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The Effects of Foot and Shoe Type on Gait Biomechanics

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ABSTRACT

The purpose of this study was to analyze the differences in gait biomechanics according to foot and shoe type. Independent variables were 3 foot types which were rectus(RCSP=0°), planus(RCSP=-4°) and cavus(RCSP=3°) and 5 shoe types which were barefeet, flexible grid outsole lightweight shoes, variable outsole shoes, arch supported shoes and five-toed shoes. Dependent variables were kinematic and kinetic variables. Statistical analysis according to foot and shoe type was performed using MANOVA and LSD for post-hoc($p<.05$) via the SPSS 20.0.

1. PURPOSE

The purpose of this study was to analyze the differences in gait biomechanics according to foot and shoe type.

2. METHOD

Nine students representing three different foot types were selected for this study. Three students with pes rectus(average RCSP=0°), three students with pes planus(average RCSP=-4°) and three students with pes cavus(average RCSP=3°) were selected.

Independent variables were foot type(3) and shoe type(5). Shoe type included barefeet, flexible grid outsole lightweight shoes, variable outsole anti-supination shoes, arch supported anti-pronation shoes, and five-toed shoes. Dependent variables were kinematic and kinetic variables. Three dimensional kinematic variables of the angle and angular velocity at the pelvic, hip, knee, and ankle joints were measured using 3D motion capture (Motion Analysis, USA). The three dimensional kinetic variables of force(active force peak, impulse, loading rate, and decay rate, restraining period force, propelling period force) were measured via force platform(Kistler 9287BA, Switzerland).

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Statistical analysis according to foot and shoe type was performed using MANOVA and LSD for pos hoc($p<.05$) via the SPSS 20.0.

3. RESULTS AND CONCLUSIONS

1) Compared to other foot types, pes planus had the most joint movement. Pes planus values were greatest for flexion and extension angle at the pelvis, hip, and knee; adduction and abduction angle at the hip and ankle; internal rotation angle at the pelvis, hip, and knee. However, pes planus also had the lowest value for internal rotation at the ankle. Except for adduction / abduction, ankle flexibility for pes planus was low. As a result, greater movement was noticeable at the pelvis, hip, and knee. Since the hip, pelvis, and knee joints require stability and not mobility, this exaggerated movement can result in fatigue, discomfort, and pain. Therefore, subjects with pes planus should practice ankle flexibility and mobility exercises, especially in the sagittal and transverse plane.

2) According to shoe type, inner arch support shoe exhibited the highest external rotational angular velocity at the pelvis for subjects with pes planus at the moment of toe off. Therefore, inner arch support could effect on hip joint outer rotational movement. Barefoot, flexible grid outsole lightweight shoes, and five fingers had lower adduction/abduction and flexion/extension angular velocity at the hip and ankle than the variable outsole anti-supination shoes, and arch supported anti-pronation shoes. Since the five-toed and flexible out soled shoes were designed to mimic barefeet, angular velocity for these shoes most closely resembled barefeet. Therefore, natural movement at the ankle joint could affects hip joint movement.

3) Pes planus had the lowest second vertical active force peak. Since this peak corresponds with push-off during gait, subjects with pes planus tend to have maximum gluteal underdevelopment. Pes planus had the lowest breaking force(y direction), Therefore, subject with pes planus was not well adapted to breaking during the break phase of the walking cycle. Barefeet and five toed shoes exhibited the largest propulsive force peak. This reflects the full articulation of foot bones during the push off phase, especially the toes. flexible grid outsole lightweight shoes did not have a high propulsive force. This shows flexible grid outsole lightweight shoes did not allow efficient toe movement.

4) Medial and lateral impulses were highest for pes rectus. There were the biomechanical differences according to foot and shoe type. Therefore for gait analysis, researcher should use subject with pes rectus.

Table 1.The Effects of Foot Type on Gait Biomechanics

FOOT TYPE		Plane	Joint	Event	kinematic	Post-hoc
Pes Rectus	kinematic	Sagittal	Pelvis	HC	angle	A<B,C
				MS	angle	A<B<C
				HO	angle	A<B,C
				TO	angle	A<B,C
			Ankle	MS	angle	A>B,C
				HO	angle	A>B>C
				HO	Angular velocity	A>B>C
				TO	angle	A>B,C
	kinetic			1^{st} vertical active max force		A<C<B
				Restraining period impulse		A>B>C
Pes Planus	kinematic	Sagittal	Hip	HC	angle	B>A,C
				MS	Angle	B>A,C
				HO	Angle	B>A,C
				TO	Angle	B>A,C
			Knee	HC	Angle	B>A>C
				MS	Angle	B>A,C
				HO	Angle	B>A>C
				TO	Angle	B>A,C
		Frontal	Pelvis	MS	Angle	B>A,C
				HO	Angle	B>A,C
				HO	Angular velocity	B>A
				TO	Angle	B>A,C
			Hip	HC	Angle	B>A,C
				MS	Angle	B>A>C
				HO	Angle	B>A>C
				TO	Angle	B>A>C
		rotation	Knee	HC	Angle	B>A,C
				MS	Angle	B>A,C
				HO	Angle	B>C>A
				TO	Angle	B>C>A
			Ankle	HC	Angle	B<A,C
				HC	Angular velocity	B<A<C
				MS	Angle	B<A,C
				HO	Angle	B<C<A
				TO	Angle	B<C<A
	kinetic			1^{st} vertical active max force		B>C>A
				2^{ND} vertical active max force		B<A,C
				Lateral force		B<A
Pes Cavus	kinematic	Sagittal	Knee	HC	Angle	C<A<B
				MS	Angular velocity	C<A,B
				HO	Angle	C<A<B
				TO	Angular velocity	C<A,B
		frontal	Hip	MS	Angle	C<A<B
				HO	Angle	C<A<B
				HO	Angular velocity	C<B<A
				TO	Angle	C<A<B
				TO	Angular velocity	B<A,B
			Knee	HC	Angle	C<A,B
				MS	Angle	C<A<B
				MS	Angular velocity	C<A<B
				HO	Angle	C<A,B
				TO	Angle	C<A,B

A=Pes Rectus, B=Pes Planus, C=Pes Cavus

Table 2. The Effects of Shoe Type on Gait Biomechanics

SHOE TYPE		Plane	Joint	Event	Kinematic	Post-hoc
Barefoot	Kinematic	Sagittal	Hip	HC	Angular velocity	a<c,d
			Ankle	HC	Angle	a<b,c,d,e
				MS	Angular velocity	a<b,c,d
				HO	Angle	a<c,d
				HO	Angular velocity	a<b,c,d
				TO	Angle	a<b<c,d
		Frontal	Ankle	HC	Angular velocity	a<b,c,d
				MS	Angular velocity	a<b,c,d,e
				HO	Angular velocity	a>d,e
		Rotation	Pelvis	HC	Angle	a<b,c,d
			Knee	HO	Angular velocity	a<c,d
	Kinetic		propelling period max force			a>b,c,d
			Vertical impulse			a<b,c,d,e
Barefoot Emulator shoes	Kinematic	Sagittal	Hip	HC	Angular velocity	b<c,d
			Ankle	TO	Angle	b<c,d
		Frontal	Hip	HC	Angular velocity	b<a,e
		Rotation	pelvis	TO	Angle	b<c,d
Different lateral and medial stiffness	Kinematic	Sagittal	Hip	HC	Angular velocity	c>a,b,e
			Ankle	MS	Angular velocity	c>a
				HO	Angle	c>a,e
				TO	Angle	c>a,b,e
		Frontal	hip	TO	Angular velocity	c<a,b,e
	kinetic		Lateral force			c>a,b,d,e
Inner Arch Support shoes	Kinematic	Sagittal	Hip	HC	Angular velocity	d>a,b,e
			Ankle	MS	Angular velocity	d>a
				HO	Angle	d>a,e
				TO	Angle	d>a,b,e
		Rotation	pelvis	TO	Angle	d>a,b
Five-toed Shoes	Kinematic	Sagittal	Hip	HC	Angular velocity	e<c,d
			Ankle	HO	Angle	e<c,d
				TO	Angle	e<c,d
		Frontal	ankle	HC	Angular velocity	e<b,c,d
	kinetic		propelling period max force			e>c,d

a=barefoot, b=barefoot emulator shoes, c=different lateral and medial stiffness, d=inner arch support shoes, e=five-toed shoes

There was relationship between ankle joint and hip joint movement. A limitation in ankle joint movement can lead to excessive flexion/extension, and inner rotation at the hip joint. That could cause pain and discomfort.

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