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Kinematic comparison & analysis of gait pattern according to loads of %BW between gravitation and buoyancy field

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국문초록

본 연구는 중력과 부력상황에서 체중비 하중의 증가에 따른 보행을 비교·분석하여 수중재활요법 및 운동효과를 위한 처방책으로 활용의 가능성을 타진하기 위해 착수되었다. 두 실험상황에서 참여한 피험자는 동일인 남자 다이버 1인(약 1000회 다이빙 경험)이었으며, 실험방법과 절차는 3차원 영상분석과 3차원 영상분석 결과에 대한 운동학적 변인들을 산출하였다. 두 상황에서 체중비에 따른 1 스트라이드의 운동학적 분석을 한 결과 부력상황의 경우 중력상황의 경우에 비하여 진행방향에서 완전한 1 스트라이드동안 무게중심의 변위와 속도는 더 길렀고 빠른 양상을 보였으며, 소요시간은 더 지연된 것으로 나타났다. 각변인의 하지분절과 동체분절에서 각변위와 속도에서 중력의 경우보다 더 많은 굴곡·신전운동으로 보였고, 더 빠른 각속도의 양상을 보였다. 본 연구의 연구변인을 종합 분석 및 결론을 내렸을 때 전신이 침수된 상황에서 운동 및 재활효과가 중력상황에 비해 부력상황의 경우가 더 큰 것으로 나타났으며, 추후 더 많은 연구대상자와 다양한 상황아래서 심도 있는 연구를 함으로서 현장에 적용할 수 있는 기초 자료를 제시할 수 있다고 사료된다.

Key words : buoyancy field, rehabilitation, therapy, gravitation field

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I. INTRODUCYION

The most basic gait of human locomotion was performed with interaction & functional coordination among interjoints of lower extremities by as a whole recruitment of neuromuscularskeletal system. Representive preceded studies related with the rehabilitation & abnormal gait included Chung, Chul-Soo etal.(2003), Kim, Ro-Bin etal(2005), Eun, Seon-Deok(2006), Ryu, Ji-Seon(2006), Yoon, Suk-Hoon(2007). Particularly the preceded studies loading weight by body each parts were as follows; on hand(Auble etal,1987), (Graves etal,1987), ankle & Lower extremity(Burse etal,1979), Jones etal,1984), Jun(1992) hand+foot+head(Soule etal,1969) and weighted shoes(Kwak,2003). Those studies was performed on centering factors influencing for normal gait and efficiency & kinematic analysis according to each parts of body loaded. That is, the preceded studies of gait performed on the ground were compared and analysed on the efficiency & rehabilitation of gait and various factors influencing to the normal gaitaccording to various situation.

Recently it was necessary for underwater industries or workers as aqua-exercise, rehabilitation, exercise therapeutics and work efficiency to move the radius of workplace in condition of submerged whole or partly of body. Ju, Sung-Bum etal(2005) and Kim, Hyeon-Ju etal(2006) related with underwater activity reported positive effects when developed & applied to exercise program partly submerged of body in underwater.

In condition of whole submerged of body, Ryew, Che-Cheong etal(2007) analysed about gait according to loads of %BW in gravitation field and also Ryew, Che-Cheong etal(2008) compared & analysed of gait according to load increaseof %BW in buoyacny field. That is , it was divided into two categories between rather light loads(0%BW, 10%BW) and 20%BW, 40%BW) in gravitation field. Also Ryew, Che-Cheong etal(2008)reported that increase of loads ofBW% counteracted the effect of buoyancy and could be more stable gait in underwater. Therefore through comparing & analysing the experimental results of Ryew, Che-Cheong etal(2007) in gravitation and Ryew, Che-Cheong etal(2008) in buoyancy field, the aims of this study was to first compare kinematic variance of both gait of gravitation and buoyancy field and second to investigate the difference of kinematic variables of gait in two situation variances by gait trials according to load increase of %BW phase and third to verify the applicable possibility of the effects of underwater gait to the various underwater exercise program. That is, to prescription for underwater rehabilitation therapy and exercise effects through comparison analysis of gait according to load increase of %BW between gravitation and buoyancy field

II. METHOD

The experimental method was performed at the same subject, procedure, loads of %BW, analysis, data process that did onstudies preceded in both situation(Ryew, Che-Cheong(2007 and Ryew, Che-Cheong(2008) except for the ground gait of gymnasium and underwater gait within waterpool(width 5m x depth 5m x length 25m). That is, the subject participated was a male diver experienced about 1,000 times in various diving point with age(28), height(176cm), weight(78kg) and performed each 3 times repetitive gait experiment for the same load byeach load of %BW. The equipments used for 3D cinematograph analysis consist of digital cam code 2ea(30f/s, VX-2000, Sony), control point box for DLT(2m x 2m x 1m, Visol.), LED(8555, V-Teck), Light(2ea) and Kwon3D Motion Analysis Package(ver3.016, Visol) for 3D motion analysis. Two stationary 45°angled-camera were used to capture at the first the control point box for DLT and the subject's gait motion according to the loads of %BW.The subject's 21 body joints were attached with reflex marker for easy digitization and performed every 3times per a gait on the each load of %BW within the range of control box point.

Direction was set to forward(y-axis), lateral(x-axis), and vertical(z-axis) to the gait progression. Analysis model was defined as total 21 joint with 17 segments and used the body segment parameters of Plagenhoef, S. C etc.(1983). Independent variables of load were consisted of load of 0%BW(only body weight), BW + 10%BW(weight belt), BW + 25%BW(weight belt + 1 air tank), BW + 40%BW(weight belt + 2 air tank).

Analysis phases & events were classified into 4 phases and 5 events during 1 stride of right leg ; supporting? swing, stance, supporting? phases and Heel-Takeoff, Toe-Takeoff, Heel-Touchdown, Toe-Touchdown, Heel-Takeoff of events. 3D coordination was obtained from DLT of Abdel-Aziz & Karara(1971) after synchronization and interpolation(interval o.o1sec.) used 3rd spline function on the basis of an extracted pair of 2D coordination as a result of digitizationused Kwon3D motion analysis program(Kwon, 2004). The error from noise was smoothed(6Hz) using low-pass filter of Butterworth. Calculated datas from the 3D coordination consisted of temporal, linear kinematic, and angular kinematic variables were normalized by each phases.

III. RESULT AND DISCUSSION

Mean±SD of all kinematic variables analysed by gait phases during 1 cycle with loads of %BW of SCUBA appratus between gravitation and buoyancy field was summarized in table 1. Variables compared and analysed consisted of temporal, linear, angular kinematics by phases according to load increase of %BW. Summerized data in the table was Mean±SD of all loads of %BW

1. Temporal

Total mean elapsed time during 1 stride was more delayed 7.75sec as 8.82±1.69sec. in buoyancy than 1.07±.14sec. of gravitation gait. The delayed results showed that the more loads of %BWdid, the more delayed in both situation. The ratio of supporting phase per 1 stride was mean 57.98% in gravitation abd 74% in buoyancy gait, which showed more ratio than 48-60% in slow gait of study preceded(Shin, Je-Min, 2006). That is , when considering the possibility which could

표 1. Mean±SD of temporal, linear & angular variables by gait phases in all loads of %BW between gravitation and underwater gait

Variable			supporting-1	airphase	Touch-down	supporting-2	total	±%BW/0 %BW
Temporl (sec)	Gr.		.33±.08 (31.52)	.36±.13 (34.24)	.08±.00 (7.78)	.28±0.5 (26.46)	1.07±.14 (100)	+15.8
	Bu.		3.83±.80 (43.42)	1.98±.91 (22.44)	.24±.18 (2.72)	2.75±.30 (31.17)	8.82±1.69 (100)	-33.5
COGdisp. (cm)	Gr.		-17.82±10.97 (122.89)	2.65±13.17 (85.96)	52.67±5.53 (88.12)	78.05±11.88 (92.67)	-	-4.9
	Bu.		-28.87±19.57 (73.10)	27.38±20.08 (202.96)	52.12±11.72 (125.28)	97.02±25.42 (123.75)	-	+55.4
COGvel. (cm/sec)	Gr.		100.09±23.20	122.34±15.97	144.33±14.49	137.24±13.58	-	
	Bu.		133.88±11.56	23.72±11.49	18.34±6.88	26.09±9.99	-	
Ang.disp. (deg.)	Gr.	Hip	166.21(100.47)	151.48(96.00)	152.04(96.39)	163.74(96.29)	-	+1.3
		Knee	163.93(101.83)	134.34(99.81)	166.69(100.59)	166.25(98.98)	-	+0.6
		Ankle	107.43(101.39)	115.44(101.78)	113.86(99.50)	104.58(96.39)	-	+0.7
	Bu.	Hip	169.17(97.52)	137.62(99.80)	109.94(108.61)	144.50(95.20)	-	+1.5
		Knee	161.14(96.49)	103.26(93.73)	108.24(108.34)	115.55(85.12)	-	-5.0
		Ankle	113.96(87.09)	132.01(97.98)	103.34(109.03)	94.89(88.54)	-	-4.6
Ang.vel. (deg/sec)	Gr.	Hip	15.16±60.78 (28.4)	-61.11±93.16 (93.3)	71.67±30.48 (64.3)	54.96±47.65 (84.1)	-	-33.3
		Knee	-98.13±134.99 (75.9)	94.69±225.38 (103.1)	-65.51±29.73 (177.4)	32.96±57.38 (70.9)	-	+10.4
		Ankle	103.04±106.60 (89.2)	-50.24±117.99 (148.2)	-44.47±35.96 (424.3)	-35.91±6.39 (89.8)	-	+86.6
	Bu.	Hip	0.06±65.64 (18.2)	-27.63±70.18 (142.1)	-1.67±32.62 (12.6)	22.20±53.60 (74.3)	-	+162.3
		Knee	0.09±54.29 (26.5)	-25.62±113.49 (147.5)	-23.65±40.43 (71.2)	13.41±64.66 (57.1)	-	+132.7
		Ankle	13.93±70.05 (156.6)	-26.07±85.26 (154.9)	24.51±66.96 (851.1)	-3.00±85.89 (3.05)	-	+560.6
Forward titling angle of trunk(deg)	Gr.	전후	78.51(94.88)	80.34(93.61)	82.52(93.58)	83.15(94.79)	-	+1.63
		좌우	91.12(102.04)	91.42(101.27)	90.24(101.17)	89.67(101.89)	-	+2.13
	Bu.	전후	75.03(105.33)	70.43(100.96)	69.41(101.62)	70.11(96.09)	-	+3.57
		좌우	87.22(99.68)	89.98(98.81)	91.81(101.13)	87.47(98.86)	-	+.09

improve the effect of exercise in underwater, It could be resulted in more positive effect in underwater exercise when provided more freely moveable condition(at condition of optimal buoyancy, load, depth, plane bottom).

2. Linear kinematics

Total forward(Y) displacement of COG during 1 stride showed the longer stride of 19cm as mean 78.05±11.88cm in gravitation than mean 97.02±25.42cm of buoyancy gait. The order of decreasing ratio to the load of 0%BW was 7.2%

of 40%BW, 4.1% of 10%BW, and 3.2% of 25%BW in gravity and 76% of 25%BW, 49.1% of 10%BW, and 40.6% of 40%BW in buoyancy gait. The result was the more load of %BW did, the shorter of propulsive displacement did in gravity, but the more load of %BW did, the longer of propulsive displacement did in buoyancy gait. There was longer than that of preceded in normal gait when comparing with result of Kim, Moo-Young(2003) of each mean 55.2cm and 72.6cm of handicapped & normal gaits. That is, when considering the possibility which could improve the effect of exercise in underwater, It could be resultedin more efficiency in underwater exercise when provided optimal load for negative buoyancy and resulted in more momentum in course of overcome the resistance of water against body and also decreased at load of joint of lower extremities.

Decreasing ratio to the load of 0%BW in COG velocity(Y) as total mean 16.73% of gravity field were the order of 20.9% of 40%BW, 19.8% of 25%BW, andas total mean 88.24% of buoyancy field were the order of 102.4% of 40%BW, 84.5% of 10%BW, and 77.4% of 25%BW, which showed the more load of %BW did, the more decrease did in gravity field, but the more load of %BW did, the more increase did n buoyancy field. Therefore if the same time & momentum of exercise in two situation, the effects of exercise & therapeutics for rehabilitation in buoyancy field was proved to be larger than that of gravity field.

3. Angular kinematics

Angular displacement of lower extremities according to the load increase of %BW in gravity field showed the smallest range of flexion at the load of 40%BW at hip, 10%BW at knee and 40%BW at ankle joint, particularly the more load of %BW did, the less range of flexion did athip joint, but thee smallest range of flexion in the load of 40%BW atknee & ankle joint. That is, It showed the irregular pattern of flexion according to load increase of %BW.

Angular displacement of lower extremitiesaccording to increase of the load of %BW in buoyancy field showed the largest range of flexion at the load of 40%BW and the more load of %BW did, the larger range of flexion did at knee & hip joints. In the case of 10%BW at knee and 40%BW at ankle joint, particularly the more load of %BW did, the less range of flexion did athip joint, In case of ankle joint, it showed largest range of flexion at load of 25%BW, but also showed the irregular pattern of flexion according to load increase of %BW.

Angular velocity of lower extremities according to the load increase of %BW in gravity field showed the largest value at the load of 25%BW at hip, knee joints & of 10%BW atankle joint, and it showed the more load of %BW did, the larger value did in angular velocity.

Angular velocity of lower extremitiesaccording to the load increaseof %BW in buoyancy field showed the largest value at the load of 25%BW at hip and the more load of %BW did, the faster flexion velocity did at all joints, which resulted in more stable gait.

Decreasing ratio to the load of 0%BW in COG velocity(Y) as total mean 16.73% of gravity field were the order of 20.9% of 40%BW, 19.8% of 25%BW, and as total mean 88.24% of buoyancy field were the order of 102.4% of 40%BW, 84.5% of 10%BW, and 77.4% of 25%BW, which showed the more load of %BW did, the more decrease did in gravity field, but the more load of %BW did, the more increase didin buoyancy field. Therefore if the same time & momentum of exercise in two situation, the effects of exercise & therapeutics for rehabilitation in buoyancy field was proved to be larger than that of gravity field.

Flexion ratio to the load of 0%BW of forward tilting of trunk during all phases of gait in gravity field showed regular pattern, which resulted in the more load of %BW did, the larger forward tilting of trunk did.

Flexion ratio to the load of 0%BW of forward tilting of trunk during all phases of gait in buoyancy field showed mean 3.57% of more flexion of trunk. Flexion at load of 0%BW of right-left laterial angle of trunk during all phases of gait inboth gravity and buoyancy field showed regular pattern, but no significant difference

IV. CONCLUSION

The study was to investigate the validity of application to therapeutics and underwater exercise program by elucidating the effects of exercise in underwater through kinematic comparison · analysis during1 stride of gait in buoyancy and gravity field. For this, 3D cinematography was accomplished by gait phases according to load increase of %BW on a skilled diver in two situations.

Elapsed time during 1 stride was more delayed of 8.2 times in buoyancythan gravity field, optimal load & normal gait was performed at load of 25%BW & 40%BW. COG displacement and COG velocity(Y) showed that the more load of %BW did, the longer & the faster by obtaining the larger negative buoyancy in buoyancy field, which could result in thelarger momentum in the course of overcoming the resistance against water.

The more load of %BW did, the more range of flexion did, thus the more stable and faster gait resulted in than that didn't inlower extremities when loaded regardless of load of %BW. The more flexion of trunk in buoyancy than that of gravity field was due to overcomingwater resistance to the propulsive direction.

Therefore 1 stride gait was completed through the more elapsed time & momentum in buoyancy than gravity field and assumed to present the available materials applicable for exercise &therapeutic program in underwater when considering the above results.

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