The Relationship Between Handlebar and Saddle Heights on Cycling Comfort

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Abstract. This study aims to clarify the relationship between handlebar and saddle heights on cycling comforts by assessing the kinematics, kinetics, physiological loading and subjective perceived exertion rating. Twenty young adults with mean age 24.6 years (SD=0.1) were recruited to participate in this study. A commercial city bike with the adjustable handlebar and saddle had been set on the indoor cycling stands. All subjects were asked to ride randomly with 9 different postures (3 handle ×3 saddle heights) for continuous one hour. A 3-D motion analysis system (Zebris Medical GmbH, Germany) was used to collect the kinematic data. The body pressure measurement system (Body Pressure Measurement System, Tekscan, U.S.A) was applied to measure the pressure distribution, force and displacement of centre of mass (COM). A heart rate monitor (Polar RS-800, Kempele, Finland) was used to record the heart rate as the physiological loading. Moreover, a subjective perceived exertion rating scale (Borg CR-10) was used to assess subjective comfort around the body regions. The results of this study indicated that the lower handlebar with higher saddle cause greater ROM in wrist-ulnar deviation, wrist extension, trunk flexion and hip abduction. It also reveals more force on hand region, more discomfort around hand, ankle and back, and higher physiological loading. While cycling with higher handlebar and lower saddle, it has more ROM in wrist flexion, more body displacement on buttock region, little trunk forward, and more discomfort rating in buttock region. For handlebar and saddle adjustment, the considerations of body dimensions and characteristics, the relationship between handlebar and saddle heights might improve the cycling comfort and diminish musculoskeletal injury.

Keywords: cycling comfort, pressure distribution, range of motion, heart rate, subjective rating.

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1 Introduction

With increasing awareness of lifestyles of health and sustainability (LOHAS) issues, more and more people ride bicycle as the means of transportation, exercise and the recreational activities worldwide. However, non-traumatic, chronic injuries, or called overuse musculoskeletal symptoms, are common in cyclists. It has been reported that up to 85% of cyclists have one or more overuse injuries, with 36% of these injuries were severe to warrant medical intervention (Dettori and Norvell, 2006). The general musculoskeletal symptoms for cyclists included the neck (48.8%), knee (41.7%), groin/buttock area (36.1%), hands (31.1%), and lower back (30.3%) discomfort (Schwellnus and Derman, 2005). Therefore, cycling posture and bike fit are closely related with performance, efficiency, safety and comfort for cyclists. For the basic components including frame, seat post, saddle, handlebar, crank arm, and pedals are used to compose across all bike designs. Saddle pressures are common to cause skin irritation and soreness in the groin regions for cyclists. Wilson and Bush (2004) indicated that vertical loads from seat were about 49~52% of body weight which were greater than shear loads during cycling. Proper handlebar and seat heights may be the most important adjustments when fitting a bicycle. Hence, this study aims to elucidate the relationship between handlebar and saddles heights on bicycle comfort. An understanding of bicycle design, fit, and function is important in treating the patient with an overuse injury.

2 Research Method

2.1 Subjects

Twenty young adults with mean age 24.6 yearswere recruited to participate in this study. None of them have history of cardiovascular and musculoskeletal disorder. Basic subject information, as well as anthropometric data, were collected and listed in Table 1. Men and women have significant difference in body height, weight, arm and leg length ($p<.05$). For the preferred height for saddle, men subjectively prefer to have higher saddle than women ($p<.05$). The preferred height for saddle was 104.4 (3.6) cm for men and 99.2 (3.4) for women, respectively.

Table 1. Subjects' information

Variables	Men (n=10)	Women (n=10)	P-values*
Age (years old)	24.7(0.4)	24.6(0.8)	0.21
Height (cm)	171.0(3.3)	160.2(2.6)	0.00*
Weight (kg)	63.7(5.9)	51.8(6.9)	0.00*
Crotch height (cm)	65.2(2.4)	65.1(2.1)	0.73
Arm length (cm)	68.2(3.3)	66.1(0.5)	0.00*
Leg length (cm)	92.7(3.2)	88.8(1.0)	0.00*
Preferred height for handlebar (PHH) (cm)	37.6(0.8)	37.9(1.5)	0.90
Preferred height for saddle (PHS) (cm)	104.4(3.6)	99.2(3.4)	0.00*

*Significant level at < .05.

2.2 Instruments and Response Measures

Motion Capture System. A ultrasound based, three-dimension motion analysis system (Zebris CMS-HS/Zebris Medical GmbH, Germany) was used to collect the kinematic data including the range of motion (ROM) of wrist ulnar-radial deviation, wrist flexion-extension, trunk flexion, hip adduction-abduction, knee flexion during exercise. Five markers were pasted on the hand back, forearm, upper arm, lower back and thigh. The hardware included two ultrasound sensors for measurement distance 2.5 meter. All data were recorded at a measurement frequency of 20Hz and processed using the software of Win Date (v.2.19.44) (Zebris Medical GmbH, Germany).

Pressure Measurement System. The body pressure measurement system (Body Pressure Measurement System/BPMS, Tekscan, U.S.A) was applied to measure and analysis the pressure distribution, force and displacement of centre of pressure (COP) on handlebar and saddle regions, respectively. Two pressure mats were placed on the hand and buttock. The data were recorded at a measurement frequency of 20Hz and processed using the software of CONFORMat (v. 6.20) (Tekscan, U.S.A).

Physiological Loading. A heart rate monitor (Polar RS-800, Kempele, Finland) was used to record the heart rate as the physiological loading. A resting heart rate (resting HR) was recorded while a subject was quiet for 1 min before the experiment. During exercise, the exercise heart rate (exercising HR) was collected with frequency of 1Hz and sustain for one hour. The physiological loading or exercise intensity was calculated by the formula: (Averaged exercising HR-Resting HR)/ [(220-age)-Resting HR].

Subjective Exertion Rating. A subjective perceived exertion rating scale (Borg CR-10 scale) was used to quantify and assess the overall perception of exertion. Subject rank fatigue level around the six body parts including wrist, upper back, lower back, buttock, knee and ankle from 0 (nothing at all) to 10 (maximal exertion), separately

2.3 Experimental Procedure

All participants were volunteers, and signed informed consent forms covering the experimental process, requirements and measurements. First, Basic subject information, as well as anthropometric data, were collected. A commercial bike (YS488 Gaint/ Gaint, Taiwan) had been set on the indoor cycling stands as a stationary trainer. The saddle and handlebar both were adjustable. At beginning, all subjects had to select the subjective preferred height for handlebar (PHH) and saddle (PHS) while cycling on this cycling trainer. Independent variables are 3 handlebars (PHH, 90% PHH and 110% PHH) and 3 saddle heights (PHS, 90% PHS and 110% PHS).The relationship between handlebar and saddle height was listed as table 2. All subjects were asked to ride randomly with 9 different postures (3 handle ×3 saddle heights) with the constant resistant, 80 rpm (revolution(s) per minute) for sustained one hour respectively. For the postures A to C, there are relative heights for handlebar and saddle but with different ratio, the conditions D to F are lower handlebar and higher saddle heights, the trails G to I are higher handlebar and lower saddle heights. The data of comforts were assessed by the measurements of kinematics, kinetics, physiological loading and subjective perceived exertion rating during the cycling.

Table 2. The relationship between handlebar and saddle heights

Postures	Definition*
A	90%PHH and 90%PHS
B	PHH and PHS
C	110%PHH and 110%PHS
D	90%PHH and 110%PHS
E	PHH and 110%PHS
F	90% PHH and PHS
G	110%PHH and PHS
H	PHH and 90%PHS
I	110%PHH and 90%PHS

*Preferred height for handlebar (PHH) and preferred height for saddle (PHS).

2.4 Statistical analysis

Statistical analyses were performed using SPSS version 14.0 statistical analysis software. Analysis of variance (ANOVA) was performed to analyze the effects of riding postures on the kinematics, kinetics, physiological loading and subjective perceived exertion rating. The level of significance was set as $\alpha = 0.05$. Duncan's multiple range tests was used to analyze the difference in between two levels of the variables.

3 Result

3.1 Handlebar, Saddle and Riding Posture

Table 3 displays the effect of cycling postures on range of motion (ROM) of wrist, trunk, hip and knee. Different riding postures influence the ROM on wrist deviation, wrist flexion –extension, trunk flexion and hip abduction-adduction ($p<0.05$). Table 4 shows the Duncan's multiple range tests for the ROM. It indicates that cycling with D, E and F postures require more ROM on wrist, trunk and hip joint and cycling with G, H and I have less ROM on these joints.

3.2 Handlebar, Saddle and Pressure Distribution

Table 5 reveals the effects of cycling postures on pressure distribution and the displacement of center of pressure (COP) on the hand and buttock region. It indicates that cycling postures have significant influence on the force on handlebar and COP displacement on buttock region ($p<0.05$). Table 6 displays he Duncan's multiple range tests for the force on handlebar and COP displacement on buttock. It shows that riding with D and E postures have higher force on handlebar and more COP displacement on buttock region ($p<0.05$).

Table 3. The cycling postures and joint range of motion of wrist, trunk, hip and knee

Postures \ ROM[a]	Wrist deviation[b.]	Wrist flexion-extension	Trunk flexion	Hip abduction-adduction	Knee flexion
A	14.5(1.1)	7.5(1.3)	38.10(1.2)	29.78(3.6)	55.4(16.1)
B	11.7(1.0)	-6.1(0.9)	37.75(1.2)	25.96(1.3)	58.7(17.6)
C	11.5(0.7)	8.3(1.2)	37.30(1.2)	45.97(8.9)	78.3(19.2)
D	15.9(1.4)	26.2(0.9)	57.35(4.6)	52.90(3.0)	77.3(21.0)
E	14.4(0.9)	24.7(1.8)	43.60(2.0)	46.16(2.2)	76.9(19.5)
F	14.0(0.7)	23.9(1.0)	44.15(1.5)	23.89(1.4)	57.5(17.2)
G	13.4(1.0)	-17.1(1.2)	18.25(1.6)	24.51(1.8)	58.0(18.1)
H	13.7(0.8)	-20.2(2.0)	27.95(1.7)	24.22(1.6)	57.9(17.4)
I	13.8(1.5)	24.1(0.7)	8.70(2.2)	25.43(1.8)	57.3(15.7)
F-test	12.82	8753.27	63.12	9.68	0.05
Significant[c.]	0.00*	0.00*	0.00*	0.00*	0.99

a. ROM: range of motion, units: degrees.
b. Wrist deviation: ulnar deviation is positive (radial is negative),
Wrist extension is positive (flexion is negative),
Trunk flexion is positive,
Hip abduction is positive and Knee flexion is positive.
c. Significant level is at *P< .05.*

Table 4. Duncan's multiple range tests for range of motion of wrist, trunk and hip

ROM[a]	Ranking[b.]
Wrist deviation	DE> F > AGH > BCI
Wrist flexion- extension	D> EF > ABC > G > H > I
Trunk flexion	D > EF > ABC >H > G > I
Hip abduction- adduction	D > EC > A > B > FGHI

a. ROM: range of motion, units: degrees.
b. Significant level is at *P< .05.*

Table 5. The cycling postures and pressure distribution

Postures \ Variables[a.]	COP displacement on hand (cm)	Force on handlebar (N)	COP displacement on buttock (cm)	Force on saddle (N)
A	2.4(0.6)	4.9(0.6)	2.5(0.5)	15.5(1.9)
B	1.8(0.6)	4.7(0.8)	2.1(0.6)	15.8(2.4)
C	2.9(1.2)	4.6(0.8)	3.4(1.8)	15.3(1.9)
D	2.2(0.6)	6.0(0.8)	3.4(1.8)	14.1(1.1)
E	2.3(0.6)	5.7(0.8)	3.7(1.8)	14.3(3.3)
F	2.2(0.5)	6.1(1.0)	2.4(0.5)	15.4(2.2)
G	3.0(1.0)	4.4(0.8)	2.5(0.5)	15.8(1.7)
H	2.2(0.5)	4.6(0.8)	2.3(0.5)	16.8(3.3)
I	3.3(1.0)	4.4(0.7)	3.8(1.6)	16.8(3.1)
F-test	1.03	13.69	8.52	0.53
Significant[b.]	0.39	0.00*	0.00*	0.72

a. COP displacement on hand: displacement range of center of pressure of hand,
COP displacement on buttock: displacement range of center of pressure of buttock.
b. Significant level is at *P< .05.*

Table 6. Duncan's multiple range tests for pressure distribution

Variable [a]	Ranking [b.]
Force on handlebar	DF > E > A > BCGHI
COP displacement on buttock	CDEI > ABFGH

a. ROM: range of motion, units: degrees.
b. Significant level is at *P< .05.*

3.3 Handlebar, Saddle and Physiological Loading

Table 7 reveals the effects of riding posture on the physiological loading. Although cycling postures didn't affect exercising heart rate, but cycling postures have significantly influence on exercise intensity ($p<0.05$). Riding with postures of C, D and E demand higher exercise intensity.

Table 7. The cycling postures and physiological loading

Variables / Postures	Resting HR	Exercising HR	Exercise intensity (%)
A	87.4 (0.3)	98.6 (7.4)	10
B	87.3 (3.0)	98.9 (3.6)	11
C	87.3 (1.9)	105.1 (2.7)	17
D	88.7 (2.2)	101.3 (10.6)	12
E	87.0 (0.9)	97.8 (8.6)	10
F	86.7 (2.6)	100.50 (5.9)	13
G	85.8 (3.3)	97.9 (3.8)	11
H	85.9 (2.5)	97.3 (8.9)	10
I	87.2 (0.4)	99.9 (2.6)	12
Significant [a.]	0.7	0.3	0.00*

a. Significant level is at *P< .05.*

3.4 Handlebar, Saddle and Perceived Exertion

Table 8 presents subjective exertion rating around the wrist, upper back, lower back, buttock, knee and ankle. It demonstrates that cycling posture have statistically influence on perceived exertion of wrist, upper back, lower back, buttock, and ankle($p<0.05$). In general, the most discomfort region during cycling which were rated as higher scores were wrist and buttock areas. Table 9 shows the results of Duncan's multiple range tests for subjective exertion rating. Cycling with postures of D, E and F would have more exertion on wrist region and riding with postures of C, G, H and I would have more discomfort on buttock areas.

Table 8. The cycling postures and subjctive erxrtion rating

Postures \ Variables	Wrist	Upper back	Lower back	Buttock	Knee	Ankle
A	3.9 (0.7)	0.9 (0.7)	1.1 (0.7)	4.3 (0.2)	0.8 (0.6)	1.0 (0.5)
B	3.4(0.7)	1.3 (0.4)	1.5 (0.4)	3.9(0.7)	1.1 (0.5)	0.9 (0.6)
C	4.9(0.7)	1.1 (0.5)	1.5 (0.5)	5.3(0.2)	1.1 (0.5)	1.4 (0.5)
D	4.5(0.6)	1.2 (0.6)	1.5 (0.3)	4.4(0.5)	1.6 (0.3)	1.3 (0.3)
E	4.8(0.3)	1.2 (0.6)	1.6 (0.6)	4.8(0.3)	1.1 (0.5)	1.9 (0.6)
F	4.8(0.1)	1.1 (0.5)	1.3 (0.4)	4.7(0.6)	0.8 (0.5)	0.9 (0.4)
G	3.7(0.8)	1.1 (0.6)	1.4 (0.8)	5.3(0.4)	1.0 (0.6)	0.9 (0.7)
H	4.3(0.6)	0.8 (0.4)	1.0 (0.3)	5.0 (0.3)	1.0 (0.6)	0.9 (0.5)
I	4.4(0.6)	0.7(0.5)	1.1 (04)	5.2(0.2)	0.8 (0.5)	0.6 (0.2)
F-test	4.149	1.685	3.015	3.91	1.48	3.595
Significant [a.]	0.00*	0.04*	0.00*	0.00*	0.07	0.00*

a. Significant level is at *P< .05.*

Table 9. Duncan's multiple range tests for subjective exertion rating

Rating of perceived exertion [a]	Ranking [b.]
Wrist	DEF > ACGHI > B
Upper back	BDE > CFG > AHI
Lower back	BCDEFG > AHI
Buttock	CGHI > DEF >AB
Ankle	DEF > CABGH > I

a. Rating of perceived exertion, range from 0 to 10.
b. Significant level is at *P< .05.*

4 Conclusions and Recommendations

The main purpose of this study was to illustrate the relationship between handlebar and saddle heights on cycling comforts by assessing the kinematics, kinetics, physiological loading and subjective perceived exertion rating. For cycling with lower handlebar and higher saddle, it reveals more range of motion on wrist ulnar deviation, wrist extension, trunk flexion and hip abduction. Lower-handlebar riding might cause higher force on hand and wide displacement of center of pressure. Moreover, lower-handlebar cycling requires higher physiological loading and might induces more perceived exertion on wrist region. For cycling with higher handlebar and lower saddle, it presents less and natural range of motion on wrist, trunk and hip and less force on handlebar, reduced physiological loading, but more perceived exertion on buttock region. For adjustable-preferred handlebar and saddle, higher handlebar and higher saddle (C postures) leads more physiological loading and more perceived exertion rating than lower handlebar and saddle. For handlebar and saddle adjustment, the considerations of body dimensions and characteristics, the relationship between handlebar and saddle heights might improve the cycling comfort and diminish musculoskeletal injury.

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