Characterizing Dynamic Pressure in Cycling with Muscle Activation

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Abstract. Dynamic pressure plays an important role in the cyclists' performance and comfort. To qualitatively analyze dynamic pressure of male lower limb with compression cycling shorts in continuous cycling motion, a novel approach was developed to characterize dynamic pressure. Four pressure measurement points were selected based on skeletal muscle simulation. It was found that pressure was dynamic during cycling, and the maximum dynamic pressure at four points was produced when pedal was at the top. Pressure gradually non-linear rose with ease allowance reduction. Dynamic pressure significantly associated with muscle activation. The investigation will contribute to theoretical guidance for clothing engineers to improve pressure comfort and motor performance.

Introduction

Clothing pressure is significantly combined with the motion performance and pressure comfort such as sportswear for athletes. In previous studies, compression clothing was mainly concerned on physiological efficacy. Effect of partial pressure suits on heart rate, arterial pressure, cardiac output and ergonomics performance was discussed [1]. However, little attention has been focused on how to determine the most appropriate pressure in different body part to benefit physiological efficacy, while excessive pressure would affect heart and lung functions, and even perhaps resulted in serious damage to heath [2, 3]. The above researches have clearly expounded the necessity of appropriate pressure. Consequently, before the proper pressure value of every part was determined, it was critical to grasp the law of pressure fluctuation of body parts completely during exercises. Previous researchers explored dynamic pressure of specified motions, and the specified motions were selected [4]. In fact, "dynamic pressure" in these studies was still static pressure of several fixed motions. The true dynamic pressure in continuous motion failed to be represented. Based on this, dynamic pressure of male lower limb wearing compression cycling shorts for continuous cycling motion was presented. A novel experimental approach to simulate dynamic pressure for continuous cycling motion was designed.

Methodology

Subjects and compression cycling shorts

Five healthy young cyclists were voluntarily participated in this study. All subjects were informed of the research purpose, and completed a health questionnaire. None of the subject was injury or pain. Six pairs of compression cycling shorts were manufactured by the same fabric with different negative ease allowance; serial numbers were C_1, C_2 …, and C_6.

Pressure measurement points

Four measurement points were selected according to lower limbs muscle activity when cycling. In cycling rectus femoris, vastus lateralis, biceps femoris were the active muscles confirmed by skeletal muscle simulation. Considering muscle activation, middle of rectus femoris (L_1), middle medial thigh (L_2), middle lateral thigh (L_3), middle of biceps femoris (L_4) were selected as pressure measurement points, the location of every point was shown in Fig. 1.

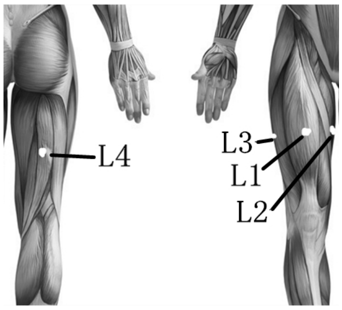

Fig. 1. Pressure measurement points.


Fig. 2. Simulation of cycling.

Simulation of cycling and skeletal muscle simulation

Cycling in situ may simulate real scenario of cycling motion on flat. Experimental bicycle rear axle was supported from the ground with U-shaped bracket (see Fig. 2). An angle dial self-made was designed and fixed on the crank axle. The angle was divided into twelve, each 30°. So a periodic motion was disintegrated into twelve continuous motions. Then pressures of twelve motions were measured without interrupting. The human body modeling and simulation system was employed in simulating skeletal muscle activity rhythm. Three kinds of most active muscles (rectus femoris, biceps femoris, and vastus lateralis) were chosen and computed muscle stretch, the degree of muscle activation, and muscle force in the process of cycling.

Pressure measurement protocol

The experiment was performed as follows: Pressure value was measured with an air-pack type contact pressure measurement system. Before the beginning of experimental, saddle was adjusted to meet proper fit with different height and leg length [5]. Every subject was demanded 3 minutes of warm-up to adapt to test procedure. Sensors were accurately and firmly pasted at pressure measurement points and record pressure data of four points. Shorts were worn in order, and then pressure of standing still and dynamic pressure (0°, 30°…, and 330°) were measured continuously.

Results and discussion

Middle rectus femoris muscle (L_1)

Pressure change was not significant from standing still to cycling posture at L_1 (Fig. 3). Dynamic pressure first decreased and then increased gradually, the maximum at 0° and the minimum at 120°~150°. Observing the result of skeletal muscle simulation in the process of cycling, the change of muscle stretch and dynamic pressure has a high consistency. Maximum stretch of rectus femoris muscle was found at 0° and minimum at 120°~150°. 0°~120° rectus femoris muscle gradually relaxed, corresponding the dynamic pressure value slowly decreased; in contrast, 150°~330° dynamic pressure increased gradually as rectus femoris muscle contracted.

Middle medial thigh (L_2)

The change trend of dynamic pressure at L_1 and L_2 were basically identical. Not only dynamic pressure corresponding same ease allowance shorts was lower compared with L_2, but the change amplitude of dynamic pressure at L_2 decreased about 50% by one-way ANOVA (Fig. 4). The result was related to shorts structure between sample shorts and thigh. Side seam was pulled to crotch. At L_2 position, due to crotch stretch, sample shorts was not tightly fit with medial thigh in cycling posture when compared with L_1 point. In this condition, pressure value measured would be smaller naturally and air-pack sensor was not sensitive to dynamic change.

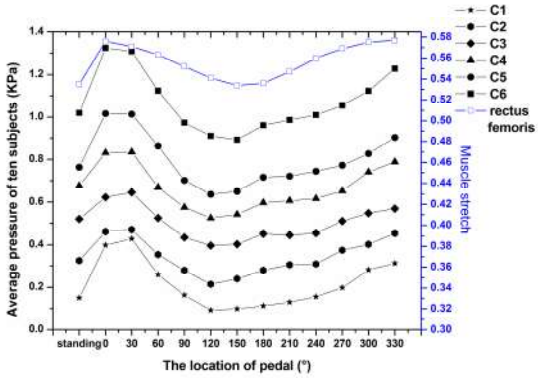

Fig. 3. Pressure change and muscle activation at L_1.

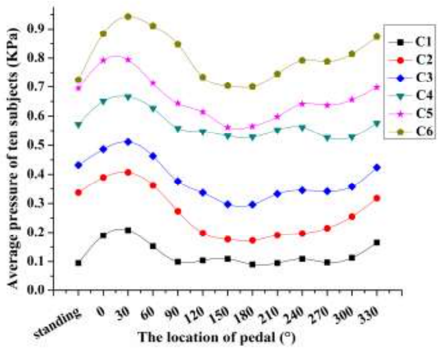

Fig. 4. Pressure change at L_2.

Middle lateral thigh (L_3)

Similarity of six curves reached more than 90% with correction analysis (Fig. 5). By ANOVA test, the result indicated that dynamic pressure of L_3 had significant difference during cycling. Minimum of dynamic pressure for L_3 occurs at 180°~210°, and vastus lateralis were relaxed state. Maximum existed at 0°~30°. The simulation of cycling motion showed muscle activity of lateral vatus lateralis was not obvious relatively. Furthermore, skin deformation of lateral thigh was smaller compared with middle anterior thigh. Dynamic pressure of C_5 and C_6 was much bigger than others. Consequently we believed that fabric properties did affect dynamic pressure.

Middle biceps femoris (L_4)

Differences between maximum dynamic pressure and pressure of standing still for six sample shorts were 0.42~0.54KPa (Fig. 6). The maximum pressure still is at 0°. With one-way ANOVA test variances of dynamic pressure of six sample shorts were calculated. The result indicated that dynamic pressure had a little difference at middle biceps femoris. The maximum and minimum of dynamic pressure with biceps femoris of muscle stretch out of sync. But dynamic pressure and muscle stretch were basically the same change trend. The result revealed that muscle relaxation and contraction resolved pressure decrease and increase. The effect of muscle stretch to dynamic pressure change was also important.

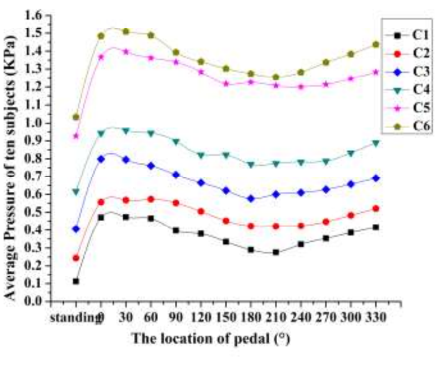

Fig. 5. Pressure change at L_3.

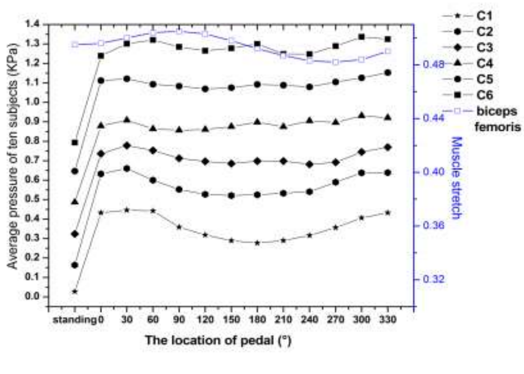

Fig. 6. Pressure change and muscle activation at L_4.

The variation of dynamic pressure at eight points has been discussed in detail, respectively. Take C_4 as example, other shorts were the similar result. Maximum pressure of all four points was at 0°~30°. Maximum pressure measured in experiment was 1.74KPa. Previous research proposed that under low pressure (less than 4.65KPa) external pressure accelerated skin blood flow of low limb [6]. On the base of this idea, in the certain pressure range shorts was the tighter the better, ease allowance of shorts still can be reduced continuously. From standing still to cycling posture, pressure of L_3 and L_4 increased highly, because skin deformation and curvature changed greatly at these two points. Variances can reflect fluctuation of dynamic pressure. According to the result of variances of four points, fluctuation of dynamic pressure was extreme at L_1. Muscle activation of the point was most active. Subsequent cycling shorts design needs to highlight the point. Fluctuation of L_4 was gentle, because muscle activation of L_4 was very small. Muscle activation was significantly correlated with dynamic pressure from the analysis of L_1, L_4. So far, similar results have not been found, other studies focused on the relationship of muscle activation and mechanical efficiency in cycling.

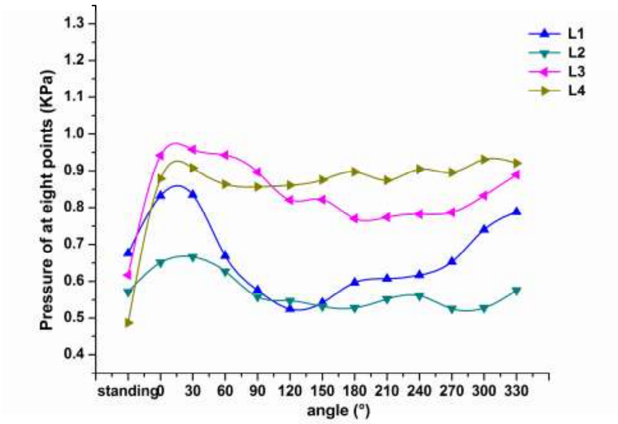

Fig. 7. Dynamic pressure of four points at L_4.

Conclusions

A novel approach was developed to characterize dynamic pressure of male lower limb in cycling. The following results were founded. Pressure was dynamic change during cycling. The maximum dynamic pressure located at 0°~30°. Pressure gradually non-linear rose with ease allowance reducing. For middle rectus femoris (L_1), middle biceps femoris (L_4), dynamic pressure significantly associated with muscle activation. For cycling shorts at present, pressure was in the range of safety. Smaller ease allowance was recommended, but selecting the most appropriate pressure needed to be further investigated combining with the effect of pressure to function of human body in subsequent study.

Acknowledgements

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