processing of the experimental data yielded the following conclusions: (1) The most significant knee joint change characteristics during skateboarding was the angle change observed during an ollie. (2) Knee joint skin stretch deformation is most evident in the anterior mid-leg line y2. (3) The relationship between kinematics and the structural design of skateboarding trousers was derived from the experimental data. Specifically, the equation for the relationship between angle change and length change is given by y2 = 0.0442x + 23.906. (4) The results show that the extreme range of skin stretching in the anterior midline is between –0.7 and 6.3 cm. Therefore, the loose design of the knee part of professional skateboarding trousers should not exceed 6.3 cm. This research approach can offer an effective design solution for professional skateboard trousers and can also be applied to other types of trousers.

Keywords: *kinematic, 3D motion capture, skin deformation, skateboarding pants, sports*

Designul pantalonilor de skateboarding profesionist: conform analizei cinematice tridimensionale pentru manevre variate de skateboarding

Popularitatea skateboarding-ului a provocat o expansiune a entuziaștilor din întreaga lume. Mai mult, skateboarding-ul devine un sport din ce în ce mai profesionist la nivel internațional. Pantalonii de skateboarding profesionist sunt priviți ca echipamente deosebit de importante, iar cercetarea designului acestora nu trebuie trecută cu vederea. Acest studiu își propune să utilizeze captura de mișcare pentru a măsura caracteristicile modificărilor unghiulare ale articulațiilor critice ale membrelor inferioare la patinatori în timpul activităților sportive, să măsoare lungimea articulației genunchiului în timpul acțiunilor și să stabilească o formulă care descrie caracteristicile schimbării dintre unghi și lungime. Formula ar permite o referință de date atunci când se proiectează elasticitatea la articulațiile genunchilor la pantalonii de skateboarding. Astfel, pasul inițial în această metodologie de cercetare a fost utilizarea unui sistem de captare a mișcării Vicon pentru a testa și analiza caracteristicile cinematice ale unui număr de șapte patinatori în pozițiile ghemuit, săritură, ollie, pop shove it, heel flip, kickflip și ollie la 180°. Pe baza caracteristicilor cinematice, mișcările dinamice au fost împărțite în posturi statice la 0°, 45°, 90°, 112,5° și 135°. Metoda de desenare a suprafeței corporale a fost apoi utilizată pentru a măsura modificările dimensiunilor suprafeței articulației genunchiului la subiecți. Apoi, datele experimentale au fost analizate pentru a explora relația dintre modificările de unghi și lungime. În cele din urmă, designul a fost dezvoltat pe baza datelor obţinute. Analiza și prelucrarea datelor experimentale au condus la următoarele concluzii: (1) Cea mai semnificativă caracteristică de modificare a articulației genunchiului în timpul skateboardingului a fost modificarea unghiului observată în timpul unui ollie. (2) Deformarea întinderii pielii articulației genunchiului este cea mai evidentă în linia mediană anterioară a piciorului y2.(3) Relația dintre cinematică și designul structural al pantalonilor de skateboarding a fost derivată din datele experimentale. Mai exact, ecuația pentru relația dintre modificarea unghiului și modificarea lungimii este dată de y2 = 0,0442x + 23,906. (4) Rezultatele arată că intervalul extrem de întindere a pielii în linia mediană anterioară este între –0,7 și 6,3 cm. Prin urmare, designul liber al părții genunchiului pantalonilor de skateboarding nu trebuie să depășească 6,3 cm. Această abordare a cercetării poate oferi o soluție eficientă de design pentru pantalonii de skateboarding profesionist și poate fi aplicată și altor tipuri de pantaloni.

Cuvinte-cheie: *cinematică, captură de mișcare 3D, deformare a pielii, pantaloni de skateboarding, sport*

INTRODUCTION

Skateboarding originated in the United States in the 1960s as a form of evolution of surfing but with greater freedom and flexibility. As skateboarding becomes more prevalent, the scale of its community of enthusiasts around the world continues to grow. On 4 February 2022, the International Olympic Committee announced that skateboarding would be included in the 2024 Paris Olympics and that it had become a permanent Olympic sport as of the 2028 Los Angeles Olympics. Since the professional and competitive development of skateboarding, sports companies and researchers alike have made professional equipment designed for the sport a new priority. Despite the athletic nature of skateboarding coupled with sporadic motions and non-standard equipment, quantitative analysis of its kinematics remains inadequate. Kristin et al., [1] referred to skateboarding injuries and suggested that research could include more standardized data collection, as well as a greater focus on kinetic analyses of this sport, and encouraging interdisciplinary research. Jeremy et al. [2] described the dynamics of skateboarding aerial landings and showed that there was no systematic understanding of the biomechanical factors responsible for injurious skateboarding at the stage before their study; Bryant et al. [3] investigated ground reaction forces, stride kinematics, and metabolic costs of skateboarding on a running motion apparatus, and the energetics of skateboarding compared to other forms of motion, however similar studies of the kinematic characteristics of skateboarding manoeuvres were less from most published research; Skateboarding have the characteristics of diversity and flexibility, Luana et al. [4] analysed the three-dimensional kinematics of skateboard ollie movements and compared the ollie movements in static and dynamic manoeuvrability. Their findings supported skateboarders to obtain higher scores in competitions

Although there were few reported cases of professional design for skateboarding trousers, examples from other sports provide beneficial insights. Jeehye et al. [5] showed that the size of the key areas in the climbing position is an important basis for determining the comfort of climbing trousers. Weirong et al. [6] chose five representative yoga poses on eight female participants selected for standard standing and yoga poses, measured the lower limbs of the participants through 3D scanning technology, analysed the skin deformation of female limbs under yoga, and established a digital design model of weft knitted seamless yoga trousers based on the skin deformation, and the results of the study can provide a basis for the structural and stylistic yoga trouser. Wenfang et al. [7] developed novel work trousers based on deformation rates that create folded structures in regions that can stretch and shorten after human movement, which can effectively improve the mobility and comfort of the wearer's limbs; meanwhile, according to human testing, these novel trousers significantly increased the range of motion in hip flexion, improved the ease of movement and comfort in the knees and limbs, and reduced the feeling of stress in these areas. A professional analysis of kinematics will provide data to support the design of skateboarding trousers

This research aimed to assess the angular changes of the ankle, knee, and hip joints in skaters' lower limbs during skateboarding. Additionally, it aimed to establish a correlation between the changes in skin surface and angular motion. Finally, this study intended to develop professional skateboarding pants.

METHODS

Subjects

Seven subjects were selected as young skaters with more than 2 years of skateboarding experience. A male-to-female ratio of 6:1, an average age of 19 years, an average height of 169.5 cm, an average weight of 54.1 kg, and an average boarding experience of 4.4 years, were obtained. Data were collected on knee, hip and ankle joint movement characteristics during skateboarding in 7 subjects who were required to perform standing, squatting, and jumping as well as two basic manoeuvres of an ollie, pop shoves and one of the movements of heel flip, kickflip or 180° ollie. The above subjects participated in two experiments, the motion capture and the skin stretching trails.

Marking for kinesiological

To safeguard the accuracy of motion capture, doors and windows were closed before the experiment, and all reflective objects in the experimental environment were removed or shaded. Calibrated the Vicon Nexus system with a T-shaped calibration stand. Basic information such as the subject's height, body mass, lower limb length, knee width, and ankle width were measured and entered.

Subjects were labelled with reflective dots and then marked with 16 marker balls of 14 mm diameter. Marker points located on the left and right (anterior superior iliac spine, posterior superior iliac spine, lateral thigh, lateral epicondyle of the knee, lateral calf, tip of the lateral ankle, second metatarsal, heel) are shown in figure 1.

Kinesiology testing process

Subjects performed standing, squatting and skateboarding manoeuvres at their usual walking speed in the test area. Formal testing began after acclimatizing to the experimental environment and meeting the experimental requirements. The Vicon Motion Capture System will record the trajectory of all marker balls as they are walked. Seven subjects were then asked to perform manoeuvres as required. The motion capture is summarized in table 1, with each manoeuvre being captured three times.

Kinematic data processing

All seven subjects completed five of the squat, jump, ollie, pop shove it, and heel flip or kickflip or 180° ollie.

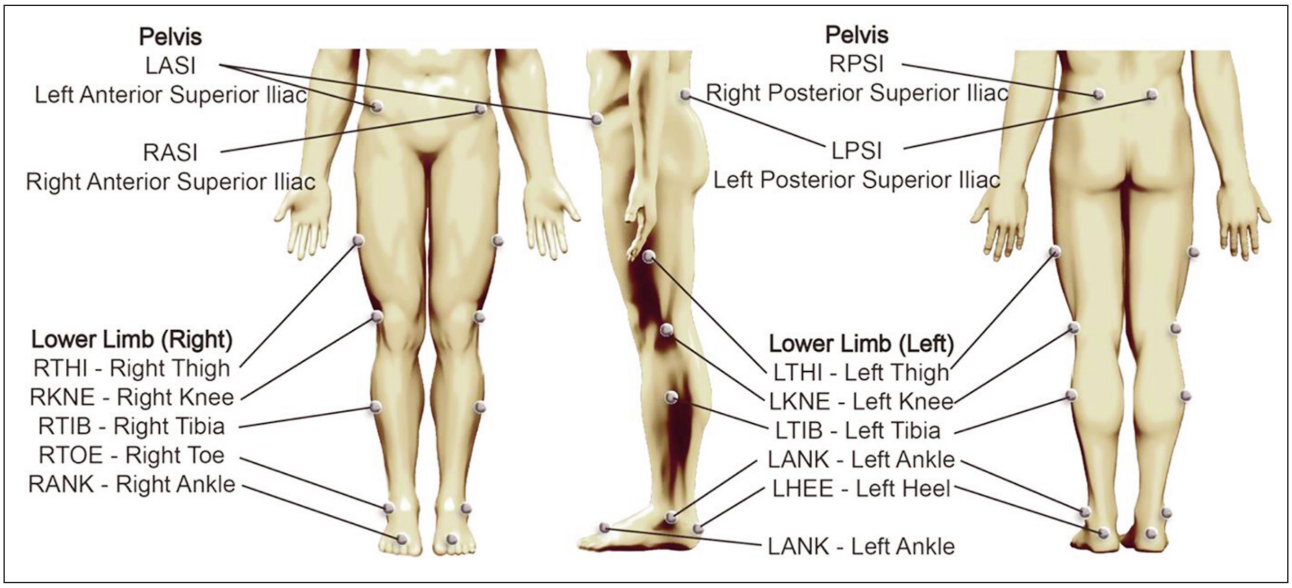
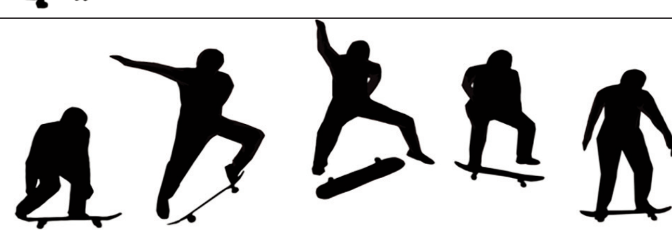
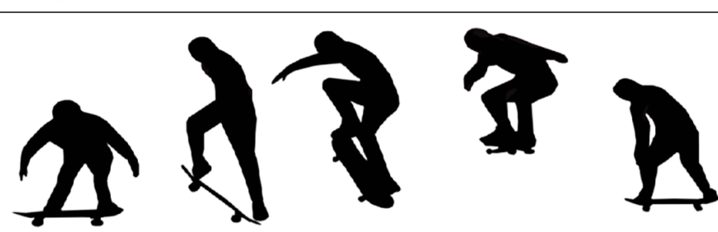


Fig. 1. *Reflective point marker before the experiment*

Table 1

MOTION CAPTURE SUMMARY TABLE	
Motion	**Figure**
Ollie	
Pop shove it	
Heel flip	
Kickflip	
180°ollie	

Specifically, they all finished the squat, jump, ollie, and pop shove it, two of the subjects completed the heel flip, three of them completed the kickflip, and one completed the 180° ollie. The Plug-in Gait lower body model was applied to output the angular data of seven subjects performing skateboarding manoeuvres, which was used to analyse the angular range of motion of the ankle, knee and hip joints in the X-axis. (Dorsiflexion and plantar flexion joint movements of the ankle, flexion and extension joint movements of the knee and hip joints, all joints in coordinates around the X-axis in the left and right directions of the spatial origin). Further, maximum, minimum, mean and standard deviation, with a range of angular movement between the maximum and minimum values, were considered

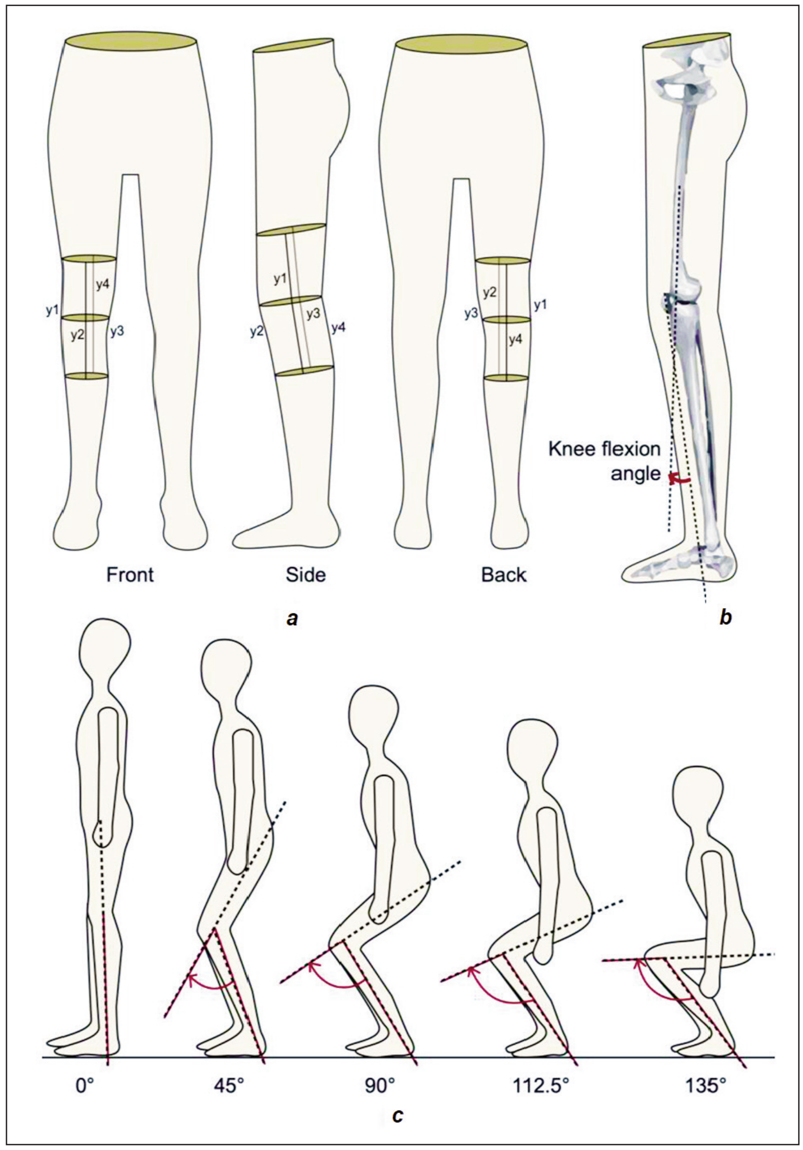


Fig. 2. Graphical representation of: *a* and *b* – The breakdown angle of the dynamic squat movement; *c* – schematic diagram of lower extremity data measurement

Skin stretching test

According to the skateboarding movement characterization, the dynamic movements were separated into five static movements for easy data measurement. The squat angles were 180°, 135°, 90°, 67.5°, and 45° as shown below (figures 2, *b* and *c*).

The subjects' lower limbs were wearing sports shorts with bare knees, and according to the human body surface characteristics, reference lines were drawn on the subjects' leg body surface with a marker pen before the measurement. It is clearly shown from figure 2, *a*, that the four longitudinal auxiliary lines targeting the knee joint kinematic characteristics were, in order, the medial suture line y1, anterior mid-leg line y2, lateral suture line y3, and posterior mid-leg line y4.

During the measurement, the static data were first measured, who stood on the ground with their hands naturally hanging down on both sides of the body and their feet 20 cm apart, keeping the symmetry of the left and right sides with the midline of the body as the standard. To reduce the error when measuring, the soft ruler should be close to the skin surface, the skin should not deform, the elasticity should be kept consistent, and the line of sight should be kept straight when reading the data. When measuring the data, the longitudinal data were measured in order from left to right and recorded in time, and the length data of each line segment of the dynamic decomposition squatting angle (0°, 45°, 90°, 112.5°, 135°) of the gliding movement were measured in order. Observe the data of y1, y2, y3, and y4 at different angles longitudinally, and measure and record the data to derive the range of variation.

RESULTS

Data results

Motion capture experimental data

The extreme, range, and mean values of the sagittal plane angles of the hip, knee, and ankle joints for different skateboarding motions are shown in table 2.

To ensure stability during movement, the sagittal planes of the ankle, knee and hip joints all produced varying degrees of angular change during the different skateboarding manoeuvres described above. The angular movements of the knee are greater than the angular range of motion values of the hip and the ankle during the same movement. Therefore, it was easy to conclude that the knee has the most pronounced changes in the X-axis, which is the joint part with the greatest change in sagittal plane angle in skateboarding.

Furthermore, the following findings were obtained:

- The angular range values in the X-axis of the hip, knee, and ankle joints were all maximal during the ollie movement in all seven tested manoeuvres.

Table 2

HIP, KNEE, AND ANKLE SAGITTAL CORONAL AXIS (X-AXIS) ANGLE EXTREMES, RANGES, AND MEANS							
Joint data	**squat**	**Jump**	**ollie**	**Heel flip**	**Kickflip**	**Pop shove it**	**180ollie**
Hip max	113.2	119.2	140.0	104.9	121.6	117.7	112.9
Hip min	–7.0	–7.6	–76.0	6.3	–6.9	–8.6	1.2
Hip range	120.1	126.8	216.0	98.5	128.5	126.3	111.7
Hip mean	53.1	55.8	32.0	55.6	57.3	54.5	57.0
Keen max	141.1	142.0	228.9	134.4	108.7	56.2	132.8
Keen min	–14.9	–21.6	–13.5	5.0	–16.1	136.1	–3.9
Keen rang	156.0	163.6	242.4	129.4	124.8	95.3	136.7
Keen mean	63.1	60.2	107.7	69.7	46.3	18.7	64.5
Ankle max	45.5	52.4	99.6	66.2	90.0	111.8	32.1
Ankle min	–149.8	–137.3	–157.6	–28.6	–69.1	–71.6	–46.2
Ankle rang	195.3	189.6	257.3	94.9	159.1	183.4	78.3
Ankle mean	–52.2	–42.5	–29.0	18.8	10.5	20.1	–7.1

- The ordering of the hip X-axis angular range values with both ends data removed was kickflip, jump, pop shove it, squat, 180ollie, and the movement with the smallest angular range was the heel flip.
- The ordering of the knee X-axis angular range values with both ends data removed was jump, squat, 180ollie, heel flip, kickflip, and the movement with the smallest angular range was pop shove it.
- The ordering of the ankle X-axis angular range values with both ends data removed was squat, jump, pop shove it, kickflip, heelflip, and the movement with the smallest angular range was the 180° ollie.

Results of body skin stretching

The length of the skin stretches produced at the knee joint varies depending on the angle of the static squat. In the case of 180° at the knee joint, the tester is in a static standing position, so the value of the skin stretch is the length at the other angles minus the length at 180°.

The graph below shows a scatter plot of the relationship between the mean change in angle length during skin stretching derived from the fit.

DISCUSSION

By investigating the characteristics of skateboarding movements, 0°, 45°, 90°, 112.5° and 135°, and the skin stretch data for the above five static angles were summarized. According to the formula between the skin stretch and squatting angle, the minimum value

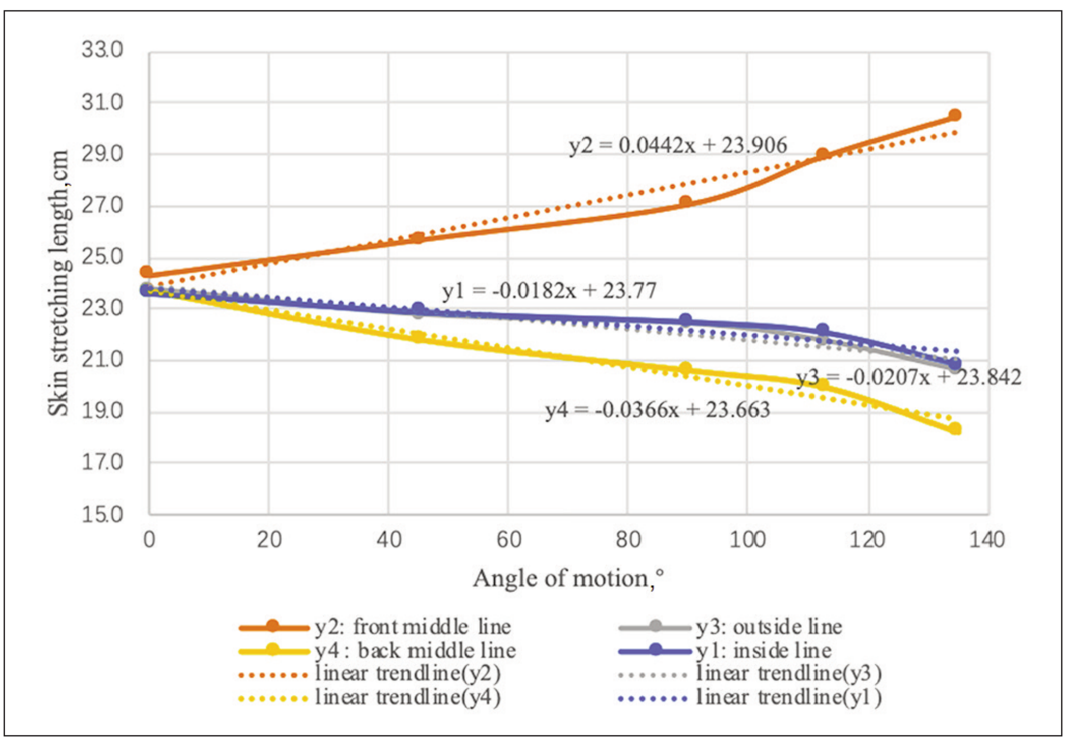


Fig. 3. Scatterplot of angle-length mean relationship

of the knee joint in the coronal axis during skateboarding was –21.6° and the mean of the minimum value was 7.6°; the maximum value of the angle was 136.1° and the mean of the maximum value of the angle was 25.4°. The corresponding range of the extreme value of the front midline y2: was 22.9 to 29.9 cm, the average range of the extreme value: was 24.2 to 25.0 cm, the stretch range of the skin of the front midline y2, which was the extreme range of the looseness of the skateboarding trousers: –0.7 to 6.3 cm, and the average stretch range of the extreme value: 0.6 to 1.4 cm. The above reference ranges can provide data reference for the design of the knee joints of the skateboarding trousers.

Besides, it is worth noting that the most common skateboarding trousers on the market come in a loose, straight fit (figure 4, *a*) on the top of the left side of the picture, which has the disadvantage of not being able to provide both fit and comfort when skateboarding. The same problem occurs with the regular fitted trousers (figure 4, *a*) at the bottom of the figure. Therefore, we divided the trousers into three types: tight (figure 4, *b*), fitted (figure 4, *c*) and slim (figure 4, *d*), as shown in the picture, and designed them with loose volume in the knee area of each of these three types of trousers. In addition, a detail worth paying attention to was that these three different levels of looseness of the trousers were designed to have different lengths of loose fit in the knee area, with the length of the loose fit decreasing from tight to slim (figure 4, *e*).

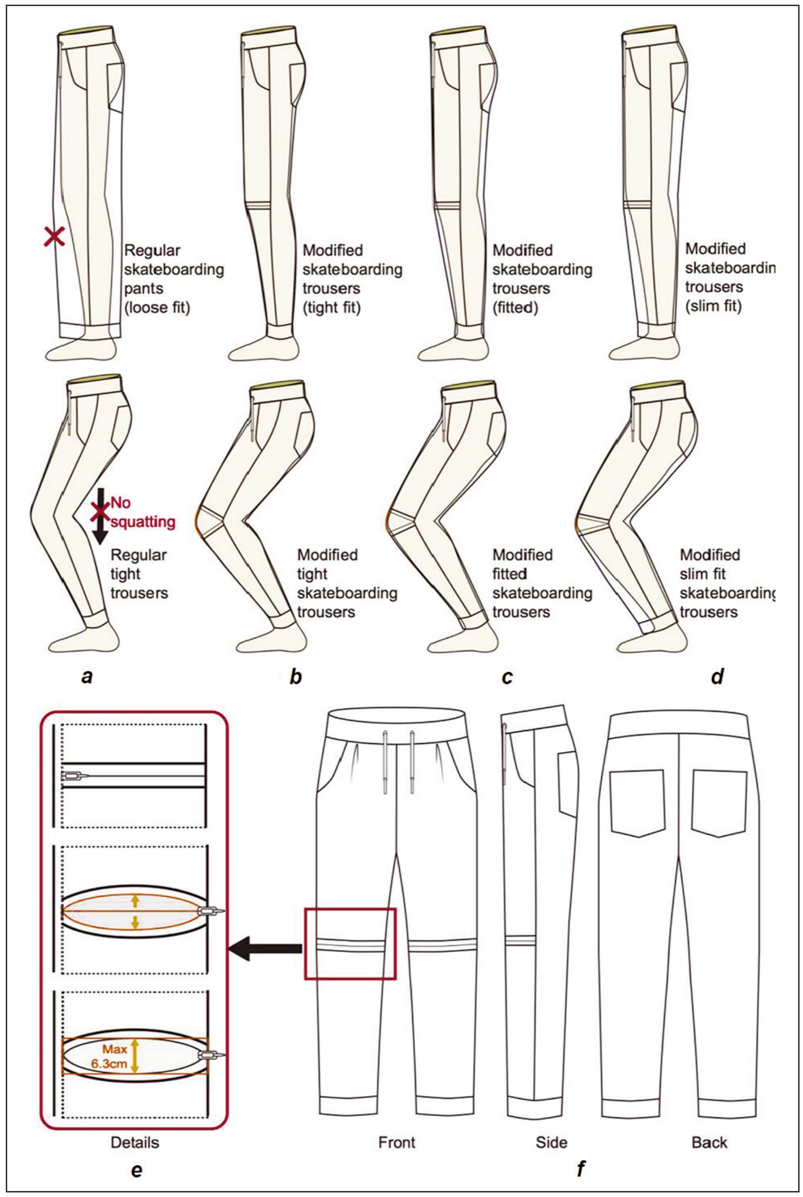


Fig. 4. Professional skateboard pants design: *a* – loose, straight fit; *b* – tight; *c* – fitted; *d* – slim; *e* – details; *f* – pant design

Based on the above data, it is concluded to design a professional skateboarding trouser as shown in figure 4, *f*. This professional sport trouser is a slim straight trouser skateboarding trouser in terms of style. Firstly, the waist is designed as an easily adjustable drawstring design. Secondly, it is designed with patch pockets at the hips as well as at the knees to thicken the wear-resistant design, and flap design at the trouser legs. Finally, the most important feature is that the knee loft is designed with an aesthetic zip-type invisible stitching design. As shown in figure 4, *e*, the maximum knee loft at the front midline is 6.3 cm, which is within the range of all the movements involved in the experiment.

Weirong et. al. [6] analysed the effect of different posture poses on the skin deformation of the lower limbs, and they pointed out that the change of the anterior midline of the knee was most obvious when the knee was bent. Meanwhile, Jeehye et.al. [5] analysed consumer needs through the functional design of sport-climbing trousers and pointed out that the flexible movement of the knee joint was one of the most important elements in the sport of rock climbing and the use of a three-dimensional design at the knee joints could enhance the wearing sensation of the trousers in the knee area. Based on our knowledge of skateboarding, it could be extended to sports such as yoga and rock climbing, which rely on the movement of the knee joints. Therefore, designing the looseness for the knee joint of skateboarding trousers would greatly enhance the amount of space in the knee joint and finally achieve a more comfortable sporting experience.

There were limitations of this study. The participants we recruited were non-professional skaters, and there was a lack of standardized movement. Meanwhile, we did not test the trouser's real performances. In future research, we will research movement characterization for professional skaters. In addition, we will also use the research methodology in this paper to further produce real professional skateboarding trousers for functional testing.

CONCLUSIONS

In summary, we have presented a new methodology for designing trousers. By analysing the kinematics of skateboarding, we have identified that the most significant change in knee joint action occurs. We then used the relationship equation between angle and skin stretch to determine the range of knee motion required for skateboarding. Finally, we determined the looseness design based on the collected range of motion data. We hypothesized that wearing this style of trousers would increase comfort while skateboarding. Additionally, this design methodology can be applied to the research of other activities such as yoga, rock climbing, and cycling, all requiring tight-fitting trousers.

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